PROCEEDINGS OF

# KERALA ENVIRONMENT CONGRESS 2012

FOCAL THEME

## AGRICULTURE AND ENVIRONMENT

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at RGCB Auditorium, Thiruvananthapuram

*Organised by*

CED

**CENTRE FOR ENVIRONMENT AND DEVELOPMENT**
THIRUVANANTHAPURAM

*In Association with*

**Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram**

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# FOREWORD

The United Nations Conference on Sustainable Development (2012) known as Rio+20 commemorating the 20th anniversary of the 1992 Earth Submit resulting in the document "The Future We Want" marks a renewed effort to embark on ways of "greening" the global economy and evolving institutional framework for sustainable development. Appropriate management of our limited resources will be necessary to ensure food security for our growing population and to eliminate poverty. It is imperative to seek a more scientific planning for proper area wise utilization of all the available resources and their sensible management at the State and local level.

Agriculture continues to be the most important and largest sector of the Kerala's economy. Kerala contributes a substantial share to the national economy with respect to four plantation crops viz. rubber, tea, coffee and cardamom. These constitute 29% of the net cropped area. Even though agriculture remains the major contributor to the state's economy, it has been showing a declining trend both in terms of area under crops and productivity except for Rubber. The most significant changes affecting agriculture are the shrinking of area under food crops, the change in land use pattern and land degradation.

The most alarming cause of land degradation includes rapid urbanization leading to conversion of good agricultural lands for other purposes, cultivated lands exposed to indiscriminate use of fertilizers and pesticides, soil erosion and loss of soil microflora and fauna affecting the quality of the soil, etc. Agriculture and environment are inextricably connected. The goal of agricultural policy has been higher production and increased efficiency, but continued increase in production has only been possible through intensification of the farming system which many times involved the clearance of native forests, the introduction of selected or novel crop varieties, increasing use and dependence upon artificial irrigational and chemical aids to soil fertility, crop protection, and food harvest, storage and processing, with a simultaneous increase of pollution risks. Integrating environmental concerns into the Agricultural Policy aims to head off the risks of environmental degradation

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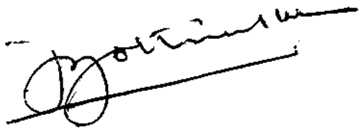
and enhancing the sustainability of agro-ecosystems. What is of great significance is integrating the principles of sustainable development into country policies and programs as well as at local level activities. The scientific community, academicians, experts in the agriculture sector, policy makers, civil society and media has a significant role to play in this context.

It is in this context that the Kerala Environment Congress organized by Centre for Environment and Development become highly relevant. The eighth KEC which will be held from $16^{th}$ to $18^{th}$ August, 2012 at Thiruvananthapuram aims at highlighting the recent advances in agriculture. The Centre for Environment and Development has once again achieved the distinction of focusing on the linkage of science, technology and the most important aspect of human environment for sustainable development.

This Proceedings Volume which contains detailed reviews and papers prepared by eminent experts in the concerned fields related to the focal theme "Agriculture and Environment" will be useful in strengthening the information base of the agencies involved in the agriculture development of the country and the State of Kerala in particular.

The inputs from the participants on technologies, processes and societal role in agriculture development and related food security issues offer deeper insight into the issues and thus options for consideration in the State. Information will be helpful in appreciation of relevant facts for formulation of agriculture and environment related policies in a more objective manner.



**K.R.Jyothilal, IAS**

Secretary, Agriculture, Government of Kerala &
Vice Chancellor, Kerala Agricultural University

# KERALA ENVIRONMENT CONGRESS-2012

The Centre for Environment and Development(CED)initiated the Kerala Environment Congress in 2005 with the objective of bringing together scientists and technologists, policy planners,decision makers, development managers and students for sharing of knowledge, expertise and experience in subjects of relevance to support the development of the country.

An autonomous research, training and consultancy organization established in 1993, CED has been focussing both on environment and development related sectors bringing complementarity, leading to sustainable development . CED has wide network and collaboration with many state, national and international agencies. The major Program Areas of the Centre are (i) Natural Resources Management (ii) Water and Environmental Sanitation,(iii) Coastal Systems Research (iv) Climate Change Studies (v) Energy Studies (vi) Geoinformatics (vii) Natural Disaster Management and (viii) Institutional Development, Innovation and Policy Studies. CED established its Eastern Regional Campus at Bhubaneswar, Orissa to give major thrust to our activities in the east and north-eastern states. CED has also became a partner of the HDF-CED School of Management at Bhubaneswar. The Centre has at present nearly 280 staff from different disciplines.CED is the "Centre of Excellence of Ministry of Urban Development, Government of India on Solid Waste and Wastewater Management", the "Regional Resource Agency" of Ministry of Environment and Forests, Government of India and also the Accredited Agency of Government of Kerala for Solid Waste Management. The Centre has its activities in the states of Odisha, Andhra Pradesh, Bihar, West Bengal and Jharkhand apart from Kerala. CED has been involved in a major project for Capacity Building of Urban Local Bodies in the states of Kerala, Odisha, West Bengal, Bihar and Jharkhand sponsored by Ministry of Urban Development, Government of India.CED is also providing technical support to many urban local bodies in India for Water Supply Engineering, Solid Waste Management, Waste Water Management, Climate Change Studies, EIA Studies, Disaster Management, Carbon Foot Print Mapping, GIS Mapping etc. CED jointly with Human Development Foundation and Regional Museum of Natural History, Bhubaneswar conducted the Odisha Environment Congress in 2010 and 2011. CED plans to organize similar Environment Congresses in the states of Chattisgarh and Andhra Pradesh this year.

During the last 19 years, CED has completed nearly 80 research, consultancy and training projects supported by various International and National Agencies like the World Bank, UNDP,GEF,JICA,RNE, IDRC, ADB, Commonwealth Local Government Forum, Ministry of Environment & Forests. Ministry of Urban Development, Department of Science & Technology. Ministry of New and Renewable Energy, Ministry of Rural Development, Kerala State Council for Science, Technology & Environment. Local Self Government Department, Kerala, State Disaster Management Agency, Kerala, Planning & Coordination Department, Orissa, Orissa Water Resources Department, Department of Urban Development & Housing, Orissa etc. The Centre is also coordinating the National Environment Awareness Campaign(NEAC) of MoEF in Kerala and Lakshadweep Islands.

The Kerala Environment Congress was initiated in 2005, at Kochi, with the focal theme “Coastal and Marine Environment-Issues, Problems and Potentials”. The second Congress was held at Kozhikode in 2006 with the focal theme” Forest Resources of Kerala” and next KEC was organized in 2007 at Thiruvananthapuram with “Wetlands of Kerala” as the focal theme. The fourth Congress focused on the theme ”Environmental Sanitation,Health and Hygiene” was held at Kerala Institute of Local Administration, Trissur in 2008. The fifth KEC was held in 2009 at Thiruvananthapuram, with the focal theme “Water Resources of Kerala”and the sixth KEC was organized on the focal theme “Solid and Liquid Waste Management” in 2010 at Thiruvananthapuram. The last KEC was held in 2011 with the focal theme”Energy and Environment” at Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram

“Agriculture and Environment” is the focal theme identified for this year’s Congress,the structure of which includes special addresses,invited paper presentations, as well as paper and poster presentations for Young Scientist Award. There are 26 invited presentations, 20 general presentations and 15 students presentations for award. Since one of the major objective of the KEC is to promote young researchers (age 35 and below), we have instituted a Young Scientist Award for the best paper and poster presentation. We expect nearly 350 researchers, policy experts, decision makers, students and development thinkers to actively participate and contribute in the Congress.

This Proceedings Volume contains full papers of special addresses,invited, general and student’s presentations of the Congress prepared by eminent experts in the field. We hope that the deliberations in the Congress and the papers published in the Proceedings will help to evolve a strategy for sustainable agriculture development in the country

CED gratefully acknowledge the support of Rajiv Gandhi Centre for Biotechnology which to a great extent helping us to successfully organize the Congress . On behalf of CED, we take this opportunity to place our sincere gratitude to all the distinguished participants and other invitees who have been supporting us for the last eight years to make this Program a success.

**Dr Babu Ambat**
*Executive Director, CED*

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# Food Security, Biotechnology and Environment: Need for a Balance Between Natural Capital and Man-made Capital

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## INTRODUCTION

Nearly 10000 years ago the hunter-gatherers began agriculture - settled at a place and domesticated plants and animals. Whether the spread of agriculture was a trigger for population growth or population growth necessitated agriculture is difficult to resolve now. However, the increasing global population was definitely a serious concern in testing innovations in agriculture production all through human history. This culminated in the second half of the last century with the advent of Green Revolution. Continuously defying the Malthusian predictions (Thomas Robert Malthus 1766 – 1834), the Green Revolution methodologies help to achieve a food production rate, which outstrip the population growth. Parallel with the success stories of Green Revolution, environmental issues also emerged. Environmentalists raised concern about the sustainability of the enhanced agricultural production achieved by Green Revolution as the high input agriculture practices exerted serious pressure on environmental fabrics. Towards the last decades of twentieth century, biotechnology emerged as a panacea for all biological problems. Biotechnologists backed by Biotech companies, who invested heavily in Ag-biotech sector, visualized engineering crops according to the needs by inserting cloned alien genes into their genomes. Soon, genetic modification and the production of tailor made crops invited severe criticism from environmentalists, resulting in heated debate globally about the commercialization of genetically modified crops. Almost at the same time the concept of organic farming emerged, wherein the proponents promised food security through environment- friendly sustainable agricultural methods.

When the proponents of different school of thoughts were busy discussing in an affluent ambience of surplus food and low commodity prices, a bomb shell fell between them in 2007/2008. The prices of essential supplies like wheat, rice maize etc., skyrocketed, doubled or tripled from 2005, in both developed and developing countries, leading to civil unrest ranging from strikes to riots. As a consequence, not only the method of production alone but the agriculture, food production and food security also came back to the limelight. Although several reasons were assigned to the rapid price rise, at the bottom line, it was a warning that the apparently stable food security could quake before we could initiate preventive or curative measures. Now the policy developers and decision makers are concerned not only with the agriculture production methods but also about the quantum of food to be produced in next 50 years. It is estimated that the world population would reach a plateau in year 2050 with approximately 9 billion people, nearly 2 billion more than the present population. In fact, the scientific world and decision makers alike are entangled in a triangle of population growth, food security and environment intertwined with biotechnology, organic farming, global farming, biodiversity depletion and bio-fuel production constraints. However the denominator is common: can we produce sufficient food to feed 9 billion with minimum damage to the environmental fabric? Can we retain the health of Mother Earth so that future generations also could enjoy the same quality and quantity of food as we enjoy now?

## AGRICULTURE, FOOD SECURITY AND ENVIRONMENT: IMPACT AND CONCERNS

The term Green Revolution coined by William Gaud (Gaud, 1968), refers to a series of research, development, and technology transfer initiatives, led by Norman Borlaug, “Father of the Green Revolution”, which occurred between the 1940s and the late 1970s, resulting in increased agriculture production around the world. When the world’s population increased by 111% between 1961 and 2005 (from 3.08 to 6.51 billion), with the Green Revolution initiatives, the crop production rose by 162% (from 1.8 to 4.8 billion tons).

The success in Green Revolution was additive both by expanding the land area cultivated (extensification) and by improving crop yield/unit area (intensification). Global cropland grew by 27% (from 960 to 1,208 Mha), but total crop yield increased by 135% (from 1.84 to 3.96 t/ha). High yielding modern cultivars (MV) contributed 17% of the production growth during early Green Revolution (1961-1980) and 40% in the late Green Revolution (1981-2000). The extensification (increasing land area) accounted for 20% of production growth in the early Green Revolution period, but lesser in the later years as the extensification was relatively low in this period. The rest of the production growth came mostly from high input use-increased use of synthetic pesticides and fertilizers- and improved access to irrigation and mechanization.

The world population has grown by about 3.5 billion since the beginning of the Green Revolution and many believe that, without the Revolution, there would have been greater famine and malnutrition, realizing the ‘Malthusian Catastrophe’. For example, Malthusian Paul R. Ehrlich, in his 1968 book *The Population Bomb*, said that “India can’t possibly feed two hundred million more people by 1980” and “hundreds of millions of people will starve to death in spite of any crash programs. Ehrlich’s warnings failed to materialize when India became almost self-sustaining in cereal production in 1974.

However, the agriculture growth exerted serious pressure on environment, both at the pre and post Green Revolution era, but at different levels. The environmental pressure can be differentiated between the extensification and the intensification, wherein the former refers increasing cropping area while the latter refers increasing production per unit area.

Extensification and the associated problems are as old as agriculture. Extensification was more pronounced in less-developed areas of the world with poor infrastructure, poverty, and population pressure. It is often realized by reductions in the length of fallows and by encroachment into forests and fragile lands, resulting in land erosion, declining soil fertility, and loss of biodiversity. However, the major consequence of extensification is on biodiversity and climatic factors. In an operational view, this damage is integral to agriculture, because fertile land is essential for cultivation, which can be acquired only by clearing the preoccupied flora and fauna.

Intensification caused larger harm to the environmental fabric and accelerated its deterioration. Several high yielding hybrid cultivars, especially in wheat and rice, were released during the Green revolution period. Unlike the traditional cultivars, these varieties were fertilizer responsive and were specifically bred for greater yield only under high input agriculture practices. Moreover, as these varieties were mostly developed using exotic gene pool, which has not co-evolved with local pathogen populations, they were highly susceptible and farmers used heavy dose of synthetic chemicals to protect their crop from invading pathogens. Contrary to the polyculturing in traditional agriculture, monoculturing (using an isogenic single variety in a vast area of crop land) of high yielding cultivars during Green Revolution aggravated pathogen infestation. Consequently, between 1950 to1990s, overall world-wide use of fertilizers and the pesticides (including herbicides, insecticides, and fungicides) increased more than 10-fold. Each year the world uses about 3 million tonnes of pesticides, formulated from about 1,600 different chemicals, and approximately 200 million tonnes of fertilizers.

It is estimated that crops actually absorb only one-third to one-half of the nitrogen applied to farmland as fertilizer. Similarly, only 0.1% of applied pesticides reach the target pests, leaving the bulk of the pesticides (99.9%) to impact the environment. It is estimated that in China 10 million tonnes of fertilizer is discharged into water stream every year. The detailed report of Consultative Group on International Agricultural Research (CGIAR) on the environmental impact of Green Revolution in South Asia (An Assessment of the Impact of Agricultural Research in South Asia since the Green Revolution 2008) is really alarming. The Global Land Assessment of Degradation (GLASOD) mapping exercise found that 43% of South Asia's agricultural land was degraded to some degree. In India, 64% of the land area is degraded to some extent and 54% is moderately to severely degraded. In addition there are several other environmental issues such as water contamination with nitrates and phosphates from fertilizers and manures, pesticide poisoning of people and wildlife, unsustainable extraction of irrigation water from rivers and groundwater, and loss of biodiversity within agriculture and at landscape levels.

Green Revolution associated intensification pathways occurred mostly in irrigated and high potential rain-fed areas. This and the results of Global Land Assessment of Degradation mapping taken together raise a serious question: can the highly degraded crop land area ensure future food security? If they are degraded so much?

## PROSPECTUS OF BIOTECHNOLOGY AND ORGANIC FARMING IN FOOD PRODUCTION

According to the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), an international effort initiated by the World Bank, biotechnology is a broad term embracing all types of manipulation of living organisms ranging from conventional techniques of plant and animal breeding to recent innovations in tissue culture, genomics and marker-assisted breeding (MAB) used to augment natural breeding. The aim of crop improvement is straight forward: to produce varieties which support food security in terms of quantity or quality of food produced or bringing down the production cost. The success of different crop improvement protocols ultimately rely on the quality of the raw material *i.e.* quality of the genetic variability available in a given crop. Conventionally, plant breeding either choose a genotype from a pool of genotypes of land races or broaden selection platform by sexual crosses and choose the hybrids which show desirable attributes. It is to be emphasized that biotechnology cannot replace the age-old plant breeding practices, but can only harness the traditional methodologies. Harnessing can be broadly performed at two levels ranging from choosing parental combinations for marker assisted selection (non-GM biotechnology) to enhance the speed and precision of conventional methods, and to generate variability by alien gene transfer (GM biotechnology). Unfortunately, there has been too much emphasis and discussion on GM-biotechnology and too little focus on the potential merits and benefits of the many non-GM biotechnologies that are available and the positive role that they can play for food security and sustainable development. The polarized debate on GM-biotechnology has slowly infiltrated into non-GM biotechnologies, with the result that biotechnology as a whole is viewed with suspicion. The GM and non-GM biotechnologies are now used synonymously and it is often difficult for even expert to differentiate between the two.

The hectarage under GM crop cultivation increased 94 fold in last 16 years from 1.7 million hectares in 1996, when GM crops were first introduced for commercial cultivation to 160 million hectares in 2011. Soybean continued to be the principal biotech crop in 2011, occupying 75.4 million hectares or 47% of global biotech area, followed by maize (51.00 million hectares), cotton (24.7 million hectares and canola (8.2 million hectares) covering 32, 15 and 5% of the global biotech crop area respectively. Since commercialization of GM crops in 1996 to 2011, herbicide tolerance has consistently been the dominant trait. In 2011, herbicide tolerance deployed in soybean, maize, canola, cotton, sugar beet and alfalfa, occupied 59% or 93.9 million hectares of the global biotech area of 160 million hectares.

While the commercialization of Bt GM crops claims to have reduced the pesticide spraying, the commercialization of herbicide resistant GM crops accelerated the use of herbicides. For example, over 200 million pounds of glyphosate was used in US alone in 2008. Several studies have reported the severe environmental effect of wide spread application of herbicides, especially aerial spraying, on human health and eco-system. The selection pressure exerted by the Bt GM crops on insects resulted in the emergence of Bt toxin resistant insects while the extensive herbicide spraying led to the emergence of herbicide resistant weeds. The GM crop cultivation statistics clearly indicate that, although the crop area showed 94 fold increases in last 16 years, diversification of GM technology with respect of crop or trait is very little. Genetic modification still focuses on genes controlling two monogenic traits: *cry* gene from *Bacillus thuringiensis* providing insect resistance (insect species of the orders Lepidoptera, Diptera, Coleoptera, Hymenoptera and Nematodes) and herbicide (such as glyphosate) tolerant *5-enolpyruvylshikimate-3-phosphate synthase* (EPSPS) gene from bacteria. According to an assessment of International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) in 2008, yields of GM crops were "highly variable" and in some cases, "yields declined". The report noted, "Assessment of the technology lags behind its development, information is anecdotal and contradictory, and uncertainty about possible benefits and damage is unavoidable." The argument of GM proponents that the GM technology will support food security is not realistic since so far no GM crop is produced with increased intrinsic yield (potential yield). The benefit of GM crops is purely operational or derived by way of either reduced damage due to insects or weeds. All yield related traits are polygenic and a success in intrinsic yield improvement by engineering multiple genes is grim, especially in view of the increasing evidence of highly complex nature of gene regulation mediated by transcription factors, miRNAs and epigenetic factors.

Non-GM biotechnology, especially marker assisted selection (MAS), has much to offer to food security. The traditional breeding involves selection of individual plants or animals based on visible or measurable traits while MAS relies on the selection of a trait based on a molecular marker linked to it. Thus, breeding is more precise and efficient and the selection can be performed even in the absence of a visible trait. MAS also allows breeding of complex traits not feasible through previous conventional methods. Only a fraction of the massive germplasm resources of many of the crops maintained at different research institutes under Consultative Group on International Agricultural Research's (CGIAR) has yet been used. Precise genotyping coupled with high throughput association mapping may ensure a continuous supply of genetic variability for sustained varietal development. Several improved varieties have been released world over both by the private and public sector research organizations. Tissue culture and related applications, DNA and immune-diagnostic technique for accurate identification of pathogen populations, bio-fertilizers and bio-pesticides are other promising non-GM biotechnologies capable to support agricultural innovations.

Proponents of organic farming (OF) visualize food security with minimum pressure on environmental fabrics. OF has several advantages. The farmers could use traditional cultivation practices together with the locally adapted traditional cultivars, thereby protecting the environment from synthetic chemicals, producing clean products and promoting the *in situ* conservation of the biodiversity of a given crop, which is evolved, preserved and maintained under the careful surveillance of our forefathers over centuries. According to International Federation of Organic Agriculture Movements (IFOAM), 32.2 million hectares, spread across 141 countries were in organic management in the year 2007. Although this constitutes only 0.8 percent of the agricultural land of the 141 countries covered by the survey, it revealed a substantial increase in area under OF globally from 11 million hectares in 1996 to 32.2 million hectares in 2007. According to FAO (Clean production action 2005), the impacts of transition to OF from high input agriculture are: (i) The OF decrease yield in developed countries and the range depend on the intensity of external input use before OF conversion; (ii) In developing countries where the external input was minimum, the conversion to OF provided an yield identical to that of Green Revolution; (iii) In the rain-fed traditional agriculture with low input, the OF has a potential to increase the yield. In short, wherever the yield is low due to the sub-optimal farming practices, the OF gives improved yield. An example is East Africa, where, according to a UN report on OF in Africa (2008), OF increased yield.

The serious disadvantage is that the yield is low as pointed out by the FAO report (2005), and naturally the market value of OF products are nearly double than that of the non-OF products. People in developed countries may view the OF products as a symbol of luxury, but for the people of developing and under developed countries, OF practice may lead to two fold harm to their food security: low productivity and high market value. The basic question is whether we can feed 7-9 billion population by re-adopting practices we followed till 1960's, which could not produce sufficient food to feed the then population of over 3 billion? The higher yield "projected" for the GMOs may entice the farmers to adopt GMOs, but how many farmers can be enticed to follow OF practices for the noble cause of protecting the environment. Unless the state machinery intervenes with considerable subsidy and excellent management strategies OF will see difficulty in being a primary mode of agriculture. Compounded with free market economic policies and pressures, governments will find it increasingly difficult to offer subsidies. OF could be encouraged among those for whom the agriculture is for food not for money, especially among urban people in terrace farming and homestead gardens. There are two limitations for this also: mostly vegetable could be promoted in terrace farming and suitable mechanism should be identified to ensure adequate supply of manure.

**FUTURE DIRECTIONS**

*"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". (World Food Summit, 1996)*. According to WHO food security has three facets: food availability, food access, and food use. Food availability is having available sufficient quantities of food on a consistent basis. Food access is having sufficient resources, both economic and physical, to obtain appropriate foods for a nutritious diet. Food use is the appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation. However, the FAO adds a fourth facet: the stability of the first three dimensions of food security over time. In fact, of the four facets, agriculture could ensure only the first one, the food availability. Adequate food production alone does not suffice food security. Food security is a compounded effect of several factors. Latest FAO figures indicate that, in spite of abundance in food production, an estimated 925 million people are undernourished in 2010, representing almost 16 percent of the population in developing countries. Over the past two decades, the number of food

emergencies has risen from an average of 15 per year in the 1980s to more than 30 per year from 2000 onwards. These crises are fueled mainly by armed conflict, often compounded by drought and floods, proving catastrophic for millions of people who are driven from their homes, unable to work in their fields, cut off from markets for their produce and from commercial supplies of seed, fertilizer and credit.

According to FAO, approximately one third (1.3bn tonnes) of the total food produced globally is wasted. According to the report, industrialised and developing countries waste or lose roughly the same amount of food each year – 670m and 630m tonnes respectively. While rich countries waste food primarily at the level of the consumer, the main issue for developing countries is food lost due to weak infrastructure – including poor storage, processing and packaging facilities that lack the capacity to keep produce fresh. Another important factor that incur crop loss is disease and weeds, which together damage about 16% of the crop globally despite efforts to control the diseases and weeds. Reducing food/crop losses due to wastage and diseases could have an immediate and significant impact on livelihoods and food security.

Godfray et al. (2010) put across four important factors to be considered while formulating policies for designing food production system between now and 2050: factors affecting the demand for food (population growth, changes in consumption patterns, the effects on the food system of urbanization and the importance of understanding income distributions); trends in future food supply (crops, livestock, fisheries and aquaculture, and 'wild food'); exogenous factors affecting the food system (climate change, competition for water, energy and land, and how agriculture depends on and provides ecosystem services) and cross-cutting themes (food system economics, food wastage and links with health). They conclude that major advances in sustainable food production and availability can be achieved with the concerted application of current technologies and the realization of the importance of investing in research sooner rather than later to enable the food system to cope with both known and unknown challenges in the coming decades. A rapid change in socio-economic environment is predicted by 2050, wherein, of the 9 billion people predicted for 2050, 70 percent will be in urban areas with great changes in diet shifting to increased proportions of vegetables, fruits and livestock products. Number of plant species being used as source food has been reduced over centuries and currently 14 crop plants provide the bulk of food for human consumption. There are numerous plants that are less intensively grown yet fulfill important nutritional requirements. Crop diversification incorporating such plants would help to fight malnutrition. Another important factor is climate change, which is expected to have an increasingly negative impact on agriculture and food security. Today, the agricultural sector accounts for approximately 15-18 % of total global anthropogenic emissions and is expected to increase steadily. Land area under biofuel crops is expected to grow substantially in coming years and will compete with crop lands. Projected growth in biofuel production to 2030 could require from 35 million to 54 million hectares of land (2.5 to 3.8 percent of available arable land).

Man is part of the environment. Quality of life depends on the quality of environment where we live. Through agriculture, urbanization and industrialization man steadily infringed the delicate environment. By infringement of the environmental fabrics we are jeopardizing our own existence. To a greater extent the Green Revolution acted as a universal model for higher agricultural production for an increasing population. In the absence of any such model in the past - Green Revolution period, we could evaluate the pros and cons of several agricultural production methodologies and innovations in the last few decades including traditional agriculture, conventional crop improvement methodologies, high input agriculture, GM and non-GM crop improvement methodologies, organic farming and many others. It is certain that no single environmentally sustainable production technology would ensure global food security. Not being fascinated or misguided by the technology hypes, every country and every region should formulate a vision document for food production for next 40 years, emphasizing methods that are sustainable locally. Our vision for next 40 years should be in a strengthening-adoption-innovation perspective, wherein the available capabilities should be strengthened, adopted, if needed when not available locally and invest in research for innovations relevant locally. Whatsoever it may be, a balance between natural capital (soil, climate, water, air and biodiversity) and man-made capital (synthetic chemicals either pesticides or fertilizers, breeding and genetic manipulation methods, cultivation practices, irrigation machines etc.) is extremely essential because the resources of Mother Earth should be preserved for generations.

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# Extent of Climate Change Over India and its Projected Impact on Indian Agriculture

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## INTRODUCTION

In the last two decades, much has been written and talked about global warming and climate change. The topic of climate change and variability has received focussed attention in recent years from the international community. There is now incontrovertible evidence that the world's climate has been undergoing change due to global warming resulting from decades of fossil fuels powered economic development which left behind long-lasting green house gases into the atmosphere. This warming appears to have started during the industrial revolution of the 19$^{th}$ century. Modern society has relied more on technology to control or modify nature to suit lifestyles rather than live in harmony with nature. Gradually, the balance between humans and nature, evidenced by a stable climate, started to change.

Detailed and authenticated studies on global climate undertaken in the last several years have shown unequivocally that the climate system is warming which is likely to continue for several decades. This is evident from global warming trends, melting of ice and snow and rise in sea level. Over the past 50 years, nine out of ten natural disasters around the world have been caused by extreme weather and climate events. Storms, floods, droughts, heat waves, dust storms, wild-fires and other natural hazards threaten the lives and livelihoods of millions of people worldwide. Climate models suggest that several weather extremes are likely to increase in frequency and intensity. Floods, storm surges and tropical cyclones could force many people to relocate. Communities exposed to the greatest risk from climate change are mainly living in developing and least developed countries.

Nearly 40 per cent of the world population lives within 100 km of the coastline. These include the 60 million inhabitants of small island developing states, who are dependent on ocean resources and tourism. Sea-level rise and changes in ocean temperature and characteristics have profound impact on their lives and livelihoods.

By the 2050s, freshwater availability in most parts of Asia, particularly in large river basins, is projected to decrease. Coastal areas will be at greatest risk due to increased flooding from the sea and, in some mega-deltas, flooding from the rivers. By the end of the 21st century, the sea level is predicted to rise by 28 to 58 cm or even up to one metre, if continental ice sheets melt faster as temperature rises. The impact of rising seas will be felt most acutely along coasts and islands that may be far away from melting polar ice.

Climate change is now inevitable, greenhouse gases will persist over long periods of time and the atmosphere will warm progressively. There is a societal need for mitigation and adaptation to climate change which includes achieving reduction in emissions of greenhouse gases and energy efficiency. Adaptation will require further investment in coastal protection, relocation and other measures, based on improved projection of sea-level rise and extreme events.

The manifestation of Global warming and climate change in India has been extensively studied of late. India which has a large population (121 Crores in 2011) with a high population density of 364 people per square km is vulnerable to the negative effects of climate change such as sea level rise and coastal erosion. India is still an agriculture hedged economy and any shortage in food production due to failure of monsoon and other reasons leads to several adverse consequences.

In this paper we provide details on the various weather parameters which are measured and archived by India Meteorological Department (IMD) which is the country's apex weather agency, the effect of climate change over India that has already taken place, projection on future climate change and the likely effect of climate change over India on Indian agriculture.

## IMD'S OBSERVATIONAL ORGANISATION

The India Meteorological Department (IMD) was established in the 19th century in the year 1875 and is the oldest scientific department of India. The present observational network of IMD is depicted in Table 1a in brief. That of Regional Meteorological Centre, Chennai which coordinates the mandate of delivering weather services to the four southern states of Tamil Nadu, Andhra Pradesh, Karnataka and Kerala besides the union territories of Pondicherry and Lakshadweep islands is presented in Table 1b. IMD takes observations of several parameters including surface parameters such as pressure, temperature, humidity and wind. Parameters such as ozone, radiation, evaporation, air pollution are also measured. Recently IMD has established a large number of Automatic Weather/ Automatic Rain Gauge stations (AWS & ARG) all over India which take observations throughout the day and transmit them via satellite to IMD's server and the data is available in the web in a couple of hours. The data collected by IMD has been meticulously archived in the National Data Centre (NDC), IMD, Pune. Complete listing of the data archived by NDC ia available in the website http://www.imdpune.gov.in/.

**Table 1a**
**Observational Organisation of IMD**

| S.No. | Type of Observatories | Number |
|---|---|---|
| 1 | Surface Observatories | 552 |
| 2 | Pilot Balloon Observatories | 62 |
| 3 | RS/RW Observatories | 39 |
| 4 | Aerodrome Met. Offices (AMO) | 18 |
| 5 | Aerodrome Met. Stations (AMS) | 51 |
| 6 | Storm Detection Radar Stations | 17 |
| 7 | Cyclone Detection Radar Stations | 10 |
| 8 | High Wind Recording Stations | 22 |
| 9 | Stations for receiving cloud pictures from satellites | 10 |
| 10 | Automatic Weather Staions | >1350 |
| 11 | Hydrometeorological Observatories | 633 |
| 12 | i) Non-departmental raingauge stations:<br>a) Reporting<br>b) Non-Reporting<br>ii) Non-departmental Glaciological Observatories (Non-reporting) | <br>7941<br>4959<br>37 |
| 13 | Agrometeorological Observatories | 238 |
| 14 | Evaporation Stations | 238 |
| 15 | Evapotranspiration Stations | 42 |
| 16 | Seismological Observatories | 51 |
| 17 | Ozone related Observatories | 14 |
| 18 | Radiation Observatories | 54 |
| 19 | Atmospheric Electricity Oservatories | 4 |
| 20 | Pollution and Climatological Observatories | 25 |
| 21 | Ships of the Indian Voluntary Observing Fleet | 184 |
| 22 | Soil Moisture Recording Stations | 43 |
| 23 | Dew-fall Recording Stations | 76 |

**Table 1b**
**Observational network under Regional Meteorological Centre, Chennai**

| Type of Observatory | AP | KAR | KER | TN | Total |
|---|---|---|---|---|---|
| Surface (dept) | 8 | 9 | 10 | 16 | 53 |
| Surface (non-dept) | 19 | 18 | 7 | 24 | 68 |
| Pilot Balloon | 4 | 3 | 3 | 3 | 13 |
| RS-RW | 3 | 2 | 3 | 2 | 10 |
| RS-RW (GPS) | 2 | 0 | 2 | 1 | 5 |
| RS-RW Radiosonde only | | | 1 | | 1 |
| Hydromet | 10 | 8 | 2 | 2 | 22 |
| Raingauges (reporting DRMS) | 179 | 310 | 59 | 191 | 739 |
| Raingauges(non-reporting, non-dept) | 535 | 971 | 73 | 289 | 1868 |

| Type of Observatory | AP | KAR | KER | TN | Total |
|---|---|---|---|---|---|
| Seismic | 2 | 1 | 2 | 3 | 8 |
| Ozone monitoring | | | 1 | 1 | 2 |
| Radiation monitoring | 3 | 3 | 3 | 3 | 12 |
| Evaporation measurements | 7 | 4 | 4 | 11 | 26 |
| Dew measurements | 2 | 2 | 2 | 1 | 7 |
| Aviation CWO | 4 | 3 | 4 | 6 | 17 |
| Aeronautical FO | 1 | 1 | 1 | 1 | 4 |
| Storm detection radar | 1 | 1 | 0 | 1 | 3 |
| Doppler Weather Radar | 4 | 0 | 0 | 1 | 5 |
| Cyclone Detection Radar | 0 | 0 | 1 | 1 | 2 |
| BAPMON stations | 1 | 0 | 1 | 1 | 3 |
| CWDS | 80 | 5 | 5 | 58 | 148 |
| AWS | 35 | 26 | 16 | 28 | 105 |

Surface weather data of nearly 200 observatories maintained by IMD and similar data for more than 300 extra departmental observatories have been available for more than a century though the period of availability might vary from station to station. Rainfall data of more than 5000 stations are available in IMD's archives for a very long period. Upper air data called Radio sonde data was collected from the mid 1940s – and as shown in Table 1a IMD at present maintains more than 35 such observatories. Aside from daily and hourly data, the monthly means are derived for parameters such as temperature, humidity, pressure, etc. whereas cumulative totals are derived for parameters such as rainfall.

For undertaking any study on climate change over India, the vast repository of data on weather parameters collected by IMD for more than 100 years and archived would be a major input.

## MANIFESTATION OF CLIMATE CHANGE OVER INDIA AT LOCAL AND REGIONAL LEVELS

### Methodology in Brief

The study on climate change in respect of any parameter essentially boils down to a detailed and careful trend analysis of the time series in question (WMO, 1966). The climatic change can be studied for any given period such as month, season or annual and also for a given station, district, region and for a country or even continent. As the resolution of the time period chosen and the region selected gets higher, there would be more number of time series to be dealt in. The choice of the resolution would depend upon the requirement at hand.

**Rainfall**

Change in the rainfall pattern can be analysed for any given period such as month, season or annual and also for a given station, district, region and for the entire country. Fig.1 presents the geographical distribution of the 36 meteorological sub-divisions into which India is divided by IMD for describing rainfall activity and performance. The monthly / seasonal / annual rainfall of 30 meteorological sub-divisions of India for each year since 1871 is available in the website of IITM Pune (www.tropmet.res.in/). Though based on limited number of stations, this data set is homogeneous in nature. In this discussion we confine our analysis on climate change of annual rainfall only. 30 sub divisions are listed in Table 2, the mean and coefficient of variation of annual rainfall of the sub divisions considered for the 141 year period 1871-2011. The correlation coefficient (CC) betwen the rainfall time series of each sub division and the series say $T_i$ defined by $T_i$ = { $i=1,n$ $n=141$} provides an indication of linear trend in the series. The Student's *t*-value of the CC is computed . If $t > 1.96$, CC is significant at 5% level and if $t > 2.58$, at 1% level. The increase / decrease of rainfall over a decade viz.10 year period can be easily derived from the regression equation which is also given in Table 2 alongwith values of CC and *t*.

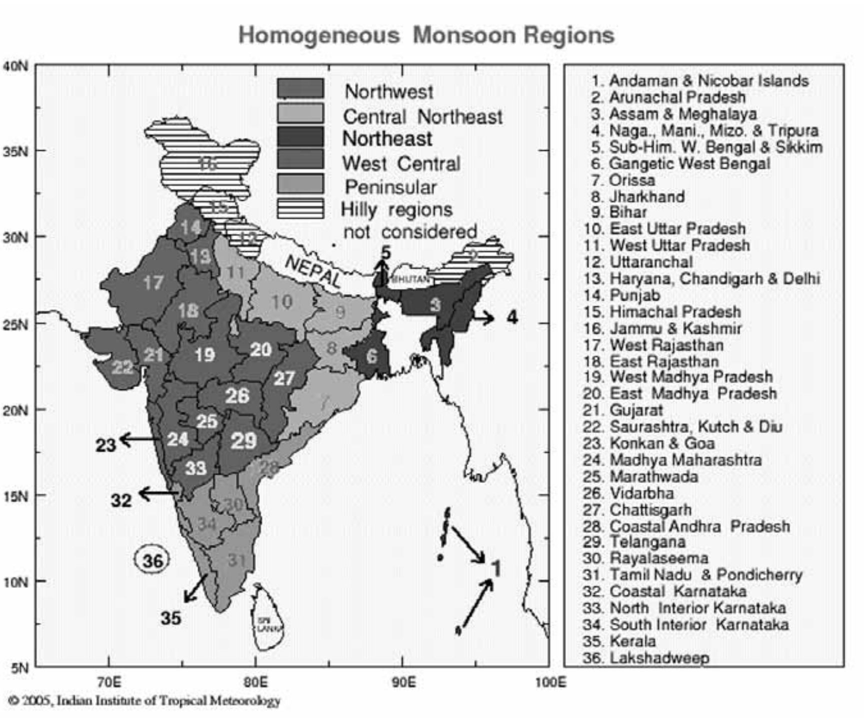


**Fig. 1**
**Geography of 36 meteorological sub-divisions of India**

**Table 2**
**Trend analysis of annual rainfall of 30 Met. subdivisions of India and of seasonal rainfall of Kerala during 1871-2011**

| S. No. | Sub division | Mean (mm) | CV% | CC | t value | Change for 10 years (mm) |
|---|---|---|---|---|---|---|
| 1 | Assam &M-laya | 2337.3 | 11.6 | -0.15 | -1.8 | -9.9 |
| 2 | NMMT | 1980.8 | 12.6 | -0.19 | -2.3* | -11.5 |
| 3 | SHWB & Sikkim | 2503.0 | 13.2 | -0.01 | -0.2 | -1.0 |
| 4 | Gangetic WB | 1542.1 | 15.3 | 0.17 | 2.0* | 9.5 |
| 5 | Orissa | 1481.6 | 13.3 | -0.03 | -0.4 | -1.6 |
| 6 | Jharkhand | 1341.6 | 14.8 | -0.05 | -0.6 | -2.6 |
| 7 | Bihar | 1223.9 | 17.8 | -0.04 | -0.5 | -2.2 |
| 8 | East Uttar Pradesh | 1022.2 | 20.6 | -0.07 | -0.8 | -3.5 |
| 9 | West Uttar Pradesh | 874.7 | 20.5 | -0.05 | -0.5 | -2.0 |
| 10 | Haryana | 556.9 | 25.8 | 0.11 | 1.3 | 3.8 |
| 11 | Punjab | 637.7 | 27.9 | 0.14 | 1.7 | 6.1 |
| 12 | West Rajasthan | 295.6 | 37.2 | 0.06 | 0.8 | 1.7 |
| 13 | East Rajasthan | 685.7 | 25.0 | -0.07 | -0.8 | -3.0 |
| 14 | West MP | 941.0 | 18.8 | -0.07 | -0.8 | -3.0 |
| 15 | East MP | 1252.3 | 16.6 | -0.20 | -2.4 * | -10.1 |
| 16 | Gujarat | 910.3 | 30.0 | -0.01 | -0.2 | -0.9 |
| 17 | Saurashtra & Kutch | 477.4 | 42.1 | 0.09 | 1.1 | 4.7 |
| 18 | Konkan & Goa | 2538.8 | 18.9 | 0.17 | 2.0* | 20.1 |
| 19 | M Maharashtra | 739.8 | 19.5 | 0.04 | 0.5 | 1.4 |
| 20 | Marathwada | 831.2 | 26.1 | 0.03 | 0.3 | 1.5 |
| 21 | Vidarbha | 1084.2 | 18.8 | -0.08 | -0.9 | -4.0 |
| 22 | Chattisgarh | 1353.3 | 17.0 | -0.27 | -3.3** | -15.4 |
| 23 | Coastal AP | 981.7 | 20.1 | 0.15 | 1.7 | 7.0 |
| 24 | Telangana | 888.4 | 21.3 | 0.13 | 1.5 | 6.0 |
| 25 | Rayalaseema | 722.3 | 22.3 | 0.14 | 1.7 | 5.6 |
| 26 | TNadu&Puduchery | 930.9 | 16.0 | 0.11 | 1.3 | 3.9 |
| 27 | Coastal Karnataka | 3278.0 | 16.4 | 0.18 | 2.1* | 23.1 |
| 28 | NI Karnataka | 833.7 | 17.9 | 0.10 | 1.1 | 3.5 |
| 29 | SI Karnataka | 883.9 | 17.0 | 0.06 | 0.7 | 2.0 |
| 30 | Kerala | 2827.7 | 14.6 | -0.01 | -0.1 | -0.5 |
| | **India** | **1087.1** | **9.3** | **-0.03** | **-0.4** | **-0.8** |
| 1 | **For Kerala** JF | 28.0 | 96.0 | 0.09 | 1.1 | 0.6 |
| 2 | MAM | 390.4 | 40.6 | 0.06 | 0.7 | 2.4 |
| 3 | JJAS | 1924.9 | 19.0 | -0.12 | -1.4 | -10.9 |
| 4 | OND | 484.4 | 30.3 | 0.21 | 2.5* | 7.5 |

*Data based on the period 1871-2011, data source IITM, Pune , CV – Coefficient of variation, CC – correlation coefficient, */** - CC significant at 5,1% level*

As shown the changes are significant with positive change having taken place over Gangetic West Bengal, Konkan & Goa and Coastal Karnataka. Significant negative changes are manifested over NMMT, East Madhya Pradesh and Chattisgarh. In CK the change per decade is 23.1 mm, i.e. 23.1 cm for a century a quite substantial figure. Over K&G, also the change is 20.1 mm per decade or 20.1cm for a century. Over Chattisgarh, it is -15.4 mm for a decade showing decrease. Over the remaining sub divisions the changes are not statistically significant. For the entire India, the mean rainfall is 1087.1 mm, CV is 9.3%, CC is -0.03 which is not statistically significant. In fig. 2 we present the rainfall graph (annual) of India and that of the subdivisions K&G, Kerala and Tamil Nadu for the period 1871-2010. For Indian annual rainfall the trend line indicates little change. The rainfall of K&G manifests significant rising trend whereas that of Kerala shows a very weak negative trend. From Fig.2 and Table 2 it is evident that some regions have reported negative trend and some positive trend and for the entire India the trend is by and large insignificant.

In Table 3 we present the annual average rainfall for the first half of the 20$^{th}$ century viz. 1901-50 and 1951-2000, for several stations of Kerala and a few stations of neighbouring states. As shown Alleppey, Punalur, Kottayam, Tiruvalla, Peermade have shown noteworthy decrease. Kasargode and Kochi have shown increase whereas raingauges located in Coastal Karnataka such as Mangalore, Karwar and Udupi have shown increase. In Kanyakumari district bordering southern parts of Kerala, Pechipparai which is in the high rainfall zone has shown decrease of rainfall. Chennai located in the northern parts of Coastal Tamil Nadu and experiencing an entirely different type of climatology compared to stations located along the west coast of India, has registered increase of 117 mm rainfall in the second half. Thus it is again evident that climate change in respect of rainfall in respect of individual stations manifests in a mixed way with positive and negative changes. It must be stated here that rainfall series for individual months / seasons in some of the series may have manifested significant trend. In some other cases there could be recent significant trend. A much more detailed analysis of time series must be performed to detect and analyse such incidences. What is presented in Table-2 is an overall trend analysis only and should be interpreted and understood in that context. A research report by IITM, Pune (IITM, 2009) has found out that there has been a significant increase in the occurrence of extreme rainfall events of rainfall of individual stations. That rainfall is a much more variable parameter in a spatial sense has to be kept in mind while interpreting temporal changes in rainfall pattern.

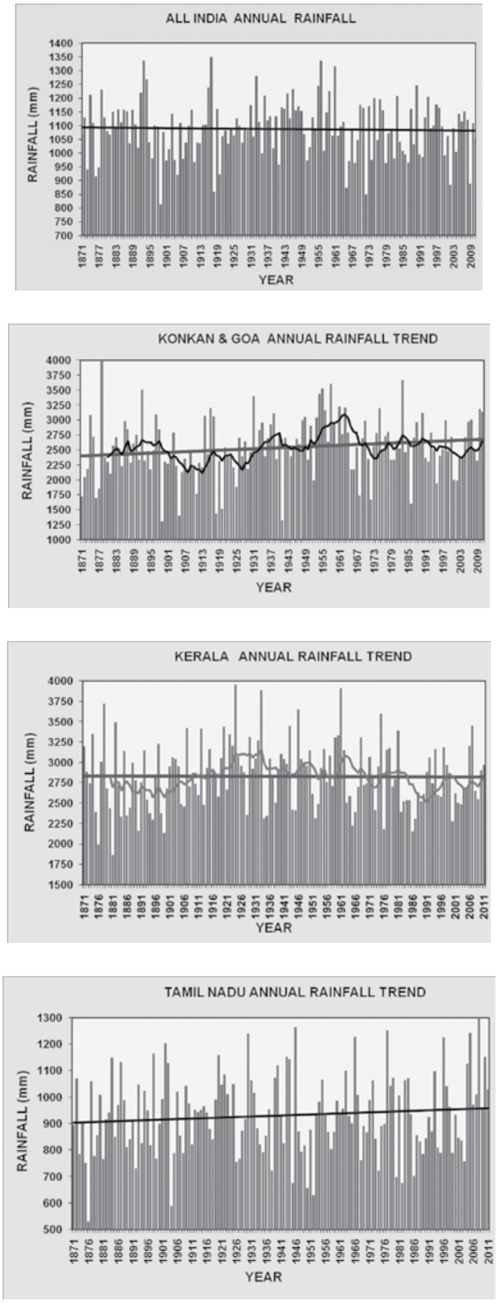


**Fig. 2**
**Time series of annual rainfall of India, K&G, Kerala and TN, 1871-2011.**

**Table 3**
**Annual mean rainfall of some stations of Kerala , Tamil Nadu and Karnataka**
**Based on the periods 1901-1950 and 1951-2000**

| Sl. No | Station Name | State | Rainfall in mm | | Difference |
|---|---|---|---|---|---|
| | | | 1901-1950 | 1951-2000 | |
| 1 | Thiruvananthapu-ram | Kerala | 1812.1 | 1792.0 | -20.1 |
| 2 | Kollam | Kerala | 2398.1 | 2357.8 | -40.3 |
| 3 | Alleppy | Kerala | 3274.8 | 3006.1 | -268.7 |
| 4 | Kochi | Kerala | 3046.6 | 3147.2 | 100.6 |
| 5 | Calicut | Kerala | 3178.1 | 3175.8 | -2.3 |
| 6 | Kannur | Kerala | 3274.4 | 3256.2 | -18.2 |
| 7 | Kasargode | Kerala | 3477.8 | 3631.3 | 153.5 |
| 8 | Palghat | Kerala | 2019.4 | 1999.1 | -20.3 |
| 9 | Munnar | Kerala | 3815.9 | 3744.3 | -71.6 |
| 10 | Peermade | Kerala | 5164.8 | 4427.7 | -737.1 |
| 11 | Punalur | Kerala | 3159.4 | 2760.6 | -398.8 |
| 12 | Tirussur | Kerala | 3096.4 | 3082.3 | -14.1 |
| 13 | Kottayam | Kerala | 3261.5 | 2858.0 | -403.5 |
| 14 | Tiruvalla | Kerala | 3093.0 | 2732.2 | -360.8 |
| 15 | Neyyattinkara | Kerala | 1653.9 | 1622.6 | -31.3 |
| 16 | Pechipara | Tamil Nadu | 2292.2 | 1990.2 | -302.0 |
| 17 | Kuzhithura | Tamil Nadu | 1459.5 | 1326.5 | -133.0 |
| 18 | Chennai | Tamil Nadu | 1285.6 | 1402.7 | 117.1 |
| 19 | Madurai | Tamil Nadu | 893.9 | 841.1 | -52.8 |
| 20 | Coimbatore | Tamil Nadu | 614.2 | 613.8 | -0.4 |
| 21 | Mangalore | Karnataka | 3397.9 | 3633.6 | 235.7 |
| 22 | Bangalore | Karnataka | 888.9 | 977.4 | 88.5 |
| 23 | Karvar | Karnataka | 3074.6 | 3238.7 | 164.1 |
| 24 | Udipi | Karnataka | 3739.1 | 3949.5 | 210.4 |

## Temperature

Surface temperature is the parameter likely to be impacted substantially in the Climate change scenario. The observatories of IMD measure surface temperature frequently but maximum and minimum temperatures are the most published and referred. The mean of the above two extremes is taken as the average temperature of the day. The monthly / seasonal / annual temperature can be computed from the daily values, for a given station. From this data, average temperature of a state, region and finally the entire India can be derived. The monthly mean temperature data for several IMD stations is available at the NDC of IMD for the period since 1901.

The derivation of mean temperature and its anomaly for every year for the entire Indian region keeping the normal at the average period 1961-1990, in analogy with similar type of methodology adopted for calculating global climate anomalies by International agencies, has been done by IMD. The graph for the period 1901-2010 and that for the global temperature anomalies are presented in Fig.3a. As shown the Indian temperature anomalies are negative for most of the years prior to 1960 and positive in the post 1960 period. Since 1991 they are substantially positive and the profile is similar to the Global temperature index indicating the presence of signal on global climate change in India. The temperature rise has been in the order of 0.2 – 0.4°C. It must be stated that the temperature rise as manifested over India could be partly due to urban heat island effort as most of the observatories of IMD are situated in towns and cities. Fig.3b presents the spatial pattern of trend for 100 years hand on data for 1901-2009. In most of the regions there is warming trend save for two regions one over North Gujarat and other over Eastern Uttar Pradesh.

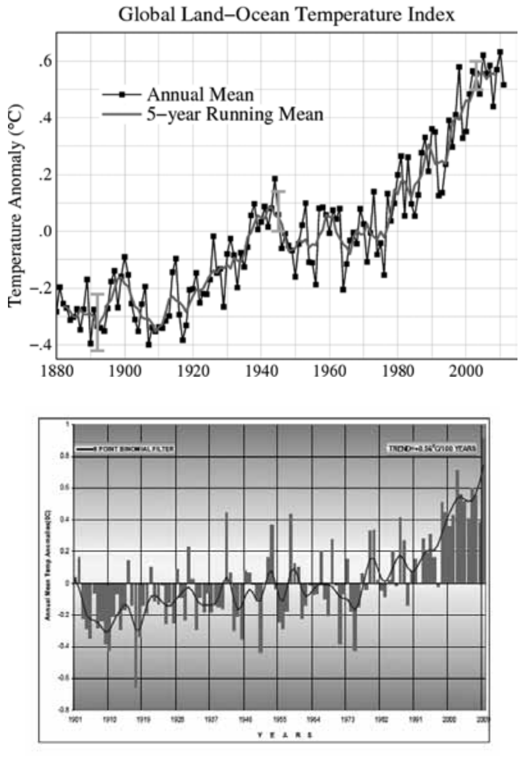


**Fig. 3a**
**Time series of mean temperature over India during 1901-2009 (bottom) and Global Land – Ocean temperature Index 1880-2006 (top).**

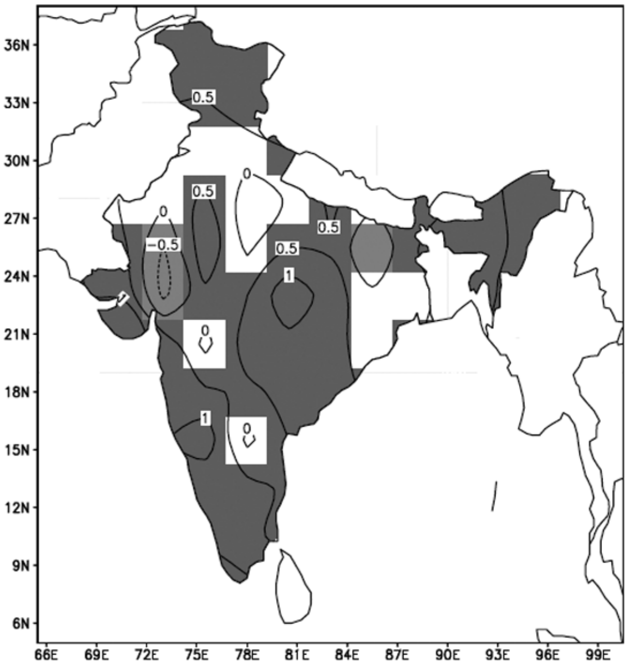


**Fig. 3b**
**Spatial Pattern of Trend ( deg c/100 years) in Mean Annual Temperature Anomalies (1901-2009) Areas where trends are significant are shaded (red: warming, blue: cooling)**

## Sea level rise

India has a very long coast line of nearly 7000 kms and the coastal areas are densely populated. As such sea level rise carries many implications making the population more vulnerable to the adverse effects of coastal erosion and cyclone related disasters such as storm surge. The estimated msl rise trends for Mumbai, Kochi, Visakhapatnam, Chennai derived based on more than 20 years of data was found to be 1-2mm/year. The fourth report of the IPCC (Inter Government Panel on Climate Change) estimated the value of global MSL rise close to 1.8 mm/ for the period 1961-2003 (Unnikrishnan, 2007)..

### Frequency of Cyclones and Depressions

IMD's Storm Track Atlas (IMD, 1979 & 1996) presents the tracks of cyclones and depressions (CDs) over the Indian seas, for the period since 1877. The computerised cyclone e-Atlas (IMD, 2008) and the recently introduced web based e-Atlas (www. rmcchennaieatlas.tn.nic.in) provide tracks of CDs since 1891 up to the most recent year viz. 2011. The CDs were tracked by IMD with the help of satellite imageries since early 1960s. In table 4 we present the trend analysis of the following three time series of CDs over North Indian Ocean (NIO), i.e. Bay of Bengal, Arabian Sea and the Indian Land mass (i) The annual frequency of D+CS+SCS, 1961-2010 (D – Depression, CS – Cyclonic Storms, SCS – Severe CS), (ii) Annual frequency of SCS and (iii) June-September D+CS+SCS which are the monsoon disturbances. Fig 4a&b presents the time series in respect of (i) and (iii) above along with the tracks of the respective CDs for the first half of 1961-2010 viz. 1961-1985 and the second half viz. 1986-2010. The tracks have been generated from IMD's Cyclone e-Atlas (2008).

As clearly evident from Fig.4a&b and Table 4 the frequencies have shown sharp decrease since the 1980s in all the cases. Whereas 367 number of CDs affected NIO during 1961-1985, the frequency decreased to 226 during 1986-2010. In respect of (ii) viz. Severe Cyclonic storms which have the highest damage causing potential, the decreasing trend is clearly evident. The frequencies for the two halves are 94 and 55 respectively. The monsoon depressions forming over Bay of Bengal and by and large moving westwards over the land are the most important synoptic disturbances during the south west monsoon season (June-September) of India. As seen there is an over all decreasing trend, frequency of CDs during 1961-85 is 184, that during 1986-2010 is 90 only, the tracks of both the periods also depicted in Fig.4a&b.

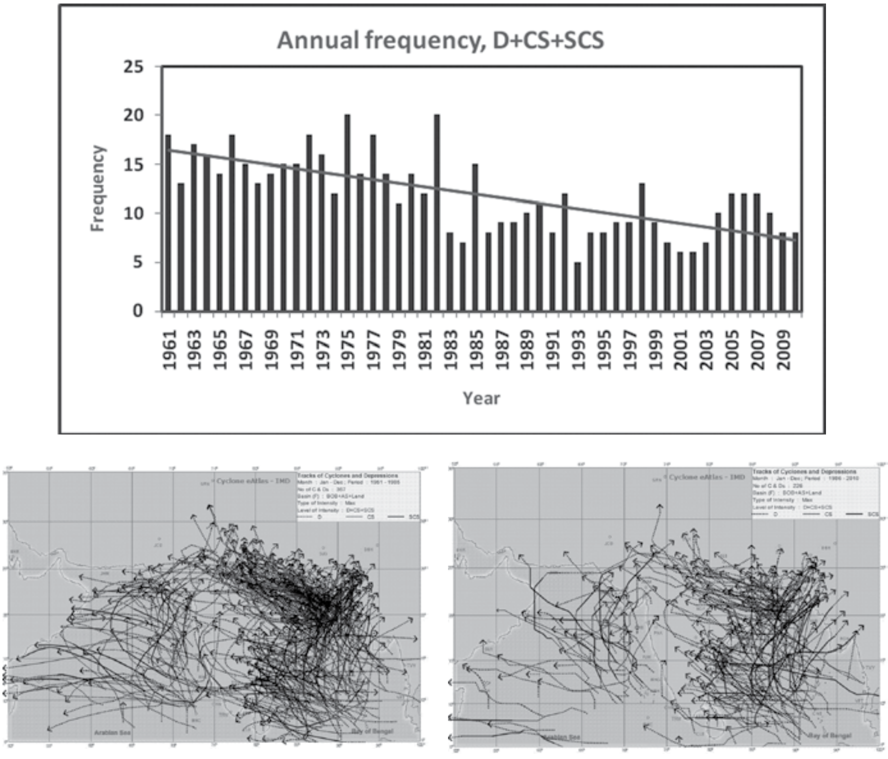


**Fig. 4a**

**Time series of frequency of D+CS+SCS over NIO, Jan-Dec & Jun-Sep 1961- 2010and Tracks 1961-85, D,CS, SCS – As in Table 4 NIO – North Indian Ocean.**

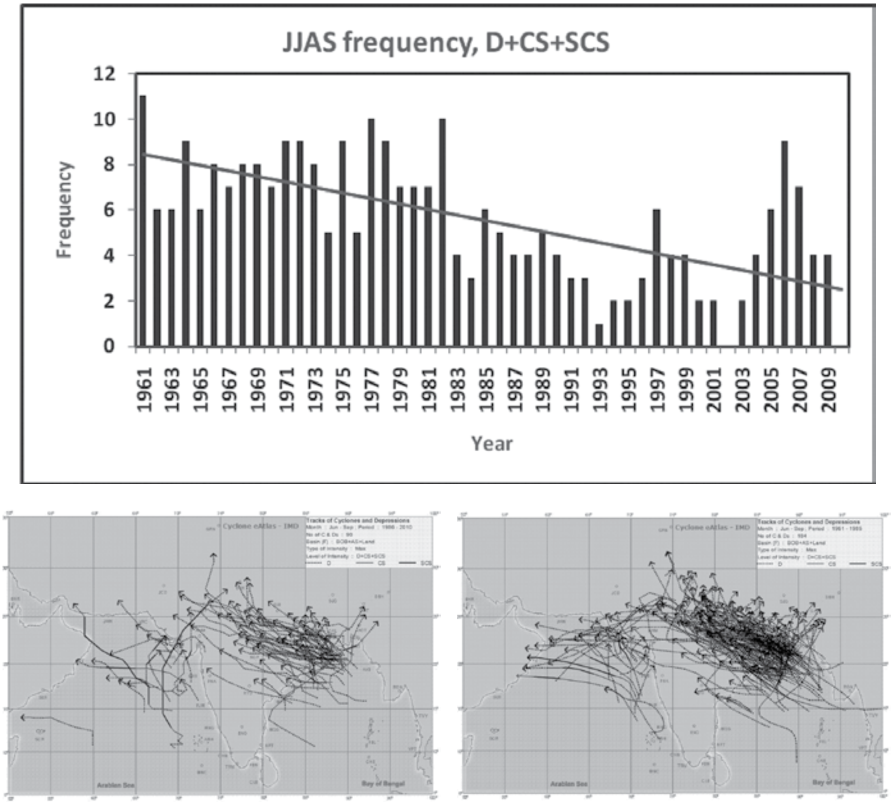


**Fig. 4b**
**Time series of frequency of D+CS+SCS over NIO, Jan-Dec & Jun-Sep 1961- 2010and Tracks 1986-2010, D,CS, SCS – As in Table 4 NIO – North Indian Ocean.**

**Table 4**
**Trend analysis of frequency of D+CS+SCS over Indian seas, 1961-2010**

| Season | Category | Mean | CC | *t* – value | Change in 10 years | Freq 1961-85 | Freq 1985-2010 |
|---|---|---|---|---|---|---|---|
| Annual (Jan-Dec) | D+CS+SCS | 11.9 | -0.67 | 6.6** | -1.86 | 367 | 226 |
| Annual | SCS | 3.0 | -0.47 | 3.7** | -0.54 | 94 | 55 |
| Jun-Sep | D+CS+SCS | 5.5 | -0.64 | 5.7** | -1.21 | 184 | 90 |

*D, CS, SCS – Depression, Cyclonic Storm, Severe Cyclonic Storm ** As in Table 2*

Thus the postulate that climatic change is leading to more cyclones forming and reaching higher intensities has not been found true in the Indian context.

## PROJECTED CLIMATE CHANGE SCENARIO OVER INDIA

In the previous section we presented the situation pertaining to climate change which has actually taken place in respect of a few but critical parameters. Projecting the climate change for the future is beset with some degree of difficulty and uncertainity due to the large number of assumptions made, type of model used - limitations which are all inherent in an analysis of such type.

The IPCC's fourth assessment report projects a warming of 0.1°C per decade for the first two decades and 0.2°C per decade for the next two decades for the entire globe. Warming for the 21st century is projected as 1.8°C for a low scenario and 4.0°C for a high scenario depending on the projections for CO2 emissions (Fig.5). Sea level rise is projected between 18 and 59 cm. depending on model and the scenario. These assessments are for the entire globe and the change for a specific region and for a country like India could be slightly different.

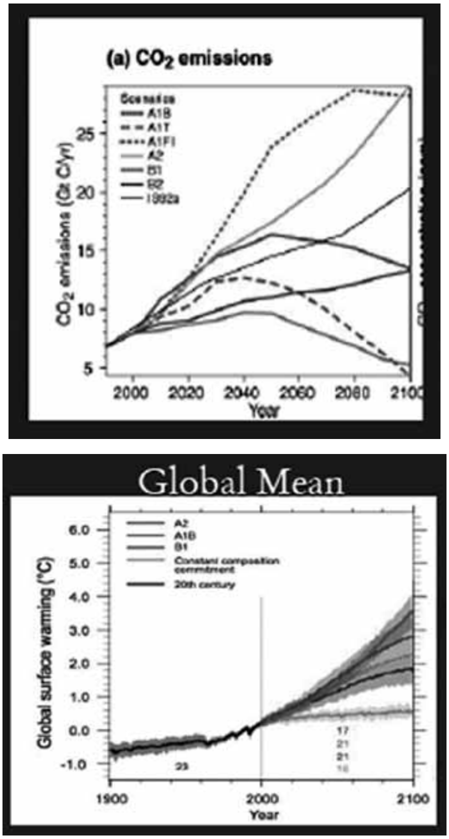


**Fig. 5**
**IPCC AR4 simulation for entire globe. CO2 emissions and Surface Temperature Warming. (AR4- Fourth assessment report of IPCC)**

The expected future changes in rainfall and temperature over India under IPCC, SRES, AIB, GHG scenario is presented in Fig.6. As shown temperature increase could cross 3°C by 2100. Rainfall could increase by 10%, the increase commencing after 2050 only. Models (Krishna Kumar, 2009) predict decrease in number of rainy days and increase in the intensity of rainfall. Extremes in rainfall and temperature are expected to increase. Increase in cyclonic storms / monsoons is not predicted but their intensity is expected to increase by 10%.

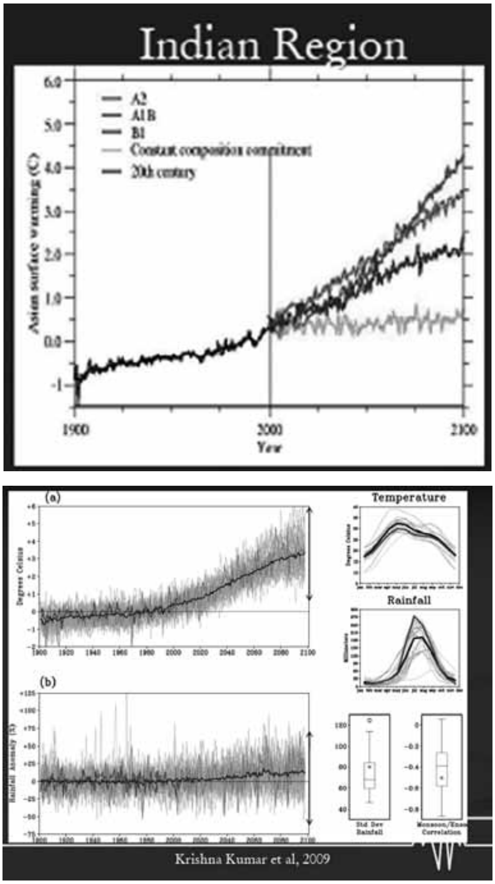


**Fig.6**
**Top: Projected future changes in temperature for Indian Region for different scenarios**
**Bottom: Projected Future Changes in temperature (inset top ) and Rainfall ( inset bottom) over India under IPCC SRES A1B GHG Scenarios ( SRES- Special report Emission scenarios, GHG- Green house gas)**

## LIKELY IMPACT OF CLIMATE CHANGE ON INDIAN AGRICULTURE

Indian economy is still agriculture oriented despite the increasing role played by industrial development. The average food consumption in India is at present 550 gm per capita per day much lower than the figures of 980 gm and 2850 gm in China and USA respectively. The present total production of food grains in the country is nearly 25 crores tonnes. India has been adding nearly 1.5 crore per year of population to its already large population which may not stabilize in the near future. Due to urbanization and industrialization, the total area of arable land has been decreasing. In India 60% of the total cropped area is rain fed and only remaining 40% is under irrigation. The dependence of Indian agriculture on climate, weather, rainfall and the timeliness of rainfall is substantial.

Estimating the effect of climate change on crop production is a difficult task due to the variety of crops, cropping systems and the levels of technology. The two crop growing seasons in India are Kharif (June-September) and Rabi (October-November). Detailed studies and simulations by agricultural experts suggest that increase of $CO_2$ in the atmosphere will increase the primary productivity of plants, but due to increase of temperature the productivity will decline. The wheat crop could decrease by 600 /m$^2$ with every 1°C increase in mean temperatures. A 2°C increase in mean air temperature could decrease rice yield by about 0.75 ton / hectare in high yield areas. A 0.5°C increase in winter temperature would reduce wheat crop duration by 7 days and reduce yield by 0.45 ton/ hectare, i.e. by nearly 10%.

Aggarwal (2009) projects that increase in $CO_2$ to 550 ppm will increase yields of rice, wheat and oil seeds by 10-20% but 1°C increase in mean temperature will reduce the yield by 3-7%. The loss will be much higher at higher temperatures, i.e. upto 10-40% by 2100. There could be some improvement in rabi, maize, sorghum, millets and coconut, less loss in potato, mustard and vegetables due to reduced frost. The loss of milk is estimated at 15 lakh tonnes. The apple production over Himachal Pradesh is expected to decrease evidently due to inadequate chilling. Further reference could be made to Ashwani (2008), Krishna Kumar et.al (2004), Mall et.al (2006) and Kavi Kumar (2009).

## CONCLUDING REMARKS

The scenario of significant climate change especially global warming is now well documented and the evidence incontrovertible. Regarding change in other crucial parameters such as rainfall and occurrence of cyclonic storms, there appears to be no clear signal over the Indian region. Projected climate change over India based on various models suggests steady increase in temperature and at a later stage slight increase of rainfall. The effect on agriculture is likely to be mixed. The increase in $CO_2$ initially favouring increase in agricultural production but increase in temperature decreasing the same. Considering that India has a very huge and rising population to feed, even a nominal persistent decrease in food production will lead to adverse consequences. Climatic change mitigation measures are frequently linked to the standard of living of masses and there is apprehension that stringent measures to curb warming will adversely impact on the poor of the developing countries. Obviously the situation is fluid and contradictory and calls for learned and measured responses based on scientific facts free from transnational political compulsions.

**ACKNOWLEDGEMENTS**

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# Potential Fishing Zone (PFZ) Advisories – Technology Perspective

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## INTRODUCTION

About 7 million people living along the Indian coastline, spanning over 7500 km, dependent on fishing for their livelihood. Locating and catching the fish is, however, becoming more challenging as fish stocks are dwindling or they are moving further offshore due to the anthropogenic stress on the nearshore waters. Such situation leads to increase in time to search for the shoals of fish expending higher costs and efforts. A reliable and timely advisory on the potential zone indicating the 'locations of fish aggregation' will certainly benefit the fishing community as that will help in reducing the time and effort spent in searching the fishing grounds. The reduced search and efforts will improve the profits in fishing thus improving the socio-economic status of fishermen.

Traditionally, the success of fishing trip depended on fisherman's keen sense of sight, smell and hearing. But, often, the fishing trips resulted in spending longer days at sea and returning with low or no catch. A good catch was mostly ascribed to the 'luck of fisherman'! Hence, it is necessary to examine the scientific data and device methods to pre-determine the locations of probable fishing grounds at sea so that the fishermen need not try out their luck or return empty handed.

Visual fish spotting from aircraft was successfully demonstrated for locating a number of pelagic species such as anchovy, swordfish, menhaden and tuna in western countries. In this case, a trained observer acts as a "sensor", spots the school of fish and communicates with the vessels in the area using radio link. The trained observer distinguishes the fish shoal based on their colour, behaviour and schooling patterns. Although the direct detection of fish would appear to be the most obvious goal, use of aircrafts on a day-to-day basis over the vast areas would be prohibitively expensive and unviable. Use of satellite remote sensing could be the other alternative, but the direct detection of fish using remote sensing is not possible with the current levels of technology.

Though the direct detection of fish is not feasible using remote sensing, their indirect detection may be possible by observing the sea surface phenomena associated with species distribution. For example, the changes in ocean colour from blue to green may serve as an indicator of increasing plankton abundance. The green colour is associated with the presence of chlorophyll, the light retaining pigment of phytoplankton. The satellite imagery can record the colour variations over a much wider area in a more precise manner. Techniques have thus can be developed to quantify the biological productivity on the basis of chlorophyll distribution and abundance. Water temperature is another important factor in determining species distribution and thermal sensors can be used to produce maps of sea surface temperature (SST). Such mapping can be used to identify cold water associated with upwelling of nutrient-rich water and to locate boundary areas between warm and cold waters where certain species are known to congregate. Thus it turns out that the remote sensing is the viable solution to develop a credible tool that can be applied to locate the potential fishing ground to satisfy man's centuries-old quest to harvest food from the sea.

**EVOLUTION OF PFZ MISSION**

The Ministry of Earth Sciences (MoES), earlier known as the Department of Ocean Development (DOD), initiated Marine Satellite Information Services (MARSIS) programme in June 1990, to device methods to use the oceanographic data, especially the satellite data to address the issues involved with the usage of oceanic resources. One of the objectives of MARSIS was the usage of remote sensing data and its applications for the management of coastal oceans and to devise the methods to use the satellite data to harvest food from sea. At this juncture, the scientists from marine sciences, remote sensing and fishery science collaborated to develop a technique that can use the remotely sensed sea surface temperature (SST) to identify the locations of fish aggregation. The concerted collaborative efforts resulted in successful demonstration of the application of satellite derived SST for the demarcation of 'Potential Fishing Zone (PFZ)' as a proxy to 'potential shoals of fish aggregation' in the Indian waters.

Accordingly, the generation of PFZ advisories started during 1996-97 at National Remote Sensing Agency/DOS, Hyderabad using NOAA-AVHRR derived SST data. The dissemination of PFZ advisories through the state fishery departments were also attempted on experimental basis. Due to the lack of modern communication devices, FAX and TELEFAX only was used to communicate the advisories to fishery departments and for further dissemination to the fishermen in the locality. Due to the usage of data from single satellite, at least 3 days data was required to cover the Indian coast and to generate the composites to prepare the PFZ maps. Thus the PFZ advisory service was limited to twice a week.

Later, on the establishment of Indian National Centre for Ocean Information Services (INCOIS), in 1999, INCOIS took up the responsibility of generation and dissemination of PFZ advisories in mission mode since 2001. Under this mission mode project, the

PFZ advisories were generated and disseminated to the fishing community in the coastal states. Simultaneously, with the launch of the IRS-P4 (Oceansat-1) in May 1999, Space Applications Centre (SAC), Ahmedabad developed the techniques to generate the PFZ advisories based on Ocean Colour or Chlorophyll data and SST. SAC, Ahmedabad transferred the technique to INCOIS in late 2001.The integrated approach, developed using IRS-P4-OCM derived Chlorophyll concentrations and AVHRR derived SST enriched the PFZ advisories. Over the years, the technology for the generation of PFZ information underwent several changes in the light of the feedbacks received from the users and the results from validation experiments.

## GENERATION OF PFZ ADVISORIES

It is well known that the adaptation of fish to the surrounding marine environment is controlled by various physico-chemical and biological factors. Fishes are known to react to the changes in the surrounding environmental conditions and migrate to areas where favorable environmental conditions in terms of seawater temperature, salinity, dissolved oxygen levels etc., exist. Availability of food is an important factor which control their occurrence, abundance and migrations in the sea. Sea Surface Temperature (SST) is an easily observable environmental parameter from space and is quite often correlated with the availability of fish, especially pelagic fish. Many pelagic species are known to concentrate at boundaries of currents especially in areas with sharp horizontal temperature gradients. Chlorophyll is the other environmental parameter easily observable from space. Usually, chlorophyll and SST images are expected to reveal common gradients due to the inverse correlation between these two parameters *(Solanki, et al, 2005).*

Monitoring the above mentioned parameters in space and time using conventional methods is time-consuming and prohibitively expensive. Neither the conventional methods are sufficient to obtain the real time picture of these parameters. Hence, satellite remote sensing is the right tool to monitor SST and Chlorophyll or phytoplankton pigments in the sea water in real time. In addition, the measurements using satellite also ensures high receptivity with large spatial coverage.

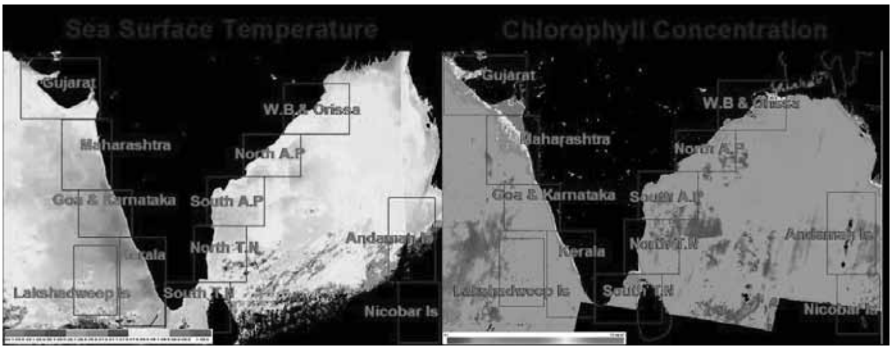



**Fig. 1**
**SST and Chlorophyll Images Overlaid with 12 PFZ Sectors**

Thus the Integrated PFZ advisories were generated using SST and Chlorophyll data derived from NOAA-AVHRR and IRS P4-OCM. The features such as oceanic fronts, meandering patterns of ocean currents reflected in the distribution of SST or chlorophyll data, eddies, rings, upwelling areas, etc. (Table 1) are identified from these satellite data through image processing techniques. Such enhanced features are then translated as advisories by marking them as PFZ area and identifying the location of such features in terms of latitude, longitude and depth of water column at the location. Also, identified are the angle (with respect to TN), direction and distance from the landing centres or nearby light houses. For the ease of delivery, generation and to conform to the different languages spoken in the coastal states, the entire coastline of India was divided in 12 sectors namely - Gujarat, Maharashtra, Goa and Karnataka, Kerala, Lakshadweep, South Tamil Nadu, North Tamil Nadu, South Andhra Pradesh, North Andhra Pradesh, West Bengal and Odisha. In each sector, the landmarks which are easily identifiable by fishermen (light house, fish landing center, fishing harbor, etc.) were used to determine the bearings of PFZ with respect to that location.

**Table 1**
**Relevance of oceanographic features to fishery resource (Solanki et al., 2003)**

| Sl. No. | Feature Type | Definition/morphology/ description | Relevance to fishery resource |
|---|---|---|---|
| 1. | Oceanic fronts (colour and thermal) | Fronts are the boundaries between two water masses with different properties. They can be easily detected as sharp gradients in ocean colour (chlorophyll concentration) or SST on an image. | High chlorophyll is an indicator of biomass production. Hence, if sustained for longer period, the chances of development of local ecosystem are greater.<br>Higher SST gradient is an indicator of upwelled water from deeper layer. Hence, the water with greater nutrient concentration would be available in euphotic zone which enables enhanced production. |
| 2. | Mushroom shaped features | The feature appears as mushroom shaped on an image. | Form as an enclosed pocket. Periphery is important. Sometimes rings form inside the feature, which may be productive. Form due to wind driven currents. |
| 3. | Coastal Upwelling | Easily detected in thermal imagery. Appear as thermal gradients in the image. | Indicates nutrient rich water transported from bottom to surface. Form in different phases like initiation phase, stabilization phase and maturity phase. Initiation phase should be avoided for fishing due to low oxygen water. In the matured phase a well developed ecosystem forms, should be exploited. |

| Sl. No. | Feature Type | Definition/morphology/ description | Relevance to fishery resource |
|---|---|---|---|
| 4. | Meandering pattern of features | A turn or winding of current that may be detached from the main stream. Easily detected through the curvatures in the image. | They cover large area. So, even if some feature shifts the potential area may not shift totally. This also helps in delayed fishing. Large concentrations of phytoplankton are available as compared to linear features. An enclosed pocket is formed, hence confining the resources. Sometimes rings are formed, which are productive and important for resource exploration. |
| 5. | Eddies | Cyclonic or anti-cyclonic features often spin off from a current of water. They move as circular currents. Easy to monitor in space and time. | Rotating water masses cause deep mixing, hence nutrient enrichment occurs leading to high production. Persist for relatively longer durations. The visual predators like tunas prefer periphery of eddies and streamers. |
| 6. | Rings | Rings of derivative of meanders and eddies. Easy to identify on an image. | Rings are productive and already localised developed eco systems. These features ensure secondary and tertiary production. |
| 7. | Plume front | Plumes form mostly in the coastal areas near river mouths as well as at discharge points of effluents. | Coastward side should be avoided because of the turbidity; generally the fish avoids turbid water due to visibility and blocking of gills. Seaward side may be explored for resources. Sediment images may be checked before suggesting the PFZs. |
| 8. | Fronts at Shelf Break | Formed due to the sudden change in bathymetry between shelf and slope. | If it is a large gradient in depth it will appear several times at same location. Persist for longer periods, supporting the ecosystem. Not suitable for bottom trawling. |
| 9. | Diverging fronts | Water flows in a different direction from the centre due to diverging current. | The process enriches the nutrient supply, which supports the enhanced production. |
| 10. | Converging fronts | Two or more fronts converge at one point. | Causes mechanical aggregation of resources and plankton, centre may be more productive. Can be used for resource exploration. |

The PFZ advisories for each sector were then prepared in English, Hindi and in the local language of the coastal population of the location of PFZ (Gujarati, Marathi, Kannada, Malayalam, Tamil, Telugu, Oriya and Bengali). For easy read of PFZ advisories by fishermen, the depth of water column, distance from the landmark, etc. are also provided in local measurement units. Till recently, the PFZ advisories were disseminated thrice a week, i.e. every Monday, Wednesday and Friday through various dissemination modes. However, since November 2011, they are being disseminated on a daily basis through the use of data from several satellites (AVHRR data from NOAA 18 & 19, MODIS, Oceansat-2, METOPS). In a nutshell, the PFZ mission can be represented as in fig. 2.

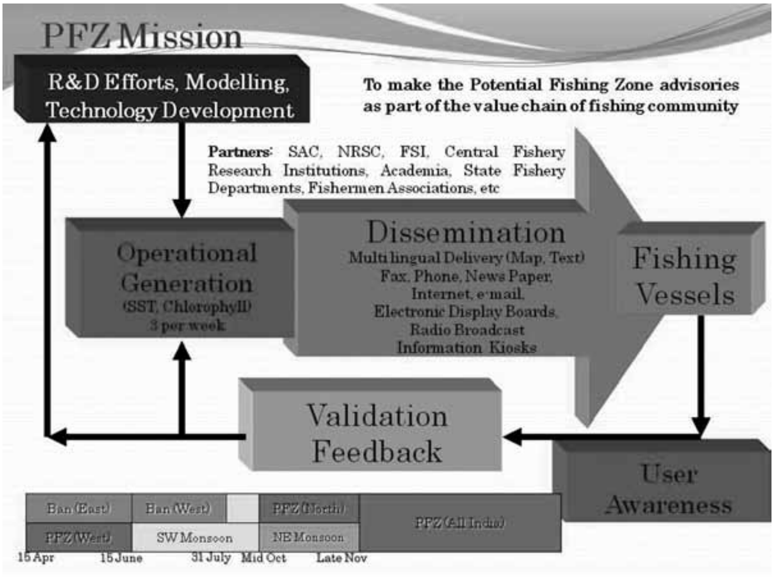



**Fig. 2**
**Mission of PFZ advisory services**

## GENERATION OF PFZ MAPS

In the beginning of this project, SST images were converted into negative films and the films were optically zoomed using Optical Zoom Transferoscope to fit onto the National Hydrographic Base Maps. The features were delineated on the base map using these analog techniques and the same maps were used for the end use. With the developments in digital techniques and their availability, INCOIS created a digital database for coastline, bathymetry, major landing centres, and light houses along the coastal states. The new base maps thus created using the digital techniques are a combination of overlaid coastline, bathymetry contours, landing centres and light houses.

SST and Chlorophyll are retrieved from AVHRR and IRS-P4 OCM using geophysical parameter algorithms and image processing techniques. SST has been obtained by the use of MCSST (Multi Channel SST) algorithm and Chlorophyll with the use of bio-optical algorithm, OC2. The SST and chlorophyll imageries are then subjected to various image processing techniques for image enhancement, restoration, geometric correction, filtering, etc. These enhanced and rectified images of SST and Chlorophyll are then used to generate the maps following the identification of various features as listed in Table 1. Finally, these maps are overlaid onto the base maps to generate the PFZ maps.

For easy understanding of fishermen, these PFZ Maps were translated into multi-lingual PFZ Text information which provides information about the location of PFZ viz. bearing angle, distance from the coast, expected depth at the location and latitude & longitude. (Fig. 3a & 3b)

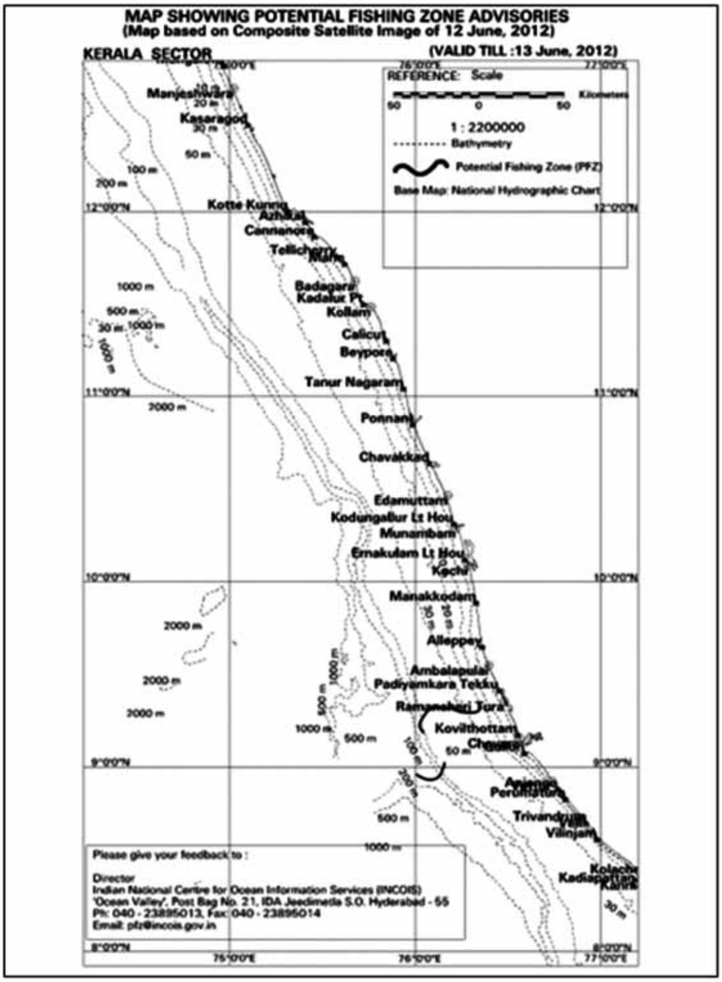



**Fig.3a**
**PFZ Map for Kerala sector**

KERALA

കേരളം

| SATELLITE DATA SHOWS LIKELY AVAILABILITY OF FISH STOCK TILL 13 ജൂൺ 2012<br>ഉപഗഹ വിവരമനുസരിച്ച് 13 ജൂൺ 2012 വരെ കൂടുതൽ മÒrം ലഭിക്കുവാൻ സാധ്യതയുള്ള Øല<br>उपग्रह आकडों से 13 ജൂൺ 2012 तक की संभावित मत्स्य भंडार की उपलब्धि | | | | | | | |
|---|---|---|---|---|---|---|---|
| തീരത്തു നിന്ന് | ദിശയിൽ | ദിശ (ഡിഗ്രി) | ദൂരം കിലോമീറ്ററിൽ | | ആഴം മീറ്ററിൽ | | Longitude Latitude |
| | | | മുതൽ | വരെ | മുതൽ | വരെ | |
| അലപ്പുഴ (Alleppey) | നൈരൂതി | 220 | 50 | 55 | 80 | 85 | 76 00.60<br>09 07.80 |
| അമ്ബാലപ്പുലൈ (Ambalapulai) | നൈരൂതി | 229 | 38 | 43 | 70 | 75 | 76 04.20<br>09 08.40 |
| പാഡിയാമകര തെക്കു (Padiyamkara Tekku) | നൈരൂതി | 251 | 29 | 34 | 60 | 65 | 76 08.40<br>09 09 N |
| രാമാഞ്ചെരി തുരാ (Ramancheri Tura) | നൈരൂതി | 254 | 23 | 28 | 50 | 55 | 76 13.80<br>09 06.60 |
| കൊവില്തോട്ടം (Kovilthottam) | വായുവ്യമു | 299 | 28 | 33 | 40 | 45 | 76 16.80<br>09 07.20 |
| കൊല്ലം (Quilon) | നൈരൂതി | 256 | 51 | 56 | 100 | 200 | 76 05.40<br>08 45.60 |
| വെട്ടൂര് (Vettur) | വായുവ്യമു | 271 | 69 | 74 | 200 | 500 | 76 03.60<br>08 43.80 |
| Chavara | നൈരൂതി | 247 | 51 | 56 | 100 | 200 | 76 05.40<br>08 46.80 |

**Fig. 3b**
**PFZ text sheet for Kerala sector**

## DISSEMINATION OF PFZ ADVISORIES

These multi-lingual advisories are being generated and disseminated during the non-ban period and non-cloudy days to the fishermen community in the coastal states and islands of India segregated under 12 sectors, viz. Gujarat, Maharashtra, Goa and Karnataka, Kerala, South Tamil Nadu, North Tamil Nadu, South Andhra Pradesh, North Andhra Pradesh, Odisha and West Bengal, Andaman Islands, Nicobar Islands and Lakshadweep Islands.

The timely dissemination of the advisories are being done, taking the advantage of advances in information and communication technology. In 1990's, the advisories were disseminated using traditional means like telephone and/or fax. In the beginning of 2000's, PFZ Advisories were also disseminated using website and emails. Later, taking the advantages of newer technology, INCOIS designed and installed Electronic Display Boards (EDB) at major fishing harbours. That made significant impacts as INCOIS could directly send the text information to these boards which are easily accessible to the fishermen. Later, the EDBs have undergone various changes and a new generation of EDB was designed and developed to facilitate the dissemination of satellite pictures, animations, short-films, ocean state forecasts, disaster information and disaster warning in addition to the normal text information. This EDB is also equipped with an audible alarm (audible within a km radius) that can be triggered from INCOIS to alert the local community in the eventuality of the danger of tsunami. At present, there are 100 EDBs installed and operational at various locations (see fig. 4).

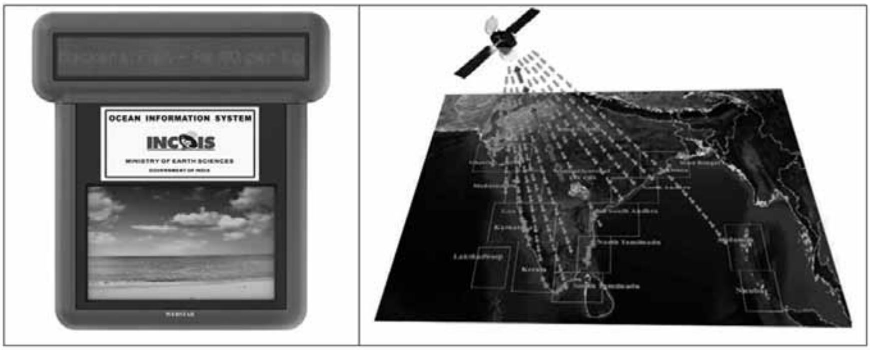
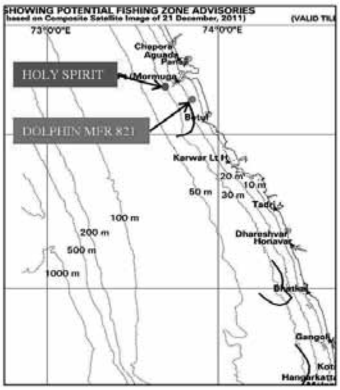



**Fig. 4**
**Picture of new Electronic Display Board and the locations along the Indian coast where they are installed**

## VALIDATION EXPERIMENTS

Validation of PFZ advisories is one essential component of the service to estimate the accuracy levels and benefits involved. To validate the efficiency of PFZs, INCOIS adopted a multi-pronged approach to carry out the validations. Among them, the controlled experiments are considered to be the most accurate validations possible. (i) Controlled experiments are conducted engaging two fishing vessels equipped with identical fishing gear. One of the boats goes and carries out fishing in the notified PFZ area and the other conducts fishing elsewhere. This strategy ensures the concurrent catches from PFZ notified and non-notified areas. The data from each catch is converted into net profit as well as to CPUE (catch per unit effort) for the purposes of comparison. Of course, the catch data is also analysed to understand the differences in the species abundance in PFZ and non-PFZ areas. Figures 5 and 6 and the accompanying tables show the typical example of the validation carried out for Goa-Karnataka and Kerala sectors. (ii) Through the collection of feedback data from the boat owners in a common feedback format and analysed statistically. From the feedbacks received from Kerala, it implies that the average CPUE for vessels fished within the notified PFZ location was about 3464 kgs as against an average of 793 kgs for vessels fishing outside the PFZ locations, on an average, net profit of vessels fished within the notified PFZ locations ranged between Rs. 14000 to Rs. 60000 as against an average profit of Rs.14000 for vessels fished in the non-notified PFZ locations and the average success rate of fishing operations within the PFZ locations was about 90% as compared to the success rate of 30% in the non-notified PFZ locations.

As is evident from the table in fig. 5, the controlled experiment conducted at outside PFZ area Goa on 22 December 2011 yielded a profit of more than one lakh rupees for the boat that carried out fishing in PFZ area, while the boat that carried out fishing made only Rs. 8000. Similarly the controlled experiment conducted at Edamuttam, Kerala on 14 March 2012 yielded a profit of Rs. 13775 from PFZ area and Rs. 1500 from non-PFZ area. Based on 630 such controlled experiments conducted during XI plan period it is reasonable to conclude that the net profit increases by at least 2-5 times and CPUE by 2 to 4 times (Fig. 6). A major portion of the savings always comes from the cost of fuel, because the fuel wastage in search of a viable fishing ground is nil when the PFZ advisories are taken in account for the fishing trip. Another important aspect of PFZ usage comes from lesser consumption of fuel and hence the lesser emissions from fossil fuel; notorious for causing global warming and climate change.




**Karnataka & Goa Sector**

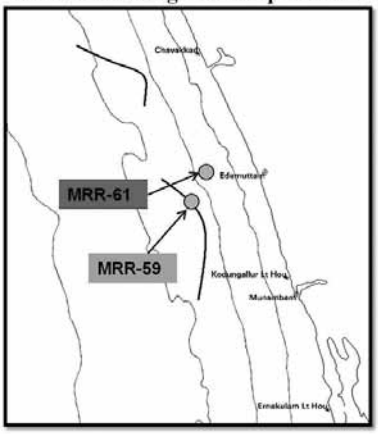
PFZ advisory based on December 21, 2011
Issued on: December 21, 2011
Valid till: December 22, 2011

| Details | PFZ | Non PFZ |
|---|---|---|
| Name of the Boat | Dolphin MFR 821 | HOLY SPIRIT |
| Type of Boat | Purse-Seine gear | Purse-Seine gear |
| Number of fishing hours | 01 | 01 |
| Number of Hauls | 01 | 01 |
| Number of Fishermen Engaged | 18 | 21 |
| Total Catch (Kgs) | 2500 | 300 |
| Major Species Caught | Oil sardine | Indian Mackerel |
| Approximate cost of total catch (Rs) | 1,62,500 (@ 65 Rs /Kg) | 30,000 (@ 100 Rs /Kg) |
| Total Expenditure in Fishing Operation (Rs) | 22,000 (Fuel: 8,000) (Wage: 11,000) (Other : 3,000) | 22,000 (Fuel: 5,000) (Wage: 12,500) (Other : 4,500) |
| Net Profit | 1,40,500 | 8,000 |

Details of Simultaneous Fishing Operation by Two Vessels (PFZ & Non PFZ) on December 22, 2011

**Fig. 5**
**Controlled experiment conducted at Goa by hiring two identical purse-seine fishing vessels on 22 December 2011**

**Potential Fishing Zone Map of Kerala**




PFZ Forecast Issued on March 13, 2012
Valid up to March 14, 2012

| Details | PFZ | Non PFZ |
|---|---|---|
| Name of the Boat | MRR-59 | MRR-61 |
| Type of Boat | Mech. Ring Seine | Mech. Ring Seine |
| Duration of Total Trip | 6 hr 30 min | 6 hr 30 min |
| Number of fishing hours | 01 | 01 |
| Number of Hauls | 01 | 01 |
| Number of Fishermen Engaged | 20 | 20 |
| Total Catch (Kgs) | 1050 | 200 |
| Major Species Caught | Carangids | Carangids |
| Approximate cost of total catch | 73,500 | 14,000 |
| Total Expenditure in Fishing Operation (Rs) | 59,725 | 12,500 |
| Net Profit | 13,775 | 1,500 |

Details of Simultaneous Fishing Operation by Two Vessels (PFZ & Non PFZ) on March 14, 2012

**Fig. 6**
**Controlled experiment conducted at Edamuttam, Kerala by hiring two identical purse-seine fishing vessels on 14 March 2012**

## ASSESSMENT OF IMPACTS AND ECONOMIC BENEFITS

In December 2010 National Council for Applied Economic Research (NCAER), New Delhi conducted an independent study, by conducting surveys, on the benefits of the usage of PFZ advisories and ocean states forecasts regularly issued by INCOIS. The study revealed that (i) identification of Potential Fishing Zones (PFZs) as well as ocean state forecast by INCOIS are found to be both timely, accurate and of significant value to the fishing community (ii) identification of potential fishing zones increases productivity, significantly improves catch size and reduces fuel consumption, while the ocean state information is quite useful in timing departure and sequencing on shore activities and avoiding extreme weather-related emergency situations and (iii) the different parameters used by the fishermen from daily weather and ocean state forecasts include wind speed, wind direction, rainfall status, height and direction of waves, maximum and minimum temperature. Further the study used 3 scenarios to project the envisaged share of domestic product from fishing as well as economic benefits resulting from identification of PFZs. In scenario 1, only mechanised crafts adopt PFZ, in scenario 2, both mechanised crafts as well as motorised crafts adopt PFZ and in scenario 3, all mechanised crafts, motorised crafts and traditional crafts adopt PFZ. In scenario 1, the domestic product can go up from the present level of 0.81 percent of national GDP to 1.47 to 1.65 percent; in Scenario 2, it can go to 1.58 to 2.0 percent of national GDP and in scenario 3 to around 2.04 percent of the national GDP. Finally, the annual net economic benefit due to the scientific identification of PFZs, based on satellite information, is estimated to lie in range of Rs. 34000 to Rs. 50000 crores.

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# *Invited Presentations*

# Agriculture and Soil Resources Management in Kerala

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**INTRODUCTION**

Soil is fundamental to crop production. Without soil, no food could be produced on a large scale, nor would livestock be fed. Because it is finite and fragile, soil is a precious resource that requires special care from its users. Many of today's soil and crop management systems are unsustainable. At one extreme, overuse of fertilizer has led, to nitrogen (N) deposition that threatens the sustainability of an estimated 70 percent of nature. At the other extreme,the under-use of fertilizer means that soil nutrients exported with crops are not being replenished, leading to soil degradation and declining yields.

**AGRICULTURE AND LAND USE IN KERALA**

Agriculture continues to be most important and single largest sector of the state economy accounting for one third of the state's income at present. Most of the crops grown in the state are of national importance by way of earning valuable foreign exchange through export /import substitution. The total cropped area of the state is 29.69ha. The cropping system followed in the state is mostly rice based and coconut based. Though agriculture remains the major contributor to the state's economy it has been showing a declining trend both in terms of area under crops and productivity except for Rubber. The most significant changes in the land use pattern are the shrinking of area under food crops . The ratio of food crop to non food crop of the state comes to 13:87.

Kerala contributes a substantial share to the national economy with respect to four plantation crops viz. rubber,tea,coffee and cardamom. These constitute 29% of the net cropped area. Rubber plantations in Kerala accounts to 83 % of total rubber in the country.

The land use in arable areas in terms of crop planning requires serious attention. The most alarming cause of land degradation includes rapid urbanization rendering good agricultural lands uselessness, cultivated lands exposed to indiscriminate use of fertilizers and pesticides.The proper land use with appropriate crop planning and recommended package of practices should be strictly followed to prevent soil degradation

**PHYSIOGRAPHY**

Kerala state is unique in its physiographic diversity with different land forms. The rise in elevation from west to east is abrupt and conspicuous. Physiographically, the state can be divided into five natural divisions viz., lowland, midland, midupland, upland, highland and mountainous region.

The *lowland* is identified as an area with elevation upto 20m above MSL. This includes coastal plains, bottomlands, gently sloping fluvial plains and undulating low-level laterite mounds. The area occurs as a narrow belt along the western part of the State. The average width of the lowland is 10km and at certain places like Kuttanad, it extends 30km east from the seacoast. The area is mostly under paddy, coconut and arecanut. All the districts except Idukki, Wayanad and Palakkad have coastal plains.

The *midland* is noticed parallel to miduplands making an irregular boundary with the lowlands. The general elevation ranges from 20 to 100m above MSL. The area under midland has undulating to rolling topography with mounds, low hills, intermittent broad and narrow valleys. This is mainly a laterite belt and the area is mostly under mixed vegetation with a variety of crops. The area is identified in all districts except Wayanad.

Towards east of midlands is the *midupland* with elevation ranging from 100 to 300m above MSL. The midupland is rolling to hilly with moderate to steep side slopes. Hill soils are noticed here. They are under rubber plantations along with mixed vegetation.

East of midupland is the *upland* with elevation ranging from 300 to 600m above MSL. Compared to midupland, the area is an irregular narrow strip of land between midland and highland. The upland is mostly hilly with elongated hills, summits and steep side slopes. The area is mostly under plantation crops. Mixed crops and forest vegetation is also noticed. The area has hill and forest soils.

Towards extreme east is the *highland* with an elevation of 600 to 1200m above MSL. The *mountainous region* with an elevation of more than 1200m MSL is identified in the extreme east, mostly in Thiruvananthapuram, Kollam, Pathanamthitta, Idukki, Palakkad, Malappuram, Kozhikode and Wayanad districts. The highest peak in the tract is at Anamudi in Idukki district with an elevation of 2694m. Highland and mountainous region occupies the Western Ghats of the State. The major tract of the region is under forest. In addition, plantation crops like tea, coffee, cardamom, pepper etc are also grown.

**NEED FOR GENERATION OF SOIL INFORMATION**

The need for scientific and sound database on soil resource of the state was experienced in the earlier periods of five year plans for formulation and implementation of micro and macro level plans. Accordingly Soil Survey was initiated in the state during 1963 for scientific inventory of the soil resources of the state. Depending upon the objective, method, type of base map available and the intensity of observations, four major types of Soil Survey are carried out namely Reconnaissance Soil Survey, Detailed Soil Survey, Semi detailed & Reconnaissance-Detailed Soil Survey. Understanding the necessity to have a database on soils at district and state level had led to the mapping of the soils of the state on a scale of 1: 50,000 and the panchayats and watersheds on 1:5000 scale.

The Department of Soil Survey & Soil Conservation has generated authentic soil resource database for all the districts and 399 panchayats and 337 watersheds.

A sound resource management strategy is fundamental to ensure sustainability of agricultural production. Soil, as a resource is the key determinant that has to be managed in a scientific manner in order to keep it sustainable. Rational use of soil resources, based on its potential is essential for an economically viable and ecologically sound agriculture. Input management decisions on macro and micro level should be based on scientifically evolved database on soil resource so as to make it effective.

Soil information is vital for proper diagnosis of soil, optimal use of soil resources, adopting land use as per land capability potential and maintenance of soil health. It is imperative to generate soil information with spatial distribution to cater the demand of various stakeholders dealing with soil related activities in the implementation for various developmental programmes in the state.

**SOIL FORMATION**

Soil is the product of various soil forming factors like climate,geology,vegetation, topography and time. Soil formation is greatly influenced by the climate, rainfall and topography. The combination of the various soil forming factors and processes have given rise to distinct soil types in the state.

Kerala experiences humid, sub humid and subtropical climate. The wide altitude variability within a short distance from sea level to 2694m produces a vertical climate, vegetational and soil zonation. The soils of Kerala are highly heterogenous due to its inherited complex geology, varied climate and relief. Besides, the very old civilization in Kerala has also had its impact on soil evolution in the region. The high incidence of rainfall with prolonged dry spells of five to six months in the northern districts of Kerala have produced highly laterised and eroded surfaces compared to the southern parts with relatively better distribution of rainfall and more acidic rocks which are less lateritic. These extensively laterised soils constitute the major soil in the state and occur at elevation upto 100m+ above MSL. The lithosequence in Kerala includes the extremely acidic khondalite group of rocks in the south which grades into acidic charnockites in Central Kerala and intermediate and basic rocks in the north.

Kerala soils in general are acidic in nature .More than 60% of the soils are laterites. Calcareous soils are encountered in Chittur in Palakkad district. More than 58% of arable lands have very compacted gravelly sub soil with poor nutrient status, low nutrient retention and exchange capacity. Reduced soil depth is observed in places having excessive soil erosion.

## SOILS OF KERALA

Kerala with Precambrian archaean rocks and sedimentary, tertiary and quaternary formation with geological history of five major tectonic upliftments and two major subsidence along its coast,has predominantly a mountainous terrain with narrow coastal belt. Soil is the product of the influence of genetic and environmental factors of parent material, climate, micro and macro organisms and topography acting over a period of time on the surface of earth.

The topo-lithosequence of Kerala along with variation in rainfall, temperature and alternate wet and dry conditions particularly from the western coast to high ranges in the east and swift flowing rivers lead to development of different types of natural vegetation and soil.

The soils of Kerala can be broadly grouped into coastal alluvium, mixed alluvium, laterite, red, hill,black cotton, forest and problem soils which include Kuttanad soils, acid saline soils, Poonthalppadam soils and Kole lands . Kuttanad soils include Kari,Karappadam and kayal soils and acid saline soils include Pokkali, Orumundakan and Kaippad.

### Coastal Alluvium

Coastal alluvium soils of marine origin are identified along the coastal plains and basin lands as a narrow strip. The coastal plain is wider in the central portion of the state. These are recent to subrecent alluvium over crystalline rocks and tertiary sediments. The area includes beach sand, marshes, paleo sand ridges and very gently to gently sloping sandy plains. The elevation of the coastal area is generally below 5m MSL. The area has high water table and in some areas it reaches above the surface during rainy season. Numerous drainage channels criss-cross the area. Saline spots are identified in this tract.

The soils of the coastal plains are very deep with sandy texture. The texture generally ranges from sand to loamy sand with greyish brown to reddish brown and yellowish red colour. Sand content ranges from 80% and clay up to 15%.

#### *Limitations*

Even though these soils have high water table, the water holding capacity is poor due to the predominance of sand. The cation exchange capacity of these soils range from 1.5 to 3.0 cmol/kg. These soils are acidic with pH range of 4.5 to 6.0. The general fertility status is very poor. These soils are low in major nutrients.

#### *Management*

Application of organic fertilizers, organic manures and clay at the base of the plants. is recommended to improve the water holding capacity.Incorporation of coirpith and husk burial is ideal to improve water retention. Drip irrigation during summer, Split application of fertilizers and fertigation is ideal for these soils. Application of fertilizers during rainy season should be avoided.

Coconut is the major crop in the area. Cashew and other fruit trees are also grown.

Poovar,Kazhakkuttam,Neendakara,Alappuzha,Vypeen,Chenthrapinni,Talakkad,Triparangode,Thikkodi,Beypore,Hosdurg are the few soil series identified along the coastal plains. These soil series are classified under Oxyaquic Quartzipsamments, Typic Ustifluvents,Ustic Quartzipsamments and Typic Fluvaquents

**Mixed Alluvium**

These soils are developed from fluvial sediments of marine, lacustrine and riverine sediments or its combinations. They occur below 20m MSL in the lowland plains, basins, valleys and along the banks of major rivers. Marine and lacustrine alluvium is mainly noticed close to coastal alluvium, Kuttanad and adjacent area and kole lands of Thrissur district. The soils are frequently flooded and submerged. Riverine alluvium is seen along the flood plains of rivers and depressions of lowland. Alluvio-colluvial sediments are seen along the valleys of midland region. A major area under this alluvium lies below 20m MSL. The soils of depressions and broad valleys are subject to occasional flooding and stagnation. The ground water table of these soils is generally high and it reaches above the surface during rainy season.

A wide variation in texture is noticed in these soils. Sandy clay loam to clay is the predominant texture. Sandy loam soils are also met with. Light grey to very dark brown is the common colour of the soil. These soils have medium to high available water holding capacity. The cation exchange capacity of these soils range from 5 to 15 cmol/kg. The soils are acidic with pH range from 4.5 to 5.5. A wide variation in NPK status is the general trend.

***Limitations***

Flooding during rainy season, high water table and poor drainage are some of the limitations.

***Management***

Irrigation during summer season, providing adequate drainage during monsoon,split dose of fertilizer based on the moisture content in the soil are recommended for these soils. A variety of crops such as coconut, arecanut, banana, vegetables, yams, sweet potato, clove, nutmeg etc can be grown in the lowland plains.

Karamana, Kallada, Vengal, Punnayurkulam and Parampuzha soils are the few soil series identified along lowland plains and flood plains of rivers. Soils of Champakulam, Changanacherry, Mylom, Marukil, Ayroor, Muthur and Manalur are identified along depressions and broad valleys of lowlands where only paddy can be grown.

These soils are generally classified under Typic Tropaquepts, Aquic Humitropepts, Typic Hydraquents, Tropic Fluvaquents, Typic Tropofluvents and Oxyaquic Dystropepts.

**Red Soils**

These are red terri soils of sub-recent origin resting over tertiary sedimentary formations/laterites. They are localized in occurrence and are found mostly in the southern parts of Thiruvananthapuram district and in pockets in catenary sequence along the foot slopes of laterite hills and mounds. These soils are identified in undulating plains of lowlands with a general slope of 3 to 10%. These aeolian and colluvial deposits are mostly very deep and homogeneous in nature.

The texture of the soil generally ranges from sandy clay loam to clay loam with red to dark red colour. Gravels are rarely noticed in these soils. Acidity ranges from pH 4.8 to 5.5 and the CEC from 4 to 5.5cmol/kg. The water holding capacity is medium

***Limitations***

The organic carbon and nutrient status of the soil is low. These soils have low CEC and low fertility status.

***Management***

Balanced application of organic fertilizers and organic manures. Husk burial in trenches to increase water retention,mulching,application of lime, providing irrigation during summer are the management practises recommended for these soils.

A variety of crops such as coconut, arecanut, banana, yams, pineapple, vegetables, groundnut,fruit trees etc., can be grown under proper management.

Vellayani and Kudlu are few of the soil series. They are classified as Rhodic Haplustalfs, Plinthustults and Rhodic Kandiustults.

**Laterite Soil**

Laterites in Kerala are identified on quarternary sediments, tertiary sediments and buried crystalline indicating prolonged phases of erosion and laterisation.

Laterite soils are the weathering products of rocks in which several course of weathering and mineral transformations take place. This involves removal of bases and substantial loss of combined silica of primary minerals. In laterite and laterite soils, over acidic rocks, induration and zonation are more pronounced. This induration is greater if the iron content is higher. These soils mainly occur in the midlands at elevation 20 to 100m above M.S.L. as a strip between the coastal belt and hilly midupland. The area comprises of mounds and low hills with gentle to steep slopes.

In the State, mainly three types of laterite soil are noticed in association.

1. Laterite soil with low gravel content of less than 30% with reasonable depth between 50 and 150cm. This category is mainly noticed in the foot slopes of laterite mounds and laterite hills. Colluvial surface material is also identified.
2. Laterite soil with gravel content of 30% to 80% with reasonable depth between 50 and 150cm. These soils are noticed in side slopes and summits of laterite mounds and hills.

3. Shallow soils of depth less than 50cm with indurated laterite and laterite outcrops. These are noticed as laterite mesa in the northern districts Malappuram, Kozhikode, Kannur and Kasargod.

In general, all these laterite soils are acidic with pH ranging from 4.5 to 6.0. These soils are gravelly clay to gravelly clay loam textured. The organic matter content is less than 1% but in the surface soil, it can range up to 3%. The cation exchange capacity generally ranges between 3 to 8cmol/kg. In general, fertility status is low to medium. The infiltration rate ranges from 9 to 12cm/hr and the available water content is 10 to 15cm/m.

***Limitations***

Low water holding capacity,low organic matter, reduced effective soil volume due to high gravel content,acidity,defieciency of Phosphosrus due to high P fixation,deficiency of K, Ca, Mg,&S & micronutrients, low CEC, low availabiltiy of plant nutrients,toxic concentrations of iron and aluminium hydroxides are the major constraint of these soils

***Management***

Application of lime to correct acidity, combined application of organic manures and chemical fertilizers, husk burial, mulching, etc recommended for improving water retention, providing irrigation during summer are the management practises recommended for these soils. Since P deficiency is one of the most widespread constraint in these soils, phosphorus application based on scientific soil test data should be adopted.

Construction of earthen /stone pitched bunds along the contour ,trenches and rain water pits along the contour are soil conservation measures recommended.

The laterite soil is generally suitable for most of the dryland crops. It is mainly cultivated with coconut, arecanut, banana, tapioca, vegetables, yams, pepper, pineapple, fruit trees etc. The percentage of gravel content in the soil and reduced soil depth limits the choice of crops. In laterite outcropped area with shallow soils, only cashew is grown with vegetables in some pockets.

Thonnackal, Neyyatinkara, Nenmada, Narikot series fall in the first category. They are put under Rhodic Kandiustults, Ustoxic Dystropepts, Ustoxic Humitropepts, Plinthustults and Plinthic Kanhaplustults.

Trivandrum, Adoor, Arpookara, Arathil, Kanjikulam and Edanad series are put in the second category. They are classified under Ustoxic Dystropepts, Ustoxic Humitropepts, Plinthohumults and Plinthustults.

Kolathur, Kalanad and Chelari are few series put in the third category. They are classified under Typic Ustorthents, Lithic Ustorthents and Plinthic Dystropepts

**Hill Soils**

These soils are developed from crystalline rocks of archaean age. The crystalline rocks comprise charnockites, khondalite suite granites, gneissic granites and basic dykes. The hill soils mostly occur above an elevation of 80m MSL. The area is hilly and has highly dissected denudational hills, elongated ridges, rocky cliffs and narrow valleys. The general slope range is above 10%.

The texture of these soils generally ranges from loam to clay loam with average gravel content of 10 to 50%. In addition, stones and boulders are noticed in the subsoil. These soils are less acidic than laterite soils . Generally, increase in clay content is noticed down the profile. These are deep soils with good drainage. The depth of the soil varies considerably from 50 to 200cm depending on the lie of the land, erodibility of soil and past erosion. These soils are mostly friable and subject to heavy soil erosion. Soils have medium to high water holding capacity. CEC of the soil ranges from 4 to 10cmol/kg. The general fertility status is medium.

***Limitations***

Low water table depth and soil erosion are the major constraints of these soils.

***Management***

Soil conservation practises to control soil erosion ,mulching, application of organic manures and chemical fertilizers in split doses to avoid leaching losses are the recommended management practises.

These soils are suitable for all dryland crops like rubber, coconut, arecanut and fruit trees based on the lie of the land. Crops such as banana, pepper, pineapple, vegetables etc can be grown in foot slopes.

Kumaranperoor, Chittar, Mavady, Payalam, Nedumangad, Channappara, Lakkattoor and Mannamkulam are some of the soil series encountered in this tract. They are classified under Ustic Haplohumults, Oxic Humitropepts, Typic Kandihumults, Ustic Palehumults and Ustoxic Dystropepts.

**Black Cotton Soils**

These soils are identified in alluvial plains, terraces and undulating plains of Chittur taluk in Palakkad district in patches. The elevation of the area ranges from 100 to 300m above MSL with gentle to moderate slope. These soils are developed on khondalite suite of rocks traversed by lenticular bands of crystalline limestone and calc-granulites.

These soils are very deep, black and calcareous. The texture of the soil ranges from clay loam to clay. The pH of the soil ranges from 6.5 to 8.5 and the CEC from 8 to 16cmol/kg. These soils contain appreciable amount of calcium and Potassium. These are low to medium in fertility status. In general, the soils have good water holding capacity but are subject to moisture stress during summer.They possess high shrink swell capacity and hence exhibit the characteristic cracking during dry months.

***Limitations***

They posses high shrink-swell capacity and hence exhibit the characteristic cracking during dry periods. These soils are low in organic matter,has poor drainage and are low in nitrogen and phosphorus.

***Management***

Application of organic manures, N & P fertilizers ,Irrigation during summer season are some of the recommended management practises. Land preparation should be based on the moisture content of the soil.

A variety of crops such as coconut, sugarcane, groundnut, cotton, chilly, pulses and vegetables are grown in these soils .

Mechira, Koraiyar, Valiyavallampathy, Gopalapuram are few representative soil series in this group. They are classified as Vertic Humitropepts, Ustic Humitropepts and Typic Haplusterts.

**Forest Soils**

These soils are developed from crystalline rocks of archaean age under forest cover. They occur along the eastern part of the State, generally above an elevation of 300m above MSL. The area is hilly and mountainous with steep slopes, escarpments, elongated rocky summits and narrow 'V' shaped valleys.

The depth of the soil varies considerably depending on erosion and vegetative cover. The soils are generally immature due to slow weathering process. Rock outcrops and stones are noticed on the surface. Gneissic boulders under different stages of weathering are noticed in the subsoil. The texture of the soil ranges from sandy clay loam to clay with reddish brown to very dark brown colour. CEC of the soil ranges from 5 to 15cmol/kg. pH ranges from 5.0 to 6.5. Fertility status is medium to high. Forest trees, shrubs and grasses are grown in these soils.

The few soil series encountered in this group are Kallar, Kattur, Channapettah, Muzhiyar, Adimali, Kalaketty and Menmala. The forest soils are classified under Typic Eutropepts, Oxic Humitropepts, Typic Dystropepts, Typic Kandiustalfs, Udic Kanhaplustults, Lithic Udorthents, Ustic Haplohumults and Typic Paleudolls.

**PROBLEM SOILS OF KERALA**

Some soils of Kerala are problematic due to the peculiar toposequence, undulating terrain, intrusion of sea water, heavy rainfall, poor drainage and high water table. These soils cannot be used for cultivation of crops without adopting reclamation measures. The major problem soils identified are Kuttanad soils distributed in and around Vembanad lake in Alappuzha, Pathanamthitta and Kottayam districts, Pokkali soils located between Thanneermukkam and Enamakkal bunds ie in the coastal areas of Ernakulam and Thrissur districts mostly distributed in Cochin, Kanayannur, Paravoor, Thrissur and Kodungalloor taluks. Kaippad soils situated in the low lying deltaic areas of river mouths *of Kannur* district, ,Kole soils of Thrissur and Malappuram districts and Poonthalpadam soils of Palakkad distirct.

**Kuttanad Soils**

Kuttanad region include parts of Ambalapuzha, Karthikapally, Mavelikara, Chenganoor in Alappuzha district, parts of Changanacherry, Kottayam, Vaikom taluks in Kottayam district and parts of Thiruvalla taluk in Pathanamthitta district.

Soils of Kuttanad are grouped into three categories viz. Kari, Karappadam and Kayal soils. Karappadom soils occur along the inland waterways and rivers which spread over a large part of upper Kuttanad. Kayal Soils are found in reclaimed lake beds in Kottayam and Alappuzha districts.

***Kari soils***

Kari soils, seen in isolated patches in Alappuzha and Kottayam districts at or below mean sea level and is subject to frequent flooding and water stagnation .They can be readily distinguished by their deep black charcoal colour which is due to high organic matter content. These pyritic soils on oxidation and subsequent hydrolysis produce sulphuric acid causing extremely acid soils ($pH<3.5$) referred to as Acid sulphate soil. They are derived from sediments high in sulfidic materials and low in bases. The texture of the soil ranges from sandy clay to clay with intermediate texture of silty clay loam and clay loam. The presence of fossil wood and partially decomposed organic residues below a depth of 50 to 100cm is a characteristic feature of this soil. Majority of these soils attain a pH value less than 2.5 with 30 percent 100 volume $H_2O_2$ , indicating that these soils are potentially dangerous acid sulphate soils. This information may help in the selection of cropping patterns, water management and amelioration of these soils. The dangerous nature of the potential acidity especially in the lower layers have to be considered during amelioration. Ferrihydrites and Jarosite mottles are occasionally encountered in the soil horizons . The colour of the mottles are pale yellow

The soil is poorly aerated and ill drained. These soils are affected by severe acidity and periodic sea water inundation with consequent accumulation of soluble salts. The soil is of low fertility status, besides these soils contain toxic concentrations of Fe, Al and many unidentified toxic organic compounds. These soils are found to be moderate in total nitrogen and potassium and high in phosphorus, but their available nutrient status was found to be low which could be attributed to the low pH, wide C/N ratio and anaerobic conditions. Copper and Zinc deficiency is also observed in these soils

These soils can be managed effectively by limiting the generation of acidity by maintaining the highest possible water table during dry periods, preflooding to allow reduction of acidity before planting the crop, double cropping of rice, which shorten the period of soil drying, frequent flushing of the surface with good quality water and intensive shallow drainage. Desilting the canals and providing sub-surface drainage will leach out the toxic concentration of soluble salts and pollutants from the sub soils.

The Soil Series identified and mapped by Soil Survey are Purakkad, Thuravur, Ambalappuzha, Kallara, Thakazhy and Thottapally. The soils are classified under Typic Sulfihemists, Thapto-Histic Tropic Fluvaquents, Typic Sulfaquents and Haplic Hydraquents.

***Karappadom soils***

Karappadom soils occur along the inland waterways and rivers. They are river borne alluvial soils and occur in fields which are about 1-2m below MSL. Soils are very deep, poorly drained dark grey colour with clay loam surface texture followed by silty clay sub soil. The sub soils show abundant prominent red and yellow mottles, gley horizons, streaks and concretions. Presence of sand pockets in sub surface horizon is another feature. Increase in CEC with depth is noticed in most soils.

Edathuva, Champakulam, Ramankari, Thottapally, and Manjoor are some of the major soil series identified under this category.

These soils can be grouped into two, based on the problems posed by these soils. The first group consists of Edathuva, Champakulam and Ramankari series. These soils generally have medium to heavy texture except Ramankari and are acid in the sense that the acidity can be reduced by liming or using other soil ameliorants.

Toxicities of Fe and Al are also noticed in these soils. These soils are found to be uniformly deficient in available copper. Zinc is also below the critical level in several locations. Presence of reddish yellow mottles, few iron concretions and dry roots are noticed down the profile. They do not have the adverse effect of salinity except in certain pockets under Champakulam series. Drainage is another major problem.

Soils such as Thottapally, Thakazhy and Manjoor are considered as para acid soils. Since the organic acid present in the soil also contribute to the development of acidity of these soils. They have light to heavy texture along with the presence of organic matter at different depth.

These highly problematic soils have impeded drainage and water stagnation, toxic concentration of soluble salts, high acidity, partially decomposed organic matter at different depth and presence of toxic compounds. The electrical conductivity upto 13 dS/m, pH as low as 3 or 2.5. Organic carbon percentage upto 17.5 %, toxic concentrations of soluble iron aluminum are noticed. Different forms of sulphur compounds such as organic sulphur, humus sulphur, water soluble sulphur and sulphate sulphur are identified in these soils.. But the availability of nutrients and lime are low due to the high content of iron and aluminium phosphate and high acidity. Salinity is also a problem at certain locations of these soils.

***Kayal Soils***

These soils are seen in the reclaimed beds of Vembanad and Kayamkulam lakes. They occur at 1-3m below MSL. These soils are more severely affected by salinity than other soil types of Kuttanad. Lime shells are seen evenly distributed throughout the profile. Calcium and magnesium are the dominant exchangeable bases in most of the profiles.

Dominance of exchangeable Sodium (Na) and deficiency of micronutrients like Cu and Zn are is noticed in some areas.

Soil Series identified by the Soil Survey department in this region is the Vechoor series. Here Lime shells are present at a depth below 30cm. A white colour due to creeping up of salt can be noticed on the surface.

The soils of Kuttanad should not be allowed to dry; hence immediately after harvest, water should be let in the field and allowed to stagnate . Lime coupled with manganese dioxide in requird quantity may be applied wherever Fe toxicity is noticed. It should be applied well before sowing during the preparation of field for cultivation. One or two days after liming, the field should be flushed with fresh water to remove the exchange acidity. Application of lime is required every year. Application of fertilizers containing sulphur should be avoided.

**Kole Lands**

These are bottom lands with concave relief located towards the central portions of Thrissur district running parallel to the sea coast on the west and the undulating region on the east. This bottom land which lies 0.5-2m below the sea level is submerged under water for a major part of the year. Paddy is extensively grown in these lands. Due to frequent flooding and deposition of fine particles the surface soil is generally heavy textured. The soil series identified are Konchira series under the former and Anthikad and Perumpuzha series in the latter.

The surface soils of Kole lands are mostly clayey in texture with good water holding capacity. Soils are rich in organic matter and total nitrogen. pH of the soil is found to range from 3.5 to 5.7. Cation exchange Capacity is seen to increase towards the lower layer and found to range from 12- 40 cmol/kg. Total nitrogen, potassium, calcium and magnesium increase with depth in the profile whereas phosphorus decrease with depth. Phosphorus fixing capacity of the soil is found to be very high.

**Acid Saline Soils**

Acid Saline soils comprises of Pokkali,Orumundakan and Kaipad soils.These are the major saline soils of the state where periodic inundation of sea water occurs. Based on the location, extent and intensity of salinity, three types of saline soils are recognized in Kerala. They are (i) Pokkali lands located between Thanneermukkam and Enamakkal bunds ie in the coastal areas of Ernakulam and Thrissur districts mostly distributed in Cochin, Kanayannur, Paravoor, Thrissur and Kodungalloor taluks; (ii) Orumundakan lands of Alappuzha and Kollam districts distributed mainly in Sherthallay and Ambalappuzha taluks and (iii) Kaippad lands of Kannur district situated in the low lying deltaic areas of river mouths. These soils comprise of low lying marshes near the rivers and streams, waterlogged and ill drained and areas subjected to tidal waves.

Soils of Pokkali lands are deep, dark bluish black in colour, impervious and clayey in texture which form hard mass cracks on drying and turned sticky on wetting. Soils of Orumundakan and Kaipad lands contain coarser fractions compared to Pokkali lands. Sea and backwater tides make these soils saline. During monsoon, when rain water and fresh water from rivers enter the field, salinity is partly washed off. Under such conditions inherent acidity of these soils become dominant. Vypeen and Thrikkakara series are identified in this region. These are fine black soils with salinity as major problem. Few yellowish red mottlings are seen in the subsoil of Vypeen series. Organic matter in various stages of decomposition and smell of hydrogen sulphide are noticed in Thrikkakara series. These soils are cultivated by paddy. Organic matter and total nitrogen is seen increasing with increase in depth. Phosphorus status is low but that of Potassium is high in Orumundakan and Kaipad lands. Rice followed by prawn culture is the cropping pattern adopted in Pokkali and

Kaipad lands. In these lands mounds are taken before monsoon.The salts get washed away by rainwater after which sprouted seeds are sown on surface of mounds. The mounds are dismantled and seedlings spread out after 30-35 days. Most of these soils are acidic with high EC.

Prevention of sea water intrusion and salinisation of the rice fields during cropping season is of prime importance. In Orumundakan lands tall ,salt and acid tolerant varieties called Orumundakan is cultivated. The soil series identified in the Kaippad lands is Chelapram series. Down the profile at a depth between 80-115 cm, black clay, extremely acidic in reaction with high content of soluble salts is seen. The most important distinguishing characteristics is the presence of highly mottled clay sub soils with decomposed organic debris.

A wide variation in texture from sandy loam to clay is noticed with dark grey to black colour. The pH of the soil ranges from 3.0 to 5.0. The cation exchange capacity of the soil is 12 to 31cmol/kg. Electrical conductivity ranges from 2 to 20 dS/m. The variation in chemical features is mainly related to tides and rainfall. The soil shows medium fertility status. Paddy is the only crop that can be cultivated.

The major soil series identified is the Chelapram series. The soils of the area are mostly classified under Haplic Hydraquents, Typic Hydraquents and Tropic Fluaquents.

**Poonthal Padoms**

These soils are locally known as Poonthalpadoms due to deep slushy nature of the soil in major part of the year. They are mainly located in the Palakkad gap of the Western Ghats. The soils exhibit swelling and shrinking properties leading to formation of deep crevices on the surface. The problems encountered in these soils are mostly physical than chemical. Impeded drainage and poor hydraulic conductivity are the major problems.

The soil series identified in this region is the Mechira series. Surface texture ranges from clay loam to clay and are moderately alkaline in reaction. Calcium dominates the exchange complex. Deep and wide cracks develop during summer season.

Higher water table due to seepage from canals and rivers and consequent slushy nature of soils during major part of the year is the main problem. Higher content of expanding types of clay minerals coupled with higher exchangeable Na and higher watertable result in poor physical condition.

Productivity of these soils can be improved by improving the hydrological properties by installing internal or subsurface drainage systems. Improvement in drainage coupled with soil management practices like application of organic manures, chemical fertilizers and soil amendments will improve the productivity of these soils substantially.

## SOIL RESOURCE INVENTORY IN KERALA

The optimal utilization of the soil resources calls for development of soil database which comprise both statistical and map information of different soils of an area,detailed morphological and physico-chemical properties and their interpretation for various purposes. Soil Survey is an established tool in the world for generation of soil database. The Soil Survey department of Kerala has carried out detailed soil and land resources inventory of the state over the years with the objective of delivering scientific information on the soil enabling it to understand, value and wisely manage this limited and most valuable natural resource.

Depending upon the objective, method, type of base map available and the intensity of observations, four major types of Soil Survey are carried out namely Reconnaissance Soil Survey, Detailed Soil Survey ,Semi Detailed & Reconnaissance-Detailed Soil Survey

The reconnaissance survey is undertaken to prepare resource inventory of large areas. It identifies broadly the kinds of soils and their extent of distribution. It enables to assess broad potentialities of soils and recognition of areas of promise that are suitable for intensive agriculture and those requiring priority treatment for amelioration. For this survey, base maps of 1:1,00,000 or smaller are used. The soil boundaries are delineated by extrapolation. The soil map provides information needed for broad land-use planning and agricultural development to precede detailed soil survey.

Detailed Soil Survey is undertaken in priority areas, such as pilot projects, agricultural research stations and in areas for urban development. For this kinds of survey, cadastral maps on 1:3000 to 1:8000 are used depending upon the intensity of survey and agricultural development needs of the area. The survey enables identification of soil units up to phases of series for planning development of individual parcels of land. The soil boundaries are demarcated based on actual traverses throughout the course. The resulting soil map provides sufficient information for interpretation of various kinds of soils and for understanding their pedogenic evolution.

Field work in Soil Survey also involve study of profiles at intervals depending upon the heterogeneity. Soil profiles are dug upto a depth of 2m or upto the parent material. In wet lands even though the soils are very deep, the study is limited to the depth at which water table occurs. Auger sampling for every ¼ to 1 km was carried out to study the variations in profile characters. The distinctive arrangement of the horizons which distinguish the morphology of the profile including their colour, depth, texture, structure, nature of parent material or parent rock and related features are noted in the case of each profile studied. Profiles showing similar horizon characters within narrowly defined limits are grouped together into soil series.

The integration of soil survey information which furnishes details in regard to the soil series and soil type occurring in the area together with the soil test data enables classification of individual management units in respect of plant nutrient content on the basis of their status as high, medium or low, which in turn facilitates assessing the nutrient supplying capacity of each soil type. This also help in rationalized planning of cropping patterns and soil management measures aimed at maximum production under varying conditions of soil type.

## SCIENTIFIC CLASSIFICATION OF SOILS (SOIL TAXONOMY)

The objective of soil classification is to organize the knowledge of soils so as to conceive the soil properties more clearly and understand their relationship more easily. It identifies, organizes and names soils in an orderly manner and formulates the relationship within the soil population. It also serves as a base for the application of soil technology for interpretation of soils as classified and delineated on soil maps and for transfer of experiences. Soil taxonomy is based on the properties of the soil as they are found in the field. Among the most significant of the properties used as the basis for classification is the presence or absence of certain diagnostic horizons. Soil Taxonomy facilitates grouping together of soils having comparable characteristics, i.e., arranging the existing knowledge of soils in a systematic way and helps in reducing the study of a number of soils into well defined classes or units.

The scientific classification of soils of Kerala is made based on classification system developed by USDA, the soil management support services.This multicategoric system is known as soil taxonomy . Each category is an aggregate of taxa ,define at about the same level of abstraction with smallest number of classes in the highest category and largest number in the lowest category. There are six categories in the classification system such as order, suborder, great group, sub group, family and series.

**Soil Series**

Soil Series is the lowest category in soil classification system. Soil profiles similar in differentiating characteristics and arrangement of horizons are grouped and identified as Soil Series. The field study and supplementary soil analytical data are used for the establishment of soil series. The soil series is named after the place where it is identified first.

As per the USDA System of Soil Classification twelve soils orders are established namely Gelisols, Andisols, Aridisols, Oxisols, Histosols, Spodosols, Vertisols, Ultisols, Mollisols, Alfisols, Inceptisols and Entisols. Out of the twelve soil orders , eight orders are identified in the state viz. Histosols, Spodosols, Vertisols, Ultisols, Mollisols, Alfisols, Inceptisols and Entisols. The details of the soil orders identified in Kerala are briefed below.

***Histosols***

Peat soils and soils rich in organic matter,that develop in lower topographic positions in permanent water saturated environment are grouped under Histosols. High acidity and high content of sulphidic material are associated with this soils.These soils are identified in Kuttanad Kari lands.

***Spodosols***

Spodosols occur sporadically on the raised coastal sandy beach deposits or the coastal sandy levees in the Alappuzha coastal plains. The spodic horizon is a subsurface horizon with accumulation of organic matter and sesquioxides. These soils have low nutrient content and nutrient holding capacity for most agricultural purposes and they are also non sustainable.

***Vertisols***

They are confined to Palghat gap and extend eastward to Tamilnadu. Internal drainage is impeded. These soils have uniform black or dark colour with more than

30% clay which swell on wetting and shrink on drying. Vertisols are very productive soils capable of producing very high yields of paddy,sugarcane and cotton.

***Ultisols***

These are base-poor mineral soils of humid region developed under high rainfall areas.They have low base saturation and a clay enriched sub surface horizon.The soils under this order occurs on all kinds of parent material and at varied geomorphic positions.

***Mollisols***

These are found in Western Ghats regions which are predominantly eastern sloping. They are dark coloured well developed base rich soils with well structured surface horizon rich in organic matter .

***Alfisols***

These are base rich mineral soils of humid and sub humid regions.These are developed from different types of parent material and at varied geomorphic positions. The subsoil contain significant accumulation of illuviated silicate clays. The soils is suitable for growing a wide variety of crops.

***Inceptisols***

These are juvenile soils developed owing to the alteration of parent material and occupy similar geomorphic positions as that of Entisols. The wet inceptisols or Aquepts form large tracts of wetlands in Kerala.

***Entisols***

Entisols lack diagnostic horizons and occur on plains of recent to sub recent deposits and on steep aspects of the hilly terrain. In the steep slopes of the Western Ghats soils are often truncate due to severe erosion losses. Young soils with less profile development are also encountered in high altitude mountain summits.

**BENCH MARK SOILS OF THE STATE**

The Bench mark Soils are selected from among the existing and established soils that represent typical range of characters.The soils which occur extensively ,soils of special nature, soils that hold a key position in Soil Taxonomy and one that has special significance to farming, engineering ,forestry, irrigation, urban development, wetland conservation or other special purposes are considered as Benchmark Soils. It is a reference point which is adequately characterized in terms of its properties and environmental conditions. The information about Benchmark Soils can be extended to other soils closely related in classification and geography.

The Benchmark soils helps the research community to focus their investigative effort on key soils that have the greatest potential for applying new technology across a large area and also for transferring new technologies to similar soils ,there by optimizing cost-benefit ratios. Benchmark Soils are useful in planning many kinds of studies including the assessment of conservation effects on soil erosion, dynamic soil properties, soil quality, studies of soil erodibility factors, crop and plant adaptation and yield and fertility.

The State Soil Survey Department has identified 82 soil series as Benchmark soils of state. The details of the benchmark soils are available in the publication entitled “Benchmark Soils of Kerala”.published by Department of Soil Survey and Soil Conservation. The district wise names of Benchmark soils identified are listed below:

1. Trivandrum district
   1. Kazhakuttam
   2. Amaravila
   3. Vellayani
   4. Trivandrum
   5. Nedumangad
   6. Kallar
   7. Ponmudi
2. Kollam district
   1. Neendakara
   2. Varkala
   3. Sooranad
   4. Mylom
   5. Ummannoor
   6. Karavaloor
3. Pathanamthitta district
   1. Airavan
   2. Adoor
   3. Ayroor
   4. Kumaranperur
   5. Gudarakal
4. Alappuzha district
   1. Alappuzha
   2. Punnapra
   3. Purakkad
   4. Champakulam
   5. Mannar
5. Kottayam district
   1. Manjoor
   2. Parampuzha
   3. Kottapuram
   4. Paippara
   5. Nellappara
6. Idukki district
   1. Manakkad
   2. Thommankuthu
   3. Chinnar
   4 Venmani
   5.Pampadumpara
   6. Anamudi
7. Ernakulam district
   1. Udayamperoor
   2. Vypeen
   3. Ikkaranad
   4. Punnamattom
   5. Perumbavoor
   6. Odakkali
8. Thrissur district
   1. Manathala
   2. Konchira
   3. Kizhapallikara
   4. Koratty
   5. Kozhukully
   6. Painkulam

| | |
|---|---|
| 9. PALAKKAD DISTRICT<br>1. Thirunarayanapuram<br>2. Karakurussi<br>3. Mannur<br>4. Bhavaji Nagar<br>5. Anuppur<br>6. Uthampallam<br>7. Agali<br>10.MALAPPURAM DISTRICT<br>1. Triparangode<br>2. Angadipuram<br>3. Naduvattom<br>4. Vazhikadavu<br>5. Mannamkulam<br>6. Walakkad<br><br>11.KOZHIKODE DISTRICT<br>1. Elathur<br>2. Chelapram<br>3. Kakkodi<br>4. Nanminda<br>5. Kunnamangalam<br>6. Thiruvampadi | 12.WAYANAD DISTRICT<br>1. Battuvady<br>2. Pulpally<br>3. Mananthavady<br>4. Sulthan Bathery<br>5. Periya<br>6. Meppadi<br>13.KANNUR DISTRICT<br>1. Narikkot<br>2. Kunhimangalam<br>3. Arathil<br>4. Kolikkadavu<br>5. Wanjiyam<br>6. Kunnathuru<br><br>14. KASARAGOD DISTRICT<br>1. Hosdurg<br>2. Thekkila<br>3. Edanad<br>4. Payalam<br>5. Maloth |

**CONCLUSION**

Agriculture in Kerala is at cross roads today. Production and productivity of almost all important crops are either stagnant or on the decline. A good understanding of the resource base and adequate information on the heterogeneous crop growing environment is essential for evolving appropriate policies, research and development activities. Considering the heterogeneity of Kerala soils, research programmes should be formulated to evolve management recommendations for each soil series. This will not only help in increasing agricultural production and maintaining soil quality but also facilitate situation based research in agriculture. The results of these research programmes should be communicated to the farmers and local people to enable them to practice situation based agricultural operations for the sustainable and efficient management of the soils of the state.

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# Role of Integrated Watershed Management Program (IWMP) in Agriculture Development

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## INTRODUCTION

Ministry of Agriculture and Ministry of Rural Development of the Government of India, the Planning Commission of India, the National Development Council, the Government of Kerala and the State Planning Board, in all their Eleventh Plan (2007-2012) and Twelfth Plan (2012-2017) related documents and discussions expressed great concern for the effective implementation of "Integrated Watershed Management Program" (IWMP) in our country. The major objectives of the IWMP are to restore the ecological balance by harnessing, conserving and developing degraded natural resources such as soil, vegetative cover and water. The outcomes are prevention of soil run-off, regeneration of natural vegetation, rain water harvesting and recharging of the ground water table. This enables multi-cropping and the introduction of diverse agro-based activities, which help to provide sustainable livelihoods to the people residing in the watershed area. In addition, there is a Scheme of Technology Development, Extension and Training (TDET) is also being implemented to promote development of cost effective and proven technologies to support watershed management. Till 1.4.2008, Agriculture Department implemented 3 Watershed Programs; (i) Integrated Wastelands Development Program, (ii) Drought Prone Areas Program and (iii) Desert Development Program. Since then, they have been brought under a comprehensive program named Integrated Watershed Management Program (IWMP) to be implemented under "Common Guidelines for Watershed Development Projects 2008".

The Watershed approach represents the principle carrier for transfer of rainfed agriculture. A watershed is a geographic area from which all water drains into a common point, which makes it an ideal planning unit for conservation of soil, water and biomass; and encourage the sustainable development of the area by empowering people at the local level to manage their own resources. Watershed is a spatial unit that includes diverse natural resources that are unevenly distributed within a given geographical area (Knox and Gupta, 2000). The water flowing in a watershed interconnects up-stream and down-stream areas and provides life support to rural people holding unequal use rights making people and animals an integral part of the watersheds. Watershed development provide immense scope for effective integration of various sectoral programs, primarily based on a "ridge to valley" approach. It also enables clarity on issues like sustainability, equity and participation that are addressed in the decentralized planning. The declining per capita land and fresh water availability couples with soil erosion and land degradation in Kerala and many parts of our country are posing serious threat to environmental, food, social and economic security. It may be noted that Watershed Development and Management approach is the need of the hour for Kerala, as we have (i) reasonable rainfall (both South-West, North-East and Summer Spells) confined to lesser number days (around 110 to 120 days in an year) with (ii) steep sloped terrains where large number of short and fast running rivers (41 west flowing rivers) dominate; (iii) human interference has substantially degraded the upper and mid catchments resulting drying up of river and siltation of reservoirs and (iv) rapid land use changes due to large scale reclamation, deforestation, plantation crops and setting up of human habitations (Vijayanand, 2012). Integrated Watershed Management is the only practical approach by which the above said issues could be reasonably addressed which can yield good results. Kerala's past experience during 9$^{th}$ Plan, in the preparation of "Master Plan for Watershed based Development" in the Block Panchayats may be utilised in developing "District Level Master Plan for Integrated Watershed Management Programs" utilising MGNREGA during the 12$^{th}$ Plan thereby People's Participation on a big way can be ensured in IWMP.

Soil, water and biomass are vital natural resources for human survival. The growing population in the world and increasing demand are placing tremendous pressure on these resources, which results in fast depletion of these resources in many countries posing serious problems to agriculture sustainability, livelihood opportunities and vulnerable communities. Soil, water and biomass conservation including micro-scale water resource development is the foundation of any watershed development programme. The Watershed approach represents the principle carrier for transfer of rainfed agriculture. Integrated Watershed Management Program is a prerequisite not only for land, water, and biomass management of degraded areas but also for improving the livelihood of farmers as well as for conservation of areas so that biodiversity is protected for future generations (Nair, 2002 a, b).

## BACKGROUND

It is unfortunate to note that there are not many good models of Watershed Development Programs in Kerala amidst a large number of attempts made under Western Ghats Development Program (WGDP), National Watershed Development Program for Rainfed Areas (NWDPRA), Integrated Waste Land Development Program (IWDP), Hariyali, etc. executed in the state during the last three decades. Watershed Management concept was introduced as part of Western Ghats Development Program (WGDP) in Kerala during the mid 80s. Subsequently in the foothills of Himalayas, Sukho-majri watershed program was successfully completed. Later Ralaegan Siddhi watershed program came out as a successful watershed model with well established linkages and social arrangements. Thereafter under the WGDP, attempts were also made to implement watershed development programs in Idukki District which did not reap much fruits. However there are many good examples of Watershed based development programs successfully completed in many other parts of India. During the middle of 9th Plan, as part of “People’s Plan” under the Decentralised Planning Program, State wide campaign was organised for the preparation of “Watershed Based Development Master Plans” in each of the 152 Block Panchayats of Kerala. Identified resource persons from Science and Technology institutions of the state, actively participated in this experiment and generated about one thousand trained man power through a TOT program in each of the Blocks whose efforts resulted in bringing out 152 “Watershed Appraisal Reports” which contained the delineated micro-watersheds in each of the Panchayats with brief note on the status of land, water, agriculture and its allied sectors including livelihood measures with gender issues of that micro-watershed, falling under each of these Blocks. Towards the end of the 9th Plan, a concept on “Watershed Grama Sabha” was brought in and these appraisal reports were presented in some of these “Watershed Grama Sabhas” could generate incredible belief in all sections of the society that Kerala was entering into a paradigm shift in the land, water and biomass development and its management in coming years. However, these efforts did not blossom in the 10th Plan activities of the state in total with a few exceptions. During the 10th Plan, the National Rural Employment Guarantee Act (NREGA) notified on 7th September, 2005, marked a rights-based approach that makes the Government legally accountable for providing employment to those who are above 18 years of age and willing to do unskilled work, in 200 districts in India with a budget allocation of Rs.10,000 crore for 2006-07 and extended to another 130 districts subsequently. Even though many state governments moved very slowly in implementing this program, the Government of Kerala implemented NREGA in Palakkad and Waynad districts from 5th February, 2006 onwards during the 10th Plan and it was extended to all the other districts in the state on 1st April 2008 in the 11th Plan and the Rajya Sabha approved the renaming of NREGA on 17th December, 2009 as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). Government of India again suggested to all the States for the preparation of Watershed Development Master Plans and integrating with MGNREGA during the Eleventh Plan (2007-2012) utilising the Common Guidelines for Watershed Development. Many local self governments took advantage of this and proposed different types of work under watershed development projects. It is apprehended that during the 12th Plan, in which consolidation of all plan programs on land, water and biomass; progressing in all the local self government bodies, may take a new path under the Integrated Watershed based Development Program (Nair, 2012).

## CONVERGENCE BETWEEN MGNREGS AND IWMP

Convergence is an evolving process and can be determined only by the available resources at the Central, State, District, LSGs and the project level. The different parameters (cost of material component, wages of skilled /semi-skilled workers and the limiting factor of 40%) and modalities ( management, planning & works) Guiding Principles; Cost Norms; Execution; Monitoring, Evaluation & Review; Post-Project Management, Non-Negotiable for works executed under MGNREGA, Technical Inputs and Funding of Projects for convergence needs to be understood properly. Pilot projects needs to be undertaken in the districts to be selected jointly by DoLR and DoRD for operationalisation of convergence between IWMP and MGNREGA for understanding the ground level issues in convergence which could be sorted out subsequently.

## INTEGRATED WATERSHED MANAGEMENT PROGRAM AND AGRICULTURE DEVELOPMENT

It is not a new technical or scientific approach, but a new strategy for carrying out the activities concerning soil, water and biomass conservation in general, conservation of forestry, irrigated and dry land farming, horticulture or other use of the land for producing biological products within a geo-hydrologically defined region in particular (Nair, 2002). Integration of these activities will yield synergic benefits and multiply the effects. Watershed management may mean different things to different people but Integrated Watershed Management deals with the use and conservation of natural resources to meet the basic needs of land users in a sustainable manner. This new approach to watershed management is 'people-friendly' and 'process-based' rather than physical target-oriented (as was the case in most of the past watershed programs). A watershed is made up of the natural resources in a basin, especially water, soil, and vegetative factors. The comprehensive development and management of a river basin so as to make productive use of all its natural resources and also protect them is termed "Integrated Watershed Management Program". It is important that integrated watershed management must consider the social, economic, and institutional factors operating within and outside the watershed area. Since integrated watershed management involves decision-making, a multidisciplinary and multi-institutional approach is essential for efficient utilization and protection of natural resources. The main developmental objectives of Integrated Watershed Development could be as follows: (i) to provide a method of integrated basic resource development of the watershed in such a manner that short term and long term goals of development are in harmony with one another, (ii) to optimize landuse and increase productivity, (iii) to conserve land degradation by impeding surface runoff, (iv) to conserve water and enhance groundwater recharge, (v) to prevent floods and siltation in rivers, dams and lakes, (vi) to develop scientifically appropriate agri-horti-silvi-pastoral-hydro systems (Sati, et al., 1998).

Lack of people's participation especially of women is a serious constraint in watershed development programs in India, however, this is not really applicable in Kerala. Lack of awareness, accessibility, difficult terrain, access to information (data base), shortage of funds, corruption, unsuitable infrastructure, socio-cultural and institution-cum-political are the main constraints. Hence, for a successful watershed management, a participatory, integrated, multidisciplinary, and multi-sectoral approach is essential. Gender issues, the needs of disadvantaged groups, and distributional equity should be considered and the ownership of the people needs to be ensured. Good communication skills at all levels are crucial to achieve the aims of participatory integrated watershed management. The Agriculture Department and the Irrigation Department of the State and its different wings and the large man power available with these departments should be effectively used for a successful IWMP. If these officers can have a close technical association with the agriculturists, through a workable mechanism, IWMP in Kerala can show a new opening in the food security issue of the state and a revised Agriculture based “Kerala Model of Development” to the Nation.

Sound IWMP means controlling floods and reducing land degradation as well as improving livelihood of farmers. Utilizing the land according to its capability, maintaining adequate vegetative cover particularly during the rainy season, conserving maximum possible rainwater at the place where it falls, draining out excess water with a safe velocity to avoid soil erosion and diverting it to storage tanks for future use, preventing gully formation and checking at suitable intervals to control soil erosion and recharge groundwater, maximizing productivity per unit area, per unit time, and per unit of water, increasing cropping intensity and land equivalent ratio through intercropping and sequential cropping, safe utilization of marginal lands through alternative land use systems, ensuring sustainability of the ecosystem benefiting the man-animal-plant-land-water complex in the watershed, maximizing the combined income from the interrelated and dynamic crop-livestock-tree-labour complex over the years, stabilizing total income and cutting down risks during aberrant weather situations, improving infrastructural facilities with regard to storage, transportation, and marketing; systematic and proper delineation of the watersheds, emphasizing locals initiatives and acknowledging larger public interest, taking long-term approach to use the best available scientific information and formulation of action plans based on an ecosystem approach. Even after withdrawal of economic resources, technical expertise and infrastructure, if the program survives, then it is sustainable. Hence it is important to note that People’s participation right from pre-planning stage along with local level people’s institution is required.

**Key elements in participatory processes**

The key elements are: (i) Participatory, multidisciplinary, and multi-sectoral approach. (ii) Envisioning of both farmers and professionals for integrated watershed based management. (iii) Farmers' empowerment and ownership of watershed management processes and programs. (iv) Assured and quick benefit generation by watershed management programs. (v) Mainstreaming gender concerns specially those of women and other disadvantaged groups.

It should be clear that unless the watershed or natural resource management activities result in quick (preferably within a crop season or a year) net direct benefits to the participating farmers, their participation cannot be expected. Without direct benefits and farmer participation, there will not be any on-farm level watershed management or conservation and better utilization of natural resources. On common property resources also, if they are to be managed better by the people, they must produce quick benefits to them. Thus, gender-sensitive processes and activities assuring quick economic benefits (along with environmental and social benefits to all) are needed. In all the above elements of the participatory process, dialogue is important to achieve true participatory watershed management. Farmers should get the chance to express their views and opinions to identify problems and to share their ideas with researchers, field scientists, practioners and managers. Local (or farmers') organization and institutional strengthening should be the important development objectives. The result of such approach will be the boosting of confidence of the farmers and the spreading of innovative ideas from farmer to farmer (Sharma and Krosschell 1997).

**BENEFITS OF INTEGRATED WATERSHED MANAGEMENT**

Some of the benefits of integrated watershed based management may be:

(i) improving water availability, controlling floods, and reducing land degradation.

(ii) maximizing productivity per unit area, per unit time, and per unit of water.

(iii) proper utilization of marginal or wastelands through alternate land use systems.

(iv) stabilizing income even under bad weather conditions.

(v) improving livelihood of farmers by maximizing the combined income from the interrelated crop livestock- tree-labour complex over years.

(vi) ensuring ecological balance and

(vii) food security. These can take a new path under the Integrated Watershed Management Program.

**CONCLUSION**

Convergence of MGNREGS and IWMP is a good step taken by the Ministry of Rural Development of the GOI in 2009 which needs to be experimented immediately through few pilot projects in selected districts and solution to teething problems may be fished out during 12$^{th}$ Plan period. The Agriculture Department, Soil Survey &Conservation Department and the Irrigation Department of the State may be identified as the nodal agencies for the effective implementation of IWMP by distinctively shouldering responsibilities in consultation for the effective implementation of IWMP in the State. The large man power available with these departments along with infrastructure available with them should be effectively made use for a successful IWMP in the state. If these officers can have a close technical association with the agriculturists, through a workable mechanism, IWMP in Kerala can show a new opening in the food security issue of the state and a revised Agriculture based “Kerala Model of Development” to the Nation. A pilot experiment in this proposed direction may be tried in watersheds of one of the districts in Kerala during the 12 Plan period.

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# Agricultural Water Management – Need for a Paradigm Shift

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## INTRODUCTION

Water is the key ingredient for agricultural production and is under increasing pressure due to the progressively increasing competition over this resource. Crop production in many parts of the country is seriously limited by water scarcity. More water and irrigation facilities will be needed for producing food for the ever increasing population and this will be further challenging in the context of changing life style and standard of living. It is estimated that roughly one litre water is needed to produce one calorie whereas for drinking purpose 2-5 litres will be sufficient. Production of milk, meat, sugar, oils etc require more water than cereals.

Over the last century, significant productivity gains in agriculture have protected the world from devastating food shortages and the threat of mass starvation. Water resource development and management in both irrigated and rain-fed agriculture had been instrumental in achieving this. On a consumptive use basis, 80-90% of all water is consumed by agriculture, but the water use efficiency remains very low with more than 50% water losses. As water use is highly dependent on temperature, global warming will most likely intensify the water demand both for human and ecosystem services upon which the human activities rely on. Recent concerns about the rising food prices and food security on one hand and increasing water scarcity, climate change and high proportion of water used in agriculture on the other hand, are drawing attention to the urgent need to improve water management in both irrigated and rain-fed agriculture.

## IRRIGATION DEVELOPMENT

Irrigation development has been a major factor responsible for the green revolution in India. However, efficient functioning of the irrigation systems are yet questionable, since many of the projects could not meet the set objectives and failed to exploit the full productive potential of the cropped land. The scope for further irrigation development is severely getting constrained by decreasing water resources coupled with the growing competition for water and the situation is exacerbated by declining quality of water and soil resources. Considerable improvement is needed in performance efficiency of irrigation projects, which will add to the saving of a large volume of water. Studies conducted in this line clearly brings to light the fact that major problems in the irrigation sector is with respect to the poor maintenance, equity/ reliability in water availability, poor canal operation, lack of conservation, conveyance losses etc.

### Irrigation System Performance

Agricultural development depends to a great extent on the effective and efficient management of the irrigation system. Irrigation gives great security in the agriculture sector, since it cuts the yield loss in dry spells, gives security to take risk in high input investment, allows growing high value crops etc. Irrigation system, weather it is surface or groundwater based, major or medium or minor, is comprised of the water source, conveyance and delivery system, control structures etc. Many of the irrigation systems provide important hydrological cycle and ecosystem functions such as flood protection, groundwater recharge, prevention of soil erosion and landslides, water and air purification, biodiversity conservation etc. The water storage and delivery system should ensure better performance efficiency, for which a rigorous and agile monitoring of the system is essential. This requires knowledge of how the canal and network should be designed or modified and also a thorough knowledge and understanding of how the water should be managed and applied. Vermillion (1992) claimed that construction of irrigation structures has for long dominated but the culture of service provision is missing to a great extent world over. For ensuring reliable water supply, there should be well designed improvement in water control, automation, scheduling, capacity building at different levels etc. Irrigation scenario can be improved by adopting innovation in irrigation system management, developing new water source, groundwater facilities etc. and also by adopting different production measures and multiple use of water.

## WATER MANAGEMENT IN AGRICULTURE

Agricultural water management involves rainwater management, irrigation management and drainage management. Scientific water management increases agricultural production and economic development, facilitates multiple water use and responds favourably to climate change. In addition to the major and medium irrigation projects, small/minor irrigation systems developed and managed by the small/ marginal farmers are usually left unnoticed.

### Rain Water Management

Agriculture is vulnerable to climate change and vagaries of weather. Conservation and management of rain water is the key to water resource development and is the foundation for water management. Efforts should be made to trap as much rain water as possible by capturing rainfall, by adopting insitu soil and water conservation, by storing water for irrigation, by reducing evaporation demand etc. Even a small quantity of rainwater saved and stored can be used for life saving and supplemental irrigation at critical stages of crops and this will improve the crop productivity many fold. Risk management in rain-fed agriculture is a very important technological intervention and hence in rain-fed farming, it is essential that farmers should have supplementary irrigation facility.

**Irrigation Management**

In irrigated agriculture there are various challenges. Water managers have to be aware of the spatial and temporal availability of water, field-level water demand, contribution of ecosystems (both aquatic and riparian) on the water sector, need and opportunities to improve infrastructure to satisfy the needs, technologies for more efficient water use, measures to expand the water resource in whatever way possible etc.

***On-farm Water Management***

Scientific on-farm water management concentrates on optimum water application / retention for meeting the production efficiency requirement of the crops. This includes both irrigation and drainage and varies in wetlands and uplands. Hence it is not possible to provide a general prescription of water management in all areas, since the strategy will vary with the soil, climate and environment. Choice of on-farm irrigation and drainage lay out and irrigation method best adapted for different environmental regimes will be determined by the nature of topography, soil, rain fall, water supply and the type of crop. It has been reported in many studies that irrigation water is used in excess in most of the irrigation commands. The main factors contributing to the excessive use of water at the farm level are evaporation and seepage losses, wind drift, absence of proper farm management, lack of operation and maintenance, poor leveling of fields, groundwater accession, low water price etc. The assessment of losses at the farm level has revealed that improvement in water management is essential and is very much possible to achieve considerable water saving, and for bringing more area under irrigation.

***On farm Water Management in low-lands***

In the low lands (wet lands), the crop generally grown is paddy and is raised either by direct seeding or by transplanting. The commonly adopted irrigation method is flooding. Since water requirement of rice crop is comparatively more, efforts should be taken to improve the efficiency and productivity of water on-farm. Attention will have to be focused on the gap between consumption and requirement, options to reduce water losses and measures for increasing on-farm water productivity. Rice yield per unit evapotranspiration (ET) can be as high as 1.6 kg/cubic meter, which is more or less comparable with that of the other cereal crops. But when other water use components (seepage, percolation, run off etc) are taken into account, the field-level water productivity of rice is reduced markedly. Command Area Development Authority (CADA) is set up with the major objective of improving the on-farm water management and thus increasing the production in the command areas. Singh (1983) reported that on-farm development alone could not overcome the deficiencies of the main canal system, but the field water distribution, irrigation scheduling etc are also very important. The time needed for distributing water in the field can be shortened significantly by adopting channel to field irrigation. Even though it is commonly recommended to maintain the standing water depth at 5cm in paddy, studies revealed that in order to reduce the water requirement, the manager can go from 5cm to ponding water condition in the field without considerable depreciation of the yield.

To optimize the use of limited water in the irrigated command area, it is important to plan crop zoning by identifying those parts of irrigated commands with comparative advantage for selected non rice crops. If scientific water management is strictly adopted in the command areas, considerable water saving is possible. Indiscipline in water management happens wherever the water supply is unpredictable and because of that the farmers show reluctance to invest in inputs (Hussain et al 2004).

***On-farm Water Management in the Uplands***

Irrigation method, irrigation scheduling and crop management techniques are important to increase the water productivity in irrigated uplands. Selection of the irrigation method should be based on the land profile, soil type, topography, crop etc. While designing the irrigation system, and recommending improved irrigation techniques in any area, the soil-plant-water relationship should be studied to understand how much water stored in the root zone is available to plants.

Irrigation methods can be surface, sub surface or underground based. In surface irrigation, since water is applied on the soil surface, if evaporation losses are not controlled, the losses will be considerably more when compared to other methods. In the underground irrigation methods, irrigation is applied in the root zone by means of porous pots or pipes placed in the root zone and hence the losses are negligible. In sub irrigation, groundwater level is raised sufficiently to dampen the soil surface. Both surface and subsurface irrigation are conventional methods of irrigation and are commonly adopted by most of the small holders since these do not require any sophisticated system and recurring operation and maintenance cost.

Land grading/ leveling is very important while adopting surface irrigation methods. Surface irrigation methods such as flood irrigation, channel irrigation, micro irrigation, surge irrigation, sprinkler irrigation etc. can be made more efficient by adopting land grading or leveling. Water delivery system should provide timely and adequate supply of water to the field considering the prevailing field conditions. The flood and channel irrigation methods are usually adopted in close growing crops and where the water is available in surplus. However, these methods are water intensive and may sometimes result in water logging and nutrient wastage. Among the surface irrigation methods, surge irrigation is a relatively new concept and is followed in some places in the Palakkad district of Kerala. In this method, 40% water saving, 25% yield increase, 20% land saving, 40% irrigation labour saving and considerable saving in tillage had been reported.

Micro irrigation methods such as drip and micro sprinkler are effective tools for water conservation. Studies have revealed significant water saving ranging between

40% and 70% in drip irrigation with yield increase as high as 100% in some crops in specific locations (Annual Report, WTC, TNAU (1985-2000). Drip irrigation technology is not complicated, but requires both investment and maintenance. Reduction in water consumption due to drip irrigation over surface method is 30-70% for different crops (Postal 2001). Productivity gain is in the range of 20-90% for various crops (INCID 1998). Substantial reduction in weeds and cost of cultivation are also reported as the additional benefits (Narayanamurthy 1996 and 2001).

Unlike in the case of flood irrigation, micro irrigation can be adopted in all land types ie, in uneven topography, hills, barren lands, shallow soils etc. One of the major reasons for the slow growth of micro irrigation in India is the high investment cost. Even though Kerala Government is financially supporting farmers to adopt micro irrigation through providing subsidy etc, farmers are reluctant to adopt the same due to the high capital cost, difficulty in availing subsidy, poor awareness, non-suitability for marginal/small farmers, free electricity and low price of canal water, fear about the system clogging, poor extension and training facilities etc.

Cablegation is another automated surface irrigation method which is easily adaptable for many field crops and orchard crops. Water application rate is designed to closely match the infiltration characteristics of the soil to minimize deep percolation and run off loss of the soil. Compared to blocked furrow irrigation method, at least more than 50% water saving can be achieved here. If properly designed cablegation system can achieve water application efficiencies of more than 80%.

### *Underground Irrigation Methods*

Underground irrigation methods are localised irrigation methods and are very efficient since the wastage is almost nil. Water is applied in the root zone of the crop and hence can be effectively absorbed by the plants.

### Drainage Management

In agricultural water management, drainage is as important as irrigation. Proper drainage on agricultural land is very important and this not only enhances crop production but also has a role in soil conservation. The main objective of agricultural drainage is to remove excess water quickly (within 24 to 48 hours) and safely to reduce the potential for crop damage due to excess water stress to the crop. Excess water has been shown to decrease yields of many crops, including perennial crops like coconut. Other benefits of drainage include increased soil aeration in root zone, increased availability of nutrients, reduced risk of delayed harvesting, less damage to agricultural equipment, less overlapping of inputs during field operations and more effective weed control.

## HOW TO INCREASE THE IRRIGATION EFFICIENCY AND WATER SAVING IN AGRICULTURE?

Potential for water saving in irrigation is enormous and substantial water saving can be attained by focusing on the correct and actual requirement of water and crop growth, by adopting modern and scientific methods of cultivation and water application techniques and also by raising new crop varieties. In many irrigation networks, less than half the irrigation water only actually benefits the crop and the rest is lost in seepage, evaporation and runoff from the fields. Irrigation water deliveries can be reduced substantially through a range of technical and management practices such as efficient irrigation methods, canal lining, pipe delivery, reduced allocation, pricing to reduce the use etc. IRRI has explored various field level water saving technologies such as systems in rice intensification, aerobic rice and ground cover management. Each of these techniques reduce one or more water outflows-such as seepage and evaporation and thus contributes to water productivity. Water saving irrigation techniques such as saturated soil culture and alternate wetting and drying also can reduce the unproductive water outflows drastically and increase water productivity.

**Crop Production Technologies**

Increase in irrigation efficiency is possible only through a combination of approaches such as agronomic, physiological, biotechnological and engineering approaches which may collectively be described as water saving agriculture. Considerable reduction in evaporation losses can be achieved through closer spacing, mulching, correct timing of irrigation at different stages and well-designed sub surface drip irrigation.

Suitable crop rotation recycles the soil fertility when combined with other practices. In monoculture, where the same crop is taken year after year, the water holding capacity of the soil gradually decreases and ultimately the soil becomes unhealthy for production. Under conditions of low water availability, irrigation at critical growth stages will increase the water efficiency. Intercultural operations, mulching, use of anti-transpirants, paired row cultivation etc can reduce the evaporation loss and thus can contribute to increased water use efficiency. Fertigation is a sophisticated and efficient method of applying fertilizer through irrigation water. Based on the studies conducted on various horticultural crops, fertigation was found to increase the yield and quality of crops besides increasing the economic efficiency of the irrigation system. Response to water stress for plant growth and yield varies with plant type and the growth stage.

**Adoption of Deficit Irrigation**

In water scarce conditions, deficit irrigation can be adopted for increasing the water productivity and hence there is a growing interest in adopting deficit irrigation for many crops. Here, the plant is exposed to certain levels of water stress during either a particular growth period or throughout the crop growth season without significant reduction in yield. The objective of regulated deficit irrigation is to save water by subjecting the crops to periods of moisture stress. This requires precise knowledge of the crop response to water in terms of species, type and crop growth stage. Irrigation technology and irrigation scheduling may have to be adopted rationally using limited water supply. Under deficit irrigation, agronomic practices may require modification eg; decreasing plant population, lesser fertilizer application, flexible planting dates, short season varieties etc. Water stress results in less ET by closure of stomata, reduced carbon assimilation and decreased biomass production. The reduced biomass production has little effect on ultimate yield where the crop is able to compensate in terms of reproductive capacity. English and Raja (1996) reported that reduction in irrigation costs were greater than reduction in revenue due to reduced yields. Deficit irrigation can lead to increased profit where water costs are high or water supply is limited and increases the water productivity to a great extent (Zhang 2003).

## MANAGEMENT TECHNIQUES

In the National Water Policy 2002 (GoI, 2002) it is stated that "Private sector participation in planning, development and management of water resources may help in introducing innovative ideas, generating financial resources and introducing corporate management and improving service efficiency and accountability of users" (section 12 and 13 of the National Water Policy). Participatory Irrigation Management (PIM) aims at handing over the distribution, operation and maintenance and management of the system after the minor outlet to farmers associations. In Participatory irrigation management, the effect will be reliable only if farmers are proactive to adopt the given technology. In place of centralized and bureaucratic methods, participatory and transparent decision making should be resorted to. Gender equity also should be considered to be fair in water resource management. Legal reforms and well executable water laws are also important. PIM helps in a big way to assess the physical condition of the irrigation system and also helps to identify the practical options for ensuring reliable and flexible options for water service delivery. PIM plays a commendable role in the modernization of the irrigation system which has to be based on strategic environmental assessment and cost/benefit analysis. PIM can also help in modernization and strengthening of the irrigation institutions.

Public Private Partnership (PPP) is also found desirable in the water management sector. The difference between PPP and privatisation is that PPP aims at improving the system performance within the existing realm of public sector responsibility of ensuring clean water at affordable price to all the users. Thus it is a joint venture of the public and the private sector and here, the responsibility of resource pooling and input management also rests with both the parties. In Kerala, this is found to best suit the small irrigation sector like tanks, ponds, springs etc. Khalil (2004) and Pandit (2004) have reported the merits and demerits of the different models of PPP. In the present scenario, where the Government cannot support all the needs of the irrigation sector due to the paucity of funds and man power, PPP can be a great relief.

### Irrigation Water Management Strategies

Water management in the irrigation sector will be either demand based or supply based. Generally, in water management, there are three distinct phases of management:

1. Phase of supply management, where the main objective is getting more water and thus the phase involves large scale engineering projects. It was the main perception in water management for many years

2. Phase of demand management, where the end use efficiency measures are given top priority. This is to 'get more crop per drop' in wherever situations water is used. ie. irrigation, domestic etc
3. Demand management by allocated efficiency- This involves getting more value out of every drop by allocating it to high value production- shifting from agriculture to industries, urban needs etc

The supply driven model underpinned most water development during the past century; however they proved less successful in managing those systems after construction. Decision making was typically top-down and bureaucratic leaving little flexibility to downstream users in choosing cropping pattern, calendars, and water delivery schedules. Supply becomes unreliable at times and this may compel the farmers to over exploit groundwater which can cause environmental degradation. In the past, water management was based on supply, but, it has been recommended from many sectors and in many studies that it is essential to go for demand based management.

Demand based management is concerned with technological, institutional, economic and behavioral mechanism (Froukh 2007). One of the demand management strategies is micro irrigation, where water is supplied at required interval and required quantity using pipe network, emitters and nozzles. Here the conveyance and distribution losses are almost nil. Considering the water availability for future use and the increasing demand for water from different sectors, a number of demand management strategies and programmes (water pricing, *warabandi*, WUAs etc) have been introduced. However the net impact of these strategies in increasing water use efficiency has not been very impressive. Implementation of this demands a strong political will.

Progress will depend to a great extent on the shift of "a culture of supply management" to the one of "demand management". In the present context, water demand management is to be promoted since; (i) water demand management can be effectively managed with participation, (ii) it considers all components of water cycle and good management, (iii) it uses water saving technologies and (iv) measures can be introduced flexibly and incrementally.

### Information Management in Irrigation Sector

Information management is very much essential for reducing water wastage and inefficiency. A thorough understanding of water use and demand will help in demand analysis and also understand the future demands. Information management strategies should be flexible since nothing in the real world is static and needs change and regular monitoring

## RESEARCH AND DEVELOPMENT (R&D) NEEDS IN WATER MANAGEMENT

Water resources sector is a key socio-economic sector involving huge investments. In view of the fear about food insecurity, there was pervasive emphasis on increasing irrigated cropped area as much as possible. This was accompanied by a decline of

R&D with regard to management aspects and on-farm development aspects. As a result, number of water related problems emerged in the irrigation sector. Systematic research and development programmes are to be evolved and continuously pursued in order to provide major science and technology inputs in various facets of water resource development in consonance with the targets and directions of the National Water Policy. Such targets can be achieved through proper R & D and also through dissemination of research outputs. R&D activities will have to be concentrated towards technological aspects, action research, policy analysis and research on supporting human resource development activities. The areas of focus should change with time as new problems develop and are recognized by the policy makers. Institutional reforms are also essential for increased efficiency and accountability.

More research is needed to be directed towards legal and socio-economic aspects of irrigation and water resource development in general. Interaction among the R&D institutions need further strengthening. Effective networking and coordination of research work done in different institutions is essential to maximize their benefit and avoid duplication of effort.

**POLICY INTERVENTIONS IN AGRICULTURAL WATER MANAGEMENT**

Policy makers need to focus both design and development of water resources infrastructure from a multiple use system perspective. This will help to increase the economic, physical and management efficiency in a sustainable manner. Food and Agricultural Organisation (FAO) emphasizes the broad scope for policy intervention to reinvent agricultural water management. It recommends a strategic approach to the development of land and water resources, inorder to meet demand for food products and agriculture commodities and a broader awareness on the productivity gains that can be achieved through wise water use. WUE can be increased by adopting policies such as food intake disciplines like consuming less water intensive crops, consumption in the raw form, importing crops from the water surplus areas etc. It has been represented from many corners that providing incentives for water saving measures, water recharging and water pricing for high water use measures will pave way for better water management at the user level. Proper pricing of irrigation, in addition to achieving higher WUE can also cover the cost of O&M of the system. So far, this has not been successful in Kerala due to the small holding size, lack of measuring control structures, political opposition, problems with respect to equity etc. and moreover, there is no incentive for economizing the water use.

**WATER GOVERNANCE**

Water governance includes the range of social, political, economic and administrative systems that are in place to regulate the development and management of water resources at different levels of the society (Rogers and Hall 2003). Good governance should aim at achieving equitable and sustainable water supply for all people, all economies and ecosystems as well as eradication of water inequality. In Kerala, the era of virtually unlimited water supply and year round water availability has almost vanished. Many problems/ gaps exist in the water governance issues. There are various agencies dealing with water resources development and management but there is absolutely no integration among these with respect to management. The governance pattern differs among these different sectors. There exists a lack of transparency about the requirements of the different sections and there is no local level involvement in the affairs. Regional and sectorial inequities exist in water management and utilization preferences. In the event of emerging uncertainties in water availability in all sectors, there is an urgent demand for ensuring water security. For arriving at solutions for the emerging problems for this political and strategic resource, it is important and vital to have a good and efficient governance.

Water governance must investigate why and how the current approaches to water allocation must evolve to address scarcity, uncertainty and complexity inherent in the natural system. Good governance necessitates to address transparency, accountability and protection of the broad public interest at an appropriate social and ecological scale.

Through integration of water management, one has to ensure the coordination of various sectorial views and stakeholder interest in both the surface and groundwater system with its critical importance for resource availability and quality. The horizontal integration relates to cross sectorial integration of policies and strategies and the integration of all relevant stakeholders in the decision making process. Vertical integration is about operationalizing the entire chain; bottom up and top down and national and regional levels. Thus, good governance brings together those who manage and those who are being managed, giving flexibility to the government and local informal institutions. Governance should ensure that society shares power, benefits and risks for which continuous dialogue needs to occur with all. In water management, governance starts where rain drops fall and hence, all sectors dealing with water should be convinced of the benefits of good management so that they will support the development process.

## CONCLUSION

In the era of growing population, industrialization and ever increasing urbanization/ globalization, each generation has an obligation to preserve the natural and agricultural heritage for its successors, so that today's production does not reduce the capacity of future generations to produce what is necessary for life. The goal of sustainable development is that natural resources remain available in the future also. Since agriculture is a multiple service providing ecosystem adopting a wider livelihood agenda, agriculture ecosystem should recognize the importance of preserving natural resources and cautiously using same. All types of water, green, blue and marginal have to be optimally conserved and used for higher output in agriculture. Agricultural water management focusing solely on crops will become unsustainable in economic and environmental terms. Modern water management needs to be based on strategic environmental assessments, and cost-benefit analysis, constant environmental monitoring and integration of irrigation into wider environmental context.

Sound water management should result in socio-economic viability, micro-climates and associated biodiversity. It is almost clear that the quantity of water for agricultural production can be reduced considerably by changing the cropping pattern, irrigation methods etc. Measures will have to be initiated to reduce the losses in irrigation systems, to adopt water saving irrigation methods and to raise water efficient crops / cropping pattern. System performance can be improved considerably by organizing farmers and involving them actively in the management, operation and maintenance of the system. Farmers are quite knowledgeable and are capable of addressing many shortcomings in the system. Decision making should be inclusive and transparent.

The ultimate objective should be to increase water productivity as value per unit of water. Strategies for increasing the value of water include increasing the yield per unit supply or depletion, changing from low to high value crop, lowering the input cost, increasing the health benefits and ecological services, obtaining multiple benefits per unit of water and achieving more livelihood support. At system or watershed level, options for improving water productivity include better land use planning, use of medium term weather forecasts, improved irrigation scheduling and use of various sources of water.

One of the most crucial inputs for deriving maximum sustained benefits from the water resources of the State is trained and motivated manpower. Hence, public consultation and education on water management through public awareness, demonstrations, technology transfer, incentives, and all possible means will help to save and use water wisely. The functioning of the already established farmer organisations in the CADA needs review and improvement. Technical and managerial up gradation also call attention.

Government policy and investment must help local markets for agricultural produce to become more effective in meeting local demands and thus helping the irrigation sector. Investment in key public goods, such as roads and storage, as well as institutional capacity, will accelerate progress in the irrigation sector. A strong political will and good governance also will help to improve the situation. Decisions have to be taken on appropriate water pricing and cost so as to reflect the true cost of water. Action should be taken to provide the needed security and flexibility to the water users and also to mitigate any general adverse impacts on water quality and environment. Continued efforts for improving the water productivity and water use efficiency will take agricultural water management sector to measured heights without causing any adverse effect on the other water demanding sectors.

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# Sustainable Energy Management for Agriculture

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**INTRODUCTION**

The standing joke against solar energy has been that “It is the energy of the future, and it will always be so!” Most advocates of conventional power and nuclear energy readily pay lip service to solar, and then invariably conclude by saying, “But it is so expensive!”

And they were right. The price of solar panels in the international market was at the rate of $3.50 per Watt, until quite recently. The cost of electricity generated using such a system would be three to four times as much as that of conventionally produced electricity. The only consolation was that its price was much higher earlier, and that it had been coming down over the years. It was generally hoped by solar enthusiasts that it would continue to come down, and soon would hit $1/ Watt, at which crucial point it could compete with electricity generated from thermal sources.

Now, that time has come. Solar panels are now being sold in the international market for $1/W. The local price is about Rs 100 per Watt, and there are agencies who will install a 1 kW solar power system on your roof top, with battery back up, for about Rs 2 lakhs. On a sunny day, it can easily yield about 4 to 5 Units of electricity. If the system can be directly connected to the Utility grid, the power generated during daytime may be fed into the grid, and you can draw from the grid as and when you require. In such an arrangement, you won’t need batteries, and the investment will be less by about Rs 50,000. If the local price of solar panels comes down further due to competition or mass procurement, the installation could become even cheaper. The long term expectation is that the cost of a 1 kW grid connected system will come down to Rs 1 lakh or even less.

Large scale installations which produce electricity from solar panels deployed over hundreds of hectares, is also feasible. Germany has installed hundreds of solar farms which feed about 28000 MW of electricity into their grids. In India also, Gujarat has taken the lead with a large solar farm which feeds 600 MW into their grid.

In other words, solar electricity has already become competitive with gas or naphtha based generation.

**The future is here!**

**ENERGY FOR AGRICULTURE**

Energy requirements for agriculture are manifold. Many agricultural operations are now mechanized, and call for the use of energy in a big way. Various inputs like chemical fertilizers and pesticides also represent hidden energy usage. Post harvest treatments also involve energy use of several kinds in mechanical operations and thermal processing. Solar Water Heaters, Solar Dryers and Wind Mill Pumping Systems have been in use for a long time. In the present paper we will concentrate on the application of Solar energy for irrigation, perhaps the most problematic of all these. Electricity for agriculture is very heavily subsidized (and rightly so!) and naturally there is a heavy dependence on electric motors for pumping. A major reason for the recent black out in the Northern Grid is alleged to be the “indiscipline” of certain states, which drew from the grid in excess of their entitlement. They couldn’t help it, because there is a heavy dependence on electrical energy for irrigation pump sets, and unlike in Kerala, farmers’ requirements cannot be ignored in those states. It is significant that the power break down occurred at about noon, at the hight of a dry spell, when all the irrigation pumps would have been in full use.

**SOLAR ENERGY FOR IRRIGATION**

It is here that solar energy provides us with an appropriate alternative, which is quite feasible, both technically and economically. The advantage of using solar energy for irrigation is that demand and supply are perfectly matched. The need for irrigation is greatest in the dry months, when solar energy is available in abundance. And when it rains, there is less sun, and of course, there is no need for irrigation, either. The use of Solar PV systems for irrigation is nothing new. The Department of Non Conventional Energy Sources (now called MNES) had been propagating them with subsidies, ever since the eighties. But the Solar Pumping Systems were so high priced that it took very heavy subsidies to make them attractive, and inevitably, their numbers were too small to make any impact. It is this scenario which has changed now. Now that the price of solar panels has come down by a factor of four, solar electricity has become competitive with electricity produced by gas based power plants. In the second round of bidding, in connection with the Jawaharlal Nehru National Solar Energy Mission, private operators have quoted a rate of Rs 7.49 /kWh for electricity to be supplied to the grid from solar farms. North India has plenty of open spaces where solar farms can be established, and the energy can be fed into the grid for powering irrigation pumps.

**THE KERALA ENERGY SCENARIO**

It has been estimated that Kerala has a potential of about 3000 MW in Hydel, but most of the proposals for new large hydro-electric plants are bogged down in environmental disputes and are unlikely to materialize soon. There is a potential of about 600 MW in Small Hydro Power, which can be harnessed, if pursued in a systematic and imaginative manner. Kerala's wind potential has been estimated as upwards of 1000 MW, but only a very tentative beginning has been made so far. One major hurdle is land availability, and we will have to evolve an imaginative land use policy to facilitate the tapping of wind energy without compromising the right of tribals and small farmers for agricultural land.

This leaves us with solar energy, which, fortunately, is abundantly available. Even though Kerala has two monsoons, when the Sun shines, it shines almost directly overhead, giving us the benefit of strong irradiation. It has been estimated that the total annual solar energy availability at Trivanadrum, for example, is comparable to that at Nagpur, which is a comparatively dry area. To put it in a different perspective, the roof area of a middle class house, measuring about 100 sq m, receives about 180,000 kWh of energy from the Sun, every year. At 10% conversion efficiency, it should be possible to generate about 18000 kWh of electricity from this area, if all of it is put under solar panels! Allowing for variations, and assuming that only 50% of the roof area is put under solar panels, the installed capacity will be 5 kW, the maximum daily energy generation will be about 20 to 25 kWh (Units) and the average annual generation can be estimated as 6000 Units.

Studies show that about 10% of Kerala families, numbering about 6 lakhs, belong to Upper or Upper Middle class. Almost all of them live in concrete houses. If all of them put up solar panels of 5 kW capacity on their roof tops, the total installed capacity will be 30 lakh kilowatts or 3000 MW, and the annual yield will be 3600 MU. The lower middle class households come to about 43% or 25 lakhs. About 55% of them (14 lakh households) live in concrete houses. If they agree to put up 1 kW solar systems (which require only 10 sq m roof area) on their roof tops, the total installed capacity will be 14 lakh kW or 1400 MW. The annual energy generation from these installations can be estimated as 1680 MU. In addition, Kerala has thousands of school and college buildings, office buildings, hospitals, railway stations and bus stands, not to mention factories, which all have a lot of roof area, suitable for mounting solar panels. It should be possible to have at least 1000 MW installed capacity and an annual generation of 1200 MU of electricity, from all these put together. Thus Roof Top Solar systems, all together, ought to provide an installed capacity of about 5400 MW and an annual generation of about 6500 MU.

This is a significant input, no doubt. Yet obviously, this will not suffice, if we want to depend completely on renewable energy sources. But that can only be a distant dream. If we want to realize that, we will have to go for large scale solar installations. Some states like Rajasthan and Gujarat are going in for large 'solar farms,' extending over hundreds or even thousands of hectares. This will not be feasible in Kerala, where we are hard pressed for land. So a novel suggestion is being put forward.

We have many backwaters and reservoirs. It should be possible to have float-mounted solar panels in these water bodies. Of course, it will not be advisable to cover them fully, because the water borne life forms also need sunshine. However, it may be possible to cover may be one half, or one third, of the surface area with solar platforms. (The ecological impact of this has to be studied.) If we take just one example, say Idukki reservoir, it has a surface area of 60 sq km or 60 million sq m. Even if we cover one third of this area with float mounted solar panels, it will have an installed capacity of 2000 MW, which can yield 3200 MU annually. This can conceivably be replicated in Pampa – Kakki, Lower Periyar, Malampuzha, Peppara, Kallada and other reservoirs. The feasibility of setting up float-mounted solar platforms in parts of Vembanad (2033 sq km), Ashtamudi (61 sq km) and other water bodies, also can be examined. The yield from these float-mounted solar platforms in water bodies can go up to several thousand million Units. This shows that solar energy, in conjunction with hydel and wind, has the potential to meet all our energy requirements.

# Agriculture and Environmental Pollution

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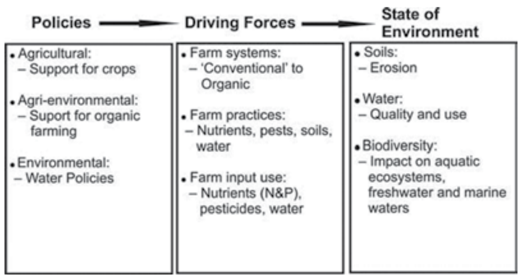
## INTRODUCTION

Agriculture and environment are inextricably connected. Agricultural production and contingent food supplies world-wide are literally vital for daily human survival. The evident abundance of food supplies within the more industrialized nations tends to obscure the fact that the present world population can now only be sustained by the technologically-based or 'intensified' agriculture with effectively diminishing land and water resources per capita. This intensification has involved the clearance of native forests and grassland, mechanization, the introduction of selected or novel crop varieties, increasing use and dependence upon artificial irrigational and chemical aids to soil fertility, crop protection, and food harvest, storage and processing. The goal of agricultural policy has been higher production and increased efficiency, but continued increase in production has only been possible through intensification of the farming system with a simultaneous increase of pollution risks (Winteringham, 1984).

Agricultural water quality has been identified as a major environmental issue in many of the countries, and as a topic for policy analysis. The primary agricultural sector is mainly responsible for nitrate, phosphorus, pesticide, soil sediment, salt, and pathogen pollution of water from crop and livestock activities, but it can also play a role under certain farm practices in terms of improving water quality through a water purification function. Water pollution from agriculture has associated costs in terms of removing pollutants from drinking water supplies, as well as damage to ecosystems and commercial fishing, recreational, and cultural values associated with rivers, lakes, groundwater and marine waters.

Recent trends in water pollution from agricultural nutrients and pesticides indicate that the overall pressure of agriculture on water quality in rivers, lakes, groundwater and coastal waters has eased since the early 1990s due to the decline in nutrient surpluses and pesticide use for most developed countries .Despite this improvement, absolute levels of agricultural nutrient pollution remain significant in many cases.

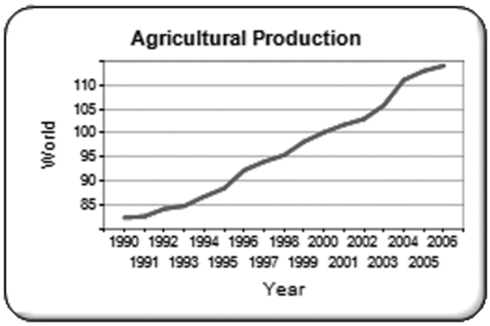
With point sources of water pollution (i.e. industrial and urban sources) falling more rapidly (Kevin Parris, 2011).Linkages between policies, driving forces and the state of the environment relevant to water is indicated in Fig.1.




*Source: OECD Secretariat, 2010.*

**Fig. 1**
**Linkages between policies, driving forces and the state of the environment relevant to water**

As per FAO statistics, the global trend in agricultural production for different years is indicated in fig 2. FAO statistics carries out environmental data collection and disseminates information relating to all aspects of the agricultural sector (FAO, 2012)




*Source: FAO, 2012*

**Fig 2**
**Global trend in agricultural production for different years**

India is an agriculture-based country. Agriculture is the mainstay of our economy. That is the reason a good crop year brings buoyancy in all the sectors of the economy whereas a bad crop year results in doom. Development in agriculture is therefore of prime importance. This development in agriculture started with green revolution in the late 60s. High yielding varieties were brought in along with chemical fertilizers and pesticides. The result was manifold increase in the yield and India has not only achieved self-sufficiency but has also become an exporter of food grains in spite of ever increasing population. Growth in agriculture and increased food demands led to over usage of fertilizers and pesticides

In a comparison of domestic, industrial, and agricultural sources of pollution from the coastal zone of Mediterranean countries, agriculture was the leading source of phosphorus compounds and sediment. (UNEP 1996) Nutrient enrichment, most often associated with nitrogen and phosphorus from agricultural runoff, can deplete oxygen levels and eliminate species with higher oxygen requirements, affecting the structure and diversity of ecosystems. Nitrate is the most common chemical contaminant in the world's groundwater aquifers. (Spalding and Exner, 1993) Mean nitrate levels have risen by an estimated 36% in global waterways since 1990 with the most dramatic increases seen in the Eastern Mediterranean and Africa, where nitrate contamination has more than doubled. (GEMS 2004) According to various surveys in India and Africa, 20-50% of wells contain nitrate1 levels greater than 50 mg/1 and in some cases as high as several hundred milligrams per liter.

**NON POINT SOURCES OF (DIFFUSE) POLLUTION**

Non point or diffuse agricultural pollution is the contamination of the soil, air and water environments resulting from farming activities. The primary agricultural nonpoint source pollutants are nutrients (particularly nitrogen and phosphorus), sediment, animal wastes, pesticides, and salts. Agricultural nonpoint sources enter surface water through direct surface runoff or through seepage to ground water that discharges to a surface water outlet. Various farming activities result in the erosion of soil particles. The sediment produced by erosion can damage fish habitat and wetlands and, in addition, often transports excess agricultural chemicals resulting in contaminated runoff. This runoff in turn affects changes to aquatic habitat such as temperature increases and decreased oxygen. The most common sources of excess nutrients in surface water from nonpoint sources are chemical fertilizers and manure from animal facilities. Such nutrients cause eutrophication in surface water. Pesticides used for pest control in agricultural operations can also contaminate surface as well as ground-water resources. Return flows, runoff, and leachate from irrigated lands may transport sediment, nutrients, salts, and other materials. Finally, improper grazing practices in riparian, as well as upland areas can also cause water quality degradation. This pollution tends to arise over a wide geographical area and is dependent on what happens on the surface of the land. Although individually minor, such pollution on a catchment scale can be significant; considering the cumulative effect which these separate discharges can have on the environment. There is therefore a wide range of potential diffuse pollution sources which are associated with farming practices and which can harm the environment.

The total effect of a number of individually minor sources of contamination can be highly significant over an entire catchment area. If the sources of water for a river are predominately contaminated, then the whole river is likely to be polluted. Small watercourses, with little dilution, are more likely to be adversely affected by diffuse pollution than larger rivers. Over abstraction of irrigation water from watercourses can exacerbate this problem by lessening the potential for dilution. However, diffuse sources of nutrients can also affect groundwater or large water bodies, especially lochs which have low levels of plant nutrients naturally

## IMPACT OF AGROCHEMICALS ON ENVIRONMENT

Agrochemicals are nowadays found in virtually all natural habitats, including those where they have never been applied. They have severe negative effects on natural flora and fauna, biodiversity, water resources and ecosystem functioning and the equilibrium of agricultural systems. Agrochemicals can contaminate soil, water, turf, and other vegetation. In addition to killing insects or weeds, pesticides can be toxic to a host of other organisms including birds, fish, beneficial insects, and non-target plants. Insecticides are generally the most acutely toxic class of pesticides, but herbicides can also pose risks to non-target organisms.

The environmental issues due to agrochemicals can be classified based on health issues, socio economic problems, pollution of water and soil, bio diversity, etc. Some of the impacts are discussed in the following sections

### Health Problems

Farmers, farm workers and their families, bystanders and consumers are exposed to dangerous synthetic pesticides. Handling, storage and disposal of these chemical agricultural inputs can cause acute and chronic negative health effects, cause cancer and negatively influence reproduction or disrupt the endocrine system. Pesticide residues in food and drinking water can cause similar problems affecting large number of people.

### Social and Economic Problems

The use of synthetic pesticides very often is connected to a vicious cycle of financial dependency and dependency on credits for these inputs. This agrochemical tread mill is leading to increasing indebtedness of farmers with immense negative effects for the economy of farm families and rural communities. Suicides committed because of debts are common. Other consequences of indebtedness are migration, loss of land and culture. External costs due to pesticides impact on health and environment are not reflected in the costs of pesticides (e.g. costs for health treatment, costs arising from illness related lack of work, loss in biodiversity and costs for water treatment). The high input of synthetic pesticides in conventional agriculture creates a spiral of dependency as they destroy beneficial organisms and induce resistance, creating the need for new and more expensive pesticides. The total dependency on chemical pesticides and the pesticides industry results in a lack of choice for farmers and their families in terms of choice of crops, choice of seeds, choice of production system, and it contradicts the right to food sovereignty.

### Water, Air and Soil Contamination

Diffuse agricultural pollution can result in the contamination of the soil, air and water environments resulting from farming activities. Diffuse agricultural pollution is principally associated with soil particles; pesticides and other potentially toxic chemicals, including veterinary medicines; nutrients, principally nitrogen and phosphorus; pathogens, for example, bacteria from livestock slurries and manures spread on land and run-off associated with intensive grazing practices; gases such as ammonia.

Pesticides can reach surface water through runoff from treated plants and soil. Contamination of water by pesticides is widespread. The results of a comprehensive set of studies done by the U.S. Geological Survey (USGS, 1999) on major river basins across the country in the early to mid- 90s yielded startling results. More than 90 percent of water and fish samples from all streams contained one, or more often, several pesticides (Kole et al., 2001). Pesticides were found in all samples from major rivers with mixed agricultural and urban land use influences and 99 percent of samples of urban streams. The USGS also found that concentrations of insecticides in urban streams commonly exceeded guidelines for protection of aquatic life.

Groundwater pollution due to pesticides is a worldwide problem. According to the USGS, at least 143 different pesticides and 21 transformation products have been found in groundwater, including pesticides from every major chemical class. Over the past two decades, pesticides was reported in the groundwater of more than 43 states (Waskom, 1994). During one survey in India, 58% of drinking water samples drawn from various hand pumps and wells around Bhopal were contaminated with Organochlorine pesticides above the EPA standards (Kole and Bagchi, 1995).

**Pollution of Soil**

Soil is effectively a non-renewable resource due to the time it takes to be formed. It should therefore be protected from damage or loss in order to sustain agricultural production, as well as for the life it supports in itself. In addition, soil and water quality are very closely linked. Eroded soil from grazed or cultivated land, muddy run-off from farm roads or yards and via field drains can cause environmental problems such as destroying gravel riffles on the bed of watercourses. These riffles are an essential habitat requirement for many aquatic insects and provide spawning areas for fish. Soil particles are also important because they can carry more serious pollutants. For example, some pesticides bind firmly onto soil particles and are therefore liable to contaminate watercourses when soil is lost from fields. Similarly, mud on farmyards and roads may carry oily residues. Phosphorus can be lost from farmland to water and can cause pollution. In excess, certain trace elements transported with the soil can also damage the aquatic environment.

A wide range of chemical compounds are used as pesticides and each of these interacts with soils and water differently. Once present in groundwater, pesticides can be present for many years and are very costly to remove. If leached in excessive amounts, nutrients such as nitrogen (N) and phosphorus (P) can cause severe problems for rivers, lochs, estuaries and coastal waters by, for instance, contributing to the development of toxic algal blooms or foul smelling mats of algae on our coastline. Nutrients can be lost from manures and slurries as well as from other organic wastes spread on land, and significant losses can also be associated with fertilisers and soil. Advice must be tailored to the particular farm and catchment area in order to prevent such losses and reduce the risk of pollution.

A large number of transformation products (TPs) from a wide range of pesticides have been documented. Not many of all possible pesticide TPs have been monitored in soil, showing that there is a pressing need for more studies in this field.

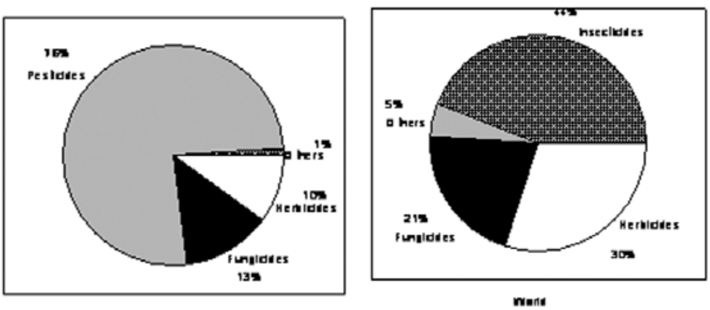
According to the USGS, pesticides have been detected in the atmosphere in all sampled areas of the USA (Savonen, 1997).Some pesticide drift occur during every application, even from ground equipment. Drift can account for a loss of 2 to 25% of the chemical being applied, which can spread over a distance of a few yards to several hundred miles. As much as 80–90% of an applied pesticide can be volatilized within a few days of application.

**Effect on Soil Fertility (Beneficial Soil Microorganisms)**

Heavy treatment of soil with pesticides can cause populations of beneficial soil microorganisms to decline. According to the soil scientist Dr. Elaine Ingham, "If we lose both bacteria and fungi, then the soil degrades (Ingham, 1985). Overuse of chemical fertilizers and pesticides have effects on the soil organisms that are similar to human overuse of antibiotics. Indiscriminate use of chemicals might work for a few years, but after a while, there are not enough beneficial soil organisms to hold onto the nutrients"

**PESTICIDES**

The term pesticide covers a wide range of compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and others. The production of pesticides started in India in 1952 with the establishment of a plant for the production of BHC near Calcutta, and India is the second largest manufacturer of pesticides in Asia after China and ranks twelfth globally (Mathur, 1999). There has been a steady growth in the production of technical grade pesticides in India, from 5,000 metric tons in 1958 to 102,240 metric tons in 1998.In 1996–97 the demand for pesticides in terms of value was estimated to be around Rs. 22 billion (USD 0.5 billion), which is about 2% of the total world market. The pattern of pesticide usage in India is different from that for the world in general. As can be seen in Fig. 4, in India 76% of the pesticide used is insecticide, as against 44% globally. The use of herbicides and fungicides is correspondingly less heavy. The main use of pesticides in India is for cotton crops (45%), followed by paddy and wheat (Aktar et al, 2009).




**India** **World**

**Fig. 4**
**Consumption pattern of pesticides**

Kerala agriculture contributes 17.2% to Kerala's economy (as of 2002-2003). Correspondingly, the sector requires a sizeable amount of pesticides (roughly 656.5 tonnes per annum), of which fungicides account for 73%. (Indira Devi , 2010) . The pesticide consumption in Kerala and India is indicated in fig 5. The consumption of pesticides is reported to be decreasing over the years.

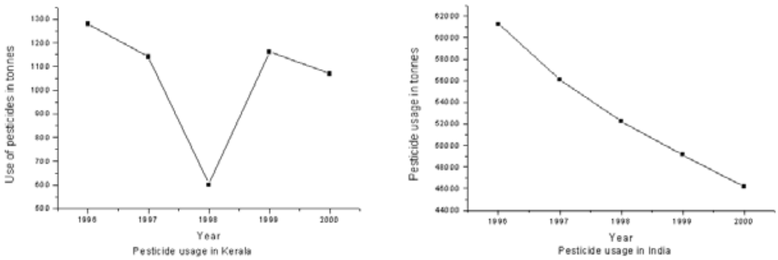



**Fig 5**
**Pesticide consumption in Kerala and India**

If the credits of pesticides include enhanced economic potential in terms of increased production of food and fibre, and amelioration of vector-borne diseases, then their debits have resulted in serious health implications to man and his environment. There is now overwhelming evidence that some of these chemicals do pose a potential risk to humans and other life forms and unwanted side effects to the environment.

Today overwhelmingly agricultural commodities are produced under so-called conventional agricultural methods. This includes a pest control strategy based on high input of synthetic pesticides as a sole means to tackle pests, weeds and diseases. Associated with this manner of production manifold problems (Aktar et al, 2009; PAN,2007)) arise

While modern societies face growing concern about global environmental issues, developing countries are experiencing complex, serious and fast-growing pollution problems of their own. The potent combination of industrialization, urban development and mass consumption trends is exacerbated by foreign companies operating with little regard for the impact on the local environment. Environmental pollution is more than just a health issue; it is a wider social issue in that pollution has the potential to destroy homes and communities. Pollution problems are also closely tied to the mode of development in developing countries. Despite this, many developing countries either have not developed environmental pollution control measures, or have not provided adequate implementation structures to ensure that policies are effective.

Pesticide sprays can directly hit non-target vegetation, or can drift or volatilize from the treated area and contaminate air, soil, and non-target plants. Pesticides are found as common contaminants in soil, air, water and on non-target organisms in our urban landscapes. Once there, they can harm plants and animals ranging from beneficial soil microorganisms and insects, non target plants, fish, birds, and other wildlife. Chlorpyrifos, a common contaminant of urban streams is highly toxic to fish, and has caused fish kills in waterways near treated fields or buildings. Herbicides can also be toxic to fish. According to the EPA, studies show that trifluralin, an active ingredient in the weed-killer Snapshot, “is highly to very highly toxic to both cold and warm water fish” (U.S. EPA, 1996; Koyama, 1996). In a series of different tests it was also shown to cause vertebral deformities in fish.

**AGRICULTURE POLLUTION IN KERALA**

The systems of ‘Pokkali’, ‘Kuttanad’ and ‘Kole’ are examples of purposeful human interventions whereas irrigated as well as rain fed rice cultivation is widely practiced in valleys of midlands and highlands( Kerala State Land Use Board, 2006; State Committee on Science, Technology and Environment, 2002).The high rainfall pattern and the undulating topography of the state resulted in a wide range of microenvironments. Over the centuries the peasants of Kerala evolved varieties and systems of rice culture to suit every conceivable agronomic condition, from totally dry to floating rice under rising flood conditions,from rain fed to irrigated conditions , sandy to clay soils , and saline to acidic soils. Taking into consideration , the variations in resource endowments ,topography, soil and abiotic factors significant rice agro ecosystems like Midland and Malayoram ecosystems, Kuttanad agroecosystem , Onattukara agroecosystem , Pokkali agroecosystem etc were identified.

The fertilizer and pesticide consumption in the catchment area of Kuttand has increased significantly in the previous years. Transport of these hazardous elements into the estuaries is indicated partly by appearance of insecticide residues in the estuarine sediments (STEC, 2002 Swaminathan et al, 2007).

A study undertaken by Indira Devi (Indira Devi 2010) reported that toxicity level and dose of pesticides exert a significant effect on health. If the dose of the most toxic chemicals used is reduced by 25%, health costs decrease by 30%. If the dose of all pesticides is reduced by 25 %, then expected average health cost decreases by 41%, Dose reductions are a feasible strategy for farmers in Kerala and can be achieved either by restricting the quantity of pesticide used or by diluting the amount sprayed with more water

Low pesticide use with shift to bio-pesticides or integrated pest management should be promoted to reduce the pesticide pollution from crops like rubber and cardamom in the catchments of rivers and paddy in Kuttanad. Expedite introduction of new crop calendar, which is expected to minimize the incidences of pests and therefore the application of pesticides. Also the shift to organic farming should be encouraged.

The problems due to pesticides started way back in 1958 following the death of more than 100 people in the year 1958 after consuming wheat flour contaminated with pesticides during transportation. The state-owned Plantation Corporation of Kerala began the aerial spraying of Endrin (later Endosulphan) way back in the 1970s in their cashew plantations and local people became the victims of severe health problems (Indira Devi 2010)

**Pollution of Vembanad Backwater System due to Agrochemicals**

The agricultural developments have resulted in the input of large quantities of agrochemicals and pesticides in the wetland bodies of Kerala; especially in Vembanad Lake. The application of fertilizers and biodegradation of organic wastes has also led to the enrichment of nitrogen in the lake waters The level of ammonia was also high near thickly populated habitations , especially near urban centres like Alappuzha.

The annual usage of pesticides/fungicides/weedicides in Kuttanad is reported to be 117 tonnes during Virippu season and 368 tonnes during the Mundakan and Puncha season (Nair and Unni, 1993). Seasonal and temporal variation of cyclodiene pesticides in the sediments of Kuttanad backwaters was estimated (Babu et al, 2008). Annual fertilizer consumption in Kuttanad is 8409 tonnes of nitrogen, 5044 tonnes of potassium. Pesticides/fungicides/ weedicides are applied to the tune of about 500 tonnes/year (James, 1998).

**Aggressive Waterweeds and Water Pollution**

The low salinity in Vembanad Lake and increased discharge of organic wastes and fertilizer residues into water bodies are promoting eutrophication. Alien invasive species like water hyacinth is densely spreading in all upper reaches of water body, canals and drains contributing to further pollution to water, preventing water navigation, depletion of dissolved oxygen, interfering in the entry of sunlight into water and thereby the fish reproduction and growth. This weed is a major problem to padasekharams causing major increase to the cost of cultivation.

The water and sediment quality data collected of the lake indicated that the eutrophication of the Vembanad Lake is mainly phosphorous limited (Harikumar et al 2006). Physico-chemical analysis of the water samples collected in different seasons gave an insight into the pollution level of Vembanad wetland system (Nasir and Harikumar, 2011) .The water quality is seriously impaired by many organic and inorganic pollutants of different origin (Harikumar etal,2009) High nutrient level caused hypereutrophic stage in many parts of the system. The high concentration of phosphorus increased the amount of algal growth, making the situation worst. The ratio of nitrate plus ammonia to soluble reactive phosphorus indicated phosphorous limited algal growth. The microbiological pollution level was so high that no stations in the monsoon season were free of coliform bacteria.

Determination of nutrient concentration indicated hypereutrophic stage of lake with vertical increase in the rate of deposition of nitrate, sulphate, and phosphate. The source of ortho-phosphorous to the system was agricultural runoff. The amount of phosphorous in sediments is so severe that even if the source of phosphorous to the system is banned, it contributes phosphorous to the water. Bindu and Harikumar (2007) studied the nutrient concentration in Vembanad Lake using a dynamic model. The lake is infested with phytoplankton growth especially during pre monsoon and beginning of monsoon months. In addition to the nutrient load received by the lake due to point sources, the lake is also polluted in the southern, eastern and western parts by diffuse pollutants such as agricultural and municipal effluents.

The simulation analyses of the lake predicted eutrophication of the lake with high concentration of phytoplankton growth and decrease of clarity indicated by lower seechi depth. The simulation also indicates that, the total phosphorous load to the lake should be regulated to 12.5 % of the present load for the lake to change to oligotrophic level.

The management of river basins in relation to Vembanad backwater has to take care of the irrigation and drinking water requirements of the area; restricting the flow of urban waste, industrial effluents and agro-chemicals to the lagoon; introducing appropriate land use in the upper reaches to conserve soil and water as well as to avoid flooding and enhanced sediment movement.

**STUDY ON THE PERSISTENCE OF PESTICIDE RESIDUES IN KASARAGOD DISTRICT**

The endosulfan case of Kasaragod district, Kerala, India is considered by many experts in the field of community health and toxicology as one of the worst pesticide disasters. This extended tragedy occurred due to a constellation of reasons that included the recommendation of the use of the pesticide in a populated, water body rich, and hilly area. Also, the application procedure was conducted by aerially spraying endosulfan over the cashew plantations, which was done for a period of 20 years by the Plantation Corporation of Kerala, without monitoring its collateral impacts.

A detailed study on the persistence of endosulphan was conducted in Kasargod district. Water, soil and sediment samples were collected from different panchayats of Kasargod district (CWRDM, 2011). Water samples did not report any pesticide residue.

A total of 20 sediment samples were collected from 11 Panchayats. Depth samples were also collected in a few cases. The maximum concentration of endosulphan detected was in the sample collected from Kallar Panchayat (6.22 $\mu$g/Kg). The source of sediment was a valley slope where the runoff water from the nearby plantation area got clogged and settled down.

Analysis of 10 soil samples collected indicated that sample from the Pullur Periya Panchayat reported maximum concentration for Endosulphan, 16.91 $\mu$g/Kg Also beta isomer was found to be present in higher concentration than the alpha isomer .This result showed that degradation of beta endosulphan was significantly slower than for the alpha isomer in this region.

As per the results obtained by the analysis of endosulphan in water, soil and sediment samples collected from eleven panchayats of Kasargod district, it could be concluded that endosulphan is still persistent in selected soil and sediments of the study area. This could be attributed to the presence of high acidic conditions prevailing in the soil and sediment of the area; whereby the persistence is increased by the acidic conditions. The degradation rates of both endosulphan isomers are greatly affected by changes in soil, water content and temperature. Re-application of endosulphan, and day and night fluctuation of temperature had contrasting effects on the degradation of the two isomers and the net effect is the prolonged overall persistence of this chemical in the soil (Ghadiri 2001). The half lives for the combined toxic residues of endosulphan (alpha endosulphan and beta endosulphan plus endosulphan sulfate) as reported by the EPA range from 9 months to 6 years (US EPA 2002). The results also indicated greater persistence of endosulphan in soil and sediment samples than water samples because of greater adsorption of endosulphan on the sediment and soil than water. Comparatively high concentrations of endosulphan was detected in the soil because of the fact that endosulphan is fairly immobile in soil and is highly persistent.

## MANAGEMENT MEASURES

### Sediment/Erosion Control

Soil erosion is one of the leading causes of water pollution. The goal of this measure is to minimize the delivery of sediment from agricultural lands to receiving waters. Land owners may apply the Agricultures Conservation Management System through such practices as conservation tillage, strip cropping, contour farming, and terracing or design and install a combination of practices to remove settleable solids and associated pollutants in runoff.

### Confined Animal Facility

Animal waste contaminates many of our waters with pathogens and nutrients. The management measure for all new facilities and existing facilities over a certain size is to limit discharges from confined animal facilities to waters. For smaller existing facilities, the management measure is to design and implement systems that collect solids, reduce contaminant concentrations, and reduce runoff to minimize the discharge of contaminants .This measure also specifies management of stored runoff and solids through proper waste utilization and use of disposal methods which minimize impacts to surface/ground water.

### Nutrient Management

This measure calls for development and implementation of comprehensive nutrient management plans. The fundamentals of a comprehensive nutrient management plan include a nutrient budget for the crop, identification of the types and amounts of nutrients necessary to produce a crop based on realistic crop yield expectations, and an identification of the environmental hazards of the site. Other items called for in the measure include soil tests and other tests to determine crop nutrient needs and proper calibration of nutrient equipment.

### Pesticide Management

This measure is designed to minimize water quality problems by reducing pesticide use, improving the timing and efficiency of application, preventing backflow of pesticides into water supplies, and improving calibration of pesticide spray equipment. A key component of this measure is use of integrated pest management (IPM) strategies. IPM strategies include evaluating current pest problems in relation to the cropping history, previous pest control measures, and applying pesticides only when an economic benefit to the producer will be achieved, i.e., application based on economic thresholds. If pesticide applications are necessary, pesticides should be selected based on consideration of their environmental impacts such as persistence, toxicity, and leaching potential.

**Livestock Grazing**

The goal of this measure is to protect sensitive areas. Sensitive areas include streambanks, wetlands, estuaries, ponds, lake shores, and riparian zones. Protection is to be achieved with improved grazing management that reduces the physical distance and direct loading of animal waste and sediment caused by livestock by restricting livestock access to sensitive areas through a range of options. In addition, upland erosion is to be reduced by either: (1) applying the range and pasture components of a Conservation Management System or (2) maintaining the land in accordance with the activity plans established by either the Bureau of Land Management or the Forest Service. Such techniques include the restriction of livestock from sensitive areas through locating salt, shade, and alternative drinking sources away from sensitive areas, and providing livestock stream crossings.

**Irrigation**

This measure promotes an effective irrigation system that delivers necessary quantities of water yet reduces nonpoint pollution to surface waters and groundwater. To achieve this, the measure calls for uniform application of water based upon an accurate measurement of cropwater needs and the volume of irrigation water applied. When applying chemicals through irrigation (a process known as chemigation), special additional precautions apply. The measure also recognizes that states water laws that conflict with the measure will take precedence over the measure.

**Control of Phosphorus from Point and Diffuse Sources**

Phosphorus is biologically available as phosphate, which binds to soil particles more effectively than nitrate. Thus, the main entry route into water bodies from land areas is as surface run-off and with erosion. Although biomass needs only about one seventh of the amount of phosphorus eutrophication is enhanced by anthropogenic activities. The three major sources of external nutrient inputs are run-off and erosion from fertilised agricultural areas, erosion resulting from deforestation, and sewage. Biological phosphorus removal can be achieved by alternating aerobic and anaerobic steps in biological treatment and thus substantially enhancing P-uptake by bacteria. This method saves flocculation chemicals and produces less sludge, but requires an adequate design of basins and careful operation of the process.

Water treatment techniques such as the creation of artificial wetlands that collect water and remove nutrients through aquatic plants. Basins can also be constructed to collect runoff water and allow settling of suspended sediment, often rich in phosphorus, before discharge downstream

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# Climate Warming in the Plantation Belt of Kerala and its Impact on Natural Rubber Productivity

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**INTRODUCTION**

It is *very likely* that greenhouse gases from anthropogenic emissions are warming the world's climate system (IPCC, 2007). Climate change as a result global warming can influence the growth and productivity of agricultural crops (Cynthia and Parry, 1994). Plantation crops, which are grown in selective ecological niches mostly along the Western Ghats and their foothills are highly sensitive to alterations in weather pattern. Natural rubber is not an exemption from the adverse effect of climate change. Climate change may affect the productivity in various direct and indirect ways (Cynthia *et al.*, 2000). For example, an extreme weather event like drought or storm directly impacts growth and productivity. Changes in weather pattern can affect the incidence of pests and diseases and thus indirectly affect the crop. While we may be able to understand to what extent climate has changed in the traditional rubber growing regions of the world in the recent past, it is extremely difficult to predict how exactly these changes will continue in the years ahead. Thus the impact of change in future climate on natural rubber growth, productivity and supply will be complex and difficult to predict.

Climate has undergone significant changes in the rubber growing regions of India in the recent decades and this has certainly impacted productivity. However, as more and more area under the high yielding clones like RRII 105 came into tapping, the national productivity of NR increased masking the actual impact of climate change on productivity during this period.

Between 2001 and 2008, consumption of natural rubber (NR) in India increased at the rate of 35.03 tons/year while its supply increased by 36.39 tons/year (IRSG, 2009). Almost all predictions show that in the years ahead, consumption of NR is expected to increase at a faster rate than its supply, both nationally and globally, provided there is sustained economic growth. Since 2006 India ranks first in the world in terms of NR productivity (IRSG, 2009). Despite the recent global economic crisis, India remained reasonably buoyant and the Indian economy is expected to grow at impressive rates in the coming years and thus the demand for NR also will be on the rise. But climate change is one important factor that may seriously jeopardize NR availability in India and other major NR producing countries in South and South East Asia, a region particularly vulnerable to the adverse impact of climate change (Manton *et al* , 2001).

**MATERIALS AND METHODS**

Long term temperature and yield data *ie.* gram/tree/tap (g/t/t) were collected from the Regional Research Stations of RRII *viz.* Agarthala, Tura, Dapchari (non traditional), Chethackal (CES) and Padiyoor (traditional) in various agro-climatic regions in India. These regions represent a wide range of climatic conditions ranging from extreme dry and hot conditions in Dapchari to severe winter conditions in NE. Dapchari is situated at $20^0$ 04'N, $72^0$ 04'E with an average elevation of 48 m above MSL in the North Konkan region of Maharashtra. During the monsoon season this region gets around 2400 mm rainfall. During peak summer days the maximum temperature goes above 38 $^0$C. Agarthala and Tura are situated in the Northeastern region, at $23^0$ 50'N, $91^0$ 16'E and $25^0$ 30'N, $90^0$ 13'E with an altitude of around 30 and 1100 m above MSL respectively. The annual rainfall in these regions ranges from 2000-2400 mm. During peak winter days the minimum temperature may be as low as 5 $^0$C or less. Compared to these two non traditional regions, the weather conditions in the traditional NR growing regions of India are more moderate. These traditional regions situated at a latitudinal range of $8^0$ 15'N to $12^0$ 5'N and longitudinal range of $74^0$ 5'E to $77^0$ 30'E with an altitude of 20-840 m above MSL. Mean annual rainfall in these regions ranges from 2000-4500 mm. The mean maximum and minimum temperatures during summer months are 33 $^0$C and 25 $^0$C and for winter days, 31 $^0$C and 22 $^0$C, respectively. India is perhaps the only major NR growing country where NR is cultivated in such extremely diverse conditions (Jacob *et.al*, 1999). In all cases we regressed the productivity with different weather parameters to determine the quantitative effect of each weather parameter on yield. We approached the data in three ways.

In the first approach, we regressed mean annual productivity in these diverse agro-climatic regions together with the prevailing weather parameters. In the multiple regression model, we used weather parameters like mean annual temperature (Tann.), mean annual maximum temperature (Tmax), mean annual minimum temperature (Tmin), mean annual rainfall (RF) and mean number of annual rainy days (RFday) as independent variables and mean yield of the year *i.e.* g/t/t as the dependent variable. In the second approach daily per tree yield (g/t/t) for several years was regressed with the weather parameters for the corresponding years separately for the different agro- climatic regions. After getting a model for each station, we predicted the yield for 1 degree rise in Tmax and Tmin. Also predicted the yield for the next 10 years by incorporating the current warming trends in these regions. In a third approach, we regressed the per hectare productivity with maximum and minimum temperatures for Kottayam, Kanjirapally and Thaliparamba and estimated the impact of rising temperature on productivity.

Long term data on $CO_2$ emission and atmospheric $CO_2$ concentration were obtained from authentic published sources (Carbon dioxide Information Analysis Center and the World Resource Institute)[5]. Data on terrestrial and ocean $CO_2$ fluxes were taken from the fourth assessment report (AR4) of the Intergovernmental Panel on Climate Change (IPCC, 2007). Using these data, rate of increase in GHG emission and removal from the atmosphere and increase in the concentration of $CO_2$ in the atmosphere were calculated through regression analysis. The present rate of terrestrial and oceanic removal of $CO_2$ and the rate of build-up of $CO_2$ concentration in the atmosphere were used to estimate the area of land and ocean that is required to fully offset the rise of $CO_2$ in the atmosphere.

## RESULTS AND DISCUSSION

### Long Term Temperature Trends

RRII, Kottayam daily maximum temperature (Tmax) and minimum temperature (Tmin) have been increasing at the rate of 0.05 $^oC$ per year and 0.03 $^oC$ per year, respectively in the last half-a-century. The mean Tmax and Tmin during 2005-2009 have been higher than the same for the period 1957-1961, almost on every day at RRII, Kottayam. At the Regional Research Station of RRII in Agartala, Tmax and Tmin increased at the rate of 0.02 $^oC$ per year and 0.06 $^oC$ per year, respectively since 1986. In every regional stations there is a warming trend, but the extend of the warming is different (Table 1)

**Table 1**
**Long term temperature trends in different regions of the study**

| Station | Period | Temperature | Mean | Rate/Year |
|---|---|---|---|---|
| Tura | 1995-2008 | Tmax | 29.3 | 0.12 |
| | | Tmin | 16.9 | 0.05 |
| Agarthala | 1984-2007 | Tmax | 30.6 | 0.02 |
| | | Tmin | 19.9 | 0.06 |
| Padiyoor | 1998-2009 | Tmax | 32.8 | 0.01 |
| | | Tmin | 21.8 | 0.11 |
| Dapchari | 1987-2009 | Tmax | 33.2 | 0.08 |
| | | Tmin | 20.6 | 0.03 |
| Kottayam | 1957-2009 | Tmax | 31.2 | 0.05 |
| | | Tmin | 22.7 | 0.03 |

### Regression Analysis of Annual Yield Data and Different Weather Parameters

In the last step of MLR, only three independent variables were left in the model, namely, T max, Tmin and RF (Y = 96.94 - 7.05 Tmax + 7.45 Tmin + 0.008 RF, $R^2$ =0.71) (Table 2). This model in which the X variables from various agro-climatic regions were incorporated in one MLR model had a fundamental flaw; in the different regions, the different X variables had qualitatively and quantitatively different impacts on yield. For example, in the NE where very low winter temperatures prevail, an increase in Tmax had a positive effect on yield unlike in other places where the effect was the opposite. This became evident when MLR analysis was made separately for the different regions.

**Table 2**
**MLR (Back ward) table obtained for the regression analysis between the annual yield and different weather parameters for all stations together.**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -26.4 | 152.224 | | -0.173 | 0.871 |
| | Tann | 2.787 | 2.628 | 0.284 | 1.061 | 0.349 |
| | Tmax | -4.922 | 6.459 | -0.607 | -0.762 | 0.488 |
| | Tmin | 6.203 | 5.56 | 1.145 | 1.116 | 0.327 |
| | RF | 5.68E-03 | 0.009 | 0.449 | 0.625 | 0.566 |
| | RFday | 8.94E-02 | 0.305 | 0.21 | 0.293 | 0.784 |
| 2 | (Constant) | -0.195 | 111.345 | | -0.002 | 0.999 |
| | Tann | 2.642 | 2.333 | 0.269 | 1.132 | 0.309 |
| | Tmax | -6.419 | 3.572 | -0.791 | -1.797 | 0.132 |
| | Tmin | 7.647 | 2.327 | 1.412 | 3.286 | 0.022 |
| | RF | 8.13E-03 | 0.003 | 0.643 | 2.58 | 0.049 |
| 3 | (Constant) | 96.938 | 72.647 | | 1.334 | 0.23 |
| | Tmax | -7.053 | 3.61 | -0.869 | -1.954 | 0.099 |
| | Tmin | 7.452 | 2.375 | 1.376 | 3.138 | 0.02 |
| | RF | 8.11E-03 | 0.003 | 0.641 | 2.515 | 0.046 |

**Regression Analysis of Daily Yield data and Temperature**

The MLR models obtained for the individual regions were Y= 433.43-7.87Tmax-4.83Tmin (CES, $9^0$ 26'N to $76^0$ 48'N), Y=171.01-2.54 Tmax-1.71Tmin (Padiyoor, $11^0$ 58'N to $75^0$ 36'N), Y=204.98-1.01Tmax-5.51Tmin (Dapchari, $20^0$ 04'N, $72^0$ 04'E), Y= 41.25+0.67Tmax-1.13Tmin (Agarthala, $23^0$ 50'N, $91^0$ 16'E) and Y= -24.85+3.58Tmax-2.59Tmin (Tura, $25^0$ 30'N, $90^0$ 13'E). From these five models, the change in yield when both Tmax and Tmin concomitantly increased by $1^0$C was calculated (Table 3). A reduction in yield was noticed in CES (16.23%) for 1 $^0$C rise in maximum and minimum temperatures. In Dapchari the yield reduction for 1 $^0$C rise in Tmax and Tmin was 11.25% followed by 8.43% in Padiyoor. But in the other regions like Agarthala and Tura in NE India where winter temperatures are very low the impact of warming was found negligible. In Agarthala the yield reduction was about 1.17% and in the case of Tura there was an increase in the yield by 2.72% for 1 $^0$C rice in maximum and minimum temperatures (Fig. 1). Thus, small rise in temperature in this region may not have much impact on rubber yield. Sometimes it may increase the yield just like what happened in the Tura region and expand NR cultivation to more parts of NE.

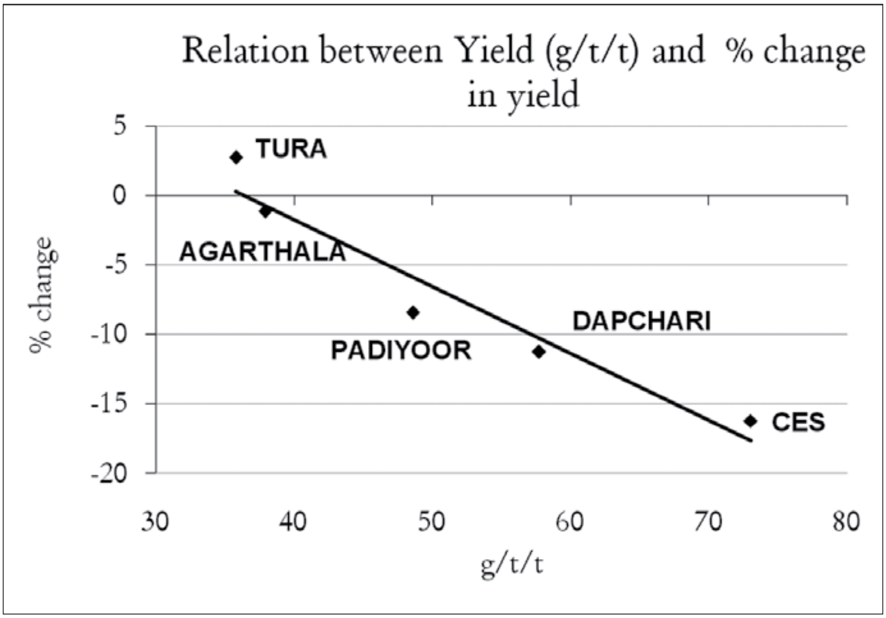


**Fig. 1**
**Percentage change in yield for 10C rise in temperature**

**Table 3**
**Percentage change in the future yield for one degree rise in temperature and predicted yield for the next 10 years with the current warming trends**

| REGION | | | MLR | | | % Change (for1⁰C rise) | % Change (for next 10 year ) | g/t/t |
|---|---|---|---|---|---|---|---|---|
| | | | Coeff. | Intercept | $R^2$ | | | |
| Tura | 2003-08 | Tx | 3.58 | -24.85 | 0.23 | **2.72** | **11.25** | **35.8** |
| | | Tn | -2.60 | | | | | |
| Agarthala | 2003-08 | Tx | 0.67 | 41.25 | 0.07 | **-1.17** | **-1.10** | **37.9** |
| | | Tn | -1.13 | | | | | |
| Chethackal | 2003-08 | Tx | -7.87 | 433.43 | 0.29 | **-16.23** | **-6.90** | **73.0** |
| | | Tn | -4.83 | | | | | |
| Padiyoor | 2007-08 | Tx | -2.54 | 171.01 | 0.19 | **-8.72** | **-4.23** | **48.6** |
| | | Tn | -1.71 | | | | | |
| Dapchari | 2007-08 | Tx | -1.01 | 204.98 | 0.50 | **-11.25** | **-3.70** | **57.7** |
| | | Tn | -5.51 | | | | | |

During the last 54 years (1956-2009) Tmax and Tmin in RRII have increased at the rate of 0.05 $^0$C/yr and 0.03 $^0$C/yr respectively. Extrapolating this data, the rise in Tmax and Tmin in the next 10 years was calculated and the same was used to estimate the expected reduction in productivity after 10 years at CES. The yield reduction after 10 years will be 6.90% in CES. In Padiyoor the rate of increase in Tmax and Tmin during the period 1998-2009 was 0.01 $^0$C/yr and 0.11 $^0$C/yr respectively and this may result in the reduction of yield by 4.23% after 10 years. In the case of Dapchari during the period 1994-2009 the rate of increase in Tmax was much higher (0.08 $^0$C/yr) but the minimum temperature increased by 0.03 $^0$C/yr. The reduction in the yield in this region will be 3.70% for the next decade. In Agarthala, the reduction in yield in the next ten years will be very small (1.10%) extrapolating the rise in Tmax (0.02 $^0$C/yr) and Tmin (0.06 $^0$C/yr) during the period 1984-2007. For the last 12 years (1992-2003) Tmax in Tura increased by 0.12 $^0$C/yr. But the minimum temperature increased by 0.05 $^0$C/yr in this region. The cumulative effect of the expected changes in Tmax and Tmin in this region could lead to an increase in the yield by 9.36% in the next ten years.

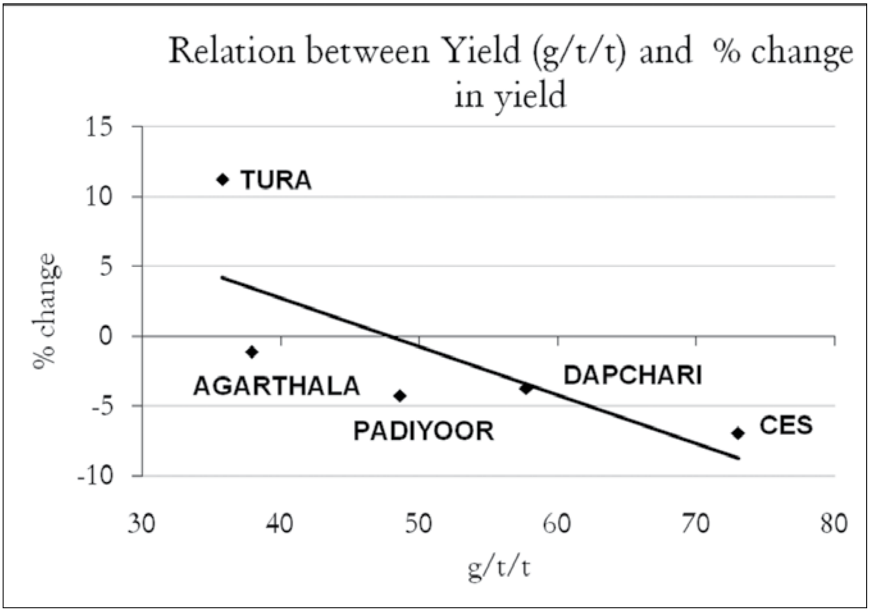


**Fig. 2**
**Percentage change in yield for next 10 year with actual change in temperature**

**Regression Analysis of Per Hectare Productivity and Temperature**

The MLR model obtained for per hectare productivity was Y= 999.53-6.14Tmax-27.68Tmin for Kottayam, Y= 789.36-11.33Tmax-12.68Tmin for Kanjirapally and Y= 281.91+4.13Tmax-11.26Tmin for Thaliparamba. The percentage reduction in productivity (for 1 $^0$C rise in both maximum and minimum temperatures) for these regions was 18.83%, 15.06% and 4.15% for Kottayam, Kanjirapally and Thaliparamba, respectively. These results were comparable with the results obtained from the regions respective when per tree yield was used as the dependent variable (Table 4).

**Table 4**
**Percentage change in the future productivity of rubber for one degree rise in temperature**

| REGION | | | MLR | | | % Change (for 1°C rise) | y/ha (kg) |
|---|---|---|---|---|---|---|---|
| | | | Coeff. | Intercept | $R^2$ | | |
| Kottayam | 2008-09 | Tx | -6.14 | 999.53 | 0.24 | -18.83 | 1965 |
| | | Tn | -27.68 | | | | |
| Thaliparamba | 2008-09 | Tx | 6.14 | -7.30 | 0.12 | -4.15 | 1950 |
| | | Tn | -1.37 | | | | |
| Kanjirapally | 2008-09 | Tx | -11.33 | 789.36 | 0.25 | -15.06 | 1902 |
| | | Tn | -12.68 | | | | |

### Carbon Sequestration Potential of the Planet

Linear regression analysis shows that the annual rate of increase in $CO_2$ emission between 1950 and 2008 was 438.01 Mt $CO_2$ per year ($R^2$ = 99%) and the atmospheric $CO_2$ concentration increased at the rate of 1.30 ppm per year which is equivalent to 10151.06 Mt $CO_2$ per year ($R^2$ = 97%) (Fig. 3). Between 1950 and 2008, $CO_2$ emission (including fossil fuel combustion and land use changes) increased from 9450 Mt to 34939 Mt. During the same period, atmospheric $CO_2$ concentration increased from 311 ppm to 386 ppm (Fig. 3). The increase in $CO_2$ emission was 270% while atmospheric $CO_2$ concentration increased only to the tune of 24%. Despite the huge increase in $CO_2$ emission, the atmospheric $CO_2$ did not increase to the same extent and this indicates that the amount of $CO_2$ sequestered by the planet must have increased at a rate greater than the rate at which $CO_2$ increased in the atmosphere between 1950 and 2008.

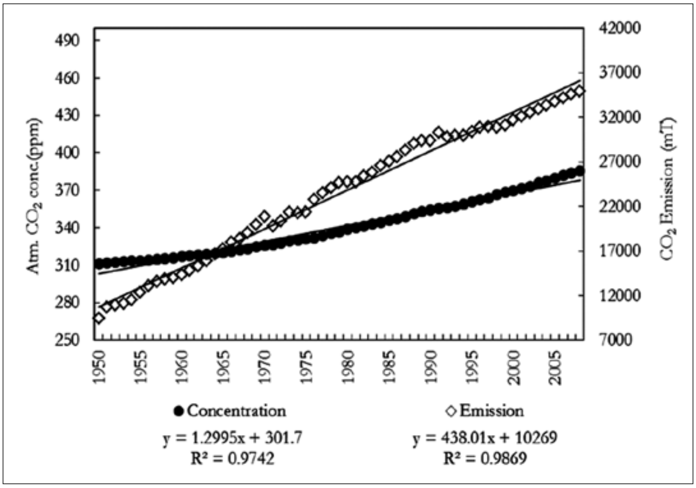


**Fig. 3**
**Rate of increase in the world $CO_2$ emission and atmospheric $CO_2$ concentration between the period 1950 and 2008.**

(*Calculated based on the data from Carbon dioxide information analysis center (CDIAC) and World Resource Institute (WRI) available at http://cait.wri.org*)

Terrestrial removal of $CO_2$ during 2000-2005 was 0.9 Gt C per year and this is equal to 3303.0 Mt $CO_2$ per year. Total vegetation area on earth surface is about 15000 M ha. From this we calculated the terrestrial carbon fixation rate which comes to 220 Kg $CO_2$ per hectare per year. At this rate, we need an additional land area of around 46141.0 M ha for planting trees so as to fully offset the current rate of increase in atmospheric $CO_2$ concentration (which is roughly 1.30 ppm per year, averaged for the period 1950-2008 (Fig. 3). This is equal to the terrestrial vegetation area of three planets.

From the emission and atmospheric $CO_2$ concentration data, we calculated the amount of $CO_2$ sequestered as the difference between the former two. The rate of $CO_2$ emission (including fossil emissions and land use changes) from 1950-2008 was 0.12 Gt C per year. The rate of removal of $CO_2$ from the atmosphere (including land and ocean sinks of $CO_2$) and the rate of addition of $CO_2$ to the atmosphere were identical (0.06 Gt C/year) (Fig 4). The rate of emission was much greater than the rate of removal and the difference was 0.06 Gt C per year. This indicates that even if we take the sequestration capacity of the land and ocean together, we will still require one more additional planet to remove the current rate of $CO_2$ emission to maintain equilibrium between the present emission and removal and thus keep the atmospheric $CO_2$ concentration stabilized at the present level.

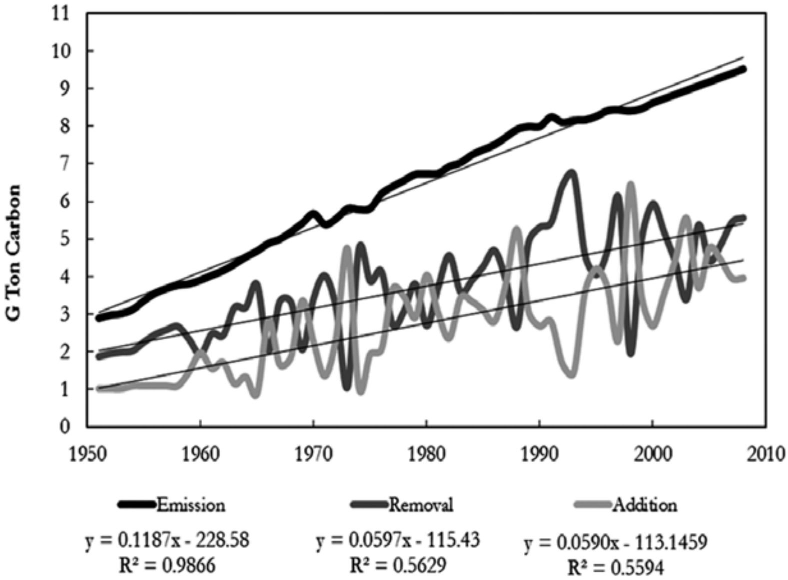


**Fig. 4**
**Global carbon balance sheet between 1950 and 2008**
*(Calculated based on data from CDIAC and WRI, 2011)*

Over the years, concentration of $CO_2$ in the atmosphere has been increasing at an increasing rate. For example, atmospheric $CO_2$ concentration been increasing at the rate of 2.07 ppm per year between 2000 and 2008 as against 1.30 ppm per year between 1950-2008. Therefore, afforestation programmes will be even more inadequate to offset the build-up of $CO_2$ in the atmosphere today than in the past. We would require a terrestrial vegetation area equivalent to 4.9 planets and a combined area of land and ocean equivalent to 1.6 planets to fully offset the recent rate of increase in atmospheric $CO_2$ concentration.

## CONCLUSION

Form the results presented here it is understood that the traditional plantation crops regions are experiencing climate warming and that this will have a profound impact on NR productivity. But as the non-traditional regions of NR cultivation such as NE India becomes warmer, more area may become suitable for the better cultivation of natural rubber because NE region is already having cold climatic conditions. Cold stress to the plants was a limiting factor in these regions. So rise in temperature especially minimum temperature would have been a positive impact in NE parts of India. The present analysis is the first attempt of its type to assess the direct impact of variations in weather parameters on daily yield of rubber. Climate change is obviously much more complex than daily variations in weather parameters. How different variables will interact positively and negatively on various aspects of rubber cultivation, including occurrence long dry spells, breaks in monsoon, extreme weather events, spread pests and diseases etc. is being investigated.

While the ecosystem services provided by NR plantations in terms of $CO_2$ sequestration are substantial, it is concluded that build-up of $CO_2$ in the atmosphere is determined more by the amount of global $CO_2$ emission rather than the $CO_2$ sequestration by the planet. While planting trees, including NR is good for the environment, and afforestation should be promoted for the various ecosystem services that they offer, including carbon sequestration, it should be borne in mind that even planting trees on the entire planet is not adequate to sequester the huge amount of $CO_2$ that the world emits today. Rather than growing more trees, deliberate reduction in the emission of $CO_2$ into the atmosphere is the realistic approach to reduce and stabilize the concentration of $CO_2$ in the atmosphere.

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# Redd$^+$ and Agriculture: Looking Back to Realities, Challenges and Opportunities

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## INTRODUCTION

Deforestation and forest degradation as a result of various activities including agricultural expansion, infrastructure development and forest fires accounted for nearly 20% of global greenhouse gas (GHG) emissions. Reducing Emissions from Deforestation and forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. REDD$^+$ goes beyond deforestation and forest degradation, and includes the role of forest conservation, sustainable management of forests and enhancement of forest carbon stocks. Financial flows for greenhouse gas emission reductions from REDD$^+$ could reach up to US$30 billion a year. Implementing REDD$^+$ requires countries to effectively address the drivers of deforestation and forest degradation

## REDD$^+$

United Nations Framework Convention on Climate Change (UNFCCC), 11th Conference of Parties (COP11) in 2005 took the decision to consider 'avoided deforestation' as a mechanism for climate change mitigation. The 'Bali Action Plan' finalized at the COP13 in Bali 2007 recognized the importance of REDD as well as additional activities. Since then countries supporting the UNFCCC have invested considerable effort in further developing the mechanism which resulted in REDD and further REDD$^+$. At COP16 in December 2010 at Cancun, the governments adopted the decision that was negotiated at COP15 in 2009 on REDD. The 'Cancun Agreement' provided a three-phase process for the developing countries to undertake mitigation through REDD$^+$ activities according to their national circumstances and capacities with financial and technological support from the developed countries (UNFCC, 2010), as described below.

***Phase 1****:* Development of a national plan, policies and measures, and capacity building.

***Phase 2*:** Implementation of the national plan, policies and measures, and further capacity building, technology development and transfer, and results-based demonstration activities.

***Phase 3:*** Results-based actions with full measurement reporting and verification.

In the Phase 1 or 'readiness' phase, the developing countries are encouraged to develop a National REDD$^+$ strategy, a National or sub-national forest reference emissions level, a robust and transparent national forest monitoring system, and a system to provide information on the safeguards to maintain environmental integrity, protect the rights of indigenous people and preserve biodiversity.

The 17th Conference of the Parties (COP17) at Durban, South Africa adopted a landmark decision to extend the Kyoto Protocol into the second commitment period while initiating a process (note 1) – to be finalized by 2015 – to negotiate a new legal basis for future climate actions to take effect from 2020 onwards. Further to the Cancun Agreement, important decisions on REDD$^+$ were made, viz. decisions on systems for providing information on safeguards; modalities for forest reference (emission) levels (FRLs) (note 2); and REDD$^+$ financing (note 3). The decision to include REDD$^+$ in a post Kyoto regime must not jeopardize the commitment of Annex I countries to reduce their own emissions.

**AGRICULTURE AND REDD$^+$**

Agriculture accounts for about 10-12% of the total global anthropogenic emissions of GHGs (IPCC, 2007). The emissions of GHGs due to agricultural activities increased rapidly during 1990 to 2005 and were recorded at 17% of total GHG emission (Verchot and Singh, 2009). Emissions are projected to increase further due to population growth, thereby increased demand for food. There are two types of GHG emissions directly attributable to agriculture, viz., (i) non-$CO_2$ GHGs from management operations which is estimated at 6.2 Gt $CO_2$e, and (ii) energy related $CO_2$ emissions, including emissions from manufacture of fertilizer, equal to 0.6 Gt $CO_2$e. Agriculture accounts for 59-63% of the world's non-$CO_2$ GHG emissions, 84% of the global $N_2O$ emissions and 54% of the global $CH_4$ emissions (USEPA, 2006a&b). Nitrous oxide emission from soils is the most important emission for the sector, followed by $CH_4$ from enteric fermentation (Table 1). $CH_4$ from rice cultivation is the third largest source. The driver of emissions from this sector is production, which will increase in the near future to keep pace with the growing population, particularly in tropical developing countries. A change in diet preferences and increased consumption of meat as societies become more affluent is also an important driver, particularly for emissions from enteric fermentation. By 2030, non-$CO_2$ GHG emissions from agriculture are expected to be almost 60% higher than that in 1990 (Verchot, 2007).

In 2000, India emitted 1523777.44 Gg $CO_2$ equivalent (1523.8 million tons of $CO_2$ eq.) from the energy, industrial processes, agriculture, and waste management sectors (MoEF, 2012). The agriculture sector emitted 355600.19 Gg $CO_2$ eq, which was 23.3% of the total GHG emissions. Agriculture sector also emitted 73.0% of total $CH_4$ and 75.0% of total $N_2O$ emissions in India.

**Table 1**
**Non-$CO_2$ GHG emissions (Mt $CO_2e$) by source in the agricultural sector**

| GHG emission source in Agricultural sector | Year | | | |
|---|---|---|---|---|
| | **1990** | **1995** | **2000** | **2005** |
| $N_2O$ Soil | 2284 | 2405 | 2610 | 2782 |
| $N_2O$ Manure | 196 | 199 | 205 | 219 |
| $CH_4$ Enteric fermentation | 1772 | 1804 | 1799 | 1929 |
| $CH_4$ Manure | 223 | 225 | 225 | 235 |
| $CH_4$ Other | 268 | 274 | 455 | 456 |
| $CH_4$ Rice | 601 | 621 | 634 | 672 |
| **Global total** | **5344** | **5528** | **5928** | **6293** |

*Source: Verchot (2007)*

As described in table 1, agriculture involves higher levels of methane and nitrous oxide emissions; lower potential for carbon sequestration; higher reversibility, patchiness and variability; politically sensitive due to food security and trade issues; higher transactions costs involving numerous owners, often on private land; and complex sectoral and supply chain incentives. Significantly agricultural expansion is one of the primary drivers of deforestation and thereby affects REDD+.

Technological changes that improve productivity on existing agricultural land save natural ecosystems (including forests) from being converted to agriculture. This is commonly known as the *Borlaug hypothesis* after Norman Borlaug (2007), who claimed that the intensification of agriculture between 1950 and 2000, partly as a result of the technological change made possible by the Green Revolution, had saved 1.2 billion hectares of forest. However, the relationship between adoption of new technologies and land use is complex. Increases in productivity from new technologies also increases the profitability of agriculture in comparison with alternative land uses (such as forest) thereby encouraging expansion of the agricultural land frontier. Therefore an integrated approach to agriculture and land use change would enable better management of the trade-offs and synergies among mitigation, food security and poverty reduction.

## AGRICULTURE, FORESTS AND DEFORESTATION

The agriculture sector and forests are essentially linked, apparently through their direct competition for land. The land area used for agriculture is increasing globally, with much of this expansion occurring onto forested lands, making agriculture one of the leading drivers of deforestation (Boucher et al., 2011). Between 1980 and 2000, 83% of new croplands in tropical areas came from natural forested land (Pirard and Treyer, 2010). Without concerted effort this is likely to continue, 38% of forested land is at high risk of conversion for agriculture, and forests have an agricultural conversion rate three times higher than the conversion of other natural landscapes (Creed et al. 2010). The close links between agriculture and forests, the fact that agriculture is the largest driver of deforestation in many developing countries, and the increasing global demand for food means that implementing REDD+ effectively will require policy interventions in the agriculture sector as well as the forest sector.

Deforestation drivers can be divided into “immediate” and “underpinning” drivers. Actual cutting of trees is due to “immediate” deforestation drivers and agricultural expansion is one of the most important immediate deforestation drivers (Geist and Lambin, 2002). The underpinning drivers are (i) Demographic factors (growth and density, urbanization and migration, etc.); (ii) Economic factors (changes in relative prices, economic structures, shifts in demand for commodities, infrastructure development, etc.); (iii) Technological factors (technological progress to increase agricultural production); (iv) Policy and institutional factors (macro-economic policies, tenure rights, corruption, etc.); and (v) Cultural factors (public and individual attitudes and values, lack of concern about forests, etc.). Population growth, low agricultural productivity and poor technology are the main factors causing agricultural land expansion and deforestation by small-scale and subsistence farmers. Access to capital, profit, large scale production systems, links to markets, etc influence the relationship of commercial agriculture with forests.

The agricultural sector is an important sector for rural growth, poverty reduction and development, and has therefore been provided with significant policy support and incentives in many countries (IFAD, 2010). This support influences the profitability of agriculture, and therefore has corresponding impacts on agricultural expansion, and deforestation.

## REDD+ INDIAN OUTLOOK

Deforestation is nothing new in India. During colonial periods forests were treated as the production of timber used for the British navy, for export, and for the creation of the railway network. Extensive tracts of forest were also converted into plantations of tea, coffee, rubber and other commercial crops. India has made significant progress in reducing deforestation through a combination of policy measures and forest management practices. The current forest and tree cover of the country is estimated to have 78.34 million hectares accounting for 23.84% of the geographic area of the country (FSI, 2009). Out of this, the forest cover is about 69.09 million hectare, which constitutes 21.02% of the geographic area of the country (Aggarwal, Das and Paul, 2009). Although an increase in the recorded forest area, the accelerated pace of population growth has resulted in declining trend in the per capita availability of forest area since the 1950s. The per capita availability of forest land declined from 0.124 hectares per capita in1961 to 0.074 hectares in 2001 (Table 2). Despite all forest management efforts, there is still diversion of forests for agriculture and other developmental activities. During 1981 to 2004, extensive tracts of forest were also converted for non-forestry activities (Table 3). A study by TERI revealed that 0.2 M ha of forest area was diverted between 2005 and 2008 (Aggarwal, Das and Paul, 2009).

**Table 2**
**Per capita availability of forest area in India (in Ha)**

| Year | Per capita availability of forest area (in Ha) |
|---|---|
| 1951 | 0.113 |
| 1961 | 0.124 |
| 1971 | 0.115 |
| 1981 | 0.099 |
| 1991 | 0.081 |
| 2001 | 0.074 |
| 2011 | 0.057 |

*Source: Data compiled from FSI (2009) and Census India (2011)*

**Table 3**
**Diversion of forest to non-forest activities**

| Year | Forest area diverted (in Ha) |
|---|---|
| 1981 | 1331.7 |
| 1985 | 7676.83 |
| 1990 | 127361.00 |
| 1995 | 51428.98 |
| 2000 | 22386.43 |
| 2004 | 33079.50 |

*Source: Forest and Wildlife Statistics, MoEF, India, 2004*

At national level large-scale farming plays the most important role in the conversion of forest lands. At the local level, a range of political, cultural and socio-economic factors, corruption, landlessness and unclear allocation rights, migration, and rural poverty are indirect drivers of deforestation. Successful REDD+ policies require tackling different drivers of deforestation in both the forestry and the agricultural sector at national and state level. While designing national REDD+ strategies, policies, laws and action plans, it is necessary to consider agricultural and rural development goals and adopt an integrated landscape approach. This approach takes into account all land uses in a holistic way and works to lessen the competition for natural resources among different sectors. Such an approach ensures that the best possible balance is achieved among a range of different development objectives, including climate change mitigation and adaptation, environmental conservation, enhanced agricultural productivity and improved livelihoods.

## POLICIES AND LAWS IN INDIA RELEVANT TO REDD+

There are a number of policies and laws which impact the conservation and management of forests in India. The key policies that are important from REDD+ perspective include National Forest Policy, 1988; Joint Forest Management Resolution, 1990; National Environment Policy, 2006; Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006; and the National Action Plan on Climate Change, 2008. The National Action Plan on Climate Change

(NAPCC, 2008) advocates bringing one-third of the geographic area of India under forest cover through afforestation of wastelands and reforestation of degraded forest areas. The NAPCC apart from the eight Missions (Table 4) has laid emphasis on numerous other climate-friendly measures.

**Table 4**
**National Missions under the National Action Plan on Climate Change (NAPCC), India**

| Sl. No. | National Mission | Objectives |
|---|---|---|
| 1 | National Solar Mission | Promoting ecologically sustainable growth while meeting energy security challenges |
| 2 | National Mission on Sustainable Habitat | Extension of Energy Conservation Building Code (optimization of energy demand)<br>Urban planning/shift to public transport: long-term transport plans for small/medium cities<br>Recycling of material and urban waste management: power from waste |
| 3 | National Mission on Green India | Double area under afforestation / eco-restoration in the next 10 years<br>Increase greenhouse gas (GHG) removals by forests to 6.35% of India's annual GHG emissions by 2020 (increase of 1.5% over baseline)<br>Enhance forests/eco-systems resilience |
| 4 | National Mission for Sustaining the Himalayan Ecosystem | Strengthening institutional capacity<br>Standardization of field and space observations<br>Prediction/projection of future trends and assessment of possible impacts<br>Governance for Sustaining Himalayan Ecosystem (G-SHE) |
| 5 | National Mission on Enhanced Energy Efficiency | Market-based approaches<br>Cumulative avoided electricity capacity addition of 19,000 MW |
| 6 | National Water Mission | Conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within States through integrated water resources development and management |
| 7 | National Mission for Sustainable Agriculture | Use of bio technology<br>Dryland (rain-fed) agriculture<br>Risk management<br>Access to information |
| 8 | National Mission on Strategic Knowledge on Climate Change | Network of institutions<br>Promotion of climate science research<br>Data sharing policy: from various arms of government<br>Building human and institutional capacity: filling knowledge gaps in modelling and technology |

*Source: NAPCC (2008)*

The different laws that are important from REDD+ perspective in India include Indian Forest Act, 1927; Forest (Conservation) Act, 1980; Wildlife (Protection) Act, 1972 (amended in 2001 & 2002); and Biological Diversity Act, 2002.

## IMPLICATIONS OF THE CANCUN AGREEMENT ON REDD+ FOR INDIA

The Cancun Agreement created a framework for REDD+ action by countries in a phased manner, specifically listing the phased actions required from the countries immediately in the first phase (UNFCC, 2010).

### National REDD+ strategy

While India has a series of policies and measures in place for addressing deforestation and degradation, an institutional structure needs to be developed in order to formulate and implement a national REDD+ strategy as required under the UNFCCC.

### Developing a MRV system for REDD+

Forest Survey of India has developed a well-developed national forest monitoring system based on remote sensing combined with extensive groundtruthing with a long time series of data on forest cover according to different canopy cover density classes (FSI, 2011). With high resolution satellite imageries, it is possible to detect the location of deforestation and degradation with adequate accuracy. Information on the areas subject to conservation, enhancement of carbon stocks and sustainable management of forest (SMF) can also be obtained through a combination of data from administrative and other sources, and remote sensing. India need to develop a robust system for monitoring of carbon stocks in forests through a network of permanent monitoring plots.

### Setting the forest reference (emission) level

In order to set a forest reference (emission) level (FRL) an analysis of factors driving deforestation and degradation is vital. Data on the various drivers of deforestation, degradation and activities resulting in carbon stock enhancement and conservation can potentially be gathered through a combination of remote sensing and non-spatial information such as forest administrative records.

### System for information on safeguards

Currently India does not have a system of providing information on environmental and social safeguards. In order to effectively monitor safeguards, it will be necessary to evolve a clearly defined set of indicators and criteria for parameters such as forest governance structures, respect for rights of indigenous peoples and full and effective participation of relevant stakeholders, along with an efficient system to monitor.

## AGRICULTURAL LAND USE CHANGES, DEFORESTATION AND REDD+ IN KERALA

Agricultural land-use changes have impacted the forest ecosystems of Kerala region of Southern Western Ghats. George and Chattopadhyay (2001) highlighted four distinct phases of deforestation in the State; *viz.*, (i) extensive conversion of forestlands to plantations following a Royal Proclamation in the late nineteenth century, (ii) the "Grow More Food" campaign of the mid-1940s when substantial areas of forests were opened up for the cultivation of food crops, (iii) colonization during the 1950s and 60s which created new settlements in the deforested areas, and (iv) infrastructure development of the post-independence era during which projects in power, irrigation and transportation sectors were set up on forestlands. Overall, the land-use changes represent an intricate pattern especially in view of the wide variations in physical settings and the complex development patterns adopted in the past. Yet, a clear shift away from food crops, mainly rice and cassava, in favour of tree crops such as rubber and coconut (Kumar, 2005). George and Chattopadhyay (2001) observed that such shifts in land-use may have profound implications for the food security of the region, which already depends on 'outside supplies' to meet more than half the its food grain requirements.

In view of the unprecedented rates of deforestation, and the rapidly rising human population pressure, the per capita forestland availability in the State declined from 0.060 in 1961 to 0.034 ha in 2001 (Kumar, 2005). Despite a substantial clearing of forestlands for agriculture, the cultivated land per capita also dropped from 0.14 to 0.077 ha between 1961 and 2001 mainly because of population growth during that period. The declining ratio of forests-to-agricultural lands and the increased intensity of land-use increased the pressure on remaining forests due to illicit cutting of trees (for firewood, charcoal and for making agricultural implements), overgrazing and collection of fodder, green leaf manure, litter and non-wood forest products (Amruth, 2004). In addition, the local people frequently set fires in the forests for promoting grass growth that benefits the grazers by enriching soil fertility of the crop fields in the fringe areas through post-fire ash transport in rains, facilitating easier extraction of non-timber forest products and so on (Muraleedharan et al., 2005).

With advances in agriculture and agricultural intensification in the State, a large proportion of the Kerala home gardens have been converted into small-scale plantations of coconut and rubber (Table 5) or cropping systems consisting of fewer crops (Kumar and Nair, 2004). Coincidentally, many local varieties of mango (*Mangifera indica*), jackfruit (*Artocapus heterophyllus*) and other traditional fruit/ vegetable crops, which were once abundant in the Kerala home gardens, are now thought to be extinct. With the advent of the high-yielding variety (HYV) program in Kerala, most of the paddy lands were also dedicated to modern varieties; consequently, cultivation of a vast majority of the distinctive landraces have vanished. The consequences of deforestation, which also has been widespread in the state, include frequent flash floods and landslides, soil erosion, and silting of reservoirs, causing serious ecological and environmental problems and complex feedback effects on agricultural production. Implementing $REDD^+$ effectively in the State will require policy interventions in the agriculture sector as well as the forest sector.

**Table 5**
**Trends in cropping pattern in Kerala, 1960-2009**

| Crops | Area under cultivation (1000Ha) | | | |
|---|---|---|---|---|
| | 1960-61 | 1980-81 | 2000-01 | 2009-10 |
| Coconut | 500.76 | 651.37 | 936.29 | 778.62 |
| Arecanut | 24.26 | 61.24 | 85.38 | 99.22 |
| Rubber | 135.8 | 237.8 | 474.36 | 525.41 |
| Cashew | 54.32 | 141.3 | 86.23 | 48.97 |
| Coffee | 16.8 | 57.56 | 84.74 | 84.8 |
| Tea | 37.61 | 36.16 | 36.85 | 36.84 |
| Pepper | 99.75 | 108.07 | 199.37 | 171.49 |
| Cardamom | 28.68 | 54 | 41.29 | 41.59 |
| Rice | 778.91 | 801.7 | 347.46 | 234.01 |
| Tapioca | 242.2 | 244.98 | 111.18 | 74.86 |
| Banana & plantain | 44.42 | 49.26 | 92.89 | 99.08 |
| Pulses | 44.12 | 33.86 | 10.81 | 4.45 |
| Ginger | 12 | 12.66 | 11.26 | 5.41 |

*Source: Compiled from GOK Economic Review; Statistics for Planning; Agricultural Statistics*

## CHALLENGES AND OPPORTUNITIES FOR REDD$^+$

REDD$^+$ requires clear and secure rights and exclusion of those who cause deforestation and degradation. This is an opportunity to clarify and secure rights (and associated benefits and responsibilities related to C emissions reductions) of people living in forests and thus engage them in REDD$^+$ for both their benefit and the benefit of the forests. By doing so, REDD$^+$ will gain their support - and therefore its legitimacy. The reverse - failure to protect the rights of forest-based peoples - is likely to lead to increased conflict, opposition and even the sabotaging of carbon reduction efforts. Government policies on land tenure and land use planning, and the capacity to implement and enforce these also affects the relationship between forests and agriculture. The location in which various policy options are implemented will also influence their effectiveness in achieving REDD$^+$ goals, and overall climate change mitigation. Landscape scale land-use planning will therefore be essential to underpin these decisions and identify areas that are appropriate for agricultural intensification, REDD$^+$ and other land uses. A combination of policies will be necessary for the successful harmonization of countries' REDD$^+$ and agriculture priorities, including the regulation of forest clearing for agricultural expansion, the reform of agricultural tariffs and subsidies, targeted support for intensification in appropriate areas, targeted support for smallholder farmers, PES and the promotion of climate smart agriculture.

## THE WAY FORWARD FOR REDD+ AND AGRICULTURE

It is crucial to adopt sustainable farming practices that, among other things, improve water management, support conservation agriculture, enhance sustainable crop production, foster integrated crop-livestock systems, regenerate degraded forest ecosystems, and support integrated feed, food and energy systems. These practices increases in agricultural productivity; contribute to climate change adaptation by increasing social and ecological resilience; mitigate climate change by reducing and/or removing greenhouse gases; and support the achievement of national food security and development goals. Climate-smart agriculture seeks to direct agricultural development along pathways that lead to sustainable development. This concept has been taken up by intergovernmental organizations and national governments as a way forward for making landscapes more resilient in the face of climate change and increase the adaptive capacity of agricultural communities. Changes in agricultural technologies may meet several objectives, including (i) improving the living conditions, (ii) improving the total productivity of factors of production in order to increase total food availability, and (iii) preserving ecosystems, especially forests. The combination of these three objectives is proving to be a particularly ambitious challenge, especially in terms of ensuring compatibility between the increase in production and the maintenance of forest cover.

## CONCLUSION

Adoption of an green agriculture practice, which combines agroforestry with conservation farming, offers multiple livelihood benefits to farmers, improves soil quality, increases agricultural production and alleviates the pressure on forests, is the need of the hour. A set of economic, institutional and capacity constraints need to be overcome in order to shift away from 'business as usual' practices which take place at the expense of the forests. Increased support for research, technological development, extension services and capacity building to extend sustainable land use practices is needed. Integrated agriculture / REDD+ strategies and policies are likely to have a strong impact on forest-dependent communities and other stakeholders.

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# Towards a Sustainable System of Innovation: The Case of Plantation Sector in Kerala

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## INTRODUCTION

It is encouraging to note that during the closing decades of the previous century and early decade of this century economic growth in a number of developing countries are catching up their developed country parts. At the same time, if the available evidence is any indication, this has further accelerated the consumption of energy and other scarce natural resources, accumulation of greenhouse gases in the atmosphere and other environmental externalities over and above the heavy toll of environment already imposed by the developed countries. Needless to say, this has led to heightened concern on ecological sustainability of higher economic growth. No wonder, the United Nations Conference on Sustainable Development (2012) known as Rio+20 commemorating the 20$^{th}$ anniversary of the 1992 Earth Submit resulting in the document "The future we want" marks a renewed effort to embark on ways of "greening" the global economy and evolving institutional framework for sustainable development. Given the growing inequality and marginalization that accompanied the high growth episodes, doubts have often been raised about its economic and social sustainability and that inclusive and sustainable development is increasingly becoming a key concern of planners and policy makers. Thus higher economic growth, the long cherished dream for many economists, doesn't appear to entail complimentarity between economic, social and ecological sustainability. Indian experience in general and that of Kerala in particular appears to be not much different; with higher rate of economic growth, the adverse effect on the environment today is more than ever before. Moreover, going by the recent empirical evidence, Kerala has emerged as one of the most unequal state in the country (The estimated value of Gini coefficient using the NSS consumption data in Kerala declined from 0.35 in 1983 to 0.32 in 1993 and was comparable to that of all India average -0.31. But by 2009-10 it increased to 0.48 in Kerala as compared to the national average of only 0.36.).

To the extent that the observed higher economic and its associated outcomes are inexorably linked to the system of innovation and production in specific sectors of the economy, addressing the issue of sustainability (both ecological, economic and social) entail a techno-economic paradigm shift that needs to be *radical*, as unsustainable technological trajectories and innovative practices need to be disrupted and replaced by new technologies and innovations in order to decouple economic development from resource consumption and carbon emissions; *rapid*, because this decoupling has to take place within the next decade or two – a failure to take immediate action will overstrain the carrying capacity of critical global ecosystems and lead to much higher costs in the future; and *systemic,* as it implies changing technological regimes and combining institutional sub-systems in innovative ways [See in this context Tilman (2012) and the special issue of Innovation and Development Vol 2, no.1, 2012].

In this paper we explore the nexus between ecology, economy and innovation (in its broader sense – covering technological and institutional) by taking the case of plantation sector in Kerala. In the context of plantation sector in India in general and Kerala in particular, while its adverse effect on environment has been an issue of perpetual concern, this nexus seems to have not received the attention of scholars that it deserves. Plantation sector in India, historically dominated by the large estates has been promoted intensively by the state given its significant contribution towards foreign exchange (As per the pioneering study on India's exports by Singh (1964), in 1950-51 tea coffee and spices accounted for nearly 21 per cent of India's total export) on the one hand its developmental role and livelihood of workers on the other (Plantation sector is shown to be highly labour intensive, especially women labour as they account for 54 per cent of the total labour force engaged (Joseph, 2010). However, there has been a growing concern over the environmental implications of plantation sector on account of the deforestation, sedimentation in the reservoirs of hydroelectric projects, environmentally hostile cultural practices, waste generation in case of certain plantations and others (Murugan et al 2011, James 2011, Nair et al 1989). Hence economic sustainability of plantation sector is considered as inimical to environmental sustainability. At the same time, the changes in environment do adversely affect yield of plantation crops and therefore their economic viability. In this paper, drawing insight from the literature on innovation systems, we examine the evolving nature of interaction between economy, ecology, innovation and see if the emerging trajectory is towards sustainability or un sustainability.

The remainder of the paper is organized as follows. The second section drawing insights from the studies on National System of Innovations (NSI) presents the broad outlines of innovation system in Kerala's plantations sector to explore the issue at hand. The third section presents a preliminary analysis of the emerging system of innovation in Kerala's plantation sector to see if the evolving nature of interactions among organizations and institutions is giving rise to relatively more sustainable outcomes. Concluding observations with a call for evolving a sustainability oriented innovation system is presented in the last section.

## IN LIEU OF AN ANALYTICAL FRAMEWORK

The recent empirical evidence on economic growth in many of the developing countries indicates that the road to high growth is no more an unchartered terrain for the laggards in developing world. Based on the observation that 13 economies from the developing world have grown at an average rate of 7 percent a year or more for 25 years since 1951, which is unheard in history, "The Growth Report" by the Commission on Growth and Development (2008) presents an optimistic future for the developing countries by identifying certain distinctive characteristics of high-growth economies that could be emulated by the laggards. High growth is possible, it has been argued, *inter alia,* because the world economy is now more open and integrated. Therefore, the division of labour is much less constrained today by the extent of market than during the times of Adam Smith. The Commission believes for the developing countries, open world economy facilitates the import of ideas, technologies and know-how from rest of the world to hasten the catching up process [It is, however, important to note, "Technologies cannot be taken off the shelf and simply put into use anywhere. Without infrastructural investment in education, training, R&D and other scientific and technical activities, very little can be accomplished by way of assimilation of imported technologies" (Freeman, 2011)].

Economists, regardless of the school of thought that they belong, from Adam smith and Karl Marx to New Growth Theorists have shown that innovation in general and technological change in particular has a crucial bearing on the rate of growth of economies. Empirical evidence on the growth experience of today's developed countries and recent growth experience of emerging economies like Brazil, Russia, India, China and South Africa (BRICS), stand as a testimony to the above argument (OECD, 2007). Today even the lay person is convinced of the comforts and conveniences that the technology and innovation have brought into her daily life from the kitchen to office and from the farm to factory.

However, by now it is generally evident that the past episodes of high growth under globalization are unsustainable viewed in terms of any of the pillars of sustainability – environmental, economic and social. The highly energy and carbon intensive growth has led to unprecedented damage to environment resulting in global warming and its associated adverse effect leading to limits to growth thesis of Club of Rome which was further reinforced by a number of influential studies and global summits.

In the sphere of economy and society, it has been shown that higher growth has been accompanied by growing inequality casting doubt on its economic and social sustainability (Wade 2004). In India also, the high growth has not been broad based, pro-poor or inclusive, to use the current fashionable term and therefore not sustainable. As noted by Abhijit Sen and Himanshu (2004) rate of decline in poverty in India has been at the lowest level during 1990s. We have also witnessed massive farmers' suicides in India that coincided with high rate of economic growth (Mishra 2006 Reddy and Mishra 2009 Mohanakumar and Sharma 2006). As observed by the Planning Commission (2008) and Vaidyanathan (2010) among others, notwithstanding an unprecedentedly high GDP growth rate of 7.7% during the 10th plan (1992-97), growth of agricultural sector that accommodated bulk of the India's labour force remained almost stagnant at 2% and the country had to live with the largest number of poor, illiterates in the world. It also underscored the need to address the growing marginalization of women and minorities and steep inequities at different levels. Indian experience and that of many other fast growing developing economies, therefore, tends to confirm what Schumpeter rightly maintained, aggregate statistics of GDP or industrial production can conceal as much as they reveal since they are the outcome of diverse trends in the economy.

It appears that while the recipe for high growth, which in a globalised context crucially dependent on competiveness, is presumably ready, what is missing is a credible cookbook for sustainable, both economically and environmentally, growth and competitiveness. However, despite the heightened interest on the issue at hand, our understanding on the ways to achieve sustainable growth and competiveness at best remains rudimentary. In a context wherein the focus of policy pendulum is being shifted from growth to sustainable growth one ponders if the innovation breeds growth, could it also be instrumental for sustainable growth?

While the concept of sustainability is more widely used in the context of environmental suitability, the term in its broad sense encompasses three dimensions – environmental, economic and social and our focus will be on the first two. The relevant point of inquiry, therefore, is whether these two dimensions of sustainability are competitive or complementary. Economists have, since long, considered a dollar worth of potato chip different from a dollar worth of microchip, implying that the product structure and sectoral composition do matter in growth (Passinetti, 1981) and competiveness. Hence to understand the micro foundations for growth and sustainability the inquiry has to be at the sectoral level which justifies our focus plantation sector.

Viewed in a static sectoral perspective, it is rather easy to see that different sectors of the economy are not equally positioned in breeding high growth with suitability. While some sectors, given the nature of production process and higher opportunities for technological progress and innovation potential, are growth boomers, the outcome may not be complimentary in terms of economic and environmental sustainability. On the other hand, there could be other sectors wherein high growth is associated with complimentarity in terms of economic and environmental sustainability. Viewed in a dynamic sense one could have cases wherein the high growth trajectory is associated either with complimentary or non complimentary relationship between environmental and economic sustainability. This in turn would depend on the growth drivers in the economy. To the extent that innovation, the driving force behind growth in any economy is crucially dependent on the underlying innovation system Fagerberg (2005) which in turn has a crucial bearing on all the three basic considerations – growth, economic sustainability and environmental sustainability – one could safely infer that if growth needs to be sustainable the underlying innovation system also has to be one that is oriented towards sustainability. This takes to the discussion on the concept of innovation system in some detail.

**The Origin of the Concept**

The concept of innovation system has its origin in the work of Georg Friedrich List (1841), leading German economist of $19^{th}$ Century. It is interesting to note that, the context which induced List to write his *magnum opus* - National System of Political Economy – is strikingly similar to the current juncture where we are in. List's primary concern was to explore the ways and means by which a developing country (Germany of $19^{th}$ century) could be enabled to catch up with a developed country (England of $19^{th}$ century). He had strong reservations with Adam Smith's belief in the free trade and cosmopolitanism (While Adam Smith considered division of labour as the key source of improvement in the productive powers of labour, List argued that in order to explain the opulence of modern nations we must look at how work of different Labour is combined. By arguing that it not Division of Labour but "Union of labour" that actually contributes towards improvement in productive power, List highlighted the interaction between different agents involved and underscored the need to see the economy in a systemic manner). This is what induced List to propose the idea of infant industry protection that formed the core of impart substitution strategy adopted by many of the countries that achieved political independence after the Second World War.

However, there was another important element of the catch up strategy proposed by List. This involved investment in human capital (education) and capacity building and emphasis on knowledge acquisition and its improvement. To quote

"The present state of the nation is the result of accumulation of all discoveries inventions, improvements perfections and exertions of all generations which have lived before us; they form the mental capital of the present human race, and every separate nation is productive only in the proportion in which it has known how to appropriate these attainments of former generations and to increase them by its own acquirements".

While the idea of infant industry protection received much attention of development planners and manifested in the tariff barriers to protect the domestic industries, it was only by 1987 that some of the ideas of List for national capability building was articulated by Christopher Freeman (1987) while analyzing the emergence of Japan as a major economic power. He has shown how Japan has opened up a new "Technology gap" over other countries as a result of developing a national system of innovation. Thus the "National System of Political Economy of List became "National system of Innovation" in the hands of Freeman.

**Development of the Concept**

Disenchanted with neoclassical paradigm that that places analytical focus on concepts like scarcity, allocation and exchange (market) in a static context, and considering theories in social sciences as focusing devices, Lundvall (1992) and Nelson (1993) made considerable contribution towards evolving further the concept of National Innovation System (NIS). They considered knowledge as the most fundamental resource in the modern economy and its acquisition as an interactive process. The concept got enriched by drawing insights from evolutionary economics, structuralists and theories on the economics of knowledge and appreciating the dangers of considering R&D on par with innovation *ala* GDP growth with development in traditional development economics. Common for these contributions was that they deviated from the linear approach to technological progress (invention-innovation diffusion) and regarded innovation as an interactive and evolutionary process at micro, meso and macro level as a driving force behind growth and development. Thus viewed they went beyond the narrow confines of product and process innovation and considered innovation as an interactive learning process in an evolutionary manner emphasizing the inter-dependence and non-linearity wherein institutions playing the central role (Joseph 2006; Edqust ). The concept has been articulated by a number of scholars at the national sectoral and regional levels. For a growing number of studies on Innovation systems the readers are referred to www.globelics.org

Almost from the beginning, innovation system research has encompassed two different perspectives, a narrow one linking innovation to science and a broader one encompassing learning, innovation and competence building (Lundvall 2007). NIS in a narrow perspective, in tune with the earlier analyses of national science systems and national technology policies (Mowery and Oxley 1995), aimed at mapping indicators of national specialization and performance with respect to innovation in new products and process, research and development efforts and science and technology organizations. In contrast, the broader approach to NSI takes into account social institutions, macro economic regulation, financial systems, education and communication infrastructures and labour market conditions as far as these have impact on learning and competence building process (Gu and Lundvall 2006). It links the micro behaviour to the system level in a two-way direction. Changes at the system level are seen as outcomes of interactions at the micro level whereas the system shapes the learning, innovation and competence building at the micro level.

Drawing from the discussion so far made the innovation system in plantation sector is depicted in fig 1.


*Source: Adapted from Cassiolato (2005)*

**Fig 1**
**Innovation system in India's Plantation Sector**

In the figure we present three different versions of the innovation system, very narrow, narrow and the wider version. Viewed from a very narrow perspective, innovation system in plantation will involve only the knowledge generating and diffusing organizations and the institutions (North,1990 says Institutions are the rules of the game in society or, more formally, are the humanly devised constraints that shape human interaction) like the rules, laws norms and practices that govern this process and its outcomes. From a narrow perspective the innovation system will also involve the producers, both small and large, workers both in the organized large estates and informal workers, and the agent involved in the processing and marketing –both in the foreign and local markets. The actions and interaction between these actors are indeed governed by varied institutions (we mean, rules, laws, norms etc) and organizations like the planters' associations, labour unions and others.

When it comes to the wider conceptualization of innovation system we also need to take into account the international organizations (eg WTO) and institutions (eg multilateral agreements with bearing of plantations like the Agreement on the Sanitary and Phytosanitary Measures and national organizations (eg commodity boards) and the organizations and institutions both at the state and national level (eg rules on land utilization). Going by the innovation system framework, the complementary on non-complimentary relationship between growth and the sustainability in plantation sector quintessentially will be dependent on the innovation system in plantation sector which in turn will be an outcome of the interaction between different actors involved and the institutional framework provided.

**EMERGING INNOVATION SYSTEM IN PLANTATIONS**

Plantation sector in general involves mono crop cultivation for the market and environmentalists consider plantations are green deserts. Tree plantations are not forests as it is a highly uniform agricultural system that replaces natural ecosystems and their rich biodiversity. It is further argued that monoculture tree plantations have a twofold impact globally: loss of biodiversity and net emitters of carbon.

Plantation sector in India in general and Kerala in particular, has been developed mostly in the ecologically fragile locations. The development of plantations in such regions, needless to say, has been at the cost of biodiversity due to large scale deforestation. The plantation sector being historically integrated with the world market, with a view to be internationally competitive has to adopt such cultural practices which involved heavy use of chemical fertilizers and fertilizers. Such cultural practices are also shown to have severe adverse effect on environment and human habitation in addition to the soil erosion and other adverse environmental consequences. Similarly, in cardamom plantations, felling of trees for firewood for cardamom curing is also having similar outcomes. Apart from the highly fertilizer and pesticide intensive cultural practices, and fuel wood intensive processing methods, the survival strategies of growers in the event drastic decline in the price of these crops also shown to have adverse ecological outcomes. Damodaran (2002) has shown that the coping up strategies of growers like felling of shade trees for sale in coffee plantations for sustaining the revenue flows in the event of decline in prices, have had deleterious consequences on the environment.

At the same time, the productivity and therefore the competitiveness and economic viability of plantation crops is highly susceptible to the state of environment (Nair et al 1989) and hence the climate change. Thus there is a nexus between technology, economy and environment in plantation sector. The technology driven agricultural practices and processing methods, along with innovations in the organization of production (in large vs small holdings) and cropping pattern (mono cropping vs mixed cropping) driven by economics of production impacts environment while such adverse environmental outcomes in turn affect the productivity and economic viability of plantations. Here there are different trajectories possible depending on the nature of interaction between different actors and organizations involved and institutional setting within which they interact. The key issue is whether the nexus between economy, ecology and technology and innovation in Kerala's plantation innovation system as evolved over the years has been tending towards a trajectory of high growth with complimentary or non complimentary relation between economic and environmental sustainability. This calls for an inquiry into the innovations in India's plantation sector in lieu of the above issues.

**Organizational Innovations: Shift from States to Small Holdings**

The origins of plantation agriculture in India could be traced to the pre independence period and has been an outcome of colonization of tropical region by European countries [Cultivation of tea, for example, began in 1830s in Assam and North Bengal. Later cultivation shifted to Nilgiris in Southern India. Hence the first phase of the development of South Indian tea industry was confined to Nilgiris. Later Chinese tea seeds seem to have been planted in Kerala on a commercial scale in early 1850s (George and Tharakan 1985)]. Going by the historical evidence, plantation sector in India has been initially in the hands of foreign companies (see Table 1). Later, especially after independence the ownership of these estates shifted to the large domestic players.

**Table 1**
**Concentration of area under tea in Kerala and Tamil Nadu by foreign controlled companies**

| | Kerala | | | Tamil Nadu | | |
|---|---|---|---|---|---|---|
| Year | No. of Companies | Area under their Control (Hectares) | Area under Control as % of total Area under Tea | No. of Companies | Area under their Control (Hectares) | Area under Control as % of total Area under Tea |
| 1925 | 5 | 19702.37 | 77.23 | 6 | 9427.12 | 59.23 |
| 1940 | 5 | 28071.58 | 73.69 | 6 | 15470.50 | 59.72 |
| 1950 | 5 | 27606.36 | 70.14 | 6 | 14021.10 | 53.05 |
| 1960 | 5 | 25248.86 | 63.29 | 6 | 13245.83 | 41.20 |
| 1970 | 5 | 22749.08 | 62.20 | 6 | 14778.46 | 41.17 |
| 1978 | 3 | 16778.54 | 46.90 | 5 | 10187.21 | 27.77 |

*Source: Planting Directory of Southern India (Various Issues), UPASI, Coonoor as quoted in George and Tharakan (1985).*

Plantations in Kerala, started with the conversion of Cardamom into plantation type agriculture along with Coffee, then moved into Tea and Rubber. It has however, been considered an instrument of modernization in the sense that it served to open up previously underdeveloped regions to open up and create the social overhead capital and monetized primitive economies. Hence the development of plantation sector was facilitated by the state in number of ways that included provision of enormous surplus land and levying a very low or negligible land tax along with maintaining a very low wage rate (George and Tharakan 1985). The plantation based production arose, as argued by Hayami and Damodaran (2004), in a context wherein virgin land had to be cleared and developed and physical infrastructures such as roads, irrigation systems, bridges and other basic facilities had to be constructed. Thus the need for lumpy investment in the context of poor infrastructure development necessitated organization of production of plantation commodities in large estates based systems. In addition, the agrarian reforms in states like Kerala is also attributed to have facilitated the perpetuation of estate based production.

In the estate based production oriented mostly towards the world market, the economic viability depended crucially on the international competitiveness which in turn was governed by factors like production per hectare of land. To enhance the productivity levels, the estate sector, very often than not, had to resort to cultural practices involving heavy use of chemical fertilizers, insecticides and pesticides. Given the larger scale of operation, organic cultural practices are unlikely to be practicable in case of large estates. Hence the estate based production, though viable economically, had its adverse effect on environment leading to non complimentary relationship between economic and environmental sustainability.

With the establishment of infrastructure facilities and the development of hitherto underdeveloped plantation areas and large scale migration of farmer families along with promotional measures by the commodity boards, there has been a large scale participation of small holders in plantation commodities. The flexibility and economies associated with family based production has also contributed to the emergence of small holder domination in the plantation sector (Hayami and Damodaran 2004). The share of small holders in the total area under natural rubber steadily increased from 21.8 per cent in 1955-56 to over 85 per cent in 2005-06 (see Table 2).

If the available evidence is any indication, during the last five years the share of holdings with less than two hectares further increased to reach the present level of over 90 per cent. When it comes to cardamom, though authentic data is not available, the available evidence is indicative of the increasing role of small holders thought not to the extent in natural rubber.

Similar trend could be observed in case of tea, which is traditionally known for large estate based production which was facilitated greatly by yet another innovation in the form proliferation of bought leaf factories. [The proliferation of small growers could also be the result of shift from export to domestic market. The growing domestic market has led to switching over from quality orthodox to cheaper CTC tea for the price conscious Indian customers. Since the domestic market is price conscious, the effort of the producers will be to restrict cost at the production stage. Further, production of quality tea is not a major concern for the producers in case of CTC tea (Thappa, 2012)]. From table 3 it is evident that the number of small growers has been growing at a compound annual growth rate of 6.88 percent while the large growers grew at 0.60 percent from 1998 to 2007. Thus indicating a higher proliferation of small growers compared to the large growers over the years. As a result, the share of area under small growers doubled from 14.5 percent in 1998 to 28.1 percent in 2007. It is also to be noted that the average size of holdings under small growers was only 0.79 hectare in 1998 and it increased marginally to 1.03 hectare in 2007. When it comes to production, the share of small holders more than doubled (11.15 percent in 1998 to 26.10 percent in 2007) indicating their higher productivity.

**Table 2**
**Trends in area under small (<2 ha) holdings in rubber and estates in cardamom**

| Year | Rubber | | Cardamom | | | |
|---|---|---|---|---|---|---|
| | Area | Share of <2 ha category | No. of Estates | % share of Total Estates | Area (Hectares) | % share of total area under Cardamom |
| 1955-56 | 18289 | 21.81 | | | | |
| 1960-61 | 38340 | 29.51 | | | | |
| 1965-66 | 51433 | 31.22 | | | | |
| 1970-71 | 68470 | 33.71 | | | | |
| 1975-76 | 81938 | 36.51 | 18795* | 67.53* | 17144* | 20.62* |
| 1980-81 | 132650 | 47.7 | 19929 | 68.06 | 18216 | 21.21 |
| 1985-86 | 217150 | 58.79 | 22857 | 68.94 | 20923 | 21.76 |
| 1990-91 | 332401 | 83.63 | | | | |
| 1995-96 | 375957 | 83.64 | | | | |
| 2000-01 | 412574 | 83.29 | | | | |
| 2005-06 | 455483 | 85.61 | | | | |

*Note: Figure with * refer to the year 1978.*
*Source: Rubber and Cardamom (spices) Statistics published by respective Commodity Boards in India*

In the light of the observed shift from last estate based production to one that is dominated by the small holders, the crucial issue relates to the differential implications of scale of operation and pattern of cropping on environmental and economic sustainability. There is significant differences in the economics of estate based production as compared to small holder production with crucial bearing on environment. While estate production is based on mono crop cultivation, it is unlikely to be viable option for the small holders. This is because, unlike the large estates, cropping by the small holders is driven by their livelihood considerations. Given the fact that the prices of most plantation crops are known to be volatile, mono crop cultivation may not be helpful in ensuring a sustainable livelihood for the small holders for whom agriculture is the only source of income. In such a context, to insure against the price risk arising out of the volatility in the price of these crops, the small holders are bound to resort to mixed cropping in contrast to mono cropping by the large estates. To the extent that mixed cropping is more environmentally friendly than mono cropping, the emergence of small holder domination in the plantation sector is likely to mitigate the conflict between economic and environmental viability in plantation sector.

**Table 3**
**Number, Area & Production of Tea for Small and Large Growers (1998- 2007)**

| Year | Small Growers (Up to 10.12 ha) | | | Large Growers ( Above 10.12 ha) | | |
|---|---|---|---|---|---|---|
| | **Number** | **Area** (Ha) | **Production** (million kg) | **Number** | **Area** | **Production** (million kg) |
| **1998** | 86517 | 68598 (14.5) | 97.46 (11.15) | 1598 | 405428 (85.5) | 776.65 (88.85) |
| **1999** | 97267 | 83152 (17.0) | 133.94 (16.22) | 1600 | 407048 (83.0) | 691.99 (83.78) |
| **2000** | 110396 | 97598 (19.4) | 154.21 (18.21) | 1614 | 406768 (80.6) | 692.71 (81.79) |
| **2001** | 115025 | 101345 (19.9) | 163.59 (19.16) | 1634 | 408461 (80.1) | 690.34 (80.84) |
| **2002** | 126167 | 106154 (20.6) | 178.09 (21.24) | 1634 | 409678 (79.4) | 660.39 (78.76) |
| **2003** | 127366 | 109198 (21.0) | 180.66 (20.57) | 1661 | 410400 (79.0) | 697.47 (79.43) |
| **2004** | 127366 | 110787 (21.2) | 201.96 (22.62) | 1661 | 410616 (78.8) | 691.01 (77.38) |
| **2005** | 139041 | 142985 (25.7) | 231.29 (24.45) | 1672 | 412626 (74.3) | 714.68 (75.55) |
| **2006** | 141544 | 154099 (27.2) | 249.71 (25.43) | 1673 | 412921 (72.8) | 732.09 (74.57) |
| **2007** | 157504 | 162431 (28.1) | 257.46 (26.10) | 1686 | 416027 (71.9) | 728.97 (73.90) |
| **Compound Annual Growth Rate (%)** | **6.88** | **10.05** | **11.40** | **0.60** | **0.29** | **-0.70** |

*Source: Thappa (2012) Various issues of Tea Statistics, Tea Board*
*Note: Figures in brackets indicates the shares of small and large growers in the total area and production of tea*

Here it may be of some relevance to see to what extent the organizations and institutions that promote plantation sector take into account the environmental benefits associated with mixed crop cultivation. Let us take the case of subsidized replanting/new planting scheme which is being implemented by all the commodity boards. Replanting and new planting subsidy is offered to the small holders by all the commodity boards because being perennial crops, there is a gestation lag between planting and harvesting. The crop is also characterized by a yield cycle that involves broadly four phases; initial pre-bearing phase followed by an early harvesting phase wherein yield is positive and increasing with high variability. During the third phase (may be called peak bearing phase) yield reaches the highest level followed by the last phase wherein the yield declines. Since the age structure of the plant has a crucial bearing (along with other factors) on the yield and production, timely replanting is needed to maintain the age profile of the plantations in such a way that the share of old-aged plants is minimized. The planting subsidy scheme is a major institutional innovation by the commodity boards to induce the growers to undertake timely replanting and to bring in new area under cultivation. The planting subsidy, both for replanting and new planting, is a fixed amount that and disabused *ex post* in installments depending on the crop characteristics like the gestation lag and cost of production.

The disbursement of such subsidies is governed by certain planting protocol (rules) specified by these boards. For instance, in case of Rubber Board, known to be most efficient among the commodity boards in accomplishing what they are expected to accomplish, the subsidy schemes for replanting and new planting appears to be inimical to mixed cropping. A major stipulation by the Rubber Board, given its mandate to increase production and productivity, is that the grower should resort to mono crop culture. Hence, for reasons like spreading risk or other reasons, if the grower chooses mixed cropping, she will be excluded from the subsidy scheme. Hence it appears that, though the holding structure as evolved over time has the potential to make the plantation sector complimentary in terms of its economic and ecological sustainability, the exiting institutional inertia appears to stand in the way of its transition to long term sustainability.

In case of small cardamom, increased small holder domination notwithstanding, a recent study (Murugan et all 2011) has shown that intensification of small cardamom farming in the Cardamom Hill reserves have the major detrimental impacts on ecosystem. The new variety of cardamom (Njallani) that was introduced in the late 1980s has contributed to almost four fold increase in yield. But this variety is also highly susceptible to varied diseases, pest and insects in addition to being highly responsive to the intense use of fertilizers (Joseph and George 2010). To illustrate, there are over 17 diseases that affect the cardamom plant from the nursery stage to estate level and as many as four major pests are found affecting the cardamom plants (see Joseph 2012)

What is more, despite the establishment of an elaborate research and extension system by the Spices Board there is a proliferation of consultants in cardamom cultivation and the growers are very often guided by the advise provided by the ferlizer/pesticide dealers (Joseph 2011). The result has been an almost 3 fold increase in the use of both nitrogen and phosphorus fertilizer as well as pesticides (4-5 fold increase in number of spray rounds). The shade regulation practice of growers is shown to have resulted in the reduction in forest canopy cover by about 40 percent (Murugan et al 2011).

Here it may be noted that there are certain salutary institutional changes at the global level. Though these are often treated as non tariff barriers by the developed countries on developing countries, they are likely to have the effect of facilitating economic and environmental sustainability. Here we are referring to the The Agreement on the Application of Sanitary and Phytosanitary Measures (the "SPS Agreement") entered into force with the establishment of the World Trade Organization on 1 January 1995. The Agreement concerns the application of food safety and animal and plant health regulations. As per this agreement, all countries could maintain measures to ensure that food is safe for consumers, and to prevent the spread of pests or diseases among animals and plants. These sanitary and phytosanitary measures can take many forms, such as requiring products to come from a disease-free area, inspection of products, specific treatment or processing of products, setting of allowable maximum levels of pesticide residues or permitted use of only certain additives in food. In a context wherein the developed importing countries of plantation crops like cardamom are strictly implementing these measures, the producers are forced to adhear to these standards and that it will call for significant changes in the existing agricultural practices. It is welcoming to note that the organizations concerned like Spices Board are today intensively promoting organic farming and research agenda of scientists are being shifted towards evolving cultural practices with reduced inputs of chemical fertilizers and pesticides.

Yet another way in which cardamom cultivation leads to deforestation is by way of shade regulation. Traditionally cardamom has been grown in the rain forests under the forest cover. However, the current agricultural practices for intensive cardamom production involve deliberately maintaining ecosystems in a highly simplified, disturbed, and nutrient rich state. To maximize cardamom yields, varieties are carefully selected by planters to suit to altered local growing conditions created by pruning and lopping of forest canopy on regular basis (Murugan et al 2011). Shade regulation, however, is a highly labour intensive activity and adds to cost of cultivation. To address this issue, there is the need for reorienting research to evolve new varieties that could be grown with high yield without shade regulation. This, issue, however, is yet to receive the attention of researchers that it deserve.

Use of firewood for cardamom curing also leads to felling of trees and deforestation. While significant progress has been achieved towards alternative curing technologies, and reducing firewood in traditional curing houses, there is the need for further institutional initiatives to arrest the deforestation induced by cardamom curing. As of now the electricity tariff charged by the KSEB for the cardamom curing devises is on par with industrial tariff. It needs to be noted that with lower electricity tariff use of firewood would be minimized leading more tree cover, more rains and more water in the reservoirs. Here again the institutional inertia appears to be a major constraint.

To offset the adverse effect of complying with the environmental standards and there is another institutional innovation at the global level. This relates to the Kyoto Protocol which mandates the rich and industrialized countries to reduce their collective carbon dioxide emission to at least 5.2% below their 1990 emissions levels between 2008-2012. Given the high cost associated with the domestic actions required to meet the Kyoto compliance targets, the Kyoto Protocol established three market mechanisms (flexible instruments) to help these countries meet their GHG emissions reduction target cost effectively. They are: International Emission Trading (IET), Joint Implementation of emission reduction projects (JI) and Clean Development Mechanism (CDM). The developed countries can purchase Assigned Amount Units (AAU) on the basis of IET or Emission Reduction Units (ERU) on the basis of JI projects from another developed country. Both IET and JI can be operated only among the developed countries.

The third mechanism, CDM encourages projects by developed countries in the developing and the least developed counties that do not have GHG emission reduction restrictions under the Protocol. The CDM aims at bringing funding from developed countries for environment-friendly projects that are in tune with the sustainable developmental needs of the people in the developing countries in the tropics and subtropics that will earn the developed countries what is called Certified Emission Reduction (CER) credits or carbon credits, that can be used by the investing developed countries to partially offset its Kyoto protocol targets. Several analyses show that given the low costs of projects implemented in developing countries under the CDM, this will be the preferred market instrument unlike JI or IET which can be operated only between developed countries

One significant approach to tackling climate change is through the growth and sustainable management of trees and forests, which naturally remove carbon dioxide (CO2) from the atmosphere as they grow and store the carbon in their wood, roots, leaves and bark, which contain around 50% carbon by dry weight. This process is true for all types of trees and forests, however some tree species and forest types absorb and store carbon more effectively than others. Due to their relatively fast growth, tree plantations are an example of a very efficient carbon absorber, with the added benefit of producing forest products that continue to store carbon and can reduce the need to use fossil fuels in energy production, a significant source of $CO_2$. The role CER credit in removing $CO_2$ from the atmosphere is widely recognized, allowing to be traded in carbon markets within and outside the country. Thus any carbon captured in the plantation sector in India like natural rubber or Cardamom may be eligible to trade through a variety of carbon brokers (James, undated)

## CONCLUDING OBSERVATIONS

This paper made a preliminary attempt towards exploring the nexus between ecology, economy and innovation (in its broader sense – covering technological and institutional) on sustainable development of plantation sector in Kerala. Plantation sector in India, historically dominated by the large estates has been promoted intensively by the state given its significant contribution towards foreign exchange on the one hand its developmental role and livelihood of workers on the other. However, there has been a growing concern over the environmental implications of plantations sector on account of the deforestation, sedimentation in the reservoirs of hydroelectric projects, environmentally hostile cultural practices, waste generation in case of certain plantations and others. Hence economic sustainability of plantation sector is considered as inimical to environmental sustainability. At the same time, the changes in environment do adversely affect yield of plantation crops and therefore their economic viability. In this paper, drawing insight from the literature on innovation systems, we examined the evolving nature of interaction between economy, ecology, innovation and finds that the emerging trajectory appears to be one that promotes sustainability notwithstanding instances of institutional inertia within the sector towards evolving a sustainability oriented innovation system.

The most important welcome change emanates from the shift from estate based cultivation to the one dominated by the small holders. While estate production is based on mono crop cultivation, it is unlikely to be viable option for the small holders. Unlike the large estates, cropping by the small holders is driven by their livelihood considerations. Given the fact that the prices of most plantation crops are highly volatile with greater integration with the world market, mono crop cultivation may not be helpful in ensuring a sustainable livelihood for the small holders for whom agriculture is the only source of income. In such a context, to insure against the price risk arising out of the volatility in the price of these crops, the small holders are bound to resort to mixed cropping in contrast to mono cropping by the large estates. To the extent that mixed cropping is more environmentally friendly than mono cropping, the emergence of small holder domination in the plantation sector is likely to mitigate the conflict between economic and environmental viability. However, such environmental benefits are yet to fully factored in by the organizations that promote plantation sector which insist on mono cropping to be eligible for state support. Hence it appears that, some organizational innovations in the form of changes in the size structure has the potential to make the plantation sector complimentary in terms of its economic and ecological sustainability, the exiting institutional inertia appears to stand in the way and calls for further institutional innovations towards evolving a sustainability oriented innovation system.

In case of small cardamom, increased small holder domination notwithstanding, the intensification of farming in the Cardamom Hill reserves has the major detrimental impacts on ecosystem. However certain salutary institutional changes at the global level in the recent past like Agreement on the Application of Sanitary and Phytosanitary Measures (the "SPS Agreement") of WTO appears to have the effect of help evolving a sustainability oriented innovations system. In a context wherein the importing countries are strictly implementing these measures, the producers are forced to adhear to these standards and organizations concerned like Spices Board are today intensively promoting organic farming and research agenda of scientists are being shifted towards evolving cultural practices with reduced inputs of chemical fertilizers and pesticides.

Shade regulation and felling of trees for cardamom curing are other ways in which cardamom cultivation contributes towards environmental degradation. Traditionally cardamom has been grown in the rain forests under the forest cover. However, the current agricultural practices involve creation of growing conditions involving pruning and lopping of forest canopy on regular basis. Shade regulation, however is a highly labour intensive activity and adds to cost of cultivation. To address this issue, there is the need for reorienting research to evolve new varieties that could be grown with high yield without shade regulation. This, issue, however, is yet to receive the attention of researchers that it deserve. While significant progress has been achieved towards alternative curing technologies, and reducing firewood in traditional curing houses, there is the need for further institutional initiatives to arrest the deforestation induced by cardamom curing by making available electricity and reasonable price and research for promoting energy efficiency in cardamom curing.

While the institutional interventions towards bringing about sustainability oriented innovation and production system is likely to have the effect of increasing the cost of production and adversely affecting economic viability, much of if it could be offset if we exploit the provisions of the Kyoto protocol. On the whole, while certain institutional innovations at the national and international level evolved over the years have the potential of making the plantation agriculture relatively more sustainable today than before, more institutional innovations especially at the national level are called for to make plantation sector sustainable

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# Sustainable Animal Husbandry Practices for Kerala

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**INTRODUCTION**

The Animal Husbandry sector plays a pivotal role in the socio economic development of Kerala and has immense potential in employment generation, poverty alleviation, resource and wealth creation, becoming the main pillar of national and regional economy. The sector contributes to approximately 5% of the state's gross domestic product which reflects as Rs 15308 crore and is a predominant arena with ample scope for development, substantially impacting rural and urban lives. This spectacular progress was achieved inspite of budgetary plan fund allocations of 120-130 crores each year. This sector has witnessed impressive progress owing to meticulous planning, comprehensive efforts and result oriented interventions in $11^{th}$ plan period. The progress has constantly evolved from sustenance to full-fledged commercial ventures. Despite a decline in cattle population in the recent years, the internal milk production has increased and also the productivity. The goat and poultry population has increased over the years in the $11^{th}$ plan period. The domestic market for livestock and poultry products also showed prospective growth during this period. The Animal Husbandry sector of Kerala is quite unique in the country that we were successful in establishing atleast one veterinary institution in each panchayat and now veterinary institutions are spread across the entire state. As a result of an effective cross breeding policy, 93% of our cattle population are crossbreds with an average milk production of 9.03 litres per day well above the national average. The advent of an Animal Disease Control Project has curtailed the occurrences of economically devastating diseases like foot and mouth disease and efficiently created a disease controlled zone in the state. The State has two ISO certified state of the art semen stations which cater to the artificial insemination network of the State. With a view to promulgate the veterinary profession and ethics in the state, the Kerala State Veterinary Council was formed as per provisions of section 32 of the Indian Veterinary Council Act 1984. This sector is an essential component of sustainable production systems and directly or indirectly influences lives of every human being. Scientific and professional intervention, research and development, knowledge updation and most profoundly uplifting the farmers of this sector and ensuring food security through self reliance is inevitable to become a developed India.

**ANIMAL POPULATION AND PRODUCTION IN KERALA**

Kerala's cattle population which accounted for 1.75% of the total cattle population in the country during 1987 declined to 1.61 % by 1996 and 1.13 % by 2003 and has now reached a staggering 17 lakh. The crossbred cattle population which stood at 22.87 lakhs (67%) as per 1996 Census decreased to 17.35 lakh numbers and in percentage terms increased to 82% by 2003. It further declined to 16.21 lakh numbers and in percentage terms increased to 93% in 2007.Estimates of milk and egg production reveals a declining trend in milk production after 2001-02 and in egg production after 1999-00 and during 2006-07,production of both the products showed a slight increase. The total milk production of the State is showing a declining trend from 27.18 lakh tonnes in 2001-02 to 20.63 lakh tonnes during 2005-06 and increased to 21.18 lakh tonnes during 2006-07. Total milk production in the state which was 24.20 lakh tonnes in 2003 declined to 21.11 lakh tonnes in 2004 and then began to increase in the subsequent years. It increased to 25.37 lakh tonnes in 2009-10 and to 26.43 lakh tonnes in 2010-11 and recorded 27.19 lakh tonne in 2011-12 (Fig. 1).

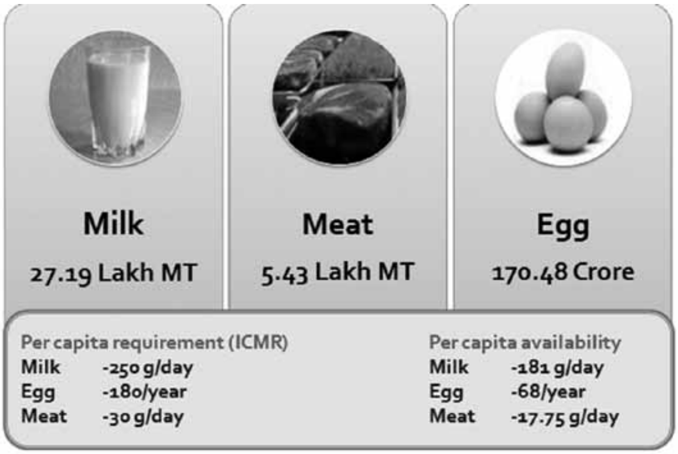


**Fig. 1**
**Production in Kerala -2011-12**

The gap between the production and requirement of egg is widening at an alarming rate. Meat production is increasing over the years to keep in pace with the demand and recorded a 5.43 lakh tonne in 2011-12. The egg production of Kerala, which recorded a growth rate of 4.89 per cent during 1980–90 period, declined subsequently and by ninth plan period it reached a negative growth rate of 0.22 per cent and declined further to 9.75% during 10th plan period. Even then the gap between requirement and production continues to remain unfavourable. Concerted efforts of the State to increase the egg production have begun to show signs of improvement. Egg production which was 1379 million in 2007-08 increased to 1633 million in 2009-10 and to 1685.6 million in 2010-11; an increase of 3.22 percent over the previous year and presently is 1704.8 million. Though meat production is increasing over the years, it cannot cater to the demand fully. Poultry meat production increased from 15482 tonnes in 2009-10 to 16153 tonnes in 2010-11 and meat other than poultry meat from 102026 tonnes in 2009-10 to 108398 tonnes in 2010-11 registering an increase of 4.33 percent and 6.24 percent respectively over the previous year. However the negative trends in milk, meat and egg production until 10th plan has compelled the sector to put things in place to reduce the demand and supply gap. We are slowly showing signs of positive trends in the 11th plan period (Fig. 2).

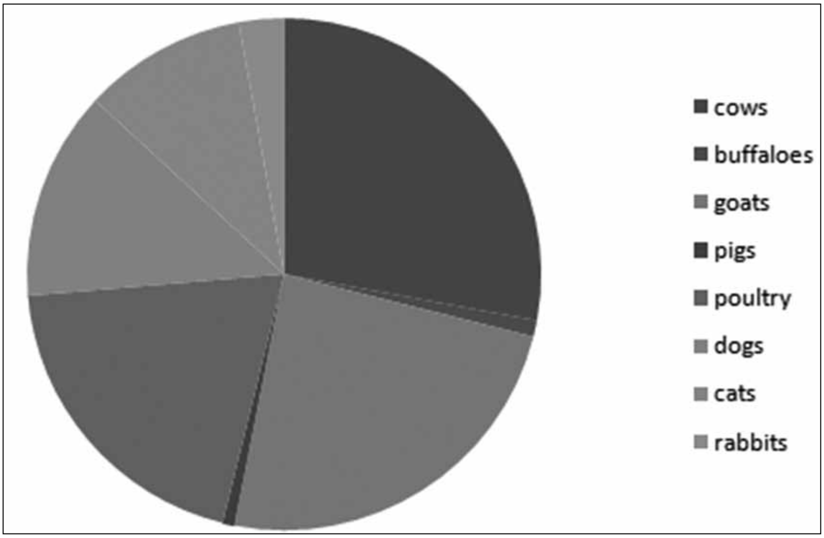


**Fig. 2**
**Percentage of animal population-2007 census**

## TECHNOLOGY FOR SUSTAINABILITY

Livestock is an integral part of agriculture in Kerala, and are likely to be the instruments of future growth and development of the agricultural sector. Although the per capita consumption of foods of animal origin is low in Kerala, demand has been rising due to the growing human population, sustained growth in per capita incomes, and increasing urbanization. The influx of migrant labours from other states to Kerala recently, coupled with incoming of foreign tourists and boom in IT Professionals have also propelled the demand for food of animal origin. This demand driven growth, besides improving food and nutritional security, can benefit many farmers. The issue that needs addressing is how current output trends of 4–5% per annum can be sustained without disturbing the equilibrium between crops and livestock. Improving food supply from animals through higher livestock numbers is now severely constrained due to the feed-fodder deficit and declining per capita land availability.

Technological and management options are the only alternatives to accelerate the growth in productivity, which is currently low. A number of livestock technologies are available for field application, but they are yet to gain wide acceptance. The importance of goes beyond the function of food production. It is an important source of draught power, manure for crop. Thus, by minimizing use of nonrenewable energy, livestock make a positive contribution to the environment. Although crops and livestock are interdependent to a large extent, the latter constitute an important mechanism for coping with the risks of crop failure. In land-scarce economies livestock provide livelihood support in terms of income and employment generation to farmers. Despite the low intensity of investment in research, animal science research over the last few decades has generated a number of technologies in the areas of animal genetics and breeding, feed and nutrition, health, and management. The technical feasibility of many of these has been proven under experimental conditions. Examples include crossbreeding in cattle, sheep, pigs, and poultry; chemical and biological treatment of cereal straws; and vaccines against rinderpest, influenza, and foot and mouth disease. Despite this, the application of many technologies in the field remains limited. Except for crossbreeding, not much information is available regarding adoption and impact of other technologies. There is, thus, considerable scope to raise the productivity of livestock through application of the existing technologies.

**Breeding Technology for Sustainability**

Genetics and breeding research have evolved many new breeds of cattle, pig, sheep, and poultry using crossbreeding techniques. These breeds have better production coefficients compared to indigenous ones. As a result of an effective cross breeding policy, 93% of our cattle population are crossbreds with an average milk production of 9.03 litres per day. However now we think of conserving indigenous breeds of cattle and native breeds of Kerala like Kasarkode dwarf and Vechur cattle. Our breeding policy also requires revamping to sustain animal population and productivity. Few years back we introduced artificial insemination in goats to promulgate goat production. Buffalo could emerge as a promising alternative to crossbred cattle because of its adaptability to varied ecological conditions, higher milk yield and higher fat content, realizing a premium price. The poultry subsector has responded well to technological changes and has grown faster than the dairy and ruminant meat sector. Enhancement of genetic potential has been the most important factor in the growth of this sector. However, this has been complemented by health and nutrition technologies. The growth trends are more prominent in specialized periurban/ urban poultry systems, because of higher demand for poultry meat and eggs in urban areas. Here, the entry of the private sector has boosted the adoption of technology and growth in poultry outputs. Backyard poultry production, however, continues to languish technologically.

**Feed and Fodder Technology for Sustainability**

A large number of Kerala's livestock, particularly in the semi-urban and rural environments, suffer from inadequate feeding. The feed and fodder shortages, in fact, have been the main limiting factors in raising livestock productivity. Cereal crop residues comprise the main feed for livestock. However, these are deficient in crude protein and several other nutrients. Concentrate feeding is restricted to lactating, high-yielding bovines and work animals. Small ruminants derive their feed requirements mainly from grazing on common lands. Animal nutrition and crop breeding research has yielded many new technologies that could augment production and improve the nutritional quality of feeds and fodder. Research on breeding for higher yield and superior quality crop residues (such as in rice, wheat, sorghum, and millets) is in progress. Studies have indicated that a 1% increase in digestibility of sorghum/millet straw increases bovine milk yield by 5–6%. Apart from traditional techniques of fodder chopping and conservation, technologies such as urea treatment of fodder, strategic supplementation, urea molasses mineral blocks, and bypass protein use have the potential to alleviate feed and fodder scarcity. These technologies improve digestibility and palatability of feed, reduce feed requirements, avoid feed wastage, and contribute towards improving animal productivity. Some of these techniques, such as fodder chopping and bypass protein use, have long been in practice in many parts of the country, but are not practiced widely. The main constraint to large-scale adoption of nutrition technologies in general has been the lack of information to users. The area under green fodder crops is also low; constituting no more than 5% of the gross cropped area. The growth in area under fodder crops has been sluggish in most parts of the country, except in the irrigated regions. This is a reflection of the rising competition between food and fodder crops for limited land and other resources. Crop breeding research has evolved high-yielding varieties of a number of forage crops. However, these have not been adopted widely due to lack of awareness about new cultivars, nonavailability of irrigation water throughout the year, and problems of insect pests/diseases. Common grazing lands comprise an important source of grasses, and there exists considerable scope to raise the production of grasses/shrubs from these lands through technological and management interventions. Technological interventions such as reseeding with high-yielding grasses and watershed development, complemented with appropriate management interventions such as preventing encroachment, promotion of rotational grazing practices, and charging grazing fees have helped raise the productivity of common grazing resources and thereby improved animal performance

**Disease Control Technologies**

Diseases reduce the production potential of livestock. In India many deadly diseases such as rinderpest, foot and mouth disease, hemorrhagic septicemia,and black quarter are major threats to profitable livestock production. Livestock disease control has undergone a paradigm shift in recent years. A number of biological products (vaccines) have been developed for preventive and curative disease management. The infrastructure for disease control has also expanded considerably. The Animal

Disease Control Project established couple of years back is instrumental is creating a disease controlled zone in Kerala and has curtailed the occurrences of many major diseases saving crores of rupees. The project conducts systematic and routine vaccinations of the animal population of Kerala and checks any untoward incidents.

**Processing Technologies**

Postharvest technologies help producers to realize better gains from technological changes in the primary production sector. But the postharvest processing facilities are lacking in Kerala. Only about 20% of the total milk production is processed into value-added products. The bulk of it however is processed into *ghee* and curds by the producers, and a large proportion of this is consumed at source. Although considerable efforts have gone into developing infrastructure for milk processing in the cooperative sector, only about 5% of the total milk output is processed into table butter, cheese, milk powder, and baby foods. Information on the proportion of other livestock products entering into the value-added chain is not available. There is a considerable demand for processed meat products, but it remains constricted due to inadequate processing facilities. The same applies to export of these products. Furthermore not enough attention has been paid towards sanitary measures. Slaughterhouses are often ill equipped and unhygienic. Low-cost processing technologies have been developed for both cottage and large scale industry are to be implemented in Kerala. The Meat Products of India and Kerala Poultry Development Corporation were successful in value addition of meat and have launched many products recently.

**Agro Climatic Zone Based Livestock Farming**

Livestock farming has always been in tandem with agriculture in Kerala and for the same reason an agro climatic zone based farming as being practised for crops has to be adopted for sustainability. Kerala's geography is quite varied in nature with a mix of coastal regions, low lying areas, mountains, tropical forests and plains. Animal farming has to be geographically specific and relevant to achieve maximum productivity and sustain natural resources. Of late many zone specific packages like Kuttanad and Idukki packages are being implemented which are tailor made to address the issues of the region. The animal husbandry sector will witness spectacular progress in the near future and majority of the new schemes are now planned keeping in mind the geo specific requirements of the zones.

**Commercialization of Dairying**

Dairying was being practiced until lately as one cow or two cow enterprises mainly catering to household needs and local needs. However, to become sustainable these single cow units have to give way to medium and large scale units. A slow but steady progress is being witnessed now in commercialization of dairying. With an effective policy if the government in place many hi tech farms have been established and thrust is given to mechanization of 10-20 cow units. Many government schemes now provide financial assistance to automate day to day dairy activities. Last few years we have witness sprouting of many medium scale modern dairy farms which holds promise for the future. More commercialization has to be encouraged to make dairy industry sustainable in the future.

**Strengthening of Dairy Cooperatives**

Kerala has a strong network of dairy cooperatives with 3512 societies and milk collection and marketing is more organized. Dairy cooperatives have to be provided more infrastructure and automation of milk collection and marketing has to be encouraged. Incentive based dairying has to be promoted to encourage farmers and augment production. More farmers have to be brought under the cover of this strong network to make milk production more organized.

**Bio-waste Disposal**

Lack of proper waste disposal is a major concern in livestock industry in Kerala and has dire consequences on the environment. Bio gas plants and other suitable bio waste disposal mechanisms should be popularized to tackle this issue and to sustain production with minimal environmental pollution.

**Scientific Slaughtering Practices**

Kerala lacks organized scientific modern abattoirs and animal slaughtering practises employed now lacks proper check mechanisms. Food safety is a growing and serious concern now a days and this issue requires prompt attention. There should be stringent food safety laws which will ensure animals are slaughtered under scientific and clean conditions that the food we eat is safe. Kerala needs authorized slaughter houses in all corporations, municipalities and selected panchayats as the case may be where animals will be slaughtered.

**Backyard Poultry Production**

Household poultry rearing holds better prospects in the egg production scenario of Kerala and with this in mind backyard poultry rearing was propagated widely. Many new schemes like Gramasree, Adukalamutate kozhi valarthal, Gramam niraye kozhi, Nagarapriya are examples of success stories in backyard poultry production. Backyard production is a sustainable means of egg production strategy in Kerala and more thrust has to be given in future. Other schemes like school poultry clubs were also launched to create awareness among children.

**Small Ruminant and Rabbit Production**

Goat production holds greater prospects in sustainable meat and milk production in Kerala which was witnessed by a spectacular 42 % growth in goat population in 2007 census. Lately government of India has been giving much importance to promulgating goat rearing by launching Integrated development of small ruminants and rabbit schemes. The state has also given prime importance to popularise goat rearing and will establish a new goat farm in Kasarkode this year. Many state schemes and other packages like Idukki package have given financial assistance to the tune of crores of rupees to this effect. Goat and rabbit production will be encouraged in future to sustain small ruminant production.

**Integrated Farming Systems**

The shrinking land and fodder availability has pushed animal production to its limits and concentrated the efforts in integrating farming systems in Kerala. The geographical diversity of the state also calls for integrated farming systems for sustainability and maximising production. The food security schemes implemented in previous years have given prime importance to integration of livestock systems. Kerala has unique ecosystems like Kuttanad where integration of duck and livestock farming alongside paddy cultivation is now being practised. Integrated farming systems will also minimise environmental concerns whilst increasing productivity and proper bio mass utilization.

## CONCLUSION

Animal husbandrying in Kerala is an age old tradition and livestock sector contributes significantly to the state's economy. Inspite of the compelling prevailing conditions, this sector has witnessed spectacular and impressive progress owing to meticulous planning, comprehensive efforts and result oriented interventions in 11$^{th}$ plan period. With more and more technology and research interventions, this sector will propel to greater heights in the future. Agro climatic zone approach, commercialization of farming, proper bio waste disposal, breeding technologies, feeding technologies and various other sustainable approaches will render this sector burgeoning in production. The sector will be self reliant in milk, meat and egg production by the end of 12$^{th}$ plan period. With proper planning and effective monitoring of animal husbandry activities, the citizens will be ensured of clean, safe and nutritious food in the future.

# Strategy for Freshwater Aquaculture Development in India

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## INTRODUCTION

Fish as the cheapest source of animal protein constitutes a major share in the global food basket and world fish production sector faces the challenge to boost the production to meet the protein hunger in the future. According to FAO (2009) global fish production stands at 147.5 million tonnes, of which about 40% is contributed by aquaculture sector. However, global capture fishery being at crossroads with over 70% of the resources exploited, aquaculture is the only option to fill up the gap of much of the future fish demand.

Indian fisheries sector has made great strides in the last five decades showing eleven fold increase, from 0.75 million tonnes in 1950-51 to 8.1 million tonnes in 2009-2010, which is a testimony to the contributions of the sector. Besides providing livelihood security to over 14 million people, the sector has been one of the major foreign exchange earners, with revenue reaching Rs. 10,048 crores in 2010-11 accounting for about 18% of the agricultural export. Producing 5.42% of the world's fish, India trades to the extent of 2.5% in the global fish market. Fisheries sector has registered an overall annual growth rate of 4.5%. During the previous five year plans contribution of fisheries sector is estimated around 1.10% to the national GDP and 5.3% to the agricultural GDP (Ayyappan *et al.*, 2011), thus boosting the agricultural growth since last several years. Capture fishery in the country being almost stagnant since last three decades, freshwater sector has been shouldering the major responsibility to meet the increased demand for fish.

Share of freshwater aquaculture in inland fisheries has gone up from 46% in the 1980s to over 80% in the recent years. The sector, during the past two decades, has shown an overwhelming ten-fold growth from 0.37 million tonnes in 1980 to 4.03 million tonnes in 2010. Freshwater aquaculture has been able to meet the increasing fish requirement of the country when the production from marine capture and other open waters has remained almost stagnant (Ayyappan *et al.*, 2011). It is estimated that only about 40% of the available area of 2.25 million ha of ponds and tanks, 1.3

million ha of beels and derelict waters and 2.3 million ha of paddy fields has been put to use and there exists amble scope for horizontal expansion.

The holistic development of aquaculture over the years has been realized through a series of standardization and development of methods in all fronts of aquaculture, i.e, resource survey, their characterization and effective utilization, production and rearing of seed, grow-out farming technology, nutritional improvement, disease and health management and the extension mechanism to transfer the technology to the field. Further, realized need to improve genetic quality and yield of cultured organism led to up gradation of the broodstock using the tools like selective breeding and cryopreservation techniques. The culture technology itself has undergone several modifications, ramifications and refinements over the years with incorporation of innovations made during scientific evaluations through multi-location trials to evolve to the present day's package of grow-out farming practices to adapt to the varied kind of water bodies. The present article attempts to summarize strategies for the development of freshwater aquaculture in India.

## DIVERSIFICATION

Carps are the main stay of aquaculture in India. But being a low valued fish in the domestic and international market, carp farming yields low benefit cost ratio compared to culture of other species elsewhere in the globe and therefore, attracts poor entrepreneurial acceptability. Further, the consumers today with their increased purchasing power looking forward for wide spectrum of fish protein. In this context, diversification of the system and species spectrum forms one of the important strategies for aquaculture development in the coming years. There is a need to bring more and more high valued fish species either under monoculture or polyculture with carps to make aquaculture more remunerative to encourage the entrepreneur investment. However, bringing any new species into the main stream aquaculture practice would require standardization of their breeding, seed production, seed rearing and grow-out technology along with the study on their nutrition, physiology and health management. As the premier research institute of the country, the Central Institute of Freshwater Aquaculture (CIFA) has the Herculean task to shoulder the responsibility of diversification.

## PRODUCTION OF QUALITY SEED AND THEIR ASSURED ROUND THE YEAR AVAILABILITY

Controlled breeding after using same population over the years results in poor genetic base leading to retarded growth and low disease resistant variety due to inbreeding depression. Effective strategy should be put in place to minimize such inbreeding depression. While conventional way of replacing the parents in every two years can minimize such risk, gamete exchange programme through development and use of cryo-technology would ensure healthy quality seed effectively. Selective breeding programme with selected traits in fish and prawn can be another efficient way to improve the seed quality. In view of the success achieved in rohu, such programme should be extended to other species of carps and freshwater prawn for increased realization of growth and production. Despite the availability of sound seed production technology, country faces acute shortage of stocking material, i.e. fingerlings. Such deficit of fingerlings could be overcome by establishing seed bank and encouraging seed-village concept as followed in agriculture. Production practices for fry, fingerling, stunted and advanced stages need to be evolved for different agro-climatic regions of the country. Use of stunted fingerlings not only ensures an extended growth period but also harnesses the compensatory growth capability of the fish resulting in proven success in increasing the grow-out production. Further emphasis on research is needed for effective utilization of the compensatory growth in the fishes to realize their maximum growth potential.

Problems of seed shortage can substantially be reduced if fish can be bred round the year. Although multiple breeding and success in off season breeding through controlled gonadal maturation in few species have been able to extend the breeding period, further effort is needed to bridge the gap and extend such breeding programme for other species. While seed production and culture technologies for some fish species viz. *Clarias batrachus, Heteropneustes fossilis, Ompok pabda,* and *Pangasius pangasius* have already been attempted, perfected and refined, there are still more fish species which need attention for their culture, breeding and seed production technologies.

Freshwater prawn species having high domestic consumer preference as well as export potential need more attention with regard to supply of stocking materials for culture. As such establishment of a chain of prawn hatcheries is the need of the hour for meeting increasing demand for seed. Therefore, high priority is to be given for such activity with public-private partnership, if needed, including development of appropriate feeds.

**INCREASING GROW-OUT PRODUCTIVITY**

Fish production in pond is a function of the composition and compatibility of the candidate species, efficient pond management, proper nutrition and effective health management. Since all the above factors need special attention for ensuring healthy fish production, there is a need to intensify the ongoing research in these areas in the face of increased intensification of fish farming. Over the years, it has been observed that market driven forces determine the species composition in grow-out culture. Further, recent years have witnessed introduction of several new species into the culture system. Therefore, impact of such external factors on aquaculture needs periodic assessment for reorienting the grow-out production research. Although carp culture technologies with varied levels of production ranging from 2.0-17.0 t/ha available in the country, there is need to refine these technologies in line with the local condition for effective result. The intensive carp culture technology could make it possible to achieve 17 t/ha/yr against the national average 2.6 t/ha/yr. Such technology is yet to be transferred through extension service after making proper assessment of cultivable freshwater resources. There exists still enough scope for expansion of aquaculture in horizontal and vertical ways. A perspective plan for aquaculture development is necessary and it is to be implemented with support from state, and at national level with support from the National Fisheries Development Board (NFDB).

The technology of sewage-fed fish culture, though well practiced in east Kolkata wetlands since long and yet to be adopted/practiced in other cities with sewage systems after treatment of water through recycling. This requires region-wise studies as a basis for the quality of the produce for human consumption. It further demands environmental research with particular reference to wastewater utilization and application of bio-filtration in aquaculture.

Culture and breeding technology vis-à-vis seed production is the prime and critical part of aquaculture practice needing both production system and species diversification to augment production by utilizing the pond ecosystem across all agro-climatic regions of the country. Therefore, fish production under low/medium/high input systems as well as culture trials on minor carps, murrels and other miscellaneous fish species needs to be conducted. Species like minor carps and small indigenous fishes need to be studied for their production potential either as the main crop or inter-cropping with the major carp based culture system.

**ORGANIC FARMING**

Due to the increased health consciousness and increased purchasing power of the consumers, demand for organic fish has increased in recent years. Though few studies on the organic fish production have revealed quality fish production and good environmental sustainability, efforts in this area need to be intensified to ensure mass scale production in future along with minimal degradation of environmental quality. Further, suitable mechanism should be evolved to establish the organic standards for fish farming and certification of the organic fish as that followed in agricultural and horticultural produces.

**FARM MECHANIZATION AND AUTOMATION**

In view of the impending labour scarcity, aquaculture is going to face major challenge in terms of farm operation in the coming years if timely steps will not be taken in terms of mechanization and automation. Though technology of mechanization and automation for many of the fish farming activities are already in place in other countries, many of such systems may not be cost effective to use in the low valued carp culture. Therefore, there is an urgent need to develop indigenous farm mechanization and automation technology and implements so as to reduce the operational cost and drudgery.

Hi-tech aquaculture with use of automatic pond environment monitoring, oxygenation, monitoring of feeding, water exchange and efficient health management aimed at high fish production is almost non-existent in the country. Effort is needed in this regard to develop state of the art technology for high scale fish production in controlled environment.

**CLIMATE CHANGE AND AQUACULTURE**

Fish being a cold-blooded animal, all stages of aquaculture including reproductive behaviour, breeding, seed production and growth and behaviour of fish are going to be largely affected by the climate change phenomena. Therefore, aquaculture is going to be one of the worst hit sectors by the global warming. Impact of the climate change has already been felt on fisheries and aquaculture in terms of modification of the distribution and productivity of marine and freshwater species, effect on biological processes and alteration in food webs, change in the reproductive behaviour of fishes, shift in the breeding season, shift of the habitat, etc. Therefore, in order to make fish production sustainable and provide the animal protein continuously to the ever growing population of the country, aquaculture has the responsibility not only to evolve itself against the changing climate to remain productive on a sustainable basis, but also has to make simultaneous effort to mitigate the global emission of greenhouse gases. Fortunately, aquaculture offers option for permanent sequestration of the atmospheric CO2 through its incorporation into soil and biomass of plants, crustaceans, shellfish, fish and other organisms and thus, can act as a pro-carbon sink process and an important option for mitigating the global warming process.

Use of large quantity of manure, fertilizer, feed, therapeutics and other inputs, aimed at increasing the fish production, has made the modern fish farming system more energy intensive. In this context, the vast coverage of aquaculture ponds in the country to the extent of 2.35 million hectares could be a significant source of greenhouse gas emission. However, responsible aquaculture practice can alter the trend by making aquaculture a pro-carbon sink process rather than contributing to the global greenhouse gas emission. Life Cycle Assessment tools can be effectively utilized in identifying the potential hot spot in the fish production process so that modified or alternative methods or processes can be evolved which can replace those hot spots so as to mitigate the potential impact of the various products, production systems and the different processes involved in it on the environment. Since this method relies on gathering information on all phases of the 'Life cycle' of product including raw material use, energy of productions, manufacturing, transport, use, etc. efforts should be made to document the input-output flow of the different aquaculture practice.

The Inter-Governmental Panel for Climate Change (IPCC) report indicated that many of the developing countries tend to be vulnerable to extreme climate disturbances and thus may have an adverse impact of a gradual climate change on animal production system including fish farming. Given the importance of climate in the aquaculture production system, it is essential that concerted research efforts be carried out to assess the vulnerability of aquaculture towards the impact of climate change, prioritize the strategies and also to identify the stakeholders' response.

Global warming is likely to create favourable climate conditions for the growth of causative organisms and thus increased ambient water temperature is likely to cause a rise in the responses of disease occurrences spread by vectors. Similarly alterations in other sensitive water quality parameters such as ammonia, air and water temperature may have pronounced effect on feed utilization efficiency, growth and even on the sensory qualities of the cultured fish species. Concerted efforts in aquaculture research to reduce the vulnerability of aquaculture due to the impact of climate change (variables like solar radiation and air temperature) are therefore vital to make aquaculture more resilient.

## WATER MANAGEMENT

A study made by the International Water Management Institute (IWMI) reveals that by 2025 nearly 1/3rd of world's population would live in the regions of severe water scarcity (less than 1,000 $m^3$ per head per year) and the same proportion of population in India could face absolute water scarcity (less than 500 $m^3$ per head per year). The common notion that "Water is a free commodity" is no more a reality. Therefore, it is high time to think for judicious management of this natural resource and to develop strategies for its efficient and multiple uses. Since water is the prime requirement for aquaculture activity, maintaining the pace of aquaculture development is possible only through making it available adequately for aquaculture besides satisfying the agricultural, industrial and domestic need. The limited nature of the water resource, therefore, warrants a more holistic approach to water management.

In aquaculture ponds/tanks, possible water sources are regulated inflow either from feeder canal, ground water, precipitation and runoff. Possible causes of water losses may be evaporation, seepage, effluent discharge and overflow and associated factors which are to be carried out to assess the water requirement for aquaculture ponds. Based on the observation attempts may be made to develop a suitable model to predict the water requirement in aquaculture pond. The water budgeting for different species and target of productions may form the practical tools for generating useful information for mitigating the challenges on water for aquatic production.

Development of the re-circulatory system for fish farming is an effective way of fish production while ensuring greater water productivity. There is a need to standardize technology in this area for culture of the Indian species. Productivity of water can be enhanced through integration of fish and other aquatic organisms into existing farming systems in addition to diversification to agri-horticulture crops. This integration is especially important in places where natural aquatic ecosystems have been degraded for production of desired level of protein and other benefits as produced from the system. Fish farming needs to be extended to reservoirs and open waters, the supply canals, and small trenches within rice fields depending on the suitability and creating scope for community based aqua farming. Flood-prone ecosystems can also be made use of for additional fish production.

## FISH GENETICS AND BIO-TECHNOLOGY

Genetic upgradation and breed improvement are key areas to be strategized for sustainable aquaculture. Prioritization of species, development of a broad genetic base thereof and subsequent development of improved strains through selective breeding should be prioritized in the coming decades. Controlled breeding after using same population over the years results in poor genetic base leading to retarded growth and low disease resistance due to inbreeding depression. Therefore, replacement of parent fishes should be mandatory once in every two years while in use for commercial purpose. Milt cryopreservation can be used in gamete exchange programmes. Selective breeding programme of more number of cultivable fish and prawn species should be taken up. Traditional breeding has to take advantage of biotechnological tools that are available and being developed in each potential species. Fish genomics has been emphasized recently in order to gather basic knowledge as well as application tools and resources for genetic improvement of cultivable species. Development of genomic resources has to be taken up in each prioritized species through multidisciplinary approach in order to address marker assisted breeding, nutrition, health, transgenics, etc. The approaches are as follows:

1. National brood stock upgradation and genetic improvement program conventional selective breeding, DNA marker technology and transgenics
2. Generation of genomic resources such as marker maps, large insert libraries, DNA constructs and protocols for gene manipulation, cDNA libraries and transcriptome databases of tissues related to various abiotic stresses, developmental stages and disease conditions
3. Whole genome sequencing of important cultivable species
4. Identification of genes/ proteins underlying different performance traits
5. Incorporation of DNA chip technology and development of integrated, cost effective marker assisted breeding plans in prioritized fish and shellfish species
6. Determination of whole genome sequence of a couple of species as reference towards functional and comparative genomics in fishes
7. Stem cell technology

**NUTRITION AND FEED DEVELOPMENT**

To meet the challenges of feed deficit, identification of locally available feed ingredients and their use in fish feeds would be the suitable solutions. Formulation of on-farm farm-made feeds would be another sustainable approach to narrow the gap of feed deficit. To develop low-cost aquafeeds, studies are required on nutrient requirement of newer commercially important diversified fishes. Similarly, suitable feed processing and manufacturing technology can improve the feeds utilization by the fish, resulting decreased feed requirement with low price. Use of suitable feeding devices is the option for better feed management and reduction of pond bottom sediments. Development of generic feeds and feeds for different life stages of cultivable species are to be relooked. Formulation and use of sustainable aquafeeds to maximise health benefits of farmed fish for consumers is another area of fish nutrition research which needs immediate attention. In order to achieve this goal, suitable aquafeeds need to be developed based on sustainable alternatives to fish meal and fish oil to produce healthy and minimally contaminated fish that are highly nutritious and acceptable to consumers.

The genetic control of different enzymes and metabolic pathways in response to nutrients, the use of nutrients to increase disease resistance in fish, the use of functional food aids in the prevention of health disorders need to be emphasized in future. Enrichment and culture of natural fish food organisms and assessment of their nutrient contributions in fish performance in aquaculture systems needs to be initiated.

## HEALTH MANAGEMENT

Health management would play a pivotal role in the coming years for sustainability of semi-intensive or intensive systems of aquaculture. The misuse and drawbacks in antibiotics, problems of emerging pathogens, transboundary diseases, poor quarantine etc. are further adding up to this issues for moving into better health management practices. To meet the challenges of newer and emerging pathogens, there is a need to emphasize on the development of newer molecular-based, specific, sensitive and farmer-friendly disease diagnostics. Exploration of immune system of major cultured candidate species and understanding pathogenesis of important diseases would pave the way in developing suitable immunoprophylaxsis using latest molecular approaches. Diseases like argulosis, edwardsiellosis etc. that pose major threats to the industry would be given priority using novel approaches of prevention or control. The potentiality on use of nanomaterials in diagnostics and vaccine development will also be explored.

Emphasis would be directed to map the diseases in major freshwater aquaculture systems of the country to prioritize the diseases that are causing major economic loss to the sector. Further, targeted active surveillance and health management practices would be taken up to prevent those diseases through development of molecular diagnostics and vaccines.

## PROCESSING AND POST-HARVEST TECHNOLOGY

Processing and post-harvest technology in the field of freshwater aquaculture followed by value addition are absolutely lacking in India. Therefore such field of specialization should receive immediate attention as a part of research in aquaculture.

## DATABASE DEVELOPMENT

Database of freshwater potential resources, their productivity and production from different water bodies namely ponds, tanks, beels and jheels are yet to be updated. Moreover, the national basis network for such purpose is lacking barring few attempts made by CIFRI, Barrackpore and IIM, Ahmedabad. Systematic and periodic survey of freshwater aquaculture resources is required to fill up this void. Therefore electronics, remote sensing and computer technology are to be pressed into service for such purpose.

## TRANSFER OF TECHNOLOGY

Transfer of technology from lab to land or from experimental result to field demonstration is one of the important aspects in extension work which inspires farmers for learning by doing. Therefore viable technologies are to be transmitted to the mass through KVKs, training programme, farmers' meet, farmers' day and published manuals in local languages. A strong foothold is required by making collaborative approaches with different agencies namely FFDA, State Fisheries Departments, NGOs, and SHGs so as to extend all possible useful tips (on aquaculture) which can reach up to grass root level or village level farmers. Such programmes are to be arranged in different agro-climatic zones as well as considering farmers' need and consumers' preferences.

Further emphasis, efforts and attention are to be made so as to make aquaculture an organized activity. Appreciable development and achievement have already been made in this sector in Punjab, Haryana and Andhra Pradesh. In collaboration with CIFA other agencies can take initiative to prepare a blue print on national basis so as to gear up national average fish production through aquaculture to about 5 t/ha/yr from the current production level of 2.6 t/ha/yr. Inputs and financial support are to be provided to those who remain associated with agriculture. In other words, aquaculturists should be at par with agriculturists in terms of facilities and subsidies provided to them.

All proven technologies related to aquaculture development are to be implemented in different agro-climatic zones involving all irrespective of caste, creed or sex. All backward communities, NGOs, women and State Fisheries Departments are to be involved in specific operational and developmental projects.

CIFA can play a pivotal role in planning and guiding a sustainable and economically viable production system in the wake of public private partnership when the entrepreneurs and large farmers of various states could be encouraged to involve themselves in different activities associated with aquaculture industry.

## MODELING AND FORECASTING

Research efforts on modeling and forecasting have been limited in aquaculture system particularly in the context of Indian scenario. However, considering the present context of climate change and its subsequent impact on the aquaculture, urgent need of intensifying the effort in this area has been felt in recent years. Such type of research would not only ensure efficient resource and input use but also strengthen our preparedness for the extreme climatic event.

## EPILOGUE

In order to meet the needs and aspirations of stakeholders in freshwater aquaculture and to strengthen this sector further, it is essential to adopt the frontier research areas including development of production system for efficient use of nutrients and water, enhanced tolerance to biotic and abiotic stress imposed by climate change, achieving rapid growth rate of cultured fish following nutritional principles, development of an integrated, cost effective marker assisted breeding plan through the application of biotechnology, concerted and integrated efforts with effectiveness and efficiency to meet the ever increasing demand ensuring the code of responsible aquaculture.

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# Aquaculture and Environment: Sustainability Issues

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## INTRODUCTION

Aquaculture, the farming of aquatic organisms such as fish, mollusks, crustaceans and plants, is the fastest growing food production sector in the world. Aquaculture production is playing an increasing role in meeting the demand for fish and other fishery products. Total fisheries production including capture fisheries and aquaculture was about 142 million tonnes in 2008 (FAO, 2010a) Cultured food fish supplies currently account for nearly 50 percent (Bartley, et.al., 2007), of what is consumed globally and are targeted to increase to 60 percent by 2020 (FAO, 2008). The average annual per capita supply of food fish from aquaculture for human consumption has also increased by 10 times, from 0.7 kg in 1970 to 7.8 kg in 2008, at an average rate of 6.6 percent per year (FAO, 2010b). During this period the production of food fish from aquaculture increased at an average annual rate of 8.3 percent, while the world population grew at an average of 1.6 percent per year (Swaminathan, 2012).

## FOOD AND NUTRITIONAL SECURITY

As people get richer, they eat more fish. Average consumption of fish has also doubled over the last 50 years. Fish has also become more expensive as demand has increased and supply declined. According to Food Policy Research Institute, United States, rise in prices of fish has been most remarkable as compared to prices of beef, chicken, pork and milk which has actually fell in real terms over the past 30 years. The reason that people have been able to eat more fish in spite of over declining of wild fisheries is because aquaculture production has been flourishing. The contribution of aquaculture to the total production also continued to grow, rising from 34.5 percent in 2006 to 36.9 percent in 2008. It is believed that by 2030, aquaculture will supply most of the fish the people eat.

## AQUACULTURE IN ASIA

Traditional aquaculture that are followed in China and India, the prominent players has been a low-tech affair involving not more than a pond, using organic manures and agricultural byproducts and by growing freshwater fish that are not very tolerant to all sorts of water quality. Almost 80 % of the fish produced by aquaculture in such systems were herbivores or omnivore species mostly produced in low density systems. This fish was produced for local consumption with moderate levels of inputs and organic-based fertilizers contributed to alleviate nutritional deficiencies and poverty in rural areas. Aquaculture in such places contribute immensely to food security. Strong linkages between research and development agencies, increased investment in fish and prawn hatcheries, establishment of aquaculture estates, feed mills and ancillary industries have all changed the state of affairs and pace of growth of the sector to the shape of an industry.

The technologies of induced carp breeding and polyculture in static ponds and tanks virtually revolutionized the freshwater aquaculture sector and turned the sector into a fast growing industry. Over the years, however, culture practices have undergone considerable intensification for obtaining high production levels. Conventional farming practices using carp or diversified culture of freshwater prawns and to some extent catfishes that contributed to growth in the freshwater aquaculture sector has further changed. The farming of giant river prawn (*Macrobrachium rosenbergii*) has gained increased interest due to its high economic value and an annual production of over 30,000 tonnes has been achieved under monoculture system. In India, Andhra Pradesh dominated the sector with over 86 percent of the total production with approximately 60 percent of the total water area dedicated to prawn farming. This was followed by West Bengal.

### Integrated to Semi Intensive

Brackish water farming in India has been an age-old system confined mainly to the *Bheris* or manmade impoundments in coastal wetlands of West Bengal and *Pokkali* rice fields of Kerala coast where salt resistant deepwater paddy is cultivated, with no additional input. The naturally entering juvenile fish and shrimp seed from the coastal seas have been sustaining production levels of 500-750 kg/ha/year. Commercial shrimp contribute 20-25 percent of the total production in such system. The *pokkali* fields were operated by farmers and fishers in the most structured manner. This system, lately in some places has given way for perennial high density shrimp culture round the year.

With high density shrimp farming taking hold under a perennial system, skipping rice farming altogether, and pumping feed and chemicals, the system got deteriorated to such a level that it has been destructive not only to rice but also counterproductive also to shrimp aquaculture. Perennial and continuous shrimp farming by maintaining sea water round the year virtually made parts of *Pokkali* region in to biological desert with destruction of fresh water sources and decimation of plant cover on land fringes. Shrimp farming is now an environmental nightmare in such pockets of *pokkali* fields and the people have demonstrated their gross discontent through conflict and litigation. Unplanned development of aquaculture in these places has led to adverse impacts on environment.

Brackish water aquaculture has been confined to a single species, *Penaeus monodon*, the scientific farming of which began during the early 1990s. The problems include destruction of wetlands and mangroves, dispersion of chemicals and nutrients and the salination of the soils. The introduction of white leg shrimp (*Litopenaeus vannamei*) to Asia has given rise to a boom in the farming of this species in China, Thailand, Indonesia and Viet Nam in the last decade, resulting in an almost complete shift from the native giant tiger prawn(*Penaeus monodon*) to this introduced species. In India, the interdiction on the introduction and culture of white leg shrimp was lifted in 2008 in India, and this will have a major impact on the country`s shrimp farming sector in the years to come.

**INDIAN AQUACULTURE- RAPID GROWTH**

The contribution of fresh water aquaculture to inland fish production in India has been most outstanding. Aquaculture contribution has increased sharply from 46.35% in 1984 to 80% in 2010, primarily due to the tremendous rise in output from freshwater aquaculture. The success stories of carp polyculture on a commercial scale that started in the Kolleru lake basin in Andhra Pradesh in the mid 1980's were replicated in Punjab, Haryana, Uttar Pradesh, and elsewhere. Aquaculture in India has thus attained the status of an industry with increased employment opportunities.

**SLOW GROWTH AQUACULTURE-KERALA**

The state of Kerala occupies just 10 percent of the coastline of India, but the State supports over 20 % of the marine fish production. The state is also endowed with one of the richest natural resources for inland fish production and aquaculture. However, inland fisheries and aquaculture in Kerala contribute only 3% to total fish production in India. Although continuous development of pond fish culture in terms of area and intensification during the past decade at the national level has greatly contributed to the inland fisheries production, the technology of carp culture adopted in Kerala in tune with the National agenda has proved to be grossly inappropriate. This is apparently due to predominantly acidic soil conditions, poor plankton productivity, reduced photosynthetic efficiency and low sunshine hours during part of the year owing to high rainfall situations.

Diversified production of potential indigenous species also did not turn out, as seed of such species which have high commercial demand was not generally available. Seed production protocols for several endemic species of commercial value such as *Etroplus suratensis*, *Claria dussumerii, Labeo dussumeerii Horabagrus brachysosma, Macrobrachium rosenbetgii, Wallago attu, Channa* spp, *Heteropneusteus fossilis* etc have been standardized lately. Giant Freshwater prawn *Macrobrachium rosenbergii*, popularly known as '*Kuttanadan konchu*' the fastest growing freshwater prawn species in the world is endemic to Vembanad lake, Kerala. With the standardization of breeding techniques, although several hatcheries have sprung up in different parts of India, most of these hatcheries utilize the berries of pure wild stocks collected from Vembanad lake. *M. rosenbergii* stocks in Vembenad can be designated as geographical indicator for Kuttanad and prawn germplasm should be protected from contamination from genetic introgression and conserved and protected for posterity.

**Open Water Aquaculture-Cluster Based**

As land is the most scarce resource in Kerala, the scope for expanding land based aquaculture is limited in Kerala. If developed on scientific lines, the technology of open water fish farming in cages developed and demonstrated in the open Vembanad lake can bring about magnificent improvement in productive utilization of our natural waters. The indigenous fish Pearlspot (karimeen) has been shown to be the most potential candidate species for intensive cage culture (Padmakumar et al., 2007). Establishment of hatcheries and promotion of seed production of pearlspot endemic to these waters is yet to catch up. Lack of imaginative projects and judicious water lease policy for open water farming and pragmatic programs impede the development of this sector.

**Culture Based Capture Fisheries- Reservoirs**

The reservoir fisheries in India that contributed immensely to culture based capture fisheries have been largely carp centric. Major carps by virtue of their feeding habits and faster rate of growth are no doubt indispensable. However, it has been observed that unlike Chinese silver carp, Indian major carps are ill suited to utilize phytoplankton. Issue of introduction of carps, in reservoirs on the Western Ghats river systems owing to projected deleterious effect on indigenous species has been a subject of controversy. Critics argue that reservoir is part of the head river system. Others contend that the reservoir itself is not a natural system but it is a manmade artificial impoundment. This controversy need to be resolved. Diversification of stocking material involving endemic species is one necessary option for establishment of multispecies fisheries to utilize all food niches in such ecosystems.

**Waste Water Fed Aquaculture**

The practice of utilizing fish farming for treating waste waters and agro-based industrial effluents, add new dimension to aquaculture, rendering it eco-restoring, environment compatible and economical. By 2020, it is estimated that over 50 percent of our population will be urban, whereby human food chain and nutrient cycles are going to become unstable as nitrogen, phosphorus and other nutrient elements in waste waters are not going to be returned to soil, leading to ecological problems of eutrophication in all our water bodies. The signs of distress due to waste disposal have begun to surface in all our metropolitan cities.

Utilization of sewage and waste waters for aqua farming is one of the suggested methods for treatment of sewage wastes. Such waste water reuse system in engineered wetlands that promote waste water-fed crop-fish production systems near our urban centers is one strategy to alleviate environmental problems of waste waters. This can also promote formation of huge centers of food production combining agriculture, aquaculture, vegetable and horticulture production centre and animal production units. Such centers shall work under an alternate agricultural system essentially to utilize wastes and farm byproducts from our rapidly growing cities.

**Fish Keeping for Waste Utilization**

The initiatives to popularize waste management at source have not succeeded as the people have not been passionate to such ideas. It could be because the technology is not communicated properly and required motivation has not occurred. However utilization of organic waste generated at the same place and time of origin and utilizing the same for converting it to live fish in kitchen tanks maintained in homely surroundings is an exciting option. Fish species such as Pangassius catfish, *Pangassius sutchi* or such other hardy species that feed voraciously on food wastes and suited to high density farming conditions has been demonstrated to be of use for waste recycling. It can be promoted in Fung-shui fervor to raise fish by recycling biodegradable wastes for fortune and productive income.

**IMPROVING DIVERSITY IN AQUACULTURE**

Despite high fish biodiversity, and over 35 % of the freshwater fish species in the country concentrated in rivers originating from Western Ghats of Kerala, very few of these indigenous species have been utilized in aquaculture systems. Indian Major Carps (IMC) still constitute over 74 percent of cultured fish production. The index of biodiversity used for aquaculture in India is quiet low (0.13), as compared to other South East Asian countries like Taiwan (0.51). Lately, steps have been taken to identify the endemic species that can be utilized for pond culture. The National Bureau of Fish Genetic Resources (NBFGR) with the support of the State Agricultural Universities and National Institutes have completed an ambitious program to inventorise the fish germplasm of important peninsular riverine systems.(Gopalakrishnan and Ponniah,2000., Gopalakrishnan etal., 2011, Kurup,2002) Attempts have also been made to prioritize endemic species and water bodies for conservation. Captive breeding protocols for a variety of cultivable species (Padmakumar et.al. 2004) have also been developed so that seed availability is no constraint for diversifying aquaculture.

**Domesticating New Breeds**

In the west, similar to in Green revolution, blue revolution has seen companies breeding fish to improve traits such as growth rate, conversion efficiency of feed to flesh, resistance to disease, tolerance to water quality, and fertility. Modern aquaculture of the kind that began in case of salmon almost 3 decades ago in the west and the coastal shrimp farming involved technology demanded great deal of knowledge about habits of and life cycle of each species. The development of tilapia strain that is hardier and grows 60% faster than its wild variety is one such instance. There is talk of genetic modification in fish farming. Scientists are thinking of tinkering with genes for growth hormones which make fish grow bigger and faster. This project is most controversial than genetically modified crops, because of concerns as to what will happen if such fish escape, although no GM fish is being farmed for food at present.

Farmed salmon is the most popular sea food in America. The same story applies to shrimp. Cod is the great hope of European producers who are facing tough competition from salmon farms in Chile. Intensive research efforts are underway in France, Norway and Scotland to farm cod with complete predictability. It is a difficult business unlike salmon as cod fry do not have large yolks that they can live off in early days of life cycle. They must be fed and fed correctly almost as soon as they have been hatched.

It can take years of research to domesticate a new species. Stocking densities, water quality, breeding conditions, animal behavior, health care, precise nutritional needs, all have to be worked out to domesticate a wild fish. It is this scientific and technical knowledge that drive the industry by improving health and nutrition to fish , reducing stress and diseases, by use of antibiotics and vaccines. Now business houses are breeding fish of choice to customers rather than breeding fish to produce more to feed the millions. Monopoly groups involved in fish farming do not think it necessary to produce more in thousands of tonnes. Even the dropping production from the wild is seen as an opportunity by them, as there is a clear gap of demand and supply.

The recent interest in farming of indigenous fresh water fish species such as pearlspot, *Etroplus suratensis*, indigenous carps, *Labeo dussumierii, Labeo yocheilus* ,Catfish, *Horabgrus brachysoma*, *Clarias batrachus*, *Pangassius pangassius, Ompok malabaricus, Wallago attu* and a host of ornamental fishes owes to the success in development of captive breeding( Padmakumar et al., 2004, 2011). It is imperative that some such indigenous species that have high consumer preference and potential are utilized for farming.

**Biodiversity Protection and Conservation**

It is most essential to protect natural fish habitats as recognized aquatic sanctuaries for conservation of fish germplasm (Bartley,et al.,2007). Studies on life history traits of fish population is important and indispensable for planning conservation and management. A pioneering attempt has been made in the Vembanad lake by the Regional Agricultural Research Station (RARS), Kumarakom, to establish a protected fish sanctuary or fish refugia in a demarcated and designated area (Padmakumar,et. al.,2009) by simulating breeding habitats for *Etroplus suratensis,* the iconic state fish of Kerala. Studies have revealed that such engineered sanctuaries aid to promote natural recruitment and enhancement of commercial species.

**Unregulated Aquaculture - Issues**

With the monstrous development of coastal shrimp farming, environmental impacts of aquaculture received a high degree of attention during 1990's. In a few typically worst cases, welfare of society was negatively affected by unregulated aquaculture development. It is pollution and environment damages that most people now associate with aquaculture. Fish farming has developed this bad reputation due to lack of regulatory measures. However, it's supporters argue that aquaculture promises to meet the shortfalls in marine capture fisheries that has become more and more exhausted. Critics have a louder voice and they contend that farmed fish is fatty and is stuffed with antibiotics. More over they say that modern fish farming is unsustainable as it is fed with fish meal and this fish is caught from the wild putting greater and greater pressure and damage on marine life.

In this context, feed formulations that are more digestible and that leach less waste in to environment improving nutrition, feed development, and fish health are considerations of some good feed companies. They work hard to evolve feed that release less nitrogen and nutrient loading in to water. There have been also efforts to reduce the use of antibiotics in aquaculture. Vaccines have brought out these reductions. We need absolutely green technologies that does not pollute environment. There is a great opportunity to use some fishes such as tilapia or catfishes to mop up the shrimp waste. The Chinese concept, "multitrophic aquaculture can be employed to improve productivity while reducing negative impacts on the environment through nutrient stripping. Recent study carried out at the Regional Agricultural Research Station, Kumarakom reveal that the indigenous filter feeding bivalve, *Villorita cyprinoides* is miraculously efficient in bioremediation of natural waters off algal eutrophication problems (Teena and Padmakumar, 2010). Land based integrated farming techniques offer greater promise as it has no or minimal environmental costs and in fact promote complementarity.


**Fish Meal Controversy**

Critics say that modern aquaculture industry has a fatal weakness as several kilos of wild caught fish is needed to feed every kilo of farmed carnivore fish such as sea bass now popularized for farming . Thus they argue that modern aquaculture is increasing and not reducing pressure

on marine fisheries. Although aquaculture contribute to 50% of fish we consume, there is no corresponding boom in natural catches either in marine or inland sector. The catch of industrial fish used to make fish meal maintains the same level of production over decades.

The reason is that fish meal is used also to feed poultry and pigs although feeding fish meal to fish is more efficient than feeding it for animals. Today almost 40 % of the world's supply of fish oil and 31 % of fish meal is only used in aquaculture farms. FAO predict a worldwide shortage of fish oil within a few years. The most serious concern if fish meal were to run out is diversion of low value fish from the mouths of people in developing countries in to mouths of the well fed rich people in developed countries.

**By-catch/Discard as Fish Meal**

Alternatively, there is high demand for 'by-catch' or 'discards' from marine fishing, which is again a marine collateral damage. These are the fish that are accidentally caught killed and then thrown back in to the water during trawling for shrimp. By-catch in fishing amounts to tens of thousands of million tonnes every year. On the Kerala coast, it is over 2.25 - 2.62 lakh tonnes annually (Bijukumar and Deepthi, 2006) amounting to almost 30 % of the total fish caught from the state's coastal seas and around 79 % of the landings in trawling operation (George et.al., 1981). In Indian seas, large foreign fishing vessels are legally and illegally engaged in industrial fishing. Industrial fishing of this sort will reduce the amount of fish-food available to larger fish and marine animals. Fish meal content in feed is being deliberately reduced from 70% to 35% today. Omega -3 fatty acid is the main reason that fish is seen as a healthy food. However, technology can help to avert this crisis. Replacement of feed stuff with soya, rape seed oil etc are developed. China is the biggest importer of fish meal today. Chinese researchers are working on yeast based protein supplements that could be substitute for more than half of the fish meal.

**AQUACULTURE AND ENVIRONMENT- CONCERNS**

Waste from fish farms, such as uneaten food and dead fish accumulate and destroy environment. Over use of antibiotics threaten both aquatic environment and human health. Farmed Fish may transmit diseases to wild stock or interbreed with wild stock causing genetic pollution. In the last one decade, it is reported that over I million non native Atlántic salmon have escaped from fish farms and established in streams in North West America.

In Norway, 90 % of the fish have escaped from its coastal farms. Shrimp aquaculture has caused serious environmental problems, especially in countries with poor environmental regulations. A recent study by Environment Justice Foundation in Vietnam, the world's fifth largest producer of farmed shrimp, revealed that in the Mekong, mangrove cover is now only 30% of what it was in 1975. Shrimp aquaculture has been the major cause.

However, aquaculture has some good advantage over open access fisheries as it is easily managed. Environmental pressure can force the industry to change as happened in Indian shrimp aquaculture. The same is not the situation in open seas where nations ferociously complete for the dwindling supply of wild fish. Aquaculture can strive at lowering cost of production enormously. Aquaculture can compete in cost to even heavily subsidized open sea fishing. At some point of time it will help relieve pressure on wild fisheries.

The impact of aquaculture on environment is undoubtedly mixed, with aquaculture offering relief to over exploited fish stocks, at the same time causing changes and detrimental impacts on the environment. Apart from damage to ecosystems owing to effluent discharge and environmental contamination from use of drugs and introduction of exotics with impacts on wild stocks, the most serious effects are on ground water contamination and social conflicts caused by resource access (Philip and Subhasinghe, 2008). These impacts have begun to affect not only aquaculture but also other forms of production including agriculture.

As people get richer they eat more fish. Average consumption of fish has doubled over last 50 years. And fish has become more expensive as demand has increased and supply declined. According to Food Policy Research Institute, rise in prices of fish has been most remarkable as compared to prices of beef, chicken, pork and milk which has actually reduced in real terms over the past 30 years. The reason that people have been able to eat more fish in spite of over exploitation of wild fisheries is because aquaculture production has been flourishing. Already, almost half of the fish consumed in India is now farmed.

As in agriculture, modern intensive fish farming does harm the environment although the extent vary considerably. As the society may have to pay the price, consumers every where become more aware on the sources and means of production. And the writing on the wall is clear - aquaculture should grow in environmentally sustainable ways. Public pressure and continued commercial expansion should compel the sector to mitigate its environmental impacts.

## SOCIAL AND ECONOMIC CONSIDERATIONS

Aquaculture that contribute to economic growth shall not only create disruption and inequalities but conflict over resource allocation and resentment over farming practices shall be resolved. Equity shall be the policy agenda. There should be commitment to involve women, fishers and other underprivileged sections in agenda setting and policy making. Certification schemes that influence international trade and adherence of codes of conduct is to be strictly followed as access to not only foreign markets but domestic markets demand not only hygiene and traceability besides social and environmental sustainability (Brugere et.al., 2010) .

**INTEGRATION-ECOLOGICALLY HARMONIOUS**

Although aquaculture is an activity involving non consumptive water use, other activities that use water as input. To improve water productivity and use efficiency, potentials of integrating aquaculture with agriculture should receive due priority. Fish effluent has been shown to be useful source of nitrogen and nutrients for crop production There is increasing need to integration of aquaculture not as a discourse but as practice. Integrated farming paradigms such as rice-fish farming, *Oru Nellum Ooru Meenum* developed in response to proven setbacks of Green revolution technologies and declining per capita availability of land in coastal wetlands of Kuttanad, is suggested as a solution to the economic and environmental problems in coastal wetlands(Padmakumar et al., 1993., 200). Here, integration of livestock, fishery and poultry along with rice has been demonstrated to maximize the output of land without altering the physiography of these wetlands.

**Regenerative Farming**

In academic and policy discourses, many a times, economic growth and environmental sustainability are considered mutually exclusive and eco-friendly land use practices are considered economically nonviable as ecological conservation is attributed to compromises on productivity. Studies on integrated farming provide a radically different insight to this perception. The major biological feature of this regenerative farming strategy has been byproduct recycling which diminished the reliance on agro industrial inputs. The evolution of an Integrated farming system paradigm on rice-fish rotational farming from a laboratory model, and into multi-integrated farming models in Kuttanad wetlands (Padmakumar,1993.,2006) challenges the argument that eco-friendly land use models are ecologically non viable and such integrated resource management models are not just theoretical construct but more realistic approaches that ensure synergistic recycling of wastes from one farm enterprise to another. The experiences, nevertheless, demonstrate that diversification is not only ecologically harmonious but also more productive and profitable. This is a typical instance, that aquaculture play a possible role and can contribute to land based agriculture making it more environment restoring.

**CODES OF PRACTICES AND GUIDELINES**

The situation calls for approaches that ensure sustainability in aquaculture. The aquaculture sector needs co-ordinated development with other sectors and there is a dire need for consultation to minimize conflicts for land and water, not only with agriculture but also with capture fisheries. A national plan redefining the objective, policies and strategies suitable for achieving sustainable development has been emphasized by FAO (1995). A code of Conduct for Responsible Fisheries (CCRF) has been declared and the same adopt by 168 countries, including India. According the FAO Code: 1) States should promote responsible development and management of aquaculture, including advance evaluation of the effects of aquaculture development on genetic diversity and ecosystem integrity, based on the best available scientific information. 2) States should ensure that the livelihoods of local communities, and their access to fishing grounds, are not negatively affected by aquaculture developments. 3) States should establish effective procedures specific to aquaculture to undertake appropriate environmental assessment and monitoring with the aim of minimizing adverse ecological changes and related economic and social consequences resulting from water extraction, land use, discharge of effluents, use of drugs and chemicals, and other aquaculture activities.

It is the bounden responsibility of the state to conserve genetic diversity and maintain integrity of aquatic communities and ecosystems by appropriate management. In particular, steps are suggested to minimize the harmful effects of introducing 'non-native species' or genetically altered stocks used for aquaculture or culture-based fisheries-into waters, especially where there is a significant potential for the spread of such non-native species or genetically altered stocks into waters under the jurisdiction of other states or the State of origin.

In India, presently, activities pertaining to inland fisheries and aquaculture are regulated and controlled by the Aquaculture Authority of India (AAI), though much of it has been concentrated on shrimps until recently. The Fisheries Policy (2004), Kerala announced by State Government, seeks a focused endeavor on aquaculture development with provisions to protect, regulate and develop aquaculture on a responsible and sustainable manner by resorting to optimal utilization and management of resources based on a code. However, action on above are still wanting.

**WAY FORWARD**

Nobody should underscore the fact, that aquaculture has brought tremendous changes to food fish availability. It has ensured consistency of supply and lowered prices. Aquaculture has also led to increase in demand for fish. However, reliable and independent information about the environment friendliness of farmed fish is to be made available. As standards vary widely from one country to another, raising standard in one place will drive the industry to somewhere else with weaker rules. What is needed is an internationally recognized certification scheme to alert consumers to the sustainability of the farmed fish that they are eating. Only then consumers can hope to find that the products of modern aquaculture are doing more good, than harm that they prevent. Options available for managing aquaculture is to bestow greater emphasis on promoting and recognizing sustainable models and to encourage more collaboration among multi interest groups. It is indispensable to follow an Ecosystem Approach to Aquaculture(EAA), limiting production system within the assimilating capacity of the ecosystem itself. Blue revolution can really be made green only by infusion of such environmentally benign technologies.

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# Marine Fishery Development and Climate Change

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## INTRODUCTION

Marine fisheries have very important roles for food supply, food security and income generation in India. About one million people work directly in this sector, producing 3.1 million tonnes annually. The value of the marine fish landings have been estimated at Rs. 36,964 crores in 2010 and India has earned a foreign exchange of Rs. 10,000 crores through the export of 6 lakh tonnes of sea food products. The fisheries sector, presently contributes around one percent to the GDP and 4.72 percent to Agricultural GDP of our country (Sathiadhas *et al.*, 2012). Being open access to a large extent, there is intense competition among the stakeholders with varied interests to share the limited resources in the coastal waters, which has resulted in overfishing and decline in stocks of a few species. Climate change renders severity to this situation and act as a dispensatory factor on fish populations. Further, it will also have strong impact on fisheries with far-reaching consequences for food and livelihood security of a sizeable section of the population.

Concerns on global warming have been with us now for more than a decade. The global warming that is widely expected to occur over this century will not be confined to the atmosphere; the oceans would also get warmer. Over the next 50 years, sea surface temperature in the Indian seas is expected to rise by 1 to 3. The oceans are predicted to acidify, become more saline, and the sea level will rise, and currents may change. It has been recognised that it will have consequences, both benign and disadvantageous, on fisheries. Fisheries, which essentially are an advanced form of hunting, are totally dependent on what nature will or will not provide. The effects of environmental change on fisheries are likely, therefore, to be severe. Such changes are likely to affect fish migrations and habitat, augmenting fish stocks in some places and decreasing them in others, perhaps causing stocks to be displaced permanently to new habitats. Investigations are progressing to find out the possible consequences of environmental change for fisheries. Nevertheless, the effects of climate change on fish stocks and their migrations are extremely difficult to predict.

The marine fish landings of India during the year 2010 has been estimated as 3.07 million tonnes (table 1) with a decrease of about 1.31 lakh tonnes compared to the estimate for 2009. The pelagic finfishes constituted 55%, demersal fishes 26%, crustaceans 14% and molluscs 5% of the total landings. The sector-wise contributions during the year 2010 were mechanized 73%, Motorized 25% and artisanal 2%. The west coast accounted for 55 % of the total landings and east coast 45%.

**Table 1**
**Profile of Marine Fisheries in India**

| Component | Profile |
|---|---|
| **Physical Components** | |
| Coastline length (km) | 8129 |
| Exclusive Economic Zone (million $km^2$) | 2.02 |
| Continental shelf area (million $km^2$) | 0.50 |
| Area within 50m depth (million $km^2$) | 0.18 |
| **Human Components** | |
| Marine fisher population (million) | 4.0 |
| Active fisher population (million) | 1.5 |
| **Infrastructure Components** | |
| Landing centres | 1511 |
| Mechanized vessels | 72559 |
| Motorized vessels | 71313 |
| Non-motorized vessels | 50618 |
| **Fish Catches** | |
| Annual landings (2010) (million t) | 3.07 |
| Potential yield (million t) | 3.92 |

*Source: CMFRI, 2010*

## IMPACT OF CLIMATE CHANGE ON MARINE FISH

There is now ample evidence of the impacts of global climate change on marine environments. Analysis of the data set on sea surface temperature (SST) obtained from International Comprehensive Ocean – Atmosphere Data Set (ICOADS) (ESRL PSD *www.cdc.noaa.gov)* and 9-km resolution monthly SST obtained from AVHRR satellite data (provided by the NOAA/NASA) showed warming of sea surface along the entire Indian Coast. The SST increased by 0.2$^o$ C along the north-west (NW), South-west (SW) and north-east (NE) coasts, and by 0.3$^o$ C along the south-east (SE) coast during the 45 year period from 1961 to 2005. For instance, the annual average SST, which ranged between 27.7 $^o$ C and 28.8$^o$ C during 1961-1976 increased to 28.7$^o$ C 29.0$^o$ C during 1997-2005 between 9$^o$ N, 76$^o$ E and 11$^o$N $^{77oE}$ (south-west coast). The warmer surface waters (29.0 $^o$ C 29.2 $^o$ C) expanded to a very large coastal area (between 8$^o$ N, 72$^o$ E and 14$^o$ N, 68$^o$ E (off Saurashtra in the north-west coast) during

1961-1976 disappeared completely in the later years. Similar pattern of warming was evident in the Bay of Bengal too.

Based on the trajectory suggested by HadCM3 for SRES A2 scenario, it is predicted that the annual average sea surface temperature in the Indian seas would increase by 2 $^{o}$ C to 3 $^{o}$ C by 2009. The predicted trend showed that the annual average temperature is likely to increase from 28.5 $^{o}$ C during 2000-09 to 31.5 $^{o}$ C during 2089-99 in the Andaman, Nicobar, Lakshadweep and Gulf of Mannar; and from 27.5 $^{o}$ C to 30.5 $^{o}$ C in Gulf of Kutch.

Most fish species have a fairly narrow range of optimum temperatures related to their basic metabolism and availability of food organisms. Being poikilotherms, even a difference of 1$^{o}$ C or 0.1 unit pH in seawater may affect their distribution and life processes. The more mobile species should be able to adjust their ranges over time, but less mobile and sedentary species may not. Depending on the species, the area it occupies may expand, shrink or be relocated. This will include increases and shifts in the distribution of marine fish, with some areas benefiting while others lose. From the recent investigations carried out by the Indian Council of Agricultural Research (ICAR) and Central Marine Fisheries Research Institute (CMFRI), the following responses to climate change by different marine fish species are discernible in the Indian seas: (i) Extension of distributional boundary (Vivekanandan *et al.* 2009); (ii) Shift in latitudinal distribution; (iii) Shift/extension of depth of occurrence (CMFRI, 2008); and (iv) phenological changes (Vivekanandan and Rajagopalan 2009). Some evidences of the responses are given below:

**Extension of Distributional Boundary**

The oil sardine *Sardinella longiceps* and the Indian mackerel Rastrelliger kanagurta are tropical coastal and small pelagic fish, forming massive fisheries in India (catch during 2010: 4,03,932 tonnes contributing 13.1%of the total marine landings of the country). They are governed by the vagaries of ocean climate conditions, and have high population doubling time of 15 to 24 months. They are cheap source of protein, and form a staple and nutritional food for millions of coastal people. They were known for their restricted distribution between latitude 8$^{o}$ N and 14$^{o}$ N and longitude 75$^{o}$ E and 77$^{o}$ E (Malabar upwelling zone along the south-west coast of India) where the annual average sea surface temperature ranges from 27 $^{o}$ to 29$^{o}$ C. Until 1985, almost the entire catch was from the Malabar upwelling zone and the catch was either very low or there was no catch from latitudes north of 14 $^{o}$ N. In the last two decades, however, the catches from latitude 14$^{o}$ N to 20 $^{o}$ N are increasing and a positive correlation was found between the catches and sea surface temperature (SST). The surface waters of the Indian seas are warming by 0.04 $^{o}$ C per decade, and the warmer tongue (27-28$^{o}$ C) of the surface waters expanded to latitudes north of 14$^{o}$ N, enabling the oil sardine.

**Shift in Latitudinal Distribution and Abundance**

Catfish are one of the major resources along the southwest and southeast coasts of India (latitude: 8$^{o}$ N – 14$^{o}$ N). During 1970-2007, the catches from these coasts decreased from 35,000 tonnes to 7,800 tonnes. On the other hand, the catches from the northwest and northeast coasts (latitude: 15° N – 22° N) increased from 16,000 tonnes to 42,500 tonnes during the same period. There was a strong negative correlation between catfish catch and SST along the two southern coasts whereas the correlation between catch and SST was positive along the northern coasts.

**Shift/Extension of Depth of Occurrence**

The Indian mackerel, *Rastrelliger kanagurta*, the second important resource contributing 7.9% of total landings for 2010 in addition to extension of its northern boundary, is found to descend to deeper waters in the last two decades. The fish normally occupies surface and subsurface waters. During 1985-1989, only 2% of mackerel catch was from bottom trawlers, and the rest of the catch was contributed by pelagic gear such as drift gillnet. During 2003-2010, it is estimated that 15% of mackerel catch is contributed by bottom trawlers along the Indian coast. The Indian trawlers operate at a depth ranging from 20m to 80m by employing high opening trawlers. In the last 25 years, the specifications of trawlnet such as mouth opening, headrope length, otterboard and mesh size have not been modified, and hence the increase in the contribution of trawlers to the mackerel catch is not gear-related. As the surface waters are also warming up, it appears that the mackerel, being a tropical fish, has extended its vertical boundary to deeper waters.

**Phenological Changes**

Fish have strong temperature preferences to spawning. The process of spawning is known to be triggered by pivotal temperatures. The annually recurring life cycle events such as timing of spawning can provide particularly important indicators of climate change.

The threadfin breams *Nemipterus japonicas* and *N.mesoprion* are distributed along the entire Indian coast at depths ranging from 10 to 100 m. They are short-lived (longevity: about 3 years), fast growing, highly fecund (annual egg production around 0.2 million per adult female) and medium-sized fishes (maximum length: 35 cm). Data on the number of female spawners collected every month off Chennai (south-east coast of India) from 1981 to 2010 indicated wide monthly fluctuations. However, a trend in the shifting of spawning season from warmer (April-September) to cooler months (October-March) was discernible. Whereas 35.3% of the spawners of *N.japonicus* occurred during warm months, the number of spawners gradually reduced and only 5.0% of the spawners occurred during the same season. A similar trend was observed in *N.mesoprion too.* The present occurrence of spawners of the two species linearly decreased with increasing temperature during April-September, but increased with increasing temperature during October-March over the time scale.

**Vulnerability of Corals**

Coral reefs are the most diverse marine habitat, which support an estimated one million species globally. They are highly sensitive to climate influences and are among the most sensitive of all ecosystems to temperature changes, exhibiting the phenomenon known as coral bleaching when stressed by higher than normal sea temperatures. Reef-building corals are highly dependent on a symbiotic relationship with microscopic algae ( *i.e.*, zooxanthellae), which live within the coral tissues. The corals are dependent on the algae for nutrition and colouration. Bleaching results from the ejection of zooxanthellae by the coral polyps and/or by the loss of chlorophyll by the zooxanthallae themselves. Corals usually recover from bleaching, but die in extreme cases.

In the Indian seas, coral reefs are found in Gulf of Mannar, Gulf of Kachchh, Palk Bay, Andaman and Lakshadweep Seas. Indian coral reefs have experienced 29 widespread bleaching events since 1989 and intense bleaching occurred in 1998 when the SST was higher than the usual summer maxima. By using the relationship between past temperatures and bleaching events and the predicted SST for another 100 years, Vivekanandan *et al.* (2009) projected the vulnerability of corals in the Indian Seas. The outcome of this analysis suggests that if the projected increase in seawater temperature follows the trajectory suggested by the HadCM3 for an SRES A2 scenario, reefs should soon start to decline in terms of coral cover and appearance. The number of decadal low beaching events will remain between 0 and 3 during 2000-2099, but the number of catastrophic events will increase from 0 during 2000-2009 to 10 during 2000-2099.

Given the implication that reefs will not be able to sustain catastrophic events more than three times a decade, reef building corals are likely to disappear as dominant organisms on coral reefs between 2020 and 2040 and the reefs are likely to become remnant between 2030 and 2040 in the Lakshadweep region and between 2050 and 2060 in other regions in the Indian Seas.

## OPTIONS FOR FISHERIES AND AQUACULTURE SECTOR FOR ADAPTATION

### Tackling Overfishing

Options for adaptation are limited, but they do exist. The impact of climate change depends on the magnitude of change, and on the sensitivity of particular species or ecosystems (Brander 2008). Fish populations are facing the familiar problems of overfishing, pollution and habitat degradation. Food and Agriculture Organization has estimated that about 25% of all fish stocks are overexploited and 50% are fully exploited (FAO 2007). Reduction of fishing effort will benefit in relation to adaptation of fish stocks and marine ecosystems to climate impacts; and mitigation by reducing greenhouse gas emissions. Hence, some of the most effective actions which we can be taken to tackle climate impacts are to deal with the old familiar problems such as overfishing (Brander 2008) and adapt Code of Conduct for Responsible Fisheries (FAO 2007).

### Cultivation of Sea Plants

Sea plants are excellent carbon sequestration agents and many of them sequester at a rate better than their terrestrial counterparts (Zon 2005). $CO_2$ sequestration by the common sea plants such as the red algae *Gracilaria corticata* and *G.edulis*, brown alga *Sargassum polycystum* and the green alga *Ulva lactuca* has been qualified in laboratory studies in India by Kaladharan *et al.* (2008). The seaweed *Kappaphycus alvarezii* has been collected and experiments are in progress. Initial results suggest that the seaweed has good carbon sequestration potential (CMFRI, 2010).

### Cultivation of Halophytes

In coastal areas and mudflats near the sea, where the salinity does not allow farming of the usual food crops, plants that grow and flourish those conditions are advocated. One such plant is the sea asparagus, *Salicornia.* The plant grows well with maximum yields in hot climates if the seeds are sown in cool season so as to reach maturity during the hot months, (*www.hindu.com/seta/2003/09/05.htm*).

## STRATEGIES FOR EVOLVING ADAPTIVE MECHANISMS

In the context of climate change, the primary challenge to the fisheries and aquaculture sector will be to ensure food supply, enhance nutritional security, and improve livelihood and economic output, and ecosystem safety. These objectives call for identifying and addressing the concerns arising out of climate change; evolve adaptive mechanisms and implement action across all stakeholders at national, regional and international levels. In response to shifting fish population and species, the fishing sector may have to respond with the right types of craft and gear combinations, on-board processing equipments etc. Governments should consider establishing Weather Watch Groups and decision support systems on a regional basis. Allocating research funds to analyze the impacts and establishing institutional mechanisms to enable the sector are also important. The relevance of active regional and international participation and collaboration to exchange information and ideas is being felt now as never before.

## CONCERNS AND ADAPTIVE MECHANISMS

### Uncertainties in Fish Availability and Supply

- i) Adapt Code of Conduct for Responsible Fisheries
- ii) Develop knowledge-base for climate change impact of fisheries and aquaculture
- iii) Predict medium and long term probabilistic production
- iv) Assess the adaptation capacity, resilience and vulnerability of marine production systems
- v) Adjust fishing fleet and infrastructure capacity
- vi) Consider the synergistic interactions between climate change and other factors such as fishing

### New Challenges for Risk Assessment

- i) Consider increasing frequency of extreme weather events
- ii) Consider past management practices to evolve robust adaptation systems

iii) Identify and address the vulnerability of specific communities; consider gender and equity issues.

**Complexities of climate change interactions into governance frameworks to meet food security objectives**

i) Recognition of climate-related processes, and their interaction with others

ii) Action plans at national/regional level based on (a) Code of Conduct for Responsible Fisheries; (b) Integrated ecosystem-based fisheries and aquaculture management plans (c ) framework for expansion of aquaculture (d) linkage among cross-sectoral policy framework such as insurance, agriculture, rural development and trade

**Fisheries and aquaculture may be more vulnerable in conflicts with other sectors**

i) Action plans should involve not only fisheries institutions/departments, but also those for national development planning and finance

ii) Sharing and exchange of information with other sectors

iii) Existing management plans for fisheries need to be reviewed by considering climate change

**Financing climate change adaptation and mitigation measures**

i) Fishermen, fish farmers, processors, traders and exporters should increase self protection through financial mechanisms

ii) Improving equity and economic access such as microcredit should be linked to adaptation responses

iii) Investment of infrastructure such as construction of fishing harbor, should consider climate change issues

iv) Financial allocation in national budget for risk reduction and prevention practices such as early warning systems and disaster recovery programmes and for relocation of villages from low lying area

v) Fiscal incentive for reducing the sector's carbon footprint and other mitigation and adaptation options

vi) Full potential of existing financial mechanisms has to adapt and mitigate the issue of climate change.

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# Rice Based Farming Systems in Kerala

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## INTRODUCTION

It was a welcome change when the yearly decline in area and production of rice in Kerala could be arrested in 2008-09, with a marginal increase of 5000 ha, compared to the 2.29 lakh ha in the preceding year. This momentum however, could not be sustained subsequently as the area has further decreased to 2.13 lakh ha during 2010-11. During the past seven years alone, in spite of the special care and attention bestowed to increase the area and production of rice, fallowed wet lands increased by an estimated 0.8 lakh ha. The situation is alarming as a number of rice centric development activities brought out to make rice cultivation profitable and attractive could not fully retain the paddy farmers in their realm. The cropping intensity has also come down, with most of farmers opting for a single crop of rice which left the wetlands fallow for a considerable period annually. The primary cause of waning of interest in rice cultivation by farmers is its very low profitability.

## FARMING SYSTEM APPROACH

Increasing the income from rice fields by year round utilization of the farm land by a judicious mix of one or more compatible enterprises with rice can halt this negative trend in the rice production front. Livestock, fishery and duckery are some of the enterprises that are compatible with rice. Such systems ensure stability in farm income by minimizing risk since the low returns from one crop is compensated by the high returns from others. The peak and depressions in demand for resources including labour can be streamlined. It is a reliable way of obtaining fairly high productivity with substantial fertilizer economy capable of providing ecological soundness leading to sustainable agriculture. It further helps in maintaining soil health by sequencing rice and other enterprises over time and space, complimenting each other through effective recycling of wastes/ residues, which result in a well balanced productive environment.

### Integrating Rice and Livestock

Kerala has a very long tradition of integration of rice with other enterprises. Integrating paddy with livestock is the primary form of integrated farming system that existed from olden days. Prior to the fertilizer era, recycling of paddy straw and farmyard manure benefited both paddy and cattle. One or two cattle could be maintained with the paddy straw and green fodder available from an acre of paddy field. Livestock farmers depended paddy straw as the source of supplementary fodder especially during lean months. Similarly farm yard manure from homestead cattle was sufficient to meet the manure requirement of paddy. The shrinking of rice area from 7.5 lakh ha in the seventies to 2.1 lakh as on today had a negative impact on the cattle population. Effective integration of rice and livestock is necessary to rectify the fodder shortage and the soil health problems inflicting the paddy fields.

**Integrating Aquaculture with Rice**

*Pokkali* and *Kuttanad* are contiguous and together they constitute 75,000 ha of the coastal wetlands. They are interconnected low lying network of back waters, canals and streams, and are the basins of the rivers: *Periyar, Chalakudy, Muvattupuzha, Meenachil, Pampa, Achencoil* and *Manimala.* These two rice ecosystems can be considered as the two sides of the same coin separated by the *Thanneermukkom* salt exclusion barrier constructed to prevent the entry of salt water into the *Kuttanad* rice fields.

The *pokkali* farming system, which has been acclaimed as a sustainable model, is time tested and unique in several respects especially in its high efficiency standards in utilizing the natural resources and the exogenous inputs. The live feed generation by the disintegrating paddy stubbles intentionally left during the harvest of rice forms the basis of perpetual renewable bio-energic resources for the alternative production of rice and prawn in these wetlands. With the cessation of monsoon the sea water inundates the *pokkali* fields resulting a gradual change in water quality to saline, the intensity of which depends on the fresh water discharge from the up stream side. At the very same time, the *Thanneermukkom* barrier prevents the entry of salt water in to *Kuttanad* and hence, the water quality on either side of the barrier will be different, which necessitates cropping / farming system appropriate to the prevailing soil and water characteristics.

Crops and crop season of these two rice tracts are tailored to the soil and water quality parameters. In *pokkali* fields cultivation of rice is restricted to the low saline phase and as the field water shifts to the saline phase, prawn/ fishes are grown. In *Kuttanad* two rice crops are generally taken: the main season during October-March (*puncha*) and an additional crop subsequently. Rice cultivation in the beginning of the last century was done only once in two years, which became annual cultivation during 1940's and the intensification into double cropping began in the 1950's with the series of development interventions *viz.* spillways to drain off flood waters and barrage to ward off salinity incursion (Padmaja, et *al.*,1994). Though these development initiatives were aimed at increasing the cropping intensity by two fold, farmers in general opt for a single crop of rice taken either during the monsoon or *puncha* season depending on the prevailing physico- chemical properties of the soil, especially acidity and salinity.

***Rice-Fish/Prawn Integration in Pokkali Fields***

The *Pokkali* rice-fish/prawn integration has been dealt with by several workers (Purushan, 1987 and Rajendran *et al.*, 1993). Most of the workers have described the different aspects of the prawn filtration system, in which seed shrimps and fishes are allowed to enter into the post harvest *pokkali* fields through tidal water and then trapped for short term culture. Prospects of simultaneous culture of fish species *viz*., *Etroplus suratensis, Oreochromis mossambicus, Cyprinus carpio, Labeo rohita, Chanos chanos* and *Mugil cephalus* with the *pokkali* rice genotypes have been reported by Thampi (1993) and Rajendran *et al*. (1993). However the simultaneous rice-fish culture in *pokkali* fields did not get the popularity as that of the sequential rice-prawn culture.

Prawn filtration in *pokkali* fields starts after the harvest of rice with the strengthening of outer bunds and installation of sluice gates. Removal of weeds and desilting of canals, wherever necessary, are carried out for increasing the water holding potential (Rajendran, *et al*., 1993). Brackish water carrying the shrimp seed ingresses and egresses regularly at desired levels during high and low tides respectively. While regulating the entry and exit of tidal flow, a large mesh conical bag net or closely packed bamboo screen is suitably installed in the sluice gate. This process being repeated cautiously during each tide enables the shrimp and fish seed to get concentrated in the field (Purushan, 1986). The species auto stocked includes commercially important shrimps such as *Metapenaeus dobsoni, M.monoceros, Penaeus indicus* and *P.monodon*. These shrimps take shelter in between the decaying paddy stalks (Rajendran, *et al*., 1993), which release nutrients to the shrimps. A rich niche of forage organisms of phyto planktons and zooplanktons evolved from the decaying paddy stubbles forms the basis of the sustainable system of prawn culture. The shrimps attain a marketable size within 3 to 4 months period.

The actual harvesting of prawn starts by the middle of January coinciding with the lunar phase. When the water is let out of the fields, during low tide the prawn and fishes carried along with water and are collected in the prawn filtration net. Luring in of prawns continues simultaneously along with fishing until the end of March, when the fields are finally drained for taking up rice cultivation. The yield is about 800-to1000 kg $ha^{-1}$. Prawns constitute about 80 per cent of the catch. The spp. being *Metapenaeus dobsoni* (65 %), *M. monoceros* (10%), *Penaeus indicus* (22%) and P. *monodon*(3%) depending up on the season. Fishes comprises 20 percent of the harvest. The main spp. are *Oreochromis mossambicus, Etroplus suratensis*, *Mystus sp.,Lates calcarifer*, *Anabas testudineus*, *Megalops cyprinoides*, *Mugil sp*. etc. The species diversity is the strength of prawn filtration as it adds to the sustainability of this farming system. However, a higher volume of low value species dilutes the percentage of quality prawn like *Penaeus indicus* and *P. monodon* and the returns from prawn filtration under such circumstances will be less.

The traditional system of prawn filtration has now been refined to increase the percentage of shrimps preferably white prawn and tiger prawn which has very good market demand and premium price. Hence selective culture of desired prawn species and supplementary stocking of fast growing prawn species has almost replaced the conventional prawn filtration.

**Economic Viability:** The economic analysis of this integrated farming system brought forth its economic superiority also. Net returns (table 1) increased by

39 and 44% when VTL3 was replaced with cul. 1026 and 'Chettivirippu' mutant with corresponding increases in benefit: cost ratio. Cost of rice production under the *pokkali* system is generally lower than that of other rice ecosystems in view of the saving in fertilizer, pesticide, and herbicide costs (Sasidharan, 2006). Spatial integration of fish also did not increase the cultivation costs substantially as the *pokkali* fields already had deep inner channels. Removal of weed fishes, cost of fingerlings, and harvest operations were the items that required major expenditure. The low yield from rohu decreased the net returns and benefit: cost ratio while, male tilapia increased the returns by Rs. 4836 $ha^{-1}$. The most significant advantage is that the temporal integration of tiger prawn increased the cultivation costs by 163% and the returns by 203 % over rice+tilapia. Overall, temporal integration of tiger prawn rather than spatial integration of fish is the key for enhancing economic returns through integrated farming system in *pokkali* fields. Additional employment generation to the tune of 149 man days $ha^{-1}$ is yet another advantage of this system.

**Table 1**
**Economic analysis of rice-fish-prawn integration in 'pokkali' fields,**

| Farming system | Cultivation expenditure (Rs.*1000 $ha^{-1}$) | | | | Returns (Rs*1000 $ha^{-1}$) | | | | Net returns (Rs *1000 $ha^{-1}$) | Benefit: cost ratio | Additional employment generated (man-days $ha^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Main crop | Subsidiary crop | | | Main crop | Subsidiary crop | | | | | |
| | Rice | Fish | Prawn | Total | Rice | Fish | Prawn | Total | | | |
| **Rice alone** | | | | | | | | | | | |
| Vyttila-3 | 22.9 | -- | -- | 22.9 | 31.64 | -- | -- | 31.64 | 8.74 | 1.38 | 83 |
| Cul. 1026 | 22.9 | -- | -- | 22.9 | 44.14 | -- | -- | 44.14 | 21.24 | 1.93 | 83 |
| *Chettivirippu* mutant | 22.9 | -- | -- | 22.9 | 45.34 | -- | -- | 45.34 | 22.44 | 1.98 | 83 |
| **Rice-fish dual culture** | | | | | | | | | | | |
| Rice + Rohu | 22.9 | 12.5 | -- | 35.4 | 45.34 | 2.04 | -- | 47.38 | 11.98 | 1.34 | 113 |
| Rice + Male Tilapia | 22.9 | 12.5 | -- | 35.4 | 45.34 | 17.35 | -- | 62.69 | 27.29 | 1.77 | 113 |
| **Rice-fish-prawn integration** | | | | | | | | | | | |
| Rice + Tilapia followed by prawn | 22.9 | 12.5 | 58 | 93.4 | 45.34 | 17.33 | 127.5 | 190.2 | 96.78 | 2.03 | 149 |

*Source: Sasidharan (2004)*

### *Selective Culture of Quality Prawn*

Selective culture of tiger/white prawn after preparing the field is an improvement over this traditional practice of prawn filtration (Pillai, 1999). The native fish population in the fields is completely eradicated. Stocking with desirable prawn seed at desired stocking density and other cultural operations are done to get higher yields. Farmers opt for fast growing species and artificial feeds, which enhances the prawn yield and the production cost. The risk of crop failure is also high when the intensive farming techniques like higher stocking density and feeding with commercial feed formulations are resorted to. Perennial prawn culture system with out rotational rice is also being practiced by many. Monoculture of prawn with out rotational rice can erode the sustainability base of this system, since the live feed generation, which enhances the species diversity of this agro-eco system is totally ignored.

Selective culture of prawn with out supplementary feeding is seldom practiced. A yield of 425 kg $ha^{-1}$ of prawn under selective culture, when fed with the live feed generated in the Pokkali fields is reported (Sasidharan, 2004). Average weight gain of 15.9 g in 50 days and 20 g at harvest in 74 days after stocking could be observed as given in table 2.

**Table 2**
**Performance of Tiger prawn under selective culture in pokkali fields**

| Growth parameters | Range | Mean |
|---|---|---|
| Length after 50 days (cm) | 10.2 – 15.0 | 10.9 |
| Weight after 50 days (g) | 10.0 – 22.0 | 15.9 |
| Length at harvest (cm) | 15.8 – 19.3 | 18.2 |
| Weight at harvest (g) | 17.0 - 35.0 | 20.0 |

### *Rice Cum Fish Culture*

Integrated fish culture along with rice is feasible in *pokkali* fields. Most of the *pokkali* fields have peripheral channels, which are invariably required for the rice- fish dual culture. The depth of the channel may vary from 50 – 75 cm and the width from 100-200cm. The channels provide a safe habitat for fishes particularly during the low tide. A sluice with shutters facilitates exchange of water and regulation of water level, a removable net screen is provided in the sluice to prevent the escape of cultured fishes and the entry of undesirable organisms. The eradication of weed and undesirable fish can be achieved by applying bio-pesticides like mahua oil cake. Rice varieties and fish species with in the allowable tolerance limit for salinity alone are selected for culture in *pokkali* fields. Rice varieties either tall or semi tall that can thrive under flooded condition are more desirable (Thampi, 2002). When traditional tall varieties like *Pokkali* are grown they prevented light penetration and thus the plankton production in the rice field. (Rajendran *et al.*,1993). Rice varieties of varying morphological characters were evaluated for their compatibility with fish species under simultaneous rice-fish regime. Semi tall compact varieties permitted significantly more light to reach the floor of the *pokkali* fields. These varieties could give significantly higher grain yield than the traditional tall varieties (table 3). However, the straw yield for such varieties is significantly less compared to the traditional tall varieties like Vytilla-3.

**Table 3**
**Performance of rice cultivars in simultaneous rice – fish dual culture.**

| Cultivars | Height (cm) | Light intensity (lux) | Yield ($kgha^{-1}$) | | |
|---|---|---|---|---|---|
| | | | Grain | Straw | Biomass |
| Vyttila-3 | 182.2 | 925 | 3056 | 7186 | 10241 |
| Cul-1026 | 130.1 | 1625 | 3726 | 4724 | 8451 |
| *Chettivirippu* mutant | 117.4 | 1597 | 4396 | 5215 | 9611 |
| C D (.05) | 7.2 | 185 | 238 | 724 | 1357 |

*Source: Sasidharan et al. (2004)*

The fish fingerlings are stocked immediately after the dismantling of mounds and spreading of seedlings in *pokkali* fields. Fish culture is continued even after the rice harvest, when the salinity may rise to higher values, in which case it is necessary to select species, which are euryhaline. Several attempts were made to identify species capable to withstand the harsh conditions existing in *pokkali* fields. Rajendran et al. (1993) opined that the candidate species must be capable to withstand anoxic condition in field water during the post harvest decay of rice stubbles. Fast growth rate to get marketable size within the short cultural period was another criterion. Thampi (1993) identified *Cyprinus carpio, Oreochromis mossambicus, Trichogaster pectoralis, Chana striata and Clarius bratachus* as suitable species for the simultaneous culture. Among the three species, tried Sasidharan (2004) identified *Oreochromis mossambicus* as the most suitable species (table 4).

**Table 4**
**Performance of fish species in simultaneous rice – fish culture.**

| Fish spp. | Survival (%) | Fish yield ($kgha^{-1}$) | Mean length (cm) | Mean weight (g) |
|---|---|---|---|---|
| Etroplus | 0.0 | 0.0 | 0.0 | 0.0 |
| Rohu | 16.0 | 25.4 | 10.7 | 79.7 |
| Male tilapia | 37.6 | 216.7 | 20.9 | 139.1 |
| C D (0.05) | 3.8 | 21.8 | 0.6 | 16.8 |

*Source: Sasidharan et al. (2004)*

The utility of *Oreochromis mossambicus* as a suitable component of the rice-fish integrated farming system was amply illustrated by Rajendran *et al.* (1994). Its profuse occurrence, prolific breeding and shadowing effect on other species were dealt by Purushan(2002), while the possibilities of hormonal sex reversal and mono sex culture as remedial measures have been reported by Roy (1998).

The soil chemical characters after the prawn harvest denoted desirable changes in pH, organic carbon, available P and available K. The electrical conductivity and the available sodium however, registered considerable increase compared to the soil characters after the rice harvest (table 5).

**Table 5**
**Soil chemical characters after fish and prawn harvest in pokkali fields**

| Soil chemical characters | After prawn harvest | |
|---|---|---|
| | Range | Mean |
| PH | 5.70 – 6.20 | 5.80 |
| Electrical conductivity (ds $m^{-1}$) | 6.10 – 8.90 | 8.00 |
| Organic carbon (%) | 2.43 – 3.17 | 2.78 |
| Available P (kg $ha^{-1}$) | 10.60 –15.10 | 11.90 |
| Available K (kg $ha^{-1}$) | 314 – 1299 | 463 |
| Available Na (kg $ha^{-1}$) | 3564 – 13440 | 5484 |

*Source: Sasidharan et al. (2004)*

***Oru Nellum Oru Meenum Model***

Padmakumar (2006) reiterated the importance of integration of fish along with rice in *Kuttanad* especially for sustaining rice cultivation. It has observed that in addition to rice production ranging from 1.7-to 4.2 t $ha^{-1}$, fish production of 383 to 600kg $ha^{-1}$ over a period of 210 to 220 days could be obtained under a simultaneous farming regime. As observed from the subsequent studies, rice - fish rotational farming model was found more advantageous as it permitted adoption of management practices more effectively for rice and fish.

The general species mix and stocking model evolved comprised 20 per cent surface feeders, 30 per cent column feeders, 40 per cent bottom feeders, and 10 per cent macro vegetation feeders. Common carp and grass carp were found to be versatile species suitable for culture in paddy fields along with other carps. Multi size stocking of each species of fish was also found useful.

The one rice one fish model improved the biological potential of rice fields since the stubbles left after harvest decomposed and provided shelter and feed for the growth and development of live feed, which formed ideal food for fish. In an on farm trial rice fish rotation yielded fish production as high as 2500 kg $ha^{-1}$. This observation indicated that fish could attain much higher growth when left to grow in larger impoundments even under an extensive farming system (Padmakumar *et al.*, 2003). The complementary effect of fish on rotational rice is quite evident on land preparation, manuring, pest incidence and weed control (table 6). The sustainable rice yields obtained during the later years in the farmer managed trial (table 7) point out the complementary effect of fish on rice yield.

**Table 6**
**Effect of rice-fish integration on cost of production of paddy in Kuttanad**

| Item | Before fish integration | | | | After fish integration | | | |
|---|---|---|---|---|---|---|---|---|
| | 1995 (Puncha) | | 1995 (Virippu) | | 1995 (Puncha) | | 1995 (Virippu) | |
| | Cost (Rs.) | | Cost (Rs.) | | Cost (Rs.) | | Cost (Rs.) | |
| | Material | Labour | Material | Labour | Material | Labour | Material | Labour |
| Expenses | | | | | | | | |
| Land preparation | 0 | 1483 | 0 | 2238 | 0 | 634 | 0 | 486 |
| Bunding | 0 | 472 | 0 | 575 | 0 | 606 | 0 | 790 |
| Seeds & sowing | 808 | 101 | 842 | 108 | 876 | 108 | 1021 | 115 |
| Weeding | 76 | 3198 | 76 | 3631 | 0 | 1460 | 0 | 3013 |
| Plant protection | 381 | 270 | 393 | 324 | 232 | 229 | 66 | 103 |
| Manuring/Liming | 2008 | 298 | 2376 | 342 | 2200 | 319 | 2581 | 510 |
| Other inputs | 346 | 894 | 371 | 1050 | 393 | 1062 | 0 | 1465 |
| Harvesting | 0 | 427 | 0 | 674 | 0 | 685 | 0 | 642 |
| Total | 3619 | 7143 | 4058 | 8942 | 3701 | 5103 | 3668 | 7124 |
| **Income** | **Quintals** | **(Rs.)** | **Quintals** | **(Rs.)** | **Quintals** | **(Rs.)** | **Quintals** | **(Rs.)** |
| Paddy | 19 | 8967 | 28 | 14812 | 34 | 17144 | 35 | 17938 |
| Straw | 0 | 371 | 0 | 449 | 0 | 225 | 0 | 309 |
| Total | 19 | 9338 | 28 | 15261 | 34 | 17369 | 35 | 18247 |
| Profit | (-) 1405 | | 2289 | | 8599 | | 7490 | |

*Source: Padmakumar et al., 2003*

The effect of fish integration on cost of production of rice in farmers participatory trials is illustrated in table 6. The integration helped to reduce cost of production of rice appreciably by 17.6 percent during the first year besides increasing yield by 52 per cent. Although varying levels of yield in rice have been reported by fish integration the average increase in such cases was always over 15 per cent. Indirect control of pest and diseases resulted in substantial reduction in cost on plant protection. A perceptible reduction in weeding cost by 32.7 per cent and a saving of 100 per cent on weedicide was also observed. It is evident that the integration not only helped to reverse the up trend in cost of production of rice but also contributed to increase in yield of both fish and rice.

The ecological effect of rice fish integration is more convincing due to the reduction in agricultural chemicals, especially in weedicide and other hazardous plant protection chemicals (table 7). The perceptible improvement in the soil condition had favourable effect by the recycling of the nutrients and energies, which render the rice ecosystem more organic and environment friendly.

**Table 7**
**Evolution and spread of rice based farming system models in Kuttanad**

| Year | Farming System | Yield (kg/ha) | | Cost of Production (Rs./ha) | | Net returns (Rs./ha) | | | Total return (Rs./ha) |
|---|---|---|---|---|---|---|---|---|---|
| | | Rice | Fish | Rice | Fish | Rice | Fish | Others | |
| **On Station Research** | | | | | | | | | |
| 1986-87 | -do- | 1757-4208 | 383-600 | 4715 | 3535 | 990 | 6065 | -- | 7155 |
| 1987-88 | Rice-Fish rotational | 2100-4208 | 538-1000 | 4715 | 3535 | 2910 | 12465 | -- | 15375 |
| **On farm participatory trial** | | | | | | | | | |
| 1996-97 | Rice-Fish rotational | 2625 | 1140 | 8073 | 22896 | 5216 | 7878 | 4419 | 17513* |
| 1997-98 | -do- | 3219 | 1289 | 10211 | 20966 | 6091 | 12234 | 5732 | 24057** |
| **Farmer managed trials** | | | | | | | | | |
| 1995-96 | Rice mono-cropping | 2338 | -- | 12013 | -- | 859 | -- | -- | 859 |
| 1996-97 | Rice-fish rotational | 3563 | 347 | 10925 | 3350 | 8716 | 6453 | -- | 15169 |
| 1997-98 | -do- | 4105 | 673 | 11780 | 11403 | 13350 | 8460 | -- | 21810 |
| 1998-99 | -do- | 4178 | 1643 | 8563 | 21683 | 17915 | 18610 | -- | 36525 |
| 1999-00 | -do- | 3988 | 1265 | 10463 | 21995 | 15090 | 13270 | -- | 28360 |
| 2000-01 | -do- | 4058 | 815 | 9638 | 14823 | 17443 | 7898 | -- | 25341 |

** includes net returns from rice, fish, pig and cattle*
*** includes net returns from rice, fish, pig, poultry, banana and pineapple*
*Source: Padmakumar et al. (2003)*

### *Integrating Giant Fresh Water Prawn with Rice*

This system of integrating the *kuttanadan konchu* (*Macrobrachium rosenbergii*) is almost similar to the rotational integration of rice and fish. This is particularly suited to small holdings. The main drawback is that for the successful integration of this fresh water prawn weed fishes and predatory fishes are to be removed before its stocking (Padmakumar, 2006). This is not feasible in the majority of the larger polders in *kuttanad.* The prawns are incapable to facilitate the indirect complimentary services like weed control and tilling of the soil as done by fishes. Hence a combined culture of fishes and giant fresh water prawn is more advantageous to fetch these indirect benefits.

## BIODIVERSITY BASED FARMING SYSTEMS IN KUTTANAD

*Kuttanad* is the rice bowl of Kerala. All development activities on *Kuttanad* therefore have rice on the centre stage. Similar to rice, ducks of Kuttanad: *chara, chempalli,* the giant water prawn: *kuttanadan konchu,* vechoor cow; the state fish of Kerala: pearl spot etc thrives well under this unique agro ecological condition. The rich biodiversity base of *Kuttanad* has never been considered while, chalking out development strategy for the region. Hence the environmental consequences of rice centric developmental interventions were disastrous. Emergence and proliferation of new aquatic weeds, fall in fertility status of soil, resurgence of pests and diseases, indiscipline in rice cultivation practices and non-judicious use of agro-chemicals resulting environmental hazards, which arose out of the increased rice intensification etc. were the new problems surfaced (Padmakumar *et al.*,2003). It is further observed that all the economic interventions intended to boost the rice production were becoming not only ineffective but also positively counter productive, which resulted in waning of interest of farmers in rice cultivation.

The need for a farming system approach utilizing the rich biodiversity base of the region was felt. Research work on models suited to the *kuttanad* rice ecosystem was initiated at the Regional Agricultural Research Station, Kumarakom. In the laboratory model developed initially, the possibility of integrating fresh water fish and prawns along with rice was evaluated under a simultaneous farming regime. The development of these models, their evaluation at the on station and on farm levels, its transformation from simultaneous to rotational system and its lateral diffusion from scientist managed to farmer managed trials over a period of two decades are illustrated in table 7.

## MULTILEVEL INTEGRATION OF CROPS AND COMMODITIES

The income per unit area can be further increased by integrating additional components of buffaloes and duck which flourishes well under the *Kuttanad* condition. The multi level integrated farming system model laid out at the Regional Agricultural Research Station, Kumarakom has rice, fish, duck and buffaloes as the major enterprises. Banana, cassava, fodder, tuber crops and coconut forms the secondary crop components that are grown on the dikes. It has been established that a batch of 250-300 ducks provide enough manure to feed one ha of fish pond yielding 3.5- 4 t/ha fish meat .In this method housing for duck is constructed over the field to facilitate the droppings fall directly to the field. This system has a carrying capacity to accommodate two buffaloes/ha as well. The animals which are kept out of the field during the rice season are allowed to graze during the post harvest period. The annual income from a multi commodity integrated system will be four fold as that from the monoculture system of rice. The total returns obtainable from a multi level integrated rice field will be Rs. 2.5-3.0 lakh/ha. The complementary and supplementary effect on recycling the wastes/ residues, production cost, soil health, environment, carbon emission and sequestering etc are the other bonus points.

## CONCLUSION

The agro-ecological conditions as exists in the wetlands of Kerala are not fully suitable for monoculture systems. In order to get sustained yield, application of external inputs in increased quantities is done year after year. But this does not end up with desired results. Such efforts always erode the biodiversity base and upset the ecological balance. A biodiversity based farming system integrating multi commodity enterprises suited to local agro-ecological conditions can safeguard the socio- economic interest of the farmer. By ensuring the beneficial role of the auxiliary enterprises on stabilising the farm income, rice can be retained as the pivotal crop in the wetlands.

Recycling of byproducts, agro-wastes and residues can significantly reduce the use of high energy inputs like feed and fertilizer. Complementary effects of the components in the integrated system reduce the frequency of field operations like ploughing and weeding. All these process are conducive for reducing carbon emission and its sequestering in soils and plants. Considering all these advantages the wetlands of Kerala have to shift to a biodiversity based integrated farming system mode from monoculture systems of rice or shrimp.

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# Agriculture and Environment of Kerala: Kuttanad Below Sea Level Farming System (KBSFS) and A Plan for its Sustainable Management

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## INTRODUCTION

Farmers of Kuttanad developed and mastered the spectacular technique of below sea level cultivation, which has several similarities with the Dutch polder system, over 150-200 year ago. They made the agriculture and environment of Kuttanad unique as it contributes remarkably well to the conservation of biodiversity and ecosystem services including several livelihood services. The major land use structure of Kuttanad Below Sea Farming System (KBSFS) is flat stretches of rice fields in about 50,000 ha, of mostly reclaimed delta swamps that exist in three landscape elements: *Karapadam* (upland rice fields), Kayal (wetland rice fields) and Kari (land buried with black coal like materials). Traditionally KBSFS favoured only one crop of paddy followed with inland and estuarine fish wealth, notably the endemic prawn species, pearl spot and clams. The Puncha Vayals with coconut gardens on the bunds and criss-crossed water canals offer an amazing sight.

FAO has now recognized KBSFS as a *Globally Important Agricultural Heritage System*. The recognition of this unique farming tradition instigated a pride amongst the local communities and bestowed more inspiration for conservation and enhancement of this Heritage. Globally important agriculture heritage status for this distinctive system necessitates revitalization of some of the vital conservation and enhancement actions of the past that are relevant to address the concerns of sustainable food security, climate change adaptation and ecosystem services management at local level.

## AGRO BIODIVERSITY OF KBSFS

The unique ecological environment of the KBSFS and the entire Kuttanad region supports a wide variety of agrobiodiversity and wild biodiversity. The major agrobiodiversity of the region and that associated with the system can be classified as follows:

- *Mixed agro-ecosystems* such as backwaters, rivers, vast stretches of paddy fields, marshes, ponds, garden lands, edges, corridors and water ways-the characteristic feature of Kuttanad Wetland Agricultural Landscape.
- *Crop species and varieties*, largely of Rice. (Now only the released varieties-Jyothi and Uma. In the past puthari champavu and jeeraka champavu)
- *Livestock and fish diversity* The difficult water terrain in the system doesn't favour larger livestock. Ducks, poultry and enormous amount of fish diversity are prominent in the System. A traditional breed of buffalo has been reported.
- *Plant and animal germplasm* (of food and medicinal value like several edible wild greens and healing herbs). The delicacy like meat of turtle, frogs and different species of birds is still said to be available, though it is legally banned);
- *Insects, pests and fungi* (Enormous diversity of harmful ones available now, especially after practice in high intensive farming)
- *Soil biodiversity, microbes* (not much known)

The agrobiodiversity of the system is valued by the local communities largely for the production and consumption of their food, drink and for healing purpose and livelihood needs. Traditional diet included primarily rice, fish, prawns, crabs, mussels, duck meat, coconut and cassava. Abundant availability of these resources had been ensured through sustainable management of the various landscapes, ecosystems and biodiversity in the past.

**WILD BIODIVERSITY OF KUTTANAD**

The wild biodiversity of the region is indeed rich as it ranges from mixed wetland ecosystems to the associated above ground and below ground flora, fauna and microbial diversity. An enumeration of species of mangroves, mangrove associates, fish and birds of Vembanad wetland is given in the Ramsar Information checklist. The aquatic species include 24 spp of green algae, 10 blue green algae, one species of yellow brown algae, 13 desmids and 19 diatoms. There are reports of 202 angiosperm species, which include 14 mangroves and 30 mangrove associates, and 8 species of pteridophytes are reported from the region (Bijoy and Unnithan 2004). The 11 km long stretch of mangrove vegetation still found close to Kumarakom and supports a diverse array of mangrove and mangrove associates. Pathiramanal Island of the region is reported to be a sanctuary for several species of mangroves, birds and fish species.

The region is a large repository of migratory fish species and birds. A bird count in 2009 listed out 27942 birds belonging to 56 wetland and wetland associated bird species (Sreekumar 2008). The Kayal is home to the third largest population of more than 20,000 waterfowls that visit India during winter. Endangered species of waterfowl that have been identified from the region are: spot billed pelican, oriental darter, water cock and black billed tern. The region is an ideal habitat for variety of finfish, shellfish, and several varieties of prawns, black clams, white clams and shrimps. Many fish species are reported to be depended upon the wetland for food, spawning and nursery.

**GOODS AND SERVICES PROVIDE BY KBSFS**

**Environmental Goods**

***Kuttanadan Rice***

Rice cultivation is the foremost land use of the region. Though in Kerala, as a whole there is an alarming decline of rice crop, which accounted for more than 60% of the fall in rice cultivation area in the last 40 years, there is no much reduction in the Kuttanad region, thanks to the region's unique geography and the environment for rice cultivation. The rice cultivation area of Kuttanad shares about 25 % of the State's total rice production area and contributes nearly 37 % of the rice production of the state. Owing to its primacy in rice area and production, Kuttanad had been long time referred as "The Rice Bowl" of Kerala.

***Kuttanadan Fish Wealth***

Kuttanadan Agricultural Landscape, including the Puncha Rice System that surrounded with estuaries, flood plains, Kayals, ponds and canal networks known for its diverse fish wealth. Vembanad Fish Count 2009 identified 65 species of fin fish and 14 species of shell fish from the region (ATREE 2009).The wetland environment with changing salinity gradient and water levels because of cyclic shift in fresh water and saline water phases contributes to the richness and occurrence of fish and other aquatic diversity in the region. The fresh water environment closer to rice fields and the canals provide abundance of Pearl spots, perchlets, fresh water giant prawns (Attukonju) and freshwater catfishes during most part of the year, whereas it was reported the estuarine species dominate in Kayals that are closer to the sea.

Giant freshwater prawn (*Macrobrachium rosenbergii),* which grows up to the size of 40 cm and locally known as Kuttanadan konchu or Attu konchu is a highly valuable species of Vembanad lake, which provide a lucrative fishery for the region The total annual production of this species in 80's was reported as 100 tons per annum. Karimeen, the Pearl spot, another major delicacy of Kuttanad has got the status of Kerala's state fish. Kuttanad region is considered as the tharavad (family home) of this fish.

In normal course, the species count of migrant fisheries will be of maximum during summer from February to May with a peak observed in April, and declined with the onset of monsoons. Mullets (marine migrant species) migrate to the sea to spawn during December to April and large numbers of young ones return to the Kayal soon after monsoon breaks. The Mullets (marine migrant species) and penaeid prawns breed in the sea and return to the lake with large numbers of juveniles, mostly during the pre-monsoon and after monsoon breaks.

It has been reported that over the last thirty years, the fish diversity has reduced from 150 spp. to 36 spp. and many are reported as critically endangered or even extinct in the region (Padmakumar et al.1988). Some of the endangered fish species of the region are: the endemic carp of Central Travancore, Labeo dussumieri (Tooli/Pullan), the esteemed golden catfish of Kuttanad, Horobagrus brachysoma (Manjakoori), the riverine coldwater fish, Gonoproktopterus curmuca (Kooral), Wallago attu (Attuvaala), the glass perch, Parambassis dayi (Nandan), Macropodus cupanus, and Nandus nandus (Andikalli). The highly threatened endemic species in the fresh water reaches include Channa micropeltes (Manal waaha), C. leucopunctatus (Puliwaaha) Pristolepis malabaricus (Pannakarimeen), Ompok bimaculatus and Clarias dussumie (Mushi).

### *Kuttanadan Clam and Live Shell Fisheries*

Four species of Clams (Villoritta cyprinoids, Meretrix casta, Paphia malabarica and Sunetta scripta) are reported from the region, in which Black clam (Villoritta cyprinoids) is found in all sides of the lake and its harvesting for meat is still an important livelihood option for the poor families of the region. Its production was estimated about 31430 tonnes in 2000. The abundance of the clam used to be more in the intertidal zones where it was reported in dense forms.

Large quantity of lime shell deposits (white clam) is a characteristic feature of the Vembanad Lake and the inner Kayal regions. These shells are commercially dredged for Cement industries and also harvested as a means of livelihood of the people. Ravindran et al (2006) reported annual production of 30,000-40,000 tonnes of black clam and more than 7000 tonnes of fish, shellfish from the region. They calculated approximately 20,000 fishermen are directly or indirectly involved in the exploitation of the aquatic resources and annual revenue of Rs.100 million.

### *Kuttanadan Rice-fish Rotation Farming*

Rice –fish rotation is an emerging practice of the system, as double cropping of rice turned to be less lucrative and more damaging to environment (Padmakumar et al.1988). The second crop (March to October) is now taken for rearing of fish (various carps) and prawns and reported good yield, particularly in those fields cultivated less intensively with chemical fertilizers and pesticides. The rotation also helps in not only getting high yield for the rice, but less disease and pest problems for the crop.

### *Kuttanadan Duck Farming*

The ideal condition of the system allows Duck farming in a promising way. Immediately after harvesting the rice, ducks are brought in even from distant places to the fields. It mutually benefits the duck rearer and rice farmers. Famous local breeds of Kuttanadan duck are: Chara and Chempalli. The introduced breeds are Kuttanadan White, White Pecking and White Muscovi. There is now recommendation for evolving a new Kuttanadan Broiler variety by a 3-way crossing between Kuttanadan White, White Pecking and White Muscovi (Hali et al., 2009).

### *Kuttanadan Coconut Gardens*

The narrow strips of bunds of reclaimed lands are planted with long stretches of coconut palms (Kera). In garden lands coconut based agroforestry is followed where the palm is grown integrated with fruit trees like mango, jack and roots and tubers like yams and taros. The palm is also used for tapping toddy, which is another attraction of the region. Toddy gives flavor to the traditional Food basket of people of Kuttanad that included four major items- Kizhangue (tuber, mainly cassava), Karimeen (pearl spot), Konju (Giant freshwater prawn), Kakka (clams), and Kallu (toddy). Apart from the immense economic importance of this crop, its presence everywhere from small and marginal farm holdings add profound scenic beauty to the region.

### *Kuttanadan Clay and Bushes*

Clay of Kuttanad is a key resource for the people, not only for building land for them or making bricks for their housing or rice production, but also as a healing material for their wounds and cuts. They had the habit of using deep mined clay for healing their small wounds and cuts. Herbal medicine known for poisonous bites is still popular in the region. The plant and animal diversity present in the bushes in isolated patches and water are employed in various ways for their food and agricultural needs. Abundantly grown screw pines and a sedge Typha in the region offer enough raw material for Mat weaving – a livelihood option for the women in earlier days. It is a fast fading tradition now along with many other natural and bio-resource dependant heritage practices.

### *Environmental Services*

The geographic feature and complexity of the area and position of agricultural landscapes below mean sea level makes its environmental services exclusive. The major ecosystem services of the system, apart from agriculture and inland fisheries are water supply, health and sanitation, transportation, recreation and conservation of biodiversity and the crucial regulating service it plays in the control of the hydrology of the entire region. The hydrological relationship between the various matrices of the system landscape and its sources of surface and ground water plays a significant role in controlling flood during monsoon and drought in summer season. The importance of interconnectedness of the hydrological cycle and its positive impacts, unfortunately not being taken into consideration while implementing the various development packages in the region.

## SUSTAINABLE MANAGEMENT OF KBSFS

The KBSFS Management Plan needs to be looked into establishment of an enabling *social, economical*, and *physical* environment that revitalize and enhance local community heritage in the areas of conservation of biodiversity and ecosystem services of the region. This can be achieved by educating and training the key stake holders of the system in the fundamental concepts, knowledge, and skills in salinity water management, sea water farming, sustainable livelihoods and adaptation mechanisms to changing climate. The overall objective of such kind of a Plan should be improvement of livelihoods of farmers and the fisher communities of Kuttanad through a continuum of 4C components such as *conservation, cultivation, consumption* and *commercialization* pertaining to their agriculture, fisheries and other livelihood options. Some of the specific sub objectives that can be envisaged are:

- Education of farmers and fisher communities to enhance their knowledge-base and capacity in integrated land and water management focussing (i) polder system of landscape building and management of sea water intrusion; (ii) below sea level farming, and (iii) sustainable garden-land agriculture and fisheries through participatory research approaches (*Education and Training oriented*);
- Development of sustainable livelihood options by maximizing the production of rice cultivation and fisheries and bringing back the *rice- bowl* status of this region by finding opportunities for utilization of modern technologies for the community members, particularly youth in processing and value addition in rice, fishery and other agricultural produces. (*Livelihoods and Development oriented*);
- Undertaking scientific research on the issues and problems related to three high priority topics (i) below sea level farming and the related area of water resource management pertain to both inland and sea waterscapes; (ii) *integrated fisheries inclusive of prawn culture* and (iii) specially focused research on Climate Change scenario analysis in relation with the hydrology, biodiversity, water and landscape management and agriculture (*Research, Documentation & Policy oriented*).

**Action Plan for Achieving the Objective of Education and Training**

The major intervention to achieve this objective is establishment of a fully functional world class Training Institute for bringing a critical mass of scholars from different disciplines to undertake training and capacity building initiatives in the focal areas of sustainable management. Following 3 functions are identified for this training Institute.

1. Extend gender friendly and user friendly trainings to adults and youth members of Farming and Fisher communities and their representative institutions like PRIs, NGOs and CBOs on the application of sustainable agriculture and sustainable livelihoods focusing on sea water farming, in-land fisheries and water pollution management;
2. Assist farmers and fishermen in coping with climate risks by providing weather services, agro and fishery advisories, improved water and land management practices and community managed initiatives like seed-grain banks, fodder banks, aqua banks and water banks through village knowledge centres and bio-village initiatives;
3. Convene international training courses in the areas of Below Sea level Farming for the practitioners and researchers, particularly of Asian countries and organizing communication, education and public awareness through lectures, exhibitions, national and international symposia and workshops.

**Action Plan for Achieving the Objective of Livelihoods and Development**

Creating an economic stake in conservation is an important strategy to promote sustainable income generation in villages and revitalize the heritage. Applied Research into this direction supported with new bio-chemical explorations to value-chain studies and policy initiatives may form a high priority task. Undertaking activities related to income security of the local farming communities through market-driven eco-enterprises including capitalization on the world-known back water tourism of Kuttanad are very important.

Some of the priority activities to achieve this objective are:

1. Launching of ***Bio-Enterprises* Initiative** by establishing Demonstration Villages, Aqua Parks and Bio Parks for sustainable utilization of targeted resource such as rice, coconut and fish (including prawn) in cooperation with appropriate government, non-government and academic institutions. These could be spread out in strategic locations of the region- one at Lower Kuttanad one at Central Kuttanad and one at Upper Kuttanad region.
2. Enlarging the markets for traditional foods and herbal products through Cooperatives/ SHGs and by finding niche markets, by promoting brand names where appropriate. It is heartening to note that the traditional Food basket of people of Kuttanad included six major items- Kizhangue (tuber, mainly cassava that cultivated locally is far superior in cooking quality and taste), Karimeen (pearl spot), Konju (Giant freshwater prawn), Kakka (clams), Karikku (tender coconut) and Kallu (toddy);
3. Promoting organic farming methods of cultivation and linking the organic rice, coconut, fish/prawn and medicinal plants with value-added marketing techniques such as adoption of market-accepted certification procedures.

**Action Plan for achieving the objective of Research, Documentation and Policy Development**

Undertaking scientific research and bringing out high quality results on the issues and problems related to three high priority topics (i) below sea level farming and the related area of water resource management pertain to both inland and sea waterscapes; (ii) *integrated fisheries inclusive of prawn culture* and one rice –one fish cultivation*; (iii)* Climate Change scenario analysis in relation with the hydrology of the region, biodiversity, water and landscape management and agriculture.

Following are some of the required activities.

1. Facilitate establishment of a Heritage Museum for Kuttanad Agriculture by exhibiting all the known tools and equipment and demonstration of the earlier agricultural practices. Producing technical and popular multi-media publications related to the activities of KHA for example the Kuttanadan folk songs and arts for public reference will also be a major activity component;
2. Extending Consultations and Policy advocacy to public organizations and community institutions and policy makers respectively in the operational process of coastal area sustainable agriculture with focal themes of coastal agriculture/fisheries and climate risk management.
3. Facilitating formation of networks and collaborations with organizations and departments of public and private sector and community institutions for discussions, meetings and policy dialogue etc;

## CONCLUSION

It is imperative to have an understanding of the interconnectedness of the issues related to KBSFS in a holistic manner from the level of landscape structure and relationship to land use management and practices. Such plane of understanding is crucial for making any wetland agricultural production system more resilient and sustainable. The suggested study and interventions can show the best possible integration of scientific and local community knowledge and practices and yield some meaningful results for bio resource management and climate risk adaptation as well as long term benefits to the society.

The existing major Institutions in sustainable agriculture and waterscape management of KBSFS need to be strengthened and supported in funding, human resources and research directions. Once the activities listed out are implemented with appropriate administrative and monitoring mechanisms it would be possible to bring back the KBSFS to its past glory. An Action Council needs to assume the role of a spear header of the entire mission and function as a professional platform to undertake and promote research and capacity building initiatives in the focal areas of heritage revitalization. This Council should strongly advocate for promoting 'sustainable wetland agriculture development' of the state through active involvement of youth and adults in on-farm and non-farm livelihood interventions including community centric water tourism and suitable bio-resource and water based sustainable enterprises.

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# Homegardens as a Distinct Agro-Ecological Entity in Kerala

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## INTRODUCTION

Kerala Homegardens represents a distinct agro ecological entity typical of tropical South Indian, where interaction and intimate association of different production components (crop-tree-animal mix combine) *insitu* are intensively facilitated and managed by family labour so as not only to meet the food production and to generate additional income through sale of farm surplus, but also a subsistence land-use system that is of huge significance to the environmental sustainability and dynamicity of Kerala. Homegardens in Kerala which started as a means of subsistence have today transformed into a means of additional income generation. These systems developed over years have optimized their production activities that satisfies the biophysical needs, socioeconomic security and environmental requirements in which they live. (Thomas, et. al. 2011).

## HOMEGARDENS, ITS BIODIVERSITY AND STRUCTURAL DYNAMICS

Home gardening is a very old tradition that has evolved over a long time from the practices of the hunters/gatherers and continued till now. It started as a system for the production of subsistence crops for the household with or without the involvement of cash crops. For example, a prominent structural characteristic of earlier home gardens were the great diversity in life forms - varying from those creeping on the ground, such as sweet potato to tall trees of 10 m like coconut palm, bamboo poles or other multipurpose tree species along with some livestock components, birds or domestic animals. In such a system, the structure and function is very significant and of conspicuous nature. The forest-like structure has been the result of deliberate planning of home garden to mimic the forest, which has its own techno-socio-economic implication. To conceptualize the structure of homegardens, the bio diversity of South Kerala home gardens was quantified using Shannon-weiner diversity index (Sagar and Singh, 1999) for three different regions in the homegarden viz., 'Courtyard', 'Mid region', and 'Outer region' (Thomas, 2004) and the diversity index in relation to different regions are shown in table 1.

**Table 1**
**The diversity index of south Kerala homegardens in relation to the different regions**

| Region(S) / District (D) | Courtyard | Mid region | Outer region |
|---|---|---|---|
| Thiruvananthapuram | 1.040 | 2.150 | 1.642 |
| Kollam | 1.784 | 1.995 | 1.324 |
| Alappuzha | 0.608 | 1.905 | 1.714 |
| Pathanamthitta | 1.148 | 1.865 | 1.334 |
| Mean | 1.145 | 1.979 | 1.563 |
| F | $F_{DS}$ 11.778**; $F_S$ -69.446** | | |
| CD | $_{DS}$ 0.278; $_S$ 0.139 | | |
| SE | 0.1; 0.050 | | |

** - *Significant at 1 per cent level*

A perusal of table 1 shows that the mid region in case of all districts had the highest biodiversity. The mid region of Thiruvananthapuram district recorded the highest biodiversity index. The gradation in the pattern of index for Thiruvananthapuram, Alappuzha and Pathanamthitta were the same with mid region followed by outer region recording the higher diversity. On the other hand the mid region was followed by courtyard in case of Kollam district and the differences were also not significant. What must be inferred from this is that, in Kollam district, the biodiversity that exist in the courtyards made the big difference placing it on top in case of the averages of the district. The highest diversity index in the case of outer region of the homegardens was in case of Alappuzha district followed by Thiruvananthapuram, which were at par. The least was observed in Kollam district. Analysis of the index of the courtyard showed that Kollam district not only accounted for highest diversity but also was way ahead in comparison to other districts. Alappuzha on the other hand recorded the least. Hence it was inferred that of all the differences observed the big difference is recorded at the courtyard level and this contributed to the variations in the mean biodiversity between districts.

In all districts and in all the different size of holdings the mid regions accounts for the highest diversity index (table. 2). The sole exception being in the case of Alappuzha and that too only in the highest size of holding where in the outer region recorded a slightly higher index than the mid region. Though distinct differences were recorded, in none of the cases the result was significant.

**Table 2**
**The diversity index in different regions of homegardens of different holding size in four districts**

| Districts / Holding size + region | Thiruvananthapuram | Kollam | Alappuzha | Pathanamthitta |
|---|---|---|---|---|
| <25 cents + CY | 0.750 | 1.712 | 0.497 | 1.189 |
| <25 cents + MR | 2.222 | 1.882 | 2.102 | 1.809 |
| <25 cents + OR | 1.768 | 1.460 | 1.634 | 0.975 |
| 25-75 cents + CY | 1.046 | 1.735 | 0.852 | 1.032 |
| 25-75 cents + MR | 1.650 | 2.030 | 1.866 | 2.032 |
| 25-75 cents + OR | 1.396 | 1.068 | 1.702 | 1.562 |
| 75-125 cents + CY | 0.917 | 1.765 | 0.318 | 1.139 |
| 75-125 cents + MR | 2.528 | 2.033 | 1.946 | 1.792 |
| 75-125 cents + OR | 1.681 | 1.274 | 1.788 | 1.467 |
| >125 cents + CY | 1.449 | 1.925 | 0.765 | 1.231 |
| >125 cents + MR | 2.200 | 2.033 | 1.707 | 1.828 |
| > 125 cents + OR | 1.722 | 1.492 | 1.734 | 1.332 |
| F (18.576) | $0.972^{NS}$ | | | |
| CD | 0.556 | | | |
| SE | 0.201 | | | |

*NS - Non significant (Cy- Court Yard; MR- Mid region; OR- Outer region)*

From the above two tables a very special feature observed is that in the two districts with high mean index the biodiversity index was found to increase with holding size. In Pathanamthitta the mid holding size was found to have maximum index. This point to the very basic nature of homegardens, where the biodiversity increment was not to a larger extent the function of size of holdings in Thiruvananthapuram and Kollam. In Pathanamthitta and Alappuzha it was not influenced by the size at all. A major concept of the diversity index of the four districts is this very basic aspects but whether this build up or spread as the case may be remains to be identified as to whether it is deliberate, powerful or simply by chance. As the case look more or less uniform within a district it should be deemed that the index which is a result of planned diversity build up or generations is more geographic, partially interventional or deliberate and more a specialty of the region. Another factor worth discussing is that mid-region of homegarden contributed to maximum index. This reveals that irrespective of the district and size of holdings the gardens tends to preserve the maximum taxonomically distinct variance within the region. A second point is a reflection of the complementary exploitation of habitat resulting in more complete capture of resources. Such a complementarity has reported by Campbell *et al.* (1991). A third point is at the management level. As the mid-region was more convenient the gardener could have packed his gardens with more important species towards the centre and then structurally dominant towards the outer periphery, be it accidental or intentional.

## ENVIRONMENTAL SIGNIFICANCE OF HOMEGARDENS

Home garden farming system falls under the broad classification of agroforestry. It is determined by the structure of the system, its ecological functions and its continued ability to fulfill the socio-economic needs of the people. Thus Soemarwoto and Soemarwoto (1984) opined that home garden as an agroforestry system, should ideally combine the ecological functions of forests with those providing the socio-economic needs of the people. The dimensions of food security and additional income generation problem can be addressed at household levels in Kerala alone, suggesting a broad agenda for possible personal and technological interventions that may be necessary or useful in improving the conditions within which individual households must pursue their own agenda for food security, additional income and ecosystem integrity. Increase in population, emerging nuclear family structure and high rate of fragmented holdings year round leads to decreased land for agriculture that raises the conservation status of these land-use systems and necessitates for a 'homegarden policy' in Kerala. The unscrupulous intervention by man for both non agricultural and commercial agriculture has led to the erosion of this great 'gene pool' and therefore may no longer serve as an effective backup gene pool for plant breeding and crop improvement. This situation is grave in terms of Kerala's environmental sustainability and also may hamper the food security of the state in long run that is already crippled. Homegardens in Kerala was and is still the largest gene pool of wild and natural species. Homegardens in Kerala is a repository of biodiversity coupled with specialized components inclusive of sacred groves. Without this flow of novel genes from wild species and landraces into the breeding pools the adaptability of crops to changing environmental conditions and user demands would be very difficult to maintain today and in the future. Hence it is essential to preserve the wild species and landraces which are practically possible by promoting homegardens as an essential agro ecological entity.

The importance of 'Safe Food' is gaining global attention in this era of modernization. The resurging trends of organic farming have increased the scope of homegardens because it is easy and practical to convert an entire village to an 'organic farm' by concentrating on individual households at a larger level. Homegarden farmers place high value on the social, aesthetic and habitat functions of homegarden. Farmers have their own perception about the components of their homegardens. Homegarden farmers value the components of their homesteads not only as a source of income and subsistence, but also for their role in improving habitat quality and conservation of soil and water resources and aesthetic value. Kerala homegardens presents a multi-tier canopy configuration ensuring a high level of exploitation of environmental resources. For example, in a coconut dominant system the top-most canopy is occupied by coconuts, the second layer by arecanut, pepper, jack, tamarind and mango, the third layer is occupied by banana, tapioca and fruit plants and the lowermost layer of canopy consists of tuber crops, vegetables and guinea grass. The boundaries are live-fenced with Glyricidia. Homegarden farmer regulate or modify the functioning and dynamics of each plant and animal within the system. This best presents the eco-friendly nature of homegardens.

Sustainability under temporal dimension and resource recycling capacity, availability of raw materials and availability of supplies and services under environmental dimensions are important in this type of farming system because the homegardens being apparently a climax ecosystem, where ecological succession is consciously manipulated by human beings. High intensity of vertical and horizontal space use, highly dynamic chronological structure and the capacity to perform essential ecological processes makes homegarden ecosystem a sustainable one through the use of resources and resource recycling. Homegardens presenting a land use system where the different components of homegardens (tree-crop-livestock-specialised component mix) interact and associate should be more as a result of intensive intervention by the family labour. This will enable judicious use of resources, considering the ecological safeness of the homegardens. Also it will help the homegarden farmer to place before the homegarden the dimensions of social approval, social acceptability and cultural compatibility.

Also, agro-ecological components and entities promote 'clean nature' through proper maneuvering. The consumer culture in the state facilitates many products (degradable and non degradable) and the state has become a 'sink' for all such materials. The limitation of availability of space generally leads the public to litter it unscrupulously and thereby maligning the environment to its core. This has eroded the 'clean culture concept' which was one of the main stay of keralite among others during the past. No strategies will work other than initiating policies to manage the same in the place of origin itself. 'Place of origin needs to be the place of sink'. Homegardens can be a means to achieve this goal as man and homegardens forms a vital bond, as components of agro-ecological entity in the same system. 65 Lakhs homegardens that constitutes 60-70 per cent land area needs to be agro ecologically promoted as this is a system that promotes socio economic and environment sustainability through effective recycling of waste. To conclude, the effect of variance in the structure and function of Kerala homegardens implies that the match between the variation in priorities of the home and the spatial arrangement of the homegarden was strong environmentally, socio-economically and biophysically.

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# Food for All: Alternatives to Organic Farming

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## INTRODUCTION

Agriculture is the single largest employment provider in the country. About 43 percent of India's geographical area is used for agricultural activity, and it provides livelihood to almost two thirds of people in the country. In pre-Independence era, food supplies were always a problem. After Independence, India pursued a path of rapid modernization of agriculture, which paid rich dividends. However, the tempo of agricultural growth is showing signs of fatigue, and India now faces several problems like food security, profitability, sustainability, and farmer's suicides. In the recent decades, post-modern concepts like organic farming are forcefully being projected as superior to conventional modern agriculture and the only method to solve the problems affecting Indian agriculture. This has led to some widespread notions among the public that organic crop production is the best, and to satisfy this outlook, activists and public figures have strongly promoted this type of agriculture. For example, the Government of Kerala has taken a policy decision in 2010 to develop an action plan with an objective of converting annual crops such as grains, fruits and vegetables to organic within 5 years and the perennial crops within 10 years (GOK, 2010).

It must be noted that before the advent of modern farming, when farmers did not use pesticides or synthetic fertilizers, food supplies were constantly endangered through climatic and environmental fluctuations, and by the outbreak of pests and diseases. Traditional agriculture was always associated with grinding poverty, famines, and low yield as were the situation in British India. Most environmentalists ignore these realities, when they assess the impact of modern agriculture. Ardent supporters claim that whether organic farming could feed the world is not a question anymore! The debatable question is whether scientific evidences support these notions circulating in society. It seems as Bergström *et al.* (2008) stated the principles of organic practices derive from natural philosophies and not natural sciences. Nevertheless, many reports have highlighted the need for major changes in the global food system and stressed that any kind of future agriculture must meet the two challenges of feeding a growing population, with rising demand for food and high-calorie diet inclusive of meat products, while simultaneously minimizing its global environmental impacts (e.g., Godfray *et al*, 2010; Foley *et al.*, 2011). It is essential that the virtues attributed to organic farming need to be rechecked before promoting it as the only policy option or as a complementary option to feed the 8.3 billion anticipated in 2030 or 9.3 billion anticipated by 2050 (UN, 2001).

Definitions of organic agriculture generally imply alternate modes of agricultural production, which denounce the use of synthetic fertilizers and pesticides, plant growth regulators, and livestock feed additives. The Codex Alimentarius Commission defines organic agriculture as: "A holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. It emphasizes the use of management practices in preference to the use of off-farm inputs, taking into account that regional conditions require locally adapted systems. This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfill any specific function within the system" (FAO, 2001).

Humans have made agriculture the dominant environmental threat by clearing tropical forests, farming marginal lands and intensifying industrial farming in sensitive landscapes and watersheds. Whether conventional, organic, or a hybrid system, the world's food system faces three interwoven challenges; it must guarantee that all seven billion people alive today are adequately fed; double food production in the next 40 years and achieve both goals while becoming truly environmentally sustainable (Foley, 2011; Foley *et al.,* 2011).

**EVOLUTION OF FARMING PRACTICES**

About 10,000 years ago, before the dawn of agriculture, the hunting and gathering style of living supported some 5 million people in the world. When the pressure of population on their existing resources increased and the means of sustenance started decreasing quantitatively and qualitatively, human kind had to go in for settled agriculture. The first form of agriculture attempted by them could be put under the category of "do nothing farming" or "natural farming" as there were not much human involvement. Later, with the development of tools, they perfected the art of shifting cultivation or slash and burn to take care of the depletion of soil fertility. According to Boserup (1965), there were five stages of land intensification through which farm communities evolved over time: (1) forest fallow (20-25 years between crops), (2) bush fallow (6-10 years), (3) short fallow (1-2 years), (4) annual cropping, and (5) multiple cropping. In course of time, they were forced to abandon shifting cultivation because of the difficulty to find new areas for cultivation. Meanwhile, they learned that by adding animal excreta and kitchen ashes, they could grow crops in the same field year after year. Thus, traditional organic farming was born. This style of traditional agriculture prevailed upto the end of 19$^{th}$ century.

Great changes happened in the beginning of 20$^{th}$ century. The invention of the gasoline internal combustion engine ushered in the era of the tractor. Research in plant breeding led to the commercialization of high yielding cultivars. Fertilizers and pesticides began to be used in a big way in farming. Thus, the era of modern agriculture began.

The two World Wars brought drastic changes in the world agricultural scenario. The change was most spectacular since the end of World War II. Nevertheless, in the late 1960s, many experts predicted imminent global famines in which millions would perish, especially in third world countries. William Paddock and Paul Paddock, the authors of "*Famine 1975*" predicted that by 1975 at least half of Indians would die because of famine and starvation and suggested that the world turn its attention away from this hopeless land (Paddock and Paddock, 1967). In 1968, Paul R. Ehrlich published "*The Population Bomb*", warning that the growth of human population threatened the viability of planetary life-support systems (Ehrlich, 1968). The book was a best seller, raised the general awareness of population and environmental issues, and influenced policies of many governments in the 1960s and 1970s.

In 1943, an international campaign for increased food production was launched with the establishment of a joint undertaking, "Cooperative Wheat Research and Production Programme" in NW Mexico (the precursor to CIMMYT, the International Maize and Wheat Research Centre). Norman E. Borlaug headed the project, and in due course, it was replicated in many third world countries, especially India and Pakistan where it was a huge success and millions did not die in massive famines as the prophets of doom predicted. The dramatic increases in cereal-grain yields in many developing countries beginning in the late 1960s averted a great catastrophe as they predicted. This phenomenal increase in food grain production became a movement in the developing countries, later came to be known as "Green Revolution" after its inadvertent use by William Gaud, Director, United States Agency for International Development (USAID). In 1968, at a small meeting in Washington, Gaud said, "For the last five years, we've had more people starving and hungry. But something has happened. Pakistan is self-sufficient in wheat and rice, and India is moving towards it. It wasn't a red, bloody revolution as predicted. It was a green revolution". Many experts, however, felt that it was an unfortunate term because in no real sense was it a revolution at all (Tribe, 1994). In fact, its brilliant success depended on using scientific advances, which had already been made elsewhere in breeding and agronomy of wheat and rice, and then adapting them to conditions in Central America and Asia. In fact, green revolution has solved the immediate problem of feeding the ever-increasing population. This kind of modern farming methods came to be called 'green revolution style agriculture'.

## A BRIEF HISTORY OF ALTERNATE FARMING SYSTEMS

Alternative agriculture, a term usually used by postmodernists, generally refers to agricultural practices that are different from those used in conventional agriculture. Natural farming, organic farming, biodynamic farming, permaculture, Homa farming, etc. are considered as different forms of alternate agriculture. It must be noted that 'alternate agriculture' does not specifically imply the concept of 'sustainable agriculture', which is a modern ecologically based approach to raise crops and animals.

Probably, biodynamic agriculture by Rudolf Steiner (1861-1925) was the first comprehensive alternate farming system, the apparent beginning of which was a series of lectures he presented in 1924 (Steiner, 1958). It is the oldest, most radical, alternative, rule-based organic agricultural system. However, mainstream agriculture dismissed it as occult because of its belief in cosmic forces and use of cow horn, viscera, and urinary bladder of stag and other weird practices (Kirchmann, 1994). Steiner's practices influenced Sir Albert Howard (1873-1947), a British botanist who worked as an agricultural adviser in India from 1905 to 1924. Although he was critical of many of Steiner's occult practices, he found merit in his biological practices, especially composting. He perfected the Indore method of composting. Howard returned to England in 1931, and after his return, he documented traditional Indian farming practices. His research and further development of these methods is recorded in his famous book, *An Agricultural Testament* (Howard, 1940). Sir Albert Howard is often considered as the founder and pioneer of the organic movement. He put forth what he called the "Law of Return", which called for recycling of all organic waste materials including sewage and sludge back to farmland.

In 1939, influenced by Howard's work, Lady Eve Balfour of England launched the famous Haughley Experiment. Four years later, she published a book, *The Living Soil*, based on the initial findings. It led to the formation of a key international organic promotion group, the Soil Association. In fact, the present form of organic farming was developed from the philosophical views of Rudolph Steiner, Sir Albert Howard and Lady Eve Balfour.

Technological advances during World War II accelerated post-war innovation in all aspects of agriculture, resulting in big advances in mechanization, large-scale irrigation, and use of fertilizers and pesticides. A range of new pesticides appeared, for example: DDT, which had been used to control disease-carrying insects around troops, became a general insecticide, launching the era of widespread pesticide use. In 1962, Rachel Carson, a prominent scientist and naturalist, published *Silent Spring*, chronicling the effects of DDT and other pesticides on the environment (Carson, 1962). It was a truly significant event in the history of organics. The book and its author are often credited with launching the worldwide environmental movement and many post modernist philosophies in agriculture.

In Japan, Masanobu Fukuoka developed a radical no-till organic method, now known as 'natural farming'**.** In 1975, Fukuoka released his first book, "*One Straw Revolution".* In the early 1970's, Bill Mollison and David Holmgren, two Australians, started to develop ideas that they hoped could be used to create stable agricultural systems or permanent agriculture. A design approach called 'permaculture' was the result, and in 1978 , it was first made public with the publication of *Permaculture One* (Mollison and Holmgren,1978).

Some other variants of organic farming such as 'Rishi Krishi', 'Homa farming', and 'Homeaopathic farming' are also in vogue (Chhonkar and Dwivedi, 2004). Some related concepts with sustainability of resources as a main concern although not fully organic are ‘biological farming’, ‘low external input sustainable agriculture’ (LEISA), ‘low input sustainable agriculture’ (LISA), and ‘sustainable agriculture’.

The International Federation of Organic Agriculture Movements (IFOAM) was formed in 1972 with its base at Versailles, France. In the 1980s, around the world, various farming and consumer groups began seriously pressuring for government regulation of organic production. This led to legislation and certification standards being enacted through the 1990s and to date.

**ORGANIC FARMING Vs. CONVENTIONAL FARMING**

It is important to distinguish between the general notions on organic farming and conventional farming. In organic agriculture, practices followed are quite distinct from those of “conventional” modern agriculture. An organic farming system excludes the use of synthetic inputs such as synthetic fertilizers, pesticides, veterinary drugs, livestock feed additives, growth regulators, genetically modified organisms, preservatives, food additives and irradiation. In contrast to conventional agriculture, organic agriculture consciously avoids trying to maximize the yield per unit area.

Organic agriculture systems and products are not always certified and such products are referred to as “non-certified organic products”. All over the world, four different streams of organic production can be identified.

***Certified organic production***: This is consumer or market-driven organic agriculture. Products are clearly identified through certification and labelling. Consumers take a conscious decision on how their food is produced, processed, handled and marketed.

***Service-driven production:*** In certain countries, for example, in the European Union, subsidies for organic agriculture are available to generate environmental goods and services, such as reducing groundwater pollution or creating a more biologically diverse landscape.

***Farmer-driven organic agriculture***: Some farmers, especially those who are supporters of Western ideologies like deep ecology or ecofeminism, believe that conventional agriculture is unsustainable and prefer to practise alternate methods of production. The primary aim is not markets, but if there is a surplus, sold without a price distinction as it is not certified.

***Organic by default*:** In general, these are traditional systems, as was the case with resource poor farmers in third world countries. They may not be using synthetic fertilizers and pesticides as they are ignorant about them or are without the necessary resources. In Kerala, most of the small farmers are organic mainly because of the small size of the farm. In India, it is estimated that 65 percent of farmers are organic by default.

According to Trewavas (2001), only two principles distinguished organic farming from other faming methods. In organic agriculture, soluble mineral inputs are prohibited and synthetic pesticides are rejected in favour of natural pesticides. Conventional farmers apply chemical fertilizers in addition to organic manures to maintain soil fertility, and use plant protection chemicals such as insecticides, fungicides and herbicides to protect crops from pests, diseases and weeds. On the contrary, organic farmers use only natural manures. Non-chemical agents such as insect predators, mating disruption, and traps are used to protect crops from pests and disease. Weeds are managed through crop rotation, tillage, hand weeding, cover crops, mulches, flame weeding and other management methods. As a last resort, organic farmers may apply certain non-synthetic pesticides.

The meat, dairy products and eggs that organic farmers produce are from animals that are fed on organic feed and allowed access to the outdoors. Unlike conventionally raised livestock, organic livestock must be kept in living conditions that accommodate the natural behavior of the animals. For example, ruminants (including cows, sheep and goats) must have access to pasture. Although they may be vaccinated against disease, organic livestock and poultry may not be given antibiotics, hormones or medications in the absence of illness. Instead, livestock diseases and parasites are controlled largely through preventive measures such as rotational grazing, balanced diet, sanitary housing and stress reduction.

Organic and conventional food must meet the same quality and safety standards. As organic farming and marketing entered the 1970s, it began to develop as an industry. Therefore, a clearer definition was needed to distinguish its products from conventional agriculture. In many countries, organic farming is defined by formal standards regulating production methods. The International Federation of Organic Agriculture Movements (IFOAM) prescribes IFOAM basic standards. In the 1980s, many national governments began to formulate organic production guidelines and a trend towards legislation of standards began. In 2000, under the National Programme for Organic Production (NPOP), Government of India released the National Standards for Organic Products (NSOP) (GOI, 2005). Products sold or labelled as ‘organic’, thereafter, need to be inspected and certified by a nationally accredited certification agency. A trademark, “India Organic”, will be granted on the basis of compliance with the National Standards for Organic Production.

One early goal of the organic movement was to encourage consumption of locally grown food. However, with the publication of certification standards for the production of organic food, this goal has been diverted to the sidelines. Now, a large percentage of certified organic food is coming from corporate farmers. Organic food in the US and European countries is such a lucrative business that it has been almost completely taken over by big multinational food corporations. For example, big companies like Kraft and Wal-Mart are getting involved in producing and marketing a host of organic foods and groceries. Big players in the food industry is likely to drive down the price of the more expensive organic products compared to conventionally produced items. In India too, many multinationals are jumping into the bandwagon for the production of “organic foods”.

**Carrying Capacity of Earth**

The most important innovative technologies that have contributed to past increases in yield have been: (1) improved cultivars able to grow vigorously, resist pathogens, and respond to fertilizers without lodging; (2) the application of fertilizers and particularly the availability of affordable nitrogen fertilizer; (3) the development of chemicals to control weeds, pests, and diseases; and (4) improved irrigation systems, especially in rice-producing countries and for some previously rainfed crops. The consequence of these innovations has been that yields of many crops, especially the major cereal crops maize, rice, and wheat, have increased substantially over the last half century (Evans, 1993; 1998).

The implications of yield increases due to changes in farming must be examined from the perspective of human population growth as well. For example, the increases in food production allowed many people, who would otherwise have starved, to survive and to have children. Food security achieved in many countries helped to increase life expectancy by over 10 years over the last five decades.

There is an argument which is based on the notion that modern farming artificially boosted the 'carrying capacity (K)' of earth through unsustainable agricultural practices, which provided short-term relief. Carrying capacity refers to the number of individuals that can be supported without degrading the natural, cultural, and social environment; that is, without reducing the ability of the environment to sustain the desired quality of life over the long term. This perspective is referred to as "life boat ethics". The latter term was first used by Garrett Hardin, a renowned American human ecology Professor, in his 1974 essay "Living on a Lifeboat" (Hardin, 1974). His earlier essay, "The Tragedy of the Commons" first appeared in *Science* (Hardin, 1968), is also very famous. Hardin argues that if a lifeboat's carrying capacity is exceeded, everyone dies. What policies should the people on board adopt towards people wanting to board? According to Hardin, helping the drowning people threatens the people onboard. Moreover, it is not going to aid the drowning in the end. For example, if the lifeboat has a capacity of 50 people and that there are now 40 people on board, is it possible to allow anymore individual to board the boat? Suppose there are 100 people in the water. If all are allowed to board, everybody would be drowned. There is a possibility to let 10 aboard, but the choice is difficult. Further, it is not proper to fill all berths as a safety factor in case of possible emergencies.

The movement called bioregionalism emerged in the 1970's is also based on the concept of carrying capacity to counter the overexploitation of earth through practices such as green revolution style agriculture (Berg and Dasmann, 1977). According to the perspective of bioregionalism, each region or country should support only as large a population as its own resource base will allow. Further, it argues that food aids are even more problematic, if they result from agricultural practices in the donor nations that are likely to be unsustainable, for example, intensive modern farming.

Most organisms can do little to change the carrying capacity of their environments, but humans can! If food is not available in a region, we can purchase it from another region by paying cash or kind. The historical pattern of human population growth shows the effect of breakthroughs that essentially allowed increases in K. Intensive agriculture coupled with technological advances increased the effective carrying capacity of earth for humans.

A nation's land has a limited capacity to support a population and in most of the developing countries, the carrying capacity of the land has already exceeded. In short, the proponents of lifeboat ethics and bioregionalism argue that each region of the world should support only as many people, as it is able to, that is, without food subsidies or technical aid! For example, USA supports just 30 million or 5.0 percent of global population with almost 6.5 percent of world's land area, well within the natural carrying capacity. At the same time, India has only 2.4 percent of world's geographical area, but we have about 17 percent of world's human population, 15 percent of world's cattle, 46 per cent of world's buffaloes, and 17 percent of world's goats. We are feeding this population by artificially boosting the carrying capacity with the help of green revolution and white revolution!

In India, the population was 23.8 crores in 1901. It increased to 43.9 crores in 1961 (almost double within a period of 60 years) and 102.7 crores in 2001 (about two and half times increase within a period of 40 years). According to 2011 Census, it is 121 crores. This indicates that the rate of population growth in the later forty years was something phenomenal. Still, we were able to tide over the crisis with the help of green revolution and white revolution; which effectively increased the carrying capacity.

## ORGANIC FOOD AND THE WIDESPREAD NOTIONS

There are many claims and widespread notions about organic agriculture, which are for the most part unscientific and unrealistic. The validity of these notions has been discussed in detail by Chhonkar (2003), Chhonkar and Dwivedi (2004), Trewavas (2004), and Bergström *et al.,* (2008). Some of these widespread beliefs are:

- Organic farming can ensure food security by sustaining higher yields
- Organic food tastes better and is of superior quality
- Organic food is healthier because it does not contain synthetic pesticide traces
- Organic farming is environmentally better than the other forms, and is free from chemicals
- Organic farming improves soil fertility and chemical fertilizers deteriorate it.
- Organic farming sustains higher yields
- Enough organics are available to replace chemical fertilisers

### Food Security and Organic Agriculture

A general opinion in society is that conversion to organic crop production is followed by little or no yield reduction and that organic crop production is capable of feeding the world. In fact, some researchers claim that the solution for famine in Africa is large-scale organic agriculture (Pretty *et al.*, 2003). Scientists warn that, if organic farming is going to be adopted on a wider scale, per-hectare agricultural productivity will decline sharply. It is established that organic yields are lower than conventional farm yields, but the extent depends on the crop (Leake, 1999; 2000). Compared to conventional crops, the yields of organic wheat, beans and peas were 60-70 percent and that of organic oats were 85 percent. Maeder *et al*. (2002) reported the results of 20-year long-term experiment in which they compared conventional, organic and biodynamic agriculture. Compared to conventional farming, there was 20 percent yield reduction (winter wheat, potato, clover) in organic and biodynamic farming. However, input of fertilizer and energy was reduced by 34 to 53 percent and pesticide input by 97 percent.

According to Halberg *et al.* (2006), in areas with intensive high-input agriculture, conversion to organic farming will most often lead to a reduction in crop yields per ha by 20-45 per cent in crop rotations integrated with leguminous forage crops. However, in many areas with low input agricultural systems as farmers have little access to use chemical fertiliser and pesticides, yields may increase when agroecological principles are introduced. This is the case with vast rainfed farming tracts of India where more than 65 percent farmers are organic by default.

Productivity is an important issue to the acceptance of organic agriculture. The carrying capacity of organic agriculture is estimated at 3 to 4 billion, well below the present world population of 7 billion and more than 9.3 billion projected for 2050 (Buringh and van Heemst, 1979; Smil, 2001). These estimates are based on the performance of organic agriculture systems as practiced before the widespread use of inorganic fertilizers and when the world population was around 1 billion by the beginning of 1800.

Kirchmann *et al*., (2008) suggested that the following factors as responsible for lower yields in organic systems than in conventional: (1) Low nutrient input (2) low nutrient use efficiency; (3) high weed abundance; (4) limited possibilities to improve low native soil fertility in resource-poor areas; and (5) poor control of pests and diseases.

A recent study published in *Nature* concludes that crop yields from organic farming are generally 34 percent lower than conventional agriculture (Seufert *et al.,* 2012). This is more relevant for cereals, which are staples of the human diet. Nevertheless, the yield gap is much less significant for certain crops and under certain growing conditions, for which, organic farming may be applicable. When the best management practices are used for organic crops, overall yields are just 13 per cent lower than conventional levels. The study, which represents a comprehensive analysis of the current scientific literature on organic-to-conventional yield comparisons, aims to shed more light on the debate over organic versus conventional farming.

The study by Seufert *et al.,* (2012) indicates that organically fertilized systems might require higher nitrogen inputs to achieve high yields, as organic nitrogen is less readily available to crops. In some cases, organic farmers may therefore benefit by making limited use of chemical fertilizers instead of relying only on manure to supply nitrogen to their crops. They conclude that to achieve sustainable food security many different techniques are needed, including organic, conventional, and possible 'hybrid' systems to produce more food at affordable prices, ensure livelihoods to farmers, and reduce the environmental costs of agriculture. It is hoped that we can create a truly sustainable food system by combining organic and conventional practices that maximizes food production and social goods at the same time minimizes adverse impact on the environment.

The fact is organic agriculture alone cannot feed the world, because there is substantial scientific evidence that crop yields are considerably lower in organic systems. The above review suggests that long-term yield reduction could be as much as 30-40 percent compared with the corresponding conventional crops. Therefore, to obtain equivalent yields in organic systems, significantly more land would be needed for agricultural crops. However, according to recent assessments, such land is not available in the world. It is worthwhile to mention that most good agricultural soils are already under cultivation and that additional crop production would have to encroach sensitive ecosystems like forests or areas with a high risk of erosion or other degraded lands.

**Food Quality**

There is no scientific evidence to suggest that organic food is more nutritious or safer than conventional food. It is true that organic food is less likely to contain pesticide residues than conventional food. However, according to experts, if the traces of pesticides are within the limits, they are not going to pose any problems.

Many taste assessments of organic and conventional foods have shown that the public cannot easily distinguish organic from conventional foods in terms of taste (Hansen, 1981; Basker, 1992). As Chhonkar and Dwivedi (2004) suggested, the better taste of organically grown food is of psychological nature and could be attributed to 'placebo effect'. This could be easily proved by conducting 'single blind' or 'double blind' organoleptic tests. Trewavas (2004) reviewed the reports of five studies conducted on the nutrient composition of organic and conventional food and found that there were no significant differences between the two foods.

**Environmental Impacts**

The argument that organic farming is environmentally better is also a debatable issue (Nature, 2004). There is general agreement on some benefits; organic products are not likely to contain synthetic fertilizers or pesticide residues. On the other hand, organic methods have a greater environmental impact on smaller scales. For example, methane emissions from organic farms are likely to be higher per unit of food production. Studies are less definitive about the environmental impact of farm runoff through which nitrate and phosphates leach into streams, rivers, and lakes. Although several studies have suggested that organic methods would reduce nitrate leaching, according to an assessment of literature sponsored by the British Government (Nature, 2004), this is not fully correct. Nitrate is the main product of decomposition of organic manures. It is continuously released from organic matter undergoing decomposition. Since nitrate release is not synchronized with either crop demand or its uptake, it tends to accumulate in excessive amounts in soil and cause environmental pollution. This could be observed in heavily manured plots. With reference to phosphorus run off there are not much definite studies.

**Plant Nutrients**

After reviewing several long-term fertilizer experiments, Stewart *et al.* (2005) reiterated the commonly cited generalization that at least 30-50 percent of crop yield is attributable to commercial fertilizer inputs. The Broadbalk experiments started by Laws and Gilbert in 1843 (Rothamsted , England) where winter wheat was grown continuously on land with only organic manure and with inorganic manures, N fertilizer with P and K was responsible for 62 to 66 percent of wheat yield compared with P and K alone.

The most optimistic estimates at present, show that only about 25-30 per cent nutrient needs of Indian agriculture can be met by utilizing various organic sources, which include agriculture wastes, and livestock manures. However, if we take Kerala, availability of on-farm manures is a major problem.

Will organic farming completely take over from conventional food production? It has been estimated that without the production of artificial nitrogen fertilizer, the carrying capacity of the world's fertile land will support only about 60 per cent of the current population of 7 billion people. As the world's population approaches an estimated 9.3 billion by the year 2050, our dependence on artificial fertilizer will almost certainly become even greater.

**Organic Farming and Plant Protection**

Plant protection against the ravages of pests, diseases and weeds is an important issue in any modern high production system. The exclusion of pesticides for plant protection poses greater risk of yield losses. The options available under organic production systems are very few and crop specific. Often, they are very slow and the success rate depends on the prevailing weather conditions leading to low to moderate effectiveness even in the recommended crops and situations. Thus, they limit the realization of full potential of crop yields. Any sudden outbreak of insect pests or plant disease can completely destroy the crops, unless requisite chemical pesticides are used.

**FOOD FOR ALL: THE CHALLENGES AHEAD**

Considering the constraints on land, de Vries (2001) concluded that a person requires 0.05 to 0.5 ha land depending upon the intensity of farming. The present population growth percentage is 1.2. In other words, the world population may double within next 58 years, and the availability of land may still go down to 0.11ha (Pimentel and Pimentel, 2008). If all the couples of the world decide to have only two children, still it takes about 70 years to stabilize world population at 13 billion. A major problem of population growth is large scale conversion of agricultural land for other purposes. Agricultural land can become degraded completely and irreversibly by various other processes too including soil erosion, nutrient mining, salinization, and pollution. A global average of 0.5 percent loss of agricultural land per year is estimated.

Considering all these changes, it is estimated that every year, 1 million arable lands are permanently lost.

Population growth rate in India is 1.7 percent. That means, within 41 years, Indian population may double (Pimental and Pimental, 2008). In India, for the past so many years the net cultivated area hovers around 14.1 million ha. This may reduce to 10 million ha within the next 30-40 years because of urbanization and non-agricultural uses. The present per capita availability of land is only 0.12 ha. Imagine the plight of agriculture, if population doubles within 41 years; per capita arable land would be only 0.049, which is below the threshold of intensive agriculture, 0.05 ha.

If we consider the case of Kerala, the problem is still acute. In Kerala, net cultivated area is 20.7 lakh ha. The population according to 2011 Census was 3.34 crores, which means that the present per capita availability of land is just 0.06ha. If we consider only the land occupied by food crops (10%), per capita land availability may drop to a miserable level!

Feeding more people would be easier if all the food we grew went into human hands. However, only 60 percent of the world's crops are meant for people; mostly cereals, followed by pulses, oil seeds, vegetables, and fruits. Another 35 percent is used for animal feed, and the final 5 percent goes for biofuels and other industrial products (Foley *et al.*, 2011). The use of food grains as feed and biofuel are on the increase, posing a major threat to the food security of the poor nations. Globally, there is an increase of 25 percent utilization of food grains for industrial purpose. In the USA alone, within the last five years, there was 2.5 times increase in utilization of maize for biofuel. Utilizing prime lands for the cultivation of other biofuel crops like sugarcane and jatropha will also affect food grain production.

**Changes in Food Habits**

Changes in food habits are taking place rapidly especially with the rise in income and standard of living of the people. There will be a shift first from coarse grains to rice, and then from rice to wheat. More and more people may become non-vegetarians. An increased demand for maize and other coarse grains as animal feed is expected. In China, India and some other countries, there have been significant changes in the food consumption patterns with affluent families taking more of meat, milk and vegetables than cereals. Meat is the biggest issue here. Even with the most efficient meat and dairy systems, feeding crops to animals reduces the world's potential food supply. For producing one kilogram of lean meat, about 25-50 kg of grains is required (Nature, 2004).The consequent increased demand for grains as cattle and poultry feed has compounded the shortage. In Kerala in recent years, there is a quantum jump in the consumption of broiler chicken.

**Climate Change**

Climatic change impacts such as flood and drought are other factors, which affect food supply. Global warming is bound to affect the grain output further. It is feared that global warming and consequent changes in climate may decrease the total agricultural production by 16 percent globally by 2020. In the developing countries, this may touch 20 percent and in developed countries, it will be only 6.0 percent.

**Slow Down in Crop Productivity and the Causes**

Slow down in the productivity growth of major cereals, wheat and rice, especially in the intensively cultivated lowlands is apparent not only in India but throughout Asia (Pingali and Rosegrant, 2006). Slackening of infrastructure and research investment and reduced policy support partly explains the sluggish growth. According to Pingali and Rosegrant (2006), the slow down in rice and wheat productivity growth in Asia since the 1980's has been caused by two major factors: (1) world cereal price-induced factors, and (2) Intensification induced factors.

At the national level, several other issues also contributed to the stagnation in food production. For example, intensification of farming in the wheat belt of Punjab, Haryana and UP is showing signs of fatigue. Before Green Revolution, the prevailing cropping pattern was wheat-pulses/oilseeds. However, introduction of short duration wheat and rice enabled the farmers to go for wheat-rice rotation. This took a heavy toll on the environment in that this required heavy irrigation. In many parts of North India, ground water level has been receding due to over exploitation. Farmers are also abandoning cereal cultivation especially in regions like Punjab where more areas are brought under fruits and vegetables at the cost of cereals.

**Food Wastage**

Organic supporters point to the huge food wastage and excessive consumption in the developed countries which could, if more equitably distributed, make up for at least some of the current and predicted shortages. They argue that the problem is not producing enough food—the problem is getting the food that is already produced to the people who need it. This is partly true. About 30–40 percent of all food at every step of the food cycle is wasted (Giovannucci *et.al*., 2012). A good chunk of food produced in developing countries never makes it to market and consumers in rich countries waste as much food as the entire net food production of sub-Saharan Africa. Moreover, rich nations who produce more are not willing to spare their excess production, even if they empty them to seas. It is a fact that the world can produce more than enough food for everyone but human action is needed to ensure its fair distribution. Yet this is a political problem, and one that is very unlikely to be solved in the near future.

**Access to Food**

Along with production, we should also focus on two vital areas, more access to food and more nutrition or healthy food. The key issue is to increase food security by ensuring that all households have real access to adequate food for all their members and do not risk losing such access. This means not only that the food must be available but also that people can afford to buy it. However, organic agriculture is bound to decrease productivity further. Enhancing the productivity of smallholder agriculture must be an important step to eradicate hunger in the years ahead.

**The Possible Options**

As discussed earlier, organic farming is not feasible as an alternative to conventional farming under the prevailing circumstances in India. Scientists and policy makers now recommend integration of conventional farming with organic farming. Such integration on sound scientific basis will be effective in addressing the problems of deficiencies of both macro and micronutrients, recycling of crop residues and farm wastes, rural and urban wastes, besides effectively meeting growing food demands of rising populations.

Organic farming should be considered for lesser endowed region of the country. It should be started with low volume high value crops like spices and medicinal aromatic crops. A holistic approach involving integrated nutrient management, integrated pest management, enhanced input use efficiency and adoption of region-specific promising cropping systems would be the best farming strategy for India. There will also be scope for practicing organic farming on case-to-case basis in traditional strongholds like hilly areas, rain fed and dry land farming system to cater to the demands of organic produces in urban areas who would pay premium prices for such commodities. Organic foods are a matter of choice of the individuals or enterprises. If somebody wants to go in for organic farming, primarily on commercial consideration or profits motive or to take advantage of the unusually higher prices of organic food, they are free to do so. In Kerala, traditional organic farming may prevail in certain areas where modern methods are consciously avoided, for example, Pokkali rice, scented rice, and medicinal plants. With a growing population and precarious food situation, India cannot afford to take risk with organic farming alone. According to a team of agricultural experts, the scientific basis for the success of organic farming to be the only alternative to modern farming is yet to be proved. In response to the organic policy document of the Kerala State Biodiversity Board, they favoured the need to develop modern sustainable farming systems integrating the best available options (TOKAU, 2008).

Plucknett (1993) argues that the present food production in most countries is still below its potential. According to him, crop yields can be categorized into five; (1) the farm yields, which are being achieved by farmers at present; (2) the practical farm yields, which could be realized now, if farmers fully utilized known technologies; (3) the experimental station yields, which are higher again because they are produced under more controlled conditions than is usually possible on commercial farm ; (4) the record yields, which represent the highest levels of production yet recorded under field conditions on either farm or experimental stations; and (5) the theoretical yields, which are calculated based on the photosynthetic potential under specified environments and represent the highest limits of biological potential. Considerable gaps exist between each of these categories and the theoretical yields of most crops are often three or four times as large as present farm yields within the same environment. Food production in most countries is still below its maximum potential. All the categories of yield are increasing and in many countries, there is ample scope for this to continue. As basic scientific knowledge increases and technologies of genetic engineering and biotechnology improve, it is conceivable that the concept of maximum theoretical yields may be revised upwards (Tribe, 1994).

An international team of experts, has settled on five steps that, if pursued together, could raise by more than 100 percent the food available for human consumption globally, while significantly lessening greenhouse gas emissions, biodiversity losses, water use and water pollution (Foley *et al.,* 2011). According to them, five solutions, pursued together, can achieve these goals: (1) stop expanding agriculture's footprint (2) close the world's yield gaps (3) shift diets away from meat (4) use resources much more efficiently and (5) reduce food waste. To double global food production without expanding agriculture's footprint, we must significantly improve yields of existing farmlands. According to the authors, two options exist, boost the productivity of best farms by raising their yield ceiling through improved crop genetics and management, or improve the yields of the world's least productive farms by closing the yield gap between a farm's current yield and its higher potential yield.

Most agricultural scientists believe that there will be a gradual amalgamation of organic and conventional farming to produce a system appropriate to different situations – that employ the best aspects of each form of farming to allow adequate and sustainable food production with minimum disruption to the environment. This is the logic behind the evolution of sustainable agricultural systems and good agricultural practices (GAP).

## SUSTAINABLE AGRICULTURE AS A MODERN ALTERNATIVE

Sustainability is a general concept, relating to the continuity of environmental, economic, and social aspects of human society. 'Our Common Future', a 1987 report from the United Nations (Bruntland, 1987), defines 'sustainable development' as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (*Our Common Future* is the report made by the World Commission on Environment and Development in 1987. It is often called the 'Bruntland Report' after the chairperson of the commission, the then Prime Minister of Norway, Ms. Gro Harlem Bruntland). One of the main factors, which sustainable development must overcome is environmental degradation. The issue is closely tied to economic growth, and the need to find ways to expand the economy in the long term without using up natural resources for current growth. However, the concept of growth itself is a problem, as the resources of the earth are limited.

The Bruntland Report called for strategies to reinforce efforts to promote sustainable development. Prompted by the report, the UN Conference for Environment and Development in 1992 (*The Earth Summit*) became instrumental in the popularization of the concept of sustainable development. The Bruntland Commission put forth the most widely used definition of sustainable development, which contains two key concepts: The concept of "***needs***" and the idea of "***limitations***" imposed by the state of technology and social organization on the environment's ability to meet present and future needs. When the "needs" are considered, priority should be given to the essential needs of the poor.

Sustainable agriculture integrates three main goals—environmental health, economic profitability, and social and economic equity. Sustainable practices are based on an understanding of ecological principles; and insuch systems, farmers find themselves working with the ecology of the system, rather than against it. However, any farming system that is going to be truly sustainable must be so in all these senses; a farmer cannot continue the farming business, if the farming operation is not economically viable, regardless of how fine it may be ecologically! Although increased attention is paid to organic components, particularly in soil fertility management and pest control, integration is the key in sustainable agriculture. Integrated nutrient management (INM), integrated pest management (IPM), integrated weed management systems (IWMS), integrated watershed management, and better land husbandry are some of such concepts.

Population growth and increased food consumption are placing unprecedented demands on agriculture and natural resources. To meet the world's future food security and sustainability needs, food production must grow substantially while, at the same time, agriculture's environmental footprint must shrink dramatically. Incredible progress in food production could be made by halting agricultural expansion, closing yield gaps on underperforming lands, increasing cropping efficiency, changing food habits, and reducing waste. These strategies, if implemented based on sustainable principles, could double food production while greatly reducing the environmental impacts of agriculture.

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# Wealth from Waste: Potential in Agriculture, Kerala

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## INTRODUCTION

Demographic and urban growth is one of the major challenges of the next decade. Historically, cities were the driving force in the field of economic and social development. However, urbanisation not only offers advantages, but poses also environmental and social problems, including inadequate water supplies, poor environmental sanitation services and food insecurity. It is argued that all human and organic municipal solid waste can be recycled and used in urban and peri-urban agriculture, though the knowledge of the quantity of reusable waste is limited. In fact, integration of urban and peri-urban agriculture into urban environmental sanitation planning is of utmost importance. The reuse potential of different waste products as a function of crops, soil and climate conditions, including health, socio-cultural, economic, and reuse policy aspects have to form an integral part of future environmental sanitation strategies. Urban waste reduction and reuse involves, among other things, composting of urban organic wastes, where the organic fraction of municipal solid waste is high. However, with urbanisation the quantity of waste is increasing and the composition of waste is becoming more diversified.

The management of municipal solid wastes (MSW) has become increasingly complex and expensive. Communities are moving towards integrated systems involving a number of management techniques to maximize the recovery of resources from the waste stream. Organic materials comprise the majority of MSW, so composting is likely to play a critical role in achieving waste reduction goals set by various states. Composting is a controlled biological process that uses natural aerobic processes to increase the rate of biological decomposition of organic materials. It is carried out by successive microbial populations that break down organic materials into carbon dioxide, water, minerals, and stabilized organic matter. Carbon dioxide and water are released into the atmosphere, while minerals and organic matter are converted into a potentially reusable soil-like material called compost. The loss of water and carbon dioxide typically reduces the volume of remaining material by 25% to 60%; compost can be used as a soil amendment in a variety of agricultural, horticultural or landscaping applications. In traditional settlements, in many parts of the world, the age-old habit of returning household wastes to the food chain persists. Kitchen peelings and food leftovers are fed to animals, selected organics are fed into fish ponds and wastes are composted for home gardens. Composting provides a means to recover the organic fraction of the waste stream to produce a usable product. Whatever methods are employed, compost facilities will generate some "rejects" or non-compostables that must be disposed of at a landfill or incinerator.

**WASTE MANAGEMENT IN KERALA**

The Solid waste management is a mandatory responsibility of Local Self Government Institutions (LSGIs), as per provisions of the Kerala Municipality Act 1994, Kerala Panchayat Raj Act 1994 and the Municipal Solid Waste (Management & Handling) Rules, 2000. The State Government is responsible for coordinating and assisting the LSGIs for implementing the MSW Rules. The sectoral status study on Municipal Solid Waste Management done in Kerala has indicated that the total solid waste generation in the State is about 8,300 tonnes per day. Studies have also indicated that 70-80% of the total solid waste generated is biodegradable in nature. Of the total, 13% of the waste is generated by the five City Corporations, 23% by the 53 Municipalities and the rest by the 978 Gram Panchayats.

In the State, 27 Municipalities and all five Municipal Corporations have already been completed the construction of Solid Waste Processing Plants and made it operational. They have been following the treatment technology based on biological processing of Municipal Solid Waste, using mainly the Windrow Composing and Biogas Plants, as specified in the MSW Rules. Those LSGIs that have processing facilities have been facing difficulties such as lack of adequate land for disposal of rejects from the compost plants, inadequacies of processing facilities and odour nuisance, excessive leachate generation, water pollution and other environmental issues from operation of the compost plants. The major issues faced by these Plants are being highlighted by media and there are public protests in some urban local bodies. There is wide spread public concern over the management of Municipal Solid Waste especially in Corporation and major Municipalities. The waste treatment facility at Thiruvananthapuram city is closed for the last several months due to public protest and a crisis is existing in the capital city. Issues are serious at urban local bodies like, Kollam, Kottayam, Thrissur, Kannur, and Thalassery.

The problem of solid waste disposal has now become one of the most serious environmental problems facing Local Self Governments and the State Government in Kerala. Disposal of waste presents an increasing challenge to all concerned. It has even become a law and order issue at many places. In recent years, there has been a phenomenal increase in the volume of wastes generated daily. When it accumulated without proper treatment, all sorts of environmental issues were cropped up, which has affected the peaceful existence of the people.

## POTENTIAL IN AGRICULTURE

Basically a three-prong approach is resorted by Suchitwa Mission/Government for solving the issues of waste management in the State. They are, (i) popularisation of source level treatment using composting and biogas generation; (ii) modernisation/improvement of existing solid waste processing plants of LSGIs, which are mainly centred on windrow composting, vermi-composting, and biogas plants; and (iii) establishing modern waste treatment systems for cities and large urban local bodies which focus on integrated systems with a component of thermal technologies that produce energy.

Backyard composting and biogas plants are adopted as an individual strategy for management of household kitchen and garden wastes and a formal strategy for the management of the organic waste stream in small Municipalities and Panchayats. Composting is culturally familiar to most people. It is clearly a sound practice for management of compostable waste streams at the village or community scale. Encouragement is given by the Government through Horticulture Mission and through other means for kitchen gardening and backyard cultivation in a larger way in combination with the individual/source level composting. In order to popularize source level treatment systems, several indigenous technologies have been identified, in addition to different types of biogas plants, ring compost, and vermi-compost. They include pipe composting, pot composting, bio-pedastal system, mose pit, bio-digester pot composting, portable bio-bins, home compost polymer tumbler, portable HDPE/plastic bin/bucket composting, mini bio-pedastal, centralised masonry bio-tanks, aerobic ferro-cement bins, organic waste converting machine method, bio-toilets, etc. They have been popularized at household-apartment-institution levels by Suchitwa Mission, which is entrusted to help LSGIs in waste management technically and financially. It has conducted several exhibitions and exhibition cum sales for attracting attention of all concerned.

90% subsidy is offered to households for adopting source level treatment using different composting devices (75% borne by Suchitwa Mission, 15% by the Local Self Government and the rest 10% by the beneficiary). For establishing compost systems at flats and high rise apartments subsidy is given at the rate of Rs. 500 per flat subject to minimum of Rs.15,000 per flat system was given at Thiruvananthapuram. Steps have been taken for source treatment in commercial establishments like Hotels, Kalyanamandapams etc by making amendment in the Legislation. Waste management projects have been shifted from service sector to production sector, by which the LSGIs get opportunity to utilise more funds for waste management, especially using traditional technologies.

## WASTE TO ENERGY

There are several immediate requirements as far as upgradation/modernisation of solid waste management systems, including source level treatment, and establishment of sewage/septage treatment facilities due to several reasons. Hence, during the last year search was conducted for alternate or better technologies for solving the issues in the existing waste treatment plants of the urban local bodies, taking into consideration the special characteristics of waste, climatic conditions, land constraints, environmental sensitiveness, etc. In order to explore the possibility of bringing in modern technologies which are functioning in other parts of the country/world successfully, a wide search was conducted. Suchitwa Mission has done short listing of such technologies which primarily do not generate bad odour, and leachate, and technology providers, with the help of a panel of experts in the sector. The technologies shortlisted include improved biomethanation and thermal technologies, and an integrated system with a combination of them, which generate electricity. Modern modular municipal solid waste processing plant on pilot scale at Thiruvananthapuram will be started by the end of 2012 under Public Private Partnership (PPP).

Bid process for establishing modern municipal solid waste processing plants at Brahmapuram (Ernakulam), Njelianparambu (Kozhikode), Kureepuzha (Kollam), Laloor (Thrissur), Vadavathoor (Kottayam), and Chelora (Kannur) under PPP has been started. In fact, the State is now looking for implementing 'Integrated MSW Treatment Projects' utilising the latest and effective technology with useful output with minimum landfill, no leachate and without any odour nuisance. Considering the difficulties in establishing sewage systems throughout Kerala due to the peculiar habitation pattern in the State, steps are taken to establish modern septage treatment systems in all Districts of the State. Co-treatment systems will be established at Thiruvananthapuram and Ernakulam, immediately.

## CONCLUSION

As noticed above, the strategy now adopted by Suchitwa Mission/Government is to go on with popularising household/source level waste treatments using mainly composting, which facilitates to bio-agriculture. It is a fact that more than half of the total solid waste generated in Kerala is from households and institutions. Liberal incentives and encouragement are offered for popularising composting (with 90% subsidy). Windrow composting and vermi-compost systems, combined with biogas systems, of Panchayats and Municipalities are also encouraged, by giving 100% support for their upgradation and for establishing new ones. But for the cities and large municipalities, where a lot of solid waste is generated, modern waste treatment systems under Public Private Partnership (PPP), which produce energy, are opted considering the leachate, bad odour, and other environmental issues created by the large waste treatment systems in the State. As the waste to energy plants are now envisaged for cities and major urban local bodies, the relevance of source level treatment of waste using composting will not be lost. Large scale programmes such as '*Suchitwa Gramam, Haritha Gramam*', '*Vridhi Samrudhi*', etc. are already started by Suchitwa Mission to popularise source level composting by mobilising Residents' Association, NGOs, Students etc.

# Remote Sensing Application in Agriculture and Forestry

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## INTRODUCTION

The techniques of remote sensing have ushered in studying, surveying and monitoring bio-resource features. With the development of remote sensing techniques, a new era has started in the field of resource survey, management and change detection studies. Stratification of vegetation covers with respect to structural features, is highly essential for resource evaluation. The satellite remote sensing techniques coupled with aerial photographs have been found very useful for this purpose. The forest resource evaluation using remote sensing data was proved to be an invaluable tool (Harding and Scott, 1976; Porwal and Pant, 1989). The development of computer technology and various software packages were yet another boost in the field of satellite data processing.

The information on forest type classification prepared by Champion and Seth (1968) shows various forest types and vegetation formations in the country. This can neither provide spatial maps nor facilitate spatial integration of collateral data.

Remote sensing is the science and technology of making inferences about material objects from measurements made at a distance without coming into physical contact with the objects under study. Remote sensing is a tool to monitor the earth's resources using space technology in addition to ground observations. It can be used in soil mapping, land use pattern, forest mapping, geological and hydrogeological purposes, drought and flood monitoring in addition to mapping of crop coverage and crop output estimates. In essence, the remote sensing techniques can be used for the earth's resources sensing. It has several applications in the field of agro-meteorological research. The earth and cloud surface temperatures, radiation, rainfall, soil moisture and crop yield estimates based on spectral indices etc can be worked out using this technology. The technology can be applied also to monitor insect pest and disease surveillance, along with field observations. Remote sensing inputs combined with crop growth simulation models are very useful tools in crop yield forecasting. The methods are being evolved constantly for analysing crop area coverage and crop yields using remote sensing data and agroclimatic indices, which will be inputs in crop simulation modelling.

Remote sensing technology uses the visible, infrared and microwave regions of radiation to collect information about the various objects on the earth's surface. The responses of the objects to different regions of the electro-magnetic spectrum are different. These typical responses are used to distinguish objects such as vegetation, water, bare soil, concrete and other similar features. Three platforms are generally used for remote sensing techniques: ground-based, air-based and satellite-based. Since the ground-based and air-based platforms are very costly and have limited use, space-based satellite technology has become handy for wider application of remote sensing techniques.

The advantages of satellite remote sensing are:

1. *Synoptic view*-wide area can be covered by a single image or photograph (One scene of the Indian Remote Sensing Satellite (IRS) series covers about 148 x 148 sq. km area).

2. *Receptivity*-One can get the data of any area repeatedly (IRS series covers the same area every 16-22 days).

3. *Coverage*- Inaccessible areas like mountains, swampy areas and thick forests are easily covered.

Space-based remote sensing is the process of obtaining information about the earth from the instruments mounted on the Earth Observation Satellites. The satellites are subdivided into two classes. The satellites operate at an altitude of between 550 and 1,600 km along an inclined circular plane over the poles are called "polar orbiting satellite" or "resource satellite". These satellites are used for remote sensing purposes. A second set of satellite,"geostationary satellite" have orbits around the equator at an altitude of 36,000 km and move with the same speed as the earth, so as to view the same area on the earth continuously. They are used for tele-communication and weather forecasting purposes. The INSAT series satellites are launched from India for the above purposes. AII these satellites have sensors on board. operating in the visible and near infrared regions of the electromagnctic spectrum.

Yet another branch of technology, the Global Positioning System or GPS is a constellation of 27 satellites orbiting the earth at about 12000 miles. These satellites are continuously transmitting a signal and anyone with a GPS receiver on earth can receive these transmissions at no charge. By measuring the travel time of signals transmitted from each satellite, a GPS receiver can calculate its distance from the satellite. Satellite positions are used by receivers as precise reference points to determine the location of the GPS receiver.

Similarly, the Geographical Information System (GIS) is another tool used for spatial analysis. The GIS can be used along with remote sensing and GPS data as inputs. The spatial analysis functions distinguish a GIS from other types of information systems.

These functions use the spatial and non-spatial attribute data in the GIS data base to answer questions about the real world.

The answers provided by a GIS can be categorized into three types, *viz*:

1. A presentation of the current data,
2. A pattern in the current data,
3. A prediction of what the data could be at a different time or place

The type of questions to be answered can also be characterized by three categories:

1. What are the data?, ie. what is the information currently stored in the data base.
2. What is the pattern in the data?,
3. What could the data be? This type of questions implies that a predictive model will be used.

The strategy for undertaking a specific GIS analysis will depend on the answers that are to be provided.The technologies mentioned above together comes under the headline of,"geomatics". The application of these technologies in the field of Agriculture and Forestry sectors are highlighted in the current writeup.

**AGRICULTURAL APPLICATION**

The utilization of space-borne multispectral data for crop acreage and production estimation started in seventies with the launching of the Large Area Crop Inventory Experiment (LACIE) jointly by NASA, USDA and NOAA (National Oceanic and Atmospheric Administration) in 1974. In India the satellite remote sensing is mainly used for the crop acreage and production estimation of agricultural crops. The methodology for acreage and production estimation using Indian Remote Sensing Satellite (IRS1A/1B) has been in operation for major crops, namely, wheat, paddy, sorghum, soybean, groundnut and cotton in the monocropped areas (Space Application Centre, 1990). In 1970, ISRO carried out a very interesting and promising experiment for IARI, in detecting coconut root wilt disease in Kerala before it was visible on ground.

**Identification, Area Estimation and Monitoring**

The specific requirement of climate and soil conditions coupled with the specialized management practices make the distribution of plantation crops rather more localized in comparison to other agricultural crops. The identification, estimation of growing stock, analysis of distribution and monitoring at regular intervals are major aspects in plantation crops. The methodologies are based on visual interpretation of satellite images using pictorial elements like tone, texture, patterns etc. (Curren, 1985; Lillesand and Kiefer, 1987) and digital image processing method (Jensen, 1986). Methodology standardization for rubber mapping in Kerala (Menon, 1991), mapping of horticultural plantations in Himachal Pradesh (Kimoti *et. al*, 1997); identification of teak plantations (Sreevastava and Oza, 1991); growth analysis and biomass production of Eucalypts in Gujarat (Mohinder and Rauri, 1991) etc are some examples of remote sensing data utilization in plantation crops studies.

**Crop Nutrient Deficiency Detection**

The nutrient deficiency in plants affects the color, moisture content and internal structures of the leaves and as a result their reflecting power changes. The specific effects of nutrient deficiency on the reflectance property of plants are yet to be studied in detail. Since a significant correlation exists between levels of nutrient supply eg. Nitrogen and vegetation growth of plants; a deficiency or a variation of nutrient supply will cause a change in crop canopies resulting in detectable canopy reflectance or temperature variation (Das *et. al.*1989; Gardner *et. al* 1981; Idso *et. al* 1977). Since in nitrogen deficient crops the red (R) reflectance is much higher as compared to that in the infra red (IR) region, different vegetation indices based on Red and IR reflectance have been developed as spectral parameters for crop canopy under fertilized and nutrient conditions (Richardson *et. al* 1983; Ajay *et. al* 1984).

**Vegetation Indices**

The green, red and NIR reflectance could be employed as variables to estimate the Leaf Area Index (LAI). Many investigations have been conducted to assess crop characteristics, such as biomass, and LAI, by means of combinations of reflectance or digital pixel values in various spectral bands. Such a combination of reflectance values, the vegetation index, also serves to correct for undesirable influences of varying soil reflectance or atmosphere circumstances on the result. Rouse *et. al* (1973 and 1974) in their investigations into vegetation indices concerned with NIR/ Red ratio of Landsat MSS band 7/band 5, found that this ratio is suitable for the estimation of crop characteristics owing to a partial correlation for the solar position and atmospheric influence. They also used normalized vegetation index (NVI) *ie.* NIR-Red/NIR+Red for the same purpose. Often this type of vegetation index is called the *"normalized difference vegetation index"* (NDVI). Depending on the different conditions, a number of modified vegetation indices are in use (eg. *Perpendicular vegetation index* (PVI) of Richardson and Wiegand (1977); *Brightness index* of Kauth and Thomas (1976); *Soil adjusted vegetation index* (SAVI) of Hute (1998); *Transformed soil adjusted vegetation index* (TSAVI) of Baret *et.al.* (1989)etc.

**Crop Condition Assessment**

The physiological changes that occur in a plant due to stress may change the spectral reflectance/ emittance characteristics resulting in the detection of stress amenable to remote sensing techniques. Crop monitoring at regular intervals during the crop growth cycle is essential to take appropriate measures and to assess information on probable loss of production. Various canopy temperature based approaches have been reported to evaluate water stress in crops (*eg*. Canopy temperature variability (CTV) measurement by Millard *et.al.* (1978); the cumulative stress degree days (SDD) measurement of Idso *et. al.*(1977) etc.). Crop growth and its condition are often characterized through the use of various vegetation indices such as reflectance ratio, NDVI, PVI, transformed vegetation index, and greenness index. The remote sensing based methodologies can provide information on the occurrence and the aerial extent of crop stress.

**Crop Yield Modeling and Production Forecasting**

The information on production of crops before the harvest is very vital to the national food policy planning and economy of the country. Reliable crop yield estimate is one of the most important components of crop production forecasting. Recently, considerable attention has been given to the development of yield models which could be derived with remote sensing inputs. The crop yield is dependant on many factors such as crop varity, availability of nutrients and water, pest and disease control, and weather parameters. Spectral response of a crop is the integrated manifestation of various crop growth factors. In a given time domain, the growth and decay of spectral response indicates the crop performance. The spectral index for a given segment is computed and aggregated to obtain a spectral index representing the entire district. By using IRS P3 WiFS (Wide Field Sensor) and IRS-1C WiFS and LISS3 which have a good periodicity, it may be possible to construct growth profiles and retrieve yield related parameters at region level.

**Pest Management**

Integrated pest management is an important component of sustainable agriculture. Methodologies need to be perfected for identification of locust breeding grounds based on vegetation or moisture status, thereby developing strategies for preventing their spread and effective control measures. Since the area is very large and the cycle of locust breeding, growth and its spread is very short, satellite having high temporal resolution and large area coverage like AVRR may be suited well to identify and prioritize the areas to arrest and control pest menace.

**Agricultural Draught Assessment**

Draught assessment is yet another area wherein remote sensing data has been used at operational level (Chari, 1988). The district level drought assessment and monitoring using NDVI generated from NOAA-AVHRR data helps in taking timely preventive and corrective measures for combating drought. Scheduling irrigation based on environmental parameters is useful for quick adoption of management practices suitable over large areas. Several methods for irrigation scheduling based on infrared thermometry have been proposed. Nixen *et.al.* (1973) suggested that the canopy temperature variability could indicate areas of adequate or inadequate water in a field. A measure of canopy temperature variability (CTV), therefore, might be used in irrigation management (Clawsom and Blad, 1982). Weigand and Namkem (1986) proposed canopy air temperature difference (CATD) to be an indicator of crop water stress.

**Reflectance Modeling**

Physical reflectance models for crops serve the important purpose of understanding the complex interaction between solar radiation and plant canopies. In principle there are two kinds of physical reflectance model *viz.* numerical and analytical.

Bunnik (1984) has published an extensive review on this topic. In order to obtain a reliable yield prediction, growth of crops has to be modeled by means of crop growth models. Crop growth models describe the relation between physiological process in plants and environmental factors such as solar irradiation, temperature, water and nutrient availability. Optical remote sensing can provide information on the actual status of crops (Crop parameter estimation) resulting in an improvement of estimates for crop growth models. On the one hand remote sensing data may be used as direct input into crop growth models, while on the other hand RS data may be used for checking the result of crop growth modeling.

**FORESTRY APPLICATION**

Phytosociological inventory and analysis of vegetation, to derive the special patterns of plant diversity, is essential for landscape level biodiversity analysis. Emphasis on the study of spatial patterns of plant diversity is highly necessary for landscape level study. This can be achieved using remote sensing techniques. The tropical forests are rich in phytodiversity (Padalia *et.al.* 2004). The importance of spatial heterogeneity to species diversity has been well documented (Whittaker, 1972). Landscape parameter is emphasized by patch size, type, number, shape, heterogeneity and edge features, indicates spatial organization of vegetation types, biotic disturbance and habitat stability (Turner, 1989; Li and Reynolds, 1993; Ritters *et al.* 1995).

Remote sensing forms a valuable tool in mapping and monitoring of biodiversity and provides valuable information to quantify spatial patterns, biophysical patterns, ecological process that determine species richness and anthropogenic factors causing loss of species richness and for predicating response of species to global changes. Information on existing land use / land cover pattern, its spatial distribution and changes etc. are essential requisite for planning (Dinwa *et.al.* 1993). This land use planning and land management strategies hold key for development of any region. The conventional methods of detecting land use/ land cover changes are costly, low in accuracy and pretend a picture only a small area. Remote sensing, because of its capabilities of synoptic viewing and repetitive coverage, provides useful information on land use / land cover dynamics (Sharama *et. al.*1989).

The rapid depletion of forests made it essential to know the rate and trend of this degradation so that timely measures could be taken to prevent further loss of forest resources. Timely and accurate information for detecting changes over a period of time (Fig. 1) is required for forest ecosystems studies. This can be done through repetitive and cost effective technique of remote sensing. Accurate forest cover/ vegetation map information are essential for formulating various management plans. Remote sensing technology can be effectively used for change detection and monitoring activities (Menon and Chandrasekharan, 1991).

The structural information and land cover maps are essential for management of Wildlife Sanctuaries, National Parks, and Reserved Forests etc. With regard to the mapping and vegetation analysis of the Western Ghats, particularly Kerala part, very little information is available on different forest types and plant diversity.

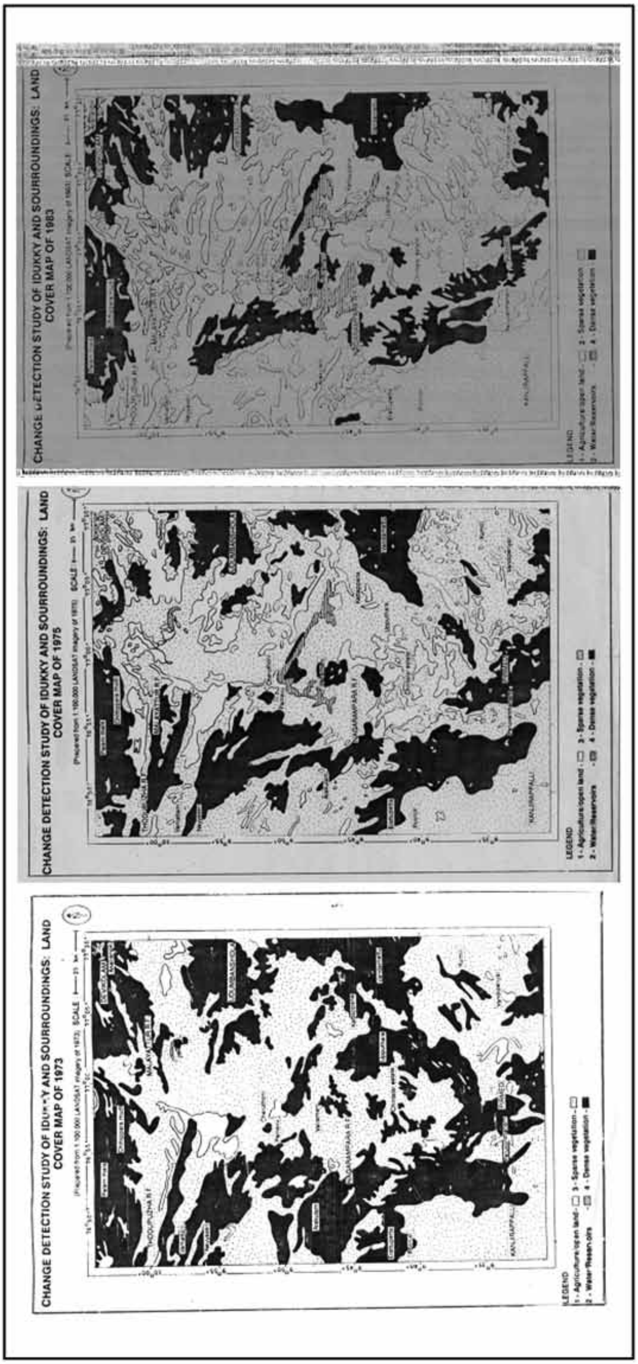


**Fig. 1**
**Change Detection of Idukki Region (Menon and Chandrasekharan, 1991)**

It was during 18th and first half of the 19th century, the basic idea about the use of aerial cameras for forestry purposes started. The inventories of aerial cameras, different types of lenses, sensitive bases to record the images, the image processing techniques and the air-born platform made revolution in this field. It was Wilber Wright in 1909, who had taken the first aerial photograph from the plane.

The use of airplanes in forest stand mapping started in 1919 at Canada. Vertical aerial photography in the 1920's in Burma, Indonesia, Papua-New Guinea, Zambia etc provided the beginning of remote sensing in tropical forestlands (Bourne, 1931). Avery (1967) described the general principles of remote sensing. In India, the pioneers of the Indian Remote sensing programme were the two well-known scientists, Vikram Sarabhai and Homi Bhabha. Prof:P.R.Pisharati organized the first successful mission of early detection of coconut wilt disease in 1970 by Remote sensing techniques using a Soviet aircraft, US equipment and Indian scientist. Since 1925, aerial photographs are in use in India for preparation of topographical maps. Since 1965, for Pre- Investment Survey of Forest Resources, aerial photographs were used for forest type mapping and inventory in Dehra Dun was a major breach in this field. With the opening of Indian Photo-interpretation Institute (IPI), presently Indian Institute of Remote Sensing (IIRS); the photo interpretation technique was more popularized and subsequently many organizations like Forest Survey of India (FSI), started photo interpretation works (Table 1).

**Table 1**
**Photointerpretation Key for Landcover Mapping**
**(Prepared from 1:15000 B&W Aerial Photographs)**

| Landcover | Tone | Texture | Pattern |
|---|---|---|---|
| **Evergreen** | *Black* | *Fine* | *Smooth* |
| **Hilltop Evergreen** | *Deep black* | *Fine* | *Smooth* |
| **Semi-evergreen** | *Medium black* | *Medium* | *Smooth* |
| Moist Deciduous | *Grayish* | *Medium* | *Coarse* |
| **Grassland** | *White* | *Fine* | *Smooth* |
| **Reservoir** | *Dark black* | *Fine* | *Distinct* |
| **Habitation** | *Yellowish white* | *Coarse* | *Definite shape* |
| **Agriculture** | *Medium grey* | *Coarse* | *Definite shape* |

Aerial photographs are being used in India for detailed forest type mapping and inventory by Maselekar (1974) and Tomar (1976).

Menon (1988) used 1:15,000 B&W aerial photographs for vegetation mapping in Attappadi region, Kerala. In this, more than 20 units were mapped. Rekha Ghosh (1989) prepared drainage map of Eastern India from aerial photographs. Porwal and Roy (1991) used 1: 10,000 B& W aerial photographs for mapping Kanha National Park, Madhya Pradesh. Five sub landscapes and physiographic units, four forest vegetation types, four crown closure classes, under storey components etc were also distinguished in this study. Aerial photographs of two different dates were used to monitor changes in Sinharaja forest, Srilanka (Banyard and Fernando, 1992). Forest cover monitoring of Rajaji National Park using aerial photographs was done by Das *et.al.* (1996). Varghese (1997) used aerial photographs of 1: 15,000 scale (see Table 2 for key) to prepare a detailed land cover map of Peppara Wildlife Sanctuary.Vegetaion mapping of Shenduruni Wildlife Sanctuary was done by Thriveen Sankar (2002). Change detection in Sal forests in Dehra Dun forest division using aerial photographs were also carried out by Parmeshwar (2003). Land cover mapping of Kerala State has been done by Menon (2000) by using aerial photographs of 1:15,000 scales and satellite imageries of 1:50,000 (Table 2). The approach for land cover mapping is as shown in fig 2.

**Table 2**
**Land cover statistics of Kerala using IRS satellite data (in sq. km)**

| District | EG | SEG | MD | DD | GR | DEG | GRS | PLN (NF) | SC | AGR | FAL/ BAR | RDS | WAT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trivandrum | 57.0 | 67 | 274.4 | | 22.2 | 33.4 | 16.1 | | 0.4 | 1492.1 | 155.4 | 3.1 | 30.5 |
| Quilon | 110.4 | 115.1 | 399.5 | 1.8 | 92.6 | 112 | 18.9 | 0.0 | 25.9 | 1311.5 | 169.1 | 15 | 101.2 |
| Pathan-amthitta | 386.8 | 270.5 | 617.2 | 7.8 | 78.4 | 50.8 | 36.8 | 1.0 | 21.3 | 1029.8 | 74.5 | 29.8 | 21.5 |
| Kottayam | 22.9 | 13.3 | 145.4 | 3.1 | 24.7 | 15.8 | 25.6 | 61.9 | 8.8 | 1577.6 | 253.3 | 5 | 46.2 |
| Aleppy | | | 4.6 | | | | | 142.4 | | 740.1 | 419.6 | 114.3 | 113.6 |
| Idukki | 799.8 | 564.3 | 1641.9 | 5 | 612.4 | 328 | 167 | 0.3 | 182.2 | 319.6 | 19 | 11.8 | 113.1 |
| Ernakulam | 19.2 | 4.2 | 115.3 | 0.8 | 56.6 | 51.2 | 17.1 | 122.2 | 21.8 | 1443.2 | 437.5 | 3.4 | 93 |
| Thrissur | 176.3 | 43.8 | 346.6 | | 101.6 | 16.9 | 77.8 | 219.2 | 9.6 | 1333 | 635.2 | | 56.8 |
| Malappuram | 209 | 95.4 | 320.5 | 1.6 | 8.1 | | 95.4 | 421.9 | | 1691.7 | 690.6 | | 29 |
| Palakkad | 335.3 | 160.6 | 670.3 | | 130.7 | 165 | 98.2 | 210.2 | | 1332.4 | 1285.8 | | 44.2 |
| Wayanad | 100.6 | 93.8 | 318.5 | 259 | | | 177.5 | 769.8 | | 127.3 | 276.2 | | 5.1 |
| kozhikode | 90.3 | 82.5 | 114.2 | 0.2 | 0 | | 87.4 | 491.4 | | 985.8 | 436.4 | | 44.7 |
| kannur | 62.6 | 77 | 61.8 | 1.5 | | 55.5 | 33.3 | 707.5 | | 989.2 | 912.1 | | 46.4 |
| Kasaragod | 10.4 | 16.5 | 0 | | | 62.1 | 5.6 | 409.3 | | 568.3 | 870.4 | | 19.7 |
| Percent of total geo-graphic area | 6.13 | 4.13 | 12.94 | 0.72 | 2.9 | 2.29 | 2.2 | 9.15 | 0.7 | 38.45 | 17.07 | 0.47 | 1.97 |

*EG - Evergreen forest, SEG – Semi-evergreen forest, MD - Moist deciduous forest, DD - Dry deciduous forest, GR - Grassland, DEG - Degraded forest, FAL/BAR - Fallow Barren, RDS – Reeds, WAT - Water, AGR - Agricultural, GRS - Gregarious species, PLN (NF) - Plantation Non forest, SC - Scrubs*

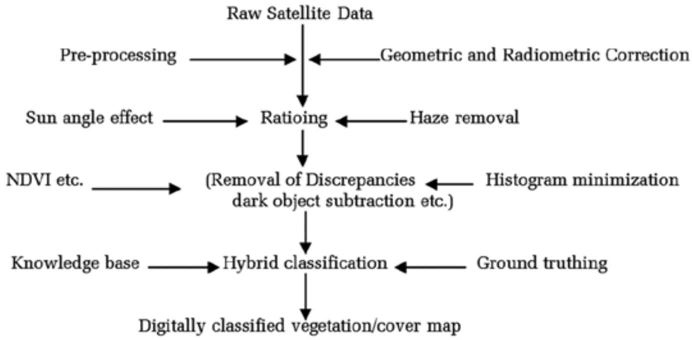


**Fig. 2**
**Schematic Approach for Landcover Mapping**

**Spatial Signature Library**

Spatial signature evaluation of the forest species and the reflectance properties of different species in different phonological stages and growth stages are yet to be explored thoroughly. It is true that, very little scattered works have undertaken in this regard. The work on this line on crop reflectance properties are conducted by organizations like Space Application Center, Ahemadabad. But, practically no works were undertaken on forest tree species reflectance characteristics. If such data are available in a *"spatial signature library"*, such data can be used for the tree distribution studies in forestry sector. The various absorption and reflectance regions of the spectrum will give an indication of the tree health status, water relation status and even draught proneness of the species. The use of spectra-radiometer in different frequency region for the canopy reflectance properties of the forest trees, using canopy elevators is an accepted practice in many countries. The spectral libraries of crop plants are available for major agriculture crops like wheat, rice, sugar cane etc. Similar spectral library information is highly essential in the forestry sector, for the evaluation of forest dynamics.

The information on forest type classification prepared by Champion and Seth (1968) shows various forest types and vegetation formations in the country. This can neither provide spatial maps nor facilitate spatial integration of collateral data.

**Forest Vegetation Mapping**

The history of satellite remote sensing began with the launching of Landsat 1 in July 1972 by NASA, United States. The first Indian Remote Sensing satellite (IRS 1A) was launched in April 17,1986. Recent research indicates that optical mechanical scanning is applicable to the identification of forest tree species (Olson, 1970). Quantitative changes in forest cover and effects of fire were successfully done using satellite remote sensing techniques with special reference to Bandipur National Park and Mudumalai Wildlife Sanctuary, (Madhavanunni *et. al*., 1986). Prince (1985) has already used satellite data successfully for studying and monitoring range conditions in Botswana. Lal *et al*. (1990) assessed the extent and location of deforestation in

Kodagu district, Karnataka using 1:2,50,000 Landsat MSS data. The application of IRS IA data in forestry was discussed by Madhavanunni *et al*. (1991). Porwal and Roy (1992) used 1:50,000 Landsat TM FCC for delineation and mapping of heterogeneous forests of Western Ghats, Kerala and estimated as overall accuracy as 88.33 percent. Roy *et.al.* (1992) used 1:50,000 Landsat TM FCC for mapping Chandaka Wildlife Sanctuary (Orissa) and compared it with aerial photomap. Application of remote sensing for rattan resources survey was done by Nandakumar and Menon (1992) and Karavannur watershed (Fig. 3), in Thrissur District of Kerala was done by Renjith et. al (2010). Land use change and analysis of Bharatpur district in Rajasthan was done by Dhinwa *et.al*. (1992). Roy *et al*., (1993) mapped tropical forests of Andaman Islands using Lands at TM FCC of 1: 50,000 scale and identified nine land cover classes. Varghese *et. al*., (1996), prepared bamboo stock map using remote sensed data. Forest cover map of Corbet National Park was prepared by Anjana Panth *et. al.* (1999) using IRS 1B -LIS II data. Forest change detection and spatial distribution of Kala Rani round (Gujarath) were studied by Jessica *et al*. in 2001. Biodiversity characterization of Western Ghats was done, by Anon, 2002 using Satellite remote sensing and GIS. A vegetation pattern analysis, monitoring and conservation natural resource of Rudraprayg was undertaken effectively by Raturi *et. al*. (2004). Land cover mapping of East Champaran district of Bihar State was done using IRS-1D LIS III Satellite data by Manju *et.al.* (2005).

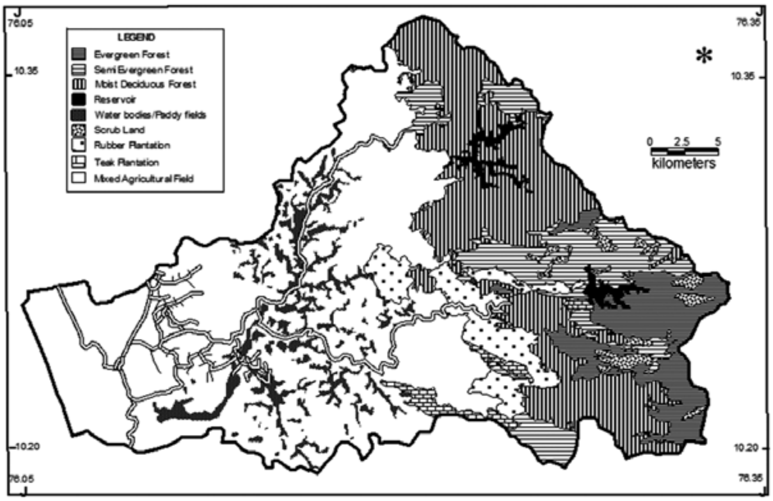


**Fig. 3**
**Landcover map of Karuvannur watershed in Thrissur district**

## Digital Image Processing

Dodge and Bryant (1976) carried out digital mapping using Landsat data. The area of hard wood/soft wood and total forested area were compared with existing records. Bryant *et al*., (1980) used Landsat digital data for forest mapping and compared it with aerial photographs. Studies on spectral separability of cover classes were done by many researchers. Adeneyi (1985) prepared land cover map of a semiarid area of Nigeria using Landsat digital data. Skidmore *et. al*., (1987) used digital Landsat data for forest mapping in Australia. In India, digital mapping were carried out by several workers. Kachhwaha (1983) used Landsat digital data for forest mapping. Singh and Khan (1989) used digital data for change detection studies. Ashbindu Singh (1990) integrated digital data with ancillary data to improve supervised classification. Menon and Sashidhar (1990) evaluated different digital techniques for land cover mapping. Menon (1991) mapped rubber area using IRS data. Menon and Ranganadh (1992) used IRS data for mapping Silent Valley region. Vegetation indices from AVIRS data were used to evaluate spatial patterns of vegetation type, productivity and potential physiological activity by John *et al*. (1993). Rathore *et. al*. (1997), Minakshi and Sharma, (1999); Kriahna *et. al.* (2001); Kushwaha (2003), Raturi *et al.* (2004) used various techniques of digital mapping techniques related to forest inventory processes. Land cover mapping of Binpur block of Midnapur District of West Bangal (India) was done by Nookaratnam *e. al*. (2005).

## CONCLUSION

In order to effectively utilize the information on crops for improvement of economy, there is a need to develop state/ district level information system based on available information on various crops derived both from conventional and remote sensing approaches in GIS environment. One of the greatest advantages in using remote sensing data is its ability to generate information in spatial and temporal domain, which is very crucial for successful model analysis, prediction and validation. The use of remote sensing technology involves large amount of spatial data management. The GIS technology provides suitable alternate for efficient management of computer database. The key to all GIS is the fundamental map base, to which all data eventually relates. Remote sensing is now being widely regarded as a layer in GIS. Remote sensing, although a specialized technique, is now accepted as a basic survey methodology, means of providing data for a resource scientist, whereas the GIS is the method by which data layers can be interrelated in order to arrive more logic conclusion.

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# Information Communication Technologies for Sustainable Agriculture: Pre Requisites and Policies for Practice

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## INTRODUCTION

ICTs have tremendously advanced in terms of applicability and sophistication, touching every facet of life and becoming increasingly affordable. Since information is factored in every human activity more than ever before, information intensive sectors such as agriculture need to be ICT enabled effectively. Agriculture for that matter involves the issues and needs of a large number of heterogeneous people and the diverse production systems of innumerable crops, across several agro climatic regions. It also includes large and complex systems of agricultural research, education and extension which are institutionalized and interlinked. Administration of development process, credit, agribusiness and market related activities are other domains in agriculture which require huge information inputs. The inherent vulnerabilities of agriculture make it respond instantaneously to socio economic transformations and shifts in international and domestic policies, which make it highly information dependent.

Employing ICTs to make agriculture sustainable warrants careful introspection into the nature of ICT applications that are currently used in the process of agricultural development. Leaving out the use of ICTs in the form of sophisticated equipments and programmes in research and commercial enterprises, application of these technologies directly in grassroots level development is alarmingly low in developing economies. Though there are several anecdotal references to successful ICT interventions in agriculture, there are no comprehensive programmes that address issues of equity and sustainability. Observation by Jhunjhunwala and Aiyar (2006) that 'only a few organisations in India have taken up ICT initiatives in any comprehensive manner and have tried to build services which can be scaled up and have a long-term sustainable impact on the society' remains absolutely true for agriculture, particularly the less endowed farmers. In fact, ICT support to conventional input intensive agriculture itself has been grossly inadequate; and the concern on sustainability has been only rarely addressed. 'Sustainability in agriculture' offers the challenges of tackling the contradictory concerns of optimum resource use and profitability simultaneously. Any ICT programme with focus on sustainability hence will have to follow a course much different from that of conventional transfer of technology initiatives.

This paper tries to review the major ICT programmes for agriculture in the country and a few interventions that work with the perspective of sustainable resource management for environmental protection, from abroad. In the light of the review and based on experiences from the field, the paper tries to outline the pre requisites of the ICT programmes in developing economies to address the issues of sustainability in agriculture, and the policy implications thereof.

**ICT IN AGRICULTURE: AN OVERVIEW**

The key concerns in employing ICT in agriculture, particularly for the rural farming communities had till recently been, and in most of the rural areas still are, connectivity, accessibility, and content adequacy. In India, there had been several initiatives in the public, private and voluntary sectors that had tried to address these issues. Different forms of ICT applications and delivery mechanisms have been tried out in facilitating the activities of farmers. An overview of the ICT initiatives in agriculture shows that majority of the ICT initiatives had focused on transfer of technology through the Internet. There are also ICT applications for e- commerce for rural communities. Sulaiman et al (2012) while categorizing the ICT applications in agriculture observe that most of the programmes intend transfer of technology and awareness creation. Though ICTs have been extensively employed in training, policy advocacy, distance learning and knowledge management, there is a major issue of lack of locally relevant content in majority of the programmes for the farming community. Only a very few initiatives have addressed the real time information requirement of the process of agricultural production at the farmers' level. Sustainability as a function of resource use and conservation does not seem to appear as a major concern in development planning.

A review of the characteristics of the ICT applications in agriculture underway in India is given in table 1.

**Table 1**
**ICT programmes for agricultural development in India- An overview**

| Sl No. | Types | Name of ICT project/programme | Major Objectives |
|---|---|---|---|
| 1 | Internet Enabled Computer Centres (Kiosks/ Knowledge Centres/Common Sservice Centres/Telecentres) | Akshaya e- learning centres, Warna Wired Village, Village Knowledge Centres, e-Choupal, Knowledge Share Centres, Common Service Centres | Dissemination of information on agricultural technologies, climate, prices, government programmes, schemes, e- literacy etc |

| Sl No. | Types | Name of ICT project/programme | Major Objectives |
|---|---|---|---|
| 2 | Portals | AGRISNET, Department of Agriculture and Co operation (DACNET), I-Kissan, Agriwatch, Agricultural Marketing Research & Information Network(AGMARKNET), Karshaka Information Systems Services and Networking(KISSAN), India Development Gateway, Agriwatch, AGMARKNET, aAQUA, Agropedia, Rice Knowledge Management Portal (ICAR and partners)<br>e- Krishi (IT Mission Kerala) | Providing users with information on varieties, cultural practices, plant protection practices, prices, advisory services, E-commerce- Linking producers to traders/consumers, on-line query management etc |
| 3 | Call Centres | KISAN Call centres in the country as well as abroad<br>Distress help line (e.g.: Bhumika, Andhra Pradesh) | Providing instantaneous information on technological solutions, problem solving through consultation with experts, legal counselling |
| 4 | Mobile Phones | Reuters Market Light (RML), IFFCO-IKSL;<br>Tata m-Krishi), Fisherman advisory services by MSSRF | Dissemination of information on technology, weather, prices of commodities in different markets, crop and animal husbandry advisory services, government schemes |
| 5 | Community Radio | Community Radios run by KVKs, NGOs etc<br>(e.g.: Sangham Radio, Kongu FM radio, Mandakini ka awaaz, Krishi Community Radio) | Wide range of information on rural life, agriculture, forests, health, handicrafts etc. Greater scope for issues on sustainability as the ownership is with the community |
| 6 | Video | Digital Green,<br>Video SEWA (Self Employed Women's Association), | Information dissemination, advocacy, communication, training, capacity building, mobilisation, distance education |
| 7 | Digital Photography | e- Sagu,<br>e-Seva and e- Velanmai in Andhra Pradesh and Tamil Nadu | Information dissemination<br>Training<br>Problem-solving<br>Advisory support |

| Sl No. | Types | Name of ICT project/programme | Major Objectives |
|---|---|---|---|
| 8 | Interactive CD ROM/<br>Touch Screen | Touch screen kiosks, Pondicherry | Problem solving, information dissemination |
| 9 | Video conferencing | Virtual academy for semi-arid tropics, CPCRI Kasargod, IGNOU | Advisory support |

*Source: Sulaiman et al (2011)*

As seen from the table, majority of the programmes try to cater to the information requirements of the end users through online and offline devices. Several of them help farmers with consultancy services and by assisting them in identifying problems. However, reach of these programmes is limited as these initiatives are highly localised and have been mostly launched by NGOs. Covering a vast area under the services of these programmes would be only a very distant possibility unless the public systems in this domain are ICT enabled comprehensively. Strikingly, agricultural information delivery through public sector outlets which would have made larger impacts seems to have skipped the urgent priorities of state and national governments. For instance, no attempt has been found to make the grassroots level agricultural extension offices ICT enabled. Apropos the question of sustainability, the existing programmes do not seem to address the issues of sustainability exclusively, other than that the content delivered to the users might contain sustainability concerns inadvertently.

**SUSTAINABLE AGRICULTURE IN DEVELOPING ECONOMIES: PERSPECTIVES AND CHALLENGES**

In order to look into the prospects of ICT enabled sustainable agriculture, the basic premises on which sustainability is construed should be taken into consideration. The goal of sustainable development policy is human well-being for people everywhere, measured in terms of factors such as security, satisfaction of material needs, health, social relations, freedom of choice and action, and following a principle of equity and fairness. To meet this goal, it is necessary to generate and distribute wealth in ways that reduce poverty and provide a decent standard of living to people everywhere (Souter et al, 2010).

It is true that the growth of agriculture so as to feed the world by keeping pace with rapid population growth and delivering food at progressively lower prices has been at the expense of the natural resource base, through overuse of natural resources as inputs(Souter et al 2010). However, agriculture would be sustainable only if current and future food demands are met without unnecessarily compromising economic, ecological, and social/political needs (Pretty, 2002). According to him, key features of agricultural sustainability imply that agricultural strategies should be based on more than simple productivity criteria, that externalities are of great importance, and that intra- and inter-generational equity are important parameters in assessing agricultural change. New understanding on sustainability in the post globalised era emphasises on sustainable livelihoods at the local level, and the need to establish linkages between local and global processes beyond agriculture.

To be more precise, the ecological impacts of agriculture include land degradation, limits to water availability, loss of biodiversity, declining agricultural genetic diversity, contributions to climate change and the like. On the other hand, sustainability at the farmer level includes, *inter alia,* dimensions of productivity, profitability, judicious use of resources and policy support for sustainable production and market access, to name a few. Equity at the regional, community and personal level are also important dimensions of sustainability as obviously felt at the ground level. These include availability of land, better use of water resources, capability to accommodate climate change and management of genetic resources among individuals and communities. Gender concerns figure out prominently in all these concerns.

For agricultural growth to occur at the rate required to meet future demand, rapid increases in productivity to avoid an undesirable expansion onto fragile and marginal lands will also be required. This implies that production increases need to happen without further damage to the environment. Any information or managerial support that could be provided by ICT programmes for sustainable agriculture should be able to help farmers tackle all these issues. It should also facilitate adaptation to the new paradigm that insists sustainable development, particularly by the poor and the less endowed, which is different from conventional approaches.

## SUSTAINABILITY OF AGRICULTURE: INTERVENTIONS AND ACTION POINTS

Converting sustainability concerns into action points require precise interventions at various fronts. For instance, as Pretty (2008) observes, there should be focus on both genotype improvements through the full range of modern biological approaches, as well as improved understanding of the benefits of ecological and agronomic management and manipulation. Moreover, strategies should be devised for better use of existing resources and technologies through ‘sustainable intensification’, rather than employing extensive approaches. At the macro level, policies, institutions and technologies need to increase synergies between initiatives on poverty reduction, agricultural production and environmental sustainability. As regards information support required to realise this, there should be better information to close knowledge gaps, including means of measurement and monitoring. In addition to this, information on community level property rights and resource management, yield-increasing and resource-conserving technologies are also critical. In short, sustainable agriculture should address not only environmental and social concerns, but also offer innovative and economically viable opportunities for all the stakeholders- growers, labourers, consumers, policymakers and many others- in the entire food system. ICT support to sustainable agriculture should then address the major dimensions and concerns as outlined above.

In view of the above, an analysis of some successful ICT programmes developed and rolled out for rural communities with focus on sustainability has been attempted to illustrate the primary objectives and the modes of intervention adopted (table 2). These initiatives demonstrate how ICTs play a major role in helping societies throughout the world learn how to manage their available natural resources effectively. The cases represent some very important environmental issues ranging from desertification and ensuring the preservation of biodiversity, to providing farmers in rural areas with daily crop prices. These programmes demonstrate how ICTs, and especially the Internet, are a major means of sharing information among scientists, civil society, governments, business and citizens.

**Table 2**
**ICT programmes for sustainable resource management: Emphases and modes of action**

| Sl No | Name of the project | Agency and Area | Major Focus | Mode of action |
|---|---|---|---|---|
| 1 | Application of ICTs in land surveys and registration systems Participatory 3D mapping in the Philippines | The Philippine Association For Intercultural Development (PAFID) is an NGO that assists indigenous communities to regain and secure ancestral domains | Conservation of ancestral domains | Participatory mapping and GIS integration |
| 2 | Logging Off | Malaysia | Conservation of forest | Mapping and modelling to represent land and the associated resources and integrating into GIS maps for community level learning and action |
| 3 | Food Insecurity and Vulnerability Information and Mapping System for Asia (Asia FIVIMS) | International Telecommunication Union (ITU), UN<br><br>Combodia, Philippines, Srilanka | Identify the most food insecure and vulnerable populations at sub-national level<br><br>Capacity building for vulnerability assessment<br><br>Poverty alleviation | Participatory mapping based on socio economic characteristics and preparation of resource databases |
| 4 | Global Fire Monitoring Centre | Joint FAO/UNECE/ ILO Committee on Forest Technology, Management and Training | Preventing forest fire, giving information on forest fire | Periodic online collection and publication of fire statistics of the member states |

| Sl No | Name of the project | Agency and Area | Major Focus | Mode of action |
|---|---|---|---|---|
| 5 | Hanoi Land Information Management | Vietnam | Easy access to information on land parcels | Maps and GIS Community training on mapping |
| 6 | Mekong Info - Information System for Natural Resources Management in the Mekong river | Mekong River Commission, South East Asia | Providing access to information about participatory natural resource management | Building information repository and providing access to various stakeholders for formulating action plans |
| 7. | Integrated Water Resource Management | Thailand | Water resource management | Development of a computerized information system on water resources and promoting the linkage of information |

*Sources: Brandl et al(2002), Gessa (2008), ITU (2012)*

The cases given above illustrate different strategies that could be adopted to address various types of environmental issues. Most of them are based on resource management and the information databases required thereof. Some of them fall under the category of decision support systems for the actors of programmes to take decisions on planning and monitoring. There are also transfer- of- technology programmes enabled by ICTs. Certain applications have tried out participatory technology development strategies to enhance the participation of stakeholders. Specific applications for localised issues have also been developed with the participation of the community. The cases provide evidence to the immense scope for developing ICT programmes in response to the features and scales of local issues and based on the institutions involved.

## KEY COMPONENTS OF THE ICT PROGRAMMES FOR SUSTAINABLE AGRICULTURE: LESSONS DRAWN

Drawing from the cases above and as under stood from the discussion on the dimensions of sustainable agriculture, the key components of a comprehensive ICT programme to practice and promote sustainable agriculture are outlined below.

### Enhancing Access to Information

Mechanisms for easy access to useful information for sustainable growth are limited. In fact, latest information on technology, climate, markets, prices and trends are required by rural communities for scheduling their operations and deciding upon production and marketing strategies. Customised information systems that provide such information would safeguard the small and marginal producers against the odds of price fluctuations, climate changes, resource scarcity etc. Other than providing content, this implies establishment of community information kiosks on a large scale with consultative functions. An enhanced and multifunctional model of the Village Knowledge Centres established by MSSRF would be able to meet the requirements of rural communities. These centres shall provide farmers with necessary information on various schemes, credit availability, inputs for cultivation, market opportunities, package of practices, entrepreneurial opportunities, training programmes by various agencies, certification processes, etc. The kiosks shall be manned by personnel trained in agriculture and ICTs.

### Online and Off Line Transfer of Technology and E- Learning

Among various ICTs, the Internet plays the most vital role in the process of technology dissemination. However, this mode of technology transfer is constrained by lack of infrastructure, relevant content in local language and the pedagogical limitation of virtual learning. These constraints should be overcome by devising illustrative multimedia demonstrations of technology packages as much interactively as possible. Tools for self instruction should be made available at rural kiosks in order to enhance the adoption of sustainable technologies. Interactive multimedia products based on crops, cultural and conservation practices etc could be produced and deployed in large scales, with emphasis on local conditions and issues. Needless to speak, all these products could also be made available online.

In addition, existing mechanisms such as call centres, video conferencing, consultation with research and training institutes etc shall be strengthened and scaled up with provisions to deal with specific issues to sustainability instead of conventional queries on package of practices.

Technical institutions such as the State Agricultural Universities and ICAR institutes shall initiate exclusive courses on sustainable agriculture through their e- learning and distance education centres. Courses on concepts of sustainability and farm level interventions to enhance sustainability can be developed and offered to the public.

### Grassroots Level Resource Maps and Resource Data Bases

Apart from the huge information systems that are maintained by national organisations, dynamic information systems that can monitor resource utilisation at the grassroots level could be developed. This can be done only by developing comprehensive databases of natural resources on a land parcel basis, with the participation of the people. This is not impractical as several pilot programmes have been successful in making participatory resource databases using GIS tools. For example, resource mapping by the *Kerala Sasthra Sahithya Parishad* and later by the Government of Kerala and resource maps and other databases developed at Thanalur in Malappuram District by the Information Kerala Mission have been utilised by the concerned local self government institutions for grassroots level planning

### Updating Legacy Databases

There are several data bases that are being traditionally used by development agencies. The basic registers of agriculture at the agricultural offices, building register at the local government institutions, cadastral maps, land registers, lists of beneficiaries, etc are all databases that could be put to effective use in planning for sustainable agriculture. However, these invaluable data sources are incomplete and are not updated. The recently debated databank on wetlands and paddy fields in Kerala is a classic example of generating natural resource database from existing records for formulating policies and local interventions

Digitisation of legacy databases to make use of the geographic, demographic and socio economic and resource related features of an area effectively could be a major ICT programme for sustainable use of resources. However, as seen from the review of ICT programmes on agriculture, no programme has been found to attempt this humongous task, which is also a pre requisite for robust and reliable planning process at the grassroots level.

### E- Governance for Better Coordination of Development Agencies

Better co-ordination among development agencies would result in responsive intervention, which is an important pre requisite for sustainable development. The archaic systems of service delivery of traditional development departments which are also lethargic tend to be counterproductive, in many cases. This would also lead to decision making process without any relevant inputs from related domains. This can be overcome only by comprehensive e- governance applications that could render co ordination and integration among various development departments effective. It is widely reported that e- governance applications that ensure integration among departments are fewer in number (Keniston and Kumar 2008). This is of great relevance in agriculture as development in this sector requires dynamic integration among various departments and service providers for the farmers to fully benefit from their interventions.

### Information Systems

Information on sustainable agricultural practices, optimisation of inputs, development and use of eco friendly technologies, sources of sustainable technologies, training resources etc can be made available to grassroots level organisations and development departments for wider adoption of sustainable alternatives.

### Decision Support Systems

Local governments at various levels and development agencies can avail decision support systems developed exclusively for using common property resources and drawing up local level plans. This would require integration of various rural databases and development related information. Tools for impact assessment and estimation of eco system services, resource optimisation etc can be employed for grassroots level planning. Access to information on natural resources and dynamic data on climate, land use etc from authorised agencies shall also be integrated with these systems. Decision support systems with a view to facilitate local level planning have not been attempted so far, on an impressive scale.

### Devising ICT Enabled Participatory Tools

Instead of centralised mechanism for resource appraisal as done in the case of soil survey, effective ICT enabled participatory tools can be developed and employed to collect data on local level needs and resources. For instance, *Akshaya* kiosks in villages can be tremendously instrumental in preparing ward level resource maps, problem matrices, databases, local information systems etc that can be further used in development planning. Problems reported by farmers shall also be consolidated and reported to concerned agencies or institutions through this mechanism.

Repositories of local traditional knowledge on crops, cultural practices, adaptation techniques, traditional tools and farming equipments etc shall also be developed locally with facilities to access the information systematically and functionally.

### Organising Local Groups and ICT Enabled Capability Building

Since participation of stakeholders is the most important pre requisite for wider adoption of sustainable agriculture, local resource groups of farmers and entrepreneurs have to be organised to facilitate the spread of sustainable practices. Existing farmer collectives shall also be trained on the concepts and issues of sustainability with local relevance. These groups can be imparted ICT enabled training to understand the issues better and to function as animators and change agents for supporting the community to find out sustainable alternate solutions.

## CONCLUSION

Information support to sustainable agriculture is becoming increasingly important consequent to the sweeping transformational changes in the developing economies. Though it is a daunting task, no effort can be spared to pursue it. Considering the global as well as local concerns on sustainable growth, robust mechanisms to devise and implement alternatives to input intensive agriculture should be put in place without any further delay. At the same time, feasibility and profitability of such alternate options also should be seriously considered as the less endowed farming community is striving to make an existence in the face of rampant globalisation. Any ICT programme with a focus on sustainability should address these two seemingly contradictory concerns. Current efforts to make agricultural development ICT enabled have to be reoriented with focus on sustainable development, both in content and form. However, development of infrastructure as well as relevant content to enhance accessibility deserves prime attention at this point. It should also be accompanied by better co ordination and integration among the change agencies and development departments for sharing information and developing new content. Discrete and solitary efforts in this regard have to be integrated with common objectives and strategies. Capacity building for local governments, line departments, civil society organisations and the farming community also seems to be necessary to drive this objective. Interaction between policy makers and other stakeholders needs to have a new sense of purpose and commitment to make innovations in this domain.

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# Geographical Indications – A Marketing Tool for Unique Goods from Specific Environments

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## INTRODUCTION

The word 'unique' comes from Latin and means 'only one'. Unique goods are being only one of its kind in the world. The uniqueness of the goods are due to a mixture of various factors including place of origin with specific climatic, geographical and environmental conditions, indigenous manufacturing skills, special traditional knowledge and cultural practices. The distinctness and superiority of unique goods add to their commercial attractiveness and reputation enhancing their market demand.

Unique goods produced and processed in a characteristic manner typical of a given region and embodied in local life styles and linked with culture could be marketed adopting distinctive signs that are protected by legal means. Different countries adopt different legal mechanisms for protecting the rights over unique goods originating in their countries and for enhancing their market potential. The present paper highlights the legal mechanisms, especially Geographical Indications, existing in various countries to enhance the market potential of unique goods.

### Appellations of Origin

Some countries have granted protection to unique goods by designating them as "Appellation of Origin". An appellation of origin is a special kind of geographical indication generally consisting of a geographical name or a traditional sign that indicates that a product originates in a specific region and the characteristic qualities of the product are exclusively due to the geographical environment in which they are produced. Tequila spirits from Mexico, Jaffa oranges from Israel and Bordeaux wines from France are some examples of products famous as appellation of origin.

### Protected Designation of Origin and Protected Geographical Indication

European Union Council Regulation on the Protection of Geographical Indications and Designations of Origin has established two types of GI designations *viz.*

Protected Designation of Origin (PDO) and Protected Geographical Indications (PGI). PDO means the product is produced, processed and prepared within the specified geographical area and the product's quality or characteristics are essentially due to that area consisting of natural and human factors. It is used to describe food stuffs and agricultural products which are produced, processed and prepared in a given geographical area using recognized know-how. For example, Champagne has a PDO label, meaning that only sparkling wines produced in a specific style in the French region of Champagne may be labeled as 'Champagne'. PGI designation describe agricultural products and food stuffs that are produced, processed or prepared in the geographical area and the quality, reputation or other characteristics are attributed to that area. At least one of the stages of production, processing or preparation takes place in the area. Mortadella Bologna, a pork sausage produced in Italy and Colombian Coffee have PGI label.

## GEOGRAPHICAL INDICATIONS (GIS)

TRIPS (Trade Related Intellectual Property Rights) Agreement had adopted the term 'Geographical Indications' to protect goods from specific geographical areas. Several Free Trade Agreements have included GIs protection to comply with TRIPs Agreement. As a member of World Trade Organization and a signatory of TRIPS Agreement, India enacted the Geographical Indications of Goods (Registration and Protection) Act, 1999 (GoI, 1999) to protect unique goods originating in specific geographical areas. The Act defines 'GIs' in relation to goods as "an indication which defines such goods as agricultural goods, natural goods or manufactured goods, which identifies such goods as originating or manufactured in the territory of a country or a region or locality in that territory where a given quality, reputation or other characteristics of such good is essentially attributable to its geographical origin." The Act is administered by the Controller General of Patents, Design and Trade Marks who is also the Registrar of Geographical Indications. The Geographical Indications Registry is established at Chennai with all India jurisdictions. In India till now 172 products have been registered as GIs.

### GI - a marketing tool for unique goods

In the interactional trade GIs are often valued as a tool for promoting marketing of unique goods. The use of GIs allows producers to obtain market recognition and often a premium price in national and international markets. The better protection of GIs can be a useful contribution to increase the income particularly in rural areas. The GIs have become a key source of niche marketing with the increased internationalization of food and product markets. Some Geographical Indications from agricultural goods registered in India are provided in Table 1.

The quality, characteristics and reputations of these products are due to the interaction of various environment factors on genotypes and also due to traditional processing skills involved in the production of goods. By registering a GI in India, the rights holder can prevent unauthorized use of the registered geographical indication by others and promote economic prosperity of producers of goods produced in a particular region. Such identification enables the product to gain reputation and goodwill all over the world consequently resulting into premium prices in national and international market. Examples of use of GIs as a marketing tool are discussed below.

**Table 1**
**Geographical Indications from agricultural goods registered in India**

| Application No. | Geographical Indications | State |
|---|---|---|
| 1 & 2 | Darjeeling Tea (word & logo) | West Bengal |
| 33 | Coorg Orange | Karnataka |
| 17 | Navara Rice | Kerala |
| 49 & 56 | Malabar Pepper | Kerala |
| 85 | Monsooned Malabar Arabica Coffee | Karnataka |
| 114 | Monsooned Malabar Robusta Coffee | Karnataka |
| 72 | Alleppey Green Cardamom | Kerala |
| 78 | Coorg Green Cardamom | Karnataka |
| 81 | Pokkali Rice | Kerala |
| 163 | Central Travancore Jaggery | Kerala |
| 186 | Wayanad Jeerakasala Rice | Kerala |
| 187 | Wayanad Gandhakasala Rice | Kerala |
| 165 | Nashik Grapes | Maharashtra |

**The Speciality Coffees**

Coffee producing countries have developed different strategies to enhance the marketability of their speciality coffee products. Origin has become an important argument for coffee promotion in developed countries at the consumer level and GIs are tool for acknowledging differentiation coming from origin.

***Cafe' de Colombia***

Café de Colombia is the first product to be registered as a GI (PGI) in the European Union. Colombia is after Brazil and Vietnam, the world's largest producer of Arabica Coffee (USDA, 2008). Colombia accounts for 12% of total coffee world exports.

Café de Colombia was defined as Arabica Coffee produced out of maximal 6 different varieties with different characteristics and origin (Tipica, Catura, Colombia, Borbon, Maragype and Tabi) produced in an altitude of 400 to 2500 meters above sea level in a limited production area. Out of the total coffee production area of 7300.000ha, 12% (869 ha) are defined as GI 'Café de Colombia' area (Gomez, 2007). The natural conditions specifying the product are two rainfall seasons per year providing a continuous production possibility with two growing cycles a year. The topographical factors include the Andean soils with special texture and high proportion of organic material. When processed 'Cafe de Colombia' has mild, clean up, of medium/high acidity and a full and pronounced aroma. The methods of production, harvesting, hulling and different processing stages are also specific.

Various legal mechanisms are adopted to provide a guarantee of origin to Colombian Coffee. Denomination of origin of Colombian Coffee is recognized in certain countries. A Denomination of Origin (DO) is a distinctive sign consistent of a specific geographic name used to identify a product that come from a certain origin and whose quality is directly connected with. To achieve the recognition of protection of a DO, it is necessary to demonstrate through data, information and documents the connection between the origin and the quality of the product. Through the protection of DO, the consumer is guaranteed in what he or she is buying, the producer is fairly compensated for his or her efforts in producing a product of superior quality that fulfills the standards of the denomination. It is recognized in Colombia, Peru, Ecuador and Bolivia (Benni and Reviron, 2009).

In the case of many European countries, the legal instrument that grants that recognition of origin to Colombian Coffee is Protected Geographical Indication (PGI). The Colombian Coffee GI is recognized in 23 countries including Germany, Austria, Belgium, Bulgaria, Denmark, Slovakia, Spain, France, Greece, Hungary, Italy, Netherlands, Portugal, Sweden and UK etc.

Ingredient Brand is a trademark strategy adopted to promote Colombian Coffee. In this case, the buyer is choosing the final products brand that he or she is buying, but his or her decision is also driven by the product of the branded input or ingredient. In this way the ingredient brand strategy constitutes a co- branding initiative for product brand and ingredient brand. In 1960s' Colombian Coffee was a pioneer in the use of an ingredient brand strategy. In North America the logo "100% Colombian Coffee" and for the rest of the world the logo 'Café de Colombia' is used as ingredient brand.

In Café de Colombia, proof of origin and the traceability of the products of Colombian Coffee are carried at several stages. The coffee growers in Colombia are organized under FNC (National Federation of Coffee Growers of Colombia) which is led by farmers themselves (not imposed by governmental or international organizations), counts now for more than 5.6 lakh producers in the coffee belt and endow every member with equal voting rights. So FNC is characterized as democratic, collaborative and participative. All representatives at all levels are coffee farmers.

Several mechanisms were established by FNC to stabilize growers' income and to fairly distribute the value of coffee exports to the farmers. For instance, the National Coffee Fund to stabilize income, 'Cenicafe' for farmers' education and ALMACAFE as quality control institution with storage facilities. In the last decades the major proportion of exports (98.7%) of Colombian Coffee was green on processed coffees. It has changed more and more to exports of value added processed coffees.

FNC has launched many specialty coffee programmes that can be divided into three different categories - Coffees of origin, Soluble coffees and Processed coffees. In total 10% of the world consumption is specialty coffee. Colombians exports of these specialty coffees are following a positive trend and have shown an increase of 70% than the export in 2002. Nowadays Colombian coffee is well known all over the world. This is due to sophisticated marketing strategies of the FNC in the last decades. As the result the export is changing from unprocessed coffee to value added processed coffee (Benni and Reviron, 2009).

***Monsooned Coffees of India***

Monsooned Malabar Arabica Coffee and Monsooned Malabar Robusta Coffee are unique specialty Coffees from India, registered as GIs. These are prepared carefully using the raw Coffee beans (green beans) from Arabica Coffee and Robusta Coffee respectively. These also derive their names from the region (Malabar) of production and the special process (Monsooning) involved in the processing. The 'A grade' Coffee beans collected from areas of production are subjected to a special processing named as 'Monsooning'. Primary processing of the raw Cherry Coffee beans are done at estate level whereas secondary processing including monsooning are done at Malabar Coast. The monsooning is done during the rainy season of South West Monsoon period (June-Sept) at the specialized coffee curing works under controlled conditions in the Malabar Coast region of India, stretching from Mangalore in Karnataka to Calicut in Kerala.

In monsooning, the Cherry Coffee is evenly spread in thick layers in airy godowns, open on all sides and raked frequently. The Coffee is packed loose in gunny bags and stalked in piles with sufficient space between rows for the monsoon air to circulate freely around the bags. The Cherry Coffee absorbs moisture from the humid monsoon atmosphere. The beans swell up to nearly double the size and the colour of the beans change to pale yellow/ straw colour. The monsooning process is completed in 12 to 16 weeks. At the end of monsooning the Coffee is polished and graded. The monsooned Coffee has the monsooned flavor, mellow taste and golden look. The natural climatic elements including the fully saturated atmospheric winds during the monsoon period play a major role in processing (monsooning) adding to flavor and uniqueness of Monsooned Coffee. Monsooned Malabar Coffee commands a premium price in overseas, due to its distinctive quality and best blending attributes. Scandinavian countries love it for its special colour and flavor.

Grade wise export of these specialty coffee during the first half of 2012 in tonnes is as follows-

| | |
|---|---|
| Monsooned Malabar - AA | 1,170.7 |
| Monsooned Arabica Triage | 87.5 |
| Monsooned Robusts AA | 633.6 |

*Source: Coffee Board of India. www.indiacoffee.org.*

It is evident that coffee export from India (Table 2) is increasing gradually. The exact implications of GI registration on export is not evident from the available data, but it can be assumed that the GI registration adds to the market demand of these specialty coffees. Monsooned Coffee is mainly exported to Italy, Russia Federation, Germany, Belgium, Spain etc.

**Table 2**
**Details of export of Coffee from India**

| Year | Quantity (tonnes) | Value (Crores) |
|---|---|---|
| 2001 | 223782 | 1136.93 |
| 2002 | 213008 | 1043.87 |
| 2003 | 222425 | 1112.35 |
| 2004 | 228246 | 1203.52 |
| 2005 | 203768 | 1451.65 |
| 2006 | 244989 | 1930.95 |
| 2007 | 214155 | 1906.52 |
| 2008 | 212806 | 2358.37 |
| 2009 | 180298 | 1929.67 |
| 2010 | 274817 | 2835.73 |
| 2011 | 310657 | 4333.30 |

*Source: www.indiacoffee.org*

## Specialty Rices of Kerala as GIs

Navara Rice: Navara is an exceptionally unique extra short duration rice cultivar indigenous to Kerala. Navara is known as 'Shashtikam' or 'Shashtikasali' in Ayurveda. 'Shashtikam' denotes sixty days and this peculiar rice cultivar has a life cycle of about sixty days. Navara is grown in nine districts of Kerala viz. Palakkad, Malappuram, Calicut, Waynad, Kannur, Trichur, Ernakulam, Kottayam and Alleppey. This rice has been registered as a GI from Kerala during 2007-08

Navara is widely utilized in the Ayurvedic system of medicine, especially in Panchakarma treatment involving baths and massages for curing paralytic condition. Navara grain is used in the treatment of circulatory, respiratory and assimilatory ailments. Molecular studies at Kerala Agricultural University have identified the presence of DNA fragments in Navara that showed homology with Bowman Birk Trypsin Inhibitor (BBI) gene. BBI is reported to have the ability to suppress tumorigenesis and thus have cancer chemo preventive potential even when administered as a dietary supplement. In certain parts of the state this peculiar variety is used as a starter solid food for infants and as a food grain for invalids. To a very limited extent, it is also used as a food grain crop as a choice variety. The grain fetches a higher market price due to its increasing demand in Ayurvedic treatment (GoI, 2007).

### *Palakkadan Matta Rice*

Palakkad is the rice bowl of Kerala. Rice varieties with red kernel colour cultivated in Palakkad are commonly designated as Palakkadan Matta Rice and have good reputation and fame in market. It is described as a unique cereal having high content of nutrients and as indispensable for those who do hard physical work. Old and popular varieties of Palakkadan Matta are "Chenkazhama", "Chettadi", "Aruvakkari", "Aryan", "Vattan", "Illapappoochampan", "Chitteni", "Thavalakkannan" and new varieties like "Kunjukunju" and Jyothy. The rice is coarse bold and red in colour. The coarse rice with red pericarp by itself ensures high content of nutrients. "Par boiling" of the rice further ensures retention of nutritional value. The peculiar soils, the humid weather, easterly winds that blow through the Palakkad gap, the rivers that flow from the Western Ghats and the bright sunshine determine the unique taste and quality of the Palakkadan Matta Rice (GoI, 2007). All these characteristics had made it possible to register Palakkadan Matta as a GI from Kerala during 2007-08.

***Pokkali Rice***

*Pokkali* rice cultivars are internationally accepted as gene donors for salt tolerance in rice. *Pokkali* soils are characterized by soluble salt accumulation, especially sodium, over an underlying acidic soil containing toxic levels of iron and manganese. The organic carbon content of the soil is highly fertile. The traditional cultivars of *pokkali* ecosystem of Kerala are *Pokkali, Cheruvirippu, Chettivirippu, Karuka, Ponkaruka, Karuthakaruka, Mundakan, Anakodan, Eravapandy, Orkayama* and *Orpandy*. All these varieties are tall (>180cm) with lodging nature. These are having a low yield potential of 1.2-1.5t/ha, amylose content of 20-27.7% and protein content of 7..2-10.9%. The volume expansion of the varieties varies from 3.1 to 4.5. *Pokkali* have an intermediate gelatinization temperature. *Pokkali* rice and other *Pokkali* rice products are claimed to have medicinal properties. *Pokkali* rice is commonly used in the preparation of '*Marunnukanji*' which is a traditional health care food consumed during the Malayalam month '*Karkidakam*' falling during peak monsoon period in Kerala. *Pokkali* rice bran is believed to be good for smoothening the problems associated with piles. *Pokkali* broken rice is also considered to be best for the preparation of starter food after recovering from certain diseases like Cholera and Typhoid. Rice gruel water (*Kanji vellam*) from Pokkali is also considered as a highly suitable drink to patients suffering from Cholera (GoI, 2008a). This rice has been registered as a GI during 2008.

***Wayanad Jeerakasala Rice and Wayanad Gandhakasala Rice***

Wayanad Gandhakasala and Wayanad Jeerakasala are the most popular traditional aromatic rice cultivars of Wayanad district. These scented (non- basmati) rice are famous for their characteristic fragrance and aroma. The grains of Gandhakasala are aromatic short bold, awnless with golden lemma and palea (hull) colour. Grains of Jeerakasala are slightly elongated with short and partial awns. Intermediary amylose content renders non stickiness to these rices.

The geographical position of Wayanad is peculiar and unique. The name Wayanad is believed to be derived from the word "*vayal nadu*" meaning 'land of paddy fields'. The altitude of Wayanad varies from 700 to 2100m above mean sea level. Annual rainfall of high rainfall areas in Wayanad like Lakkidi, Vythiri and Meppadi ranges from 3000-4000m and the average annual rainfall is 1875mm. High altitude areas experience severe cold. Wayanad experiences a high relative humidity which goes even upto 95 percent during the South West Monsoon period. *Jeerakasala* and *Gandhakasala* are mainly cultivated during *Nancha* (kharif) season. The cool climate offered by high altitude favors development of aroma in rice.

*Gandhakasala* and *Jeerakasala* are mainly cultivated in *kundu vayals* in Wayanad. The product is maintained by adopting organic method of cultivation. The faunal diversity associated with paddy fields is rich and plays a significant role in controlling harmful insects and pests. These rices are mainly cultivated by Wayanad

Chettis, Kurichya and Kuruma tribal group. These groups have a commitment for the conservation of these varieties as a gift to coming generation. In a study at Kerala Agricultural University it was revealed that the specific quality of these rices are due to the special ecological and environmental conditions of Wayanad, traditional cultivation practices followed and indigenous varieties used. These same genotypes when cultivated in Palakkad expressed different grain qualities, mainly less aroma and less amylose content. Less aroma reduced the palatability and less amylose content led to stickiness of grains.

Wayanad Jeerakasala rice and Wayanad Gandhakasala rice received GI certificate during October 2010. Now the farmers of Wayanad use the GI logo for marketing their product. During 2011, the farmers were able to sell these rices at a premium price of Rs. 75/kg in domestic markets, whereas the cost of ordinary rice was between 20-25kg/ha. Mr. Narayanan Unni from Palakkad is marketing organic Navara rice at a cost of Rs.350/kg. The GI registration had enhanced the market potential of these rices.

## OTHER BENEFITS OF GI REGISTRATION

GIs can protect and preserve intellectual property related to traditional cultures, geographical diversity and production methods. GIs grant protection to a community and not to individual right holders. It also encourages quality products to consumers and can promote the development of tourism. It helps to prevent the appropriation by unauthorised parties or to avoid bio piracy. GIs are also often associated with non-monetary benefits such as the protection of traditional knowledge and community rights. The protection of traditional knowledge contributes to the wider objective of conserving the environment, bio-diversity and sustainable agricultural practices.

## CONCLUSION

World Trade Organization had adopted GIs of goods both as a marketing tool and as tool to protect the Intellectual Property Rights of producers. The state of Kerala is a treasure house of unique goods in agriculture sector, produced from varied agro-ecological situations. Many of these products (20nos.) are registered as GIs under Indian Act. The remaining products require immediate attention to be registered as GIs. A co-ordinated effort in this aspect will help in their registration and thereafter will lead to enhanced market possibility.

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# *Panel Discussion*

# Food Security and Agriculture
# A Kerala Perspective

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## INTRODUCTION

Kerala cannot become a Hongkong or a Singapore. It cannot survive without agriculture. There are too many people. In Kerala 'food' means rice. Only 10% of its arable land is suitable for rice cultivation. Nearly half of it is left fallow for years and years. This land produces only about 20% of Kerala's requirement. Rice is imported from other states. There is surplus there. For more than a century tapioca served as a supplementary food – a carbohydrate source. During the last two-three decades of neoliberal globalization both rice production and tapioca production has come down to half of what it was – rice from 13 lakh tonnes to 6.5 lakh tonnes; tapioca from 56 lakh tonnes to 30 lakh tonnes. Rice fields succumbed to real estate, tapioca succumbed to more profitable rubber. Yams of various kinds used to be a third source of supplementary food. Their total production has come down slightly. They are, today, considered as part of the vegetable kitty. In vegetables there is however, a waking up, thanks to Kudumbashree movement. Production has almost doubled. The average consumption of vegetables by Keralites has gone up. Still it has to import vegetables from Tamil Nadu.

Coconut is the queen crop of Kerala. The state derives its name from it – land of coconuts. It occupies effectively about 40% of the total cultivated land – about 8.5 lakhs out of the total of 21 lakh hectars. The productivity of Kerala coconut palms is dismally poor about 6000-7000 nuts per hectar or 30-35 nuts per plant. This is half the productivity of Tamil Nadu and less than one fourth of the potential productivity. Partly this is so because many wet lands unsuitable for coconut cultivation have been planted with coconut, as abuse for future conversion into garden land and real estate. Paddy field may get Rs. 3000 per cent, garden land Rs.30,000 and real estate land Rs. 300,000. From three to three hundred is too large a jump and nobody, absolutely nobody can resist the temptation. No rules can regulate it. Stricter rules engender more powerful mafia to circumvent them.

About seven lakhs ha of coconut plantation are still in the real garden land or homestead land. But this belongs to two or three million land owners. The average holding size is less than 0.2 ha, the number of trees per homestead is normally less than 30 plants. They are, today, simply allowed to grow. They are not tended or cultivated, because labour has become too costly, productivity too low and prices (in real values) coming down. Today coconut is a dying crop. There are several ambitious plans, both of state and central governments to revive it, but being implemented bureaucratically, piece by piece and disjunctly none of them has succeeded and will not succeed.

Kerala is, also known for its spices since ancient times. Pepper, cardamom, cloves, ginger, turmeric and cinnamon. The over all situation with spice culture is one of stagnation in area and down fall in real income. More or less same is the case with its beverage industry – tea and coffee (True, our Beverage Corporation is quite successful! But that is another beverage)

On the whole, agriculture in Kerala does not present a bright picture – to put it mildly, a gory picture to put it truthfully. What has to be done and what can be done to make it bright! That is the theme of this paper.

**IMPEDIMENTS**

Kerala is a land scarce area. The density of population is very high. Per capita cultivable land availability is only 0.6 are or 15 cents. With effective land reform and subsequent partitions the land holding size has become very small. More than 80% of the holders are less than 1 acre in size. Large holdings of more than 5 ha are very limited. They come mostly under rubber, tea, coffee etc. Bulk of the land comes under homestead with coconut, arecanut, jack, mango, banana, with yams and vegetables are inter crops. These crops receive only scant attention. There are several reasons for this:

a) Practically none of the owners of land work on soil. The descendants of those farmers/tenants who benefited from land reforms have, all, moved away from agriculture.
b) There is shortage of supply of skilled agricultural labourers and hence their availability is extremely unreliable.
c) The wage rates are quite high, thanks to the booming construction and real estate industry.
d) The additional income – which can often become negative too – from their homestead land is negligible compared with their other sources of income.
e) Most of them find it difficult to negotiate with the casually available, often unskilled, agriculture labour.
f) So they decide to reduce labour input to an absolute minimum – less than 10-15 persons days per hectare per year.

There are, however, a substantially large number of persons, mostly women wanting work. They swell the ranks NREG schemes and Kudumbashree (KS). During the past decade, a new genre of farmers has emerged – from the ranks of Kudumbashree. They don't own any land. They take land on lease from willing owners of land. The KS farmers have shown that,

i) they are good, skilled farmers
ii) they can persuade the land to yield much more than what it used to

iii) they can earn incomes sufficient to manage a family of four at reasonably good level, from about an acre or two of land, even after paying rent.

The impediments before the spread of this system are:

i) There are not enough willing owners of land. They feel that strengthening agriculture will weaken or reduce the real estate value of land. Most of them feel that their land is worth Rs. one crore to two crore a hectare. The maximum rent they can expect is about Rs. 15,000-25,000 per year (more in the case of banana plantation)

ii) The KS concept is a holistic one. It has to incorporate an entrepreneurial concept. This is not taking place sufficiently.

There are OWNERs of land; there are OWNERs of labour power. Neither of them owns both. They have to be brought together through a new form of contract, different from the landlord-tenant system.

The slogan "land to the killer" was always a temporary one. Land cannot belong to any one. As Marx had said: "We are only the temporary possessors, the beneficiaries and are bound to pass it on to succeeding generations in a better condition than what we got." It will take still more time for the society to internalize this spirit. For the present all what we can do is to put restriction. The various regulations on land use emanate from this understanding. Real estate/construction industry is the greatest enemy of this. They consider land as an object which they can transform in any way they like – dig, fill, pollute, build, transform any thing that brings them profit.

Real estate business is the greatest enemy of agriculture and hence of the present and future generations. It does not serve any social purpose. It is not a solution but an obstacle before the housing problem. It has destroyed the culture of agriculture. It has destroyed the land – rivers, wetlands, hills, drainage etc. Interestingly, and unfortunately so, this is an industry that is bound to collapse sooner or later. It was such a collapse of the real estate industry in USA that triggered the present wave of global crisis. The impact of such a collapse in Kerala will be much more severe. Several lakh workers will be thrown out of job, a good many of them migrant labour. They will not go back and will wander in Kerala. This can lead to many unpleasant situations. Many may lose their life time savings, leading to a spurt in suicides. The cascade impact of the collapse of an industry, contributing to more than 20% of the GDP, is unpredictable, but is bound to be traumatic. The harm the real estate industry has done to agriculture will take time to cure.

Thus the new paradigm for agriculture will have three components.

i) A planned reduction of real estate industry, restricting it to the absolute use needs, including a ban on a second house, a ban on non occupation and later control over land sales.

ii) A campaign against fallowing of lands, leading to planned legislation. Prepare, at cadastral scale, a map of the labour absorption capacity of land, on the basis of 400 person days of labour per hectare per year.

iii) Prepare a labour availability calendar and labour requirement calendar, for agricultural operation. Match two calendars. Any shortage in labour availability can be made up with mechanization.

iv) Pooling of homestead land, paddy fields, etc. into agriculture production units. The owners will place their lands on the hands of the panchayat on agreeable terms and conditions. Labour will form labour collectives and brigades (JLG etc.).

v) Mount a 'produce more' campaign. This is, also, an economic campaign. Each labour family can have an assured income of more than rupees one lakh per year (Overall production of most of the crops can be doubled or even more).

vi) When agriculture becomes a culture, then there will be increase demand for fertilizers, especially organic ones. The municipal (panchayat) solid waste (organic) will become a sought after raw material. The "waste management" problem gets transformed into 'resource utilization' problem.

vii) A culture of converting all bio-waste, including human excreta - not only animal excreta – into energy and fertilizers has to be promoted. The glyricidia campaign of late fifties can be rekindled, this time with a better understanding. There is scope for about a million kilometers of fence plantation yielding fuel and fertilizer.

Imagine a situation where four million households out of a total of eight million install biogas plants using human and animal excreta, kitchen and agricultural waste, producing bulk of the cooking gas they require and get back all the N, P, K taken from the soil and consumed by them. This is what Marx and Engels wanted when they wrote in *Communist Manifesto*: "Combination of agriculture with manufacturing industries; gradual abolition of distinction between town and country by a more equable distribution of the population over the country" – a situation where what is taken away from the soil can be given back to it, reducing the necessity of inorganic fertilizers.

In place of an input intensive agriculture we can conceive knowledge and labour intensive agriculture, minimising the necessity of fertilizers, pesticides and water inputs, through drip fertigation and even poly-housing. The experience so far is not discouraging.

Thus the planks from which a new agri-CULTURAL offensive can be sprung are:

1. Systematic elimination of the speculative real estate business
2. A campaign on cent percent utilization of scarce land resources – increasing labour input
3. Matching labour demand and labour availability
4. Establish new relations of production – between owners of land and owners of labour power
5. Promoting agriculture as a culture
6. Recapturing all N, P, K from wastes and giving it back to soil

This should, also, be followed with a reduction in the relative under valuation of agricultural labour in comparison with white collar jobs – or in other words an increase in the relative price of agricultural products.

# Globalisation of Agriculture and Atomisation of Farming in India: Crisis and Resistance in Kerala

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Indian agriculture is increasingly getting globalised. This is true of most crops, not just the crops that are intensely traded in the international market, but also crops and regions which are supposedly very remote. The process of globalization is seen reflected in the progressive removal trade barriers of all sorts. Another important sign of globalization of agriculture, which is also an outcome of the same process, is the convergence of domestic and international prices. The difference between national and international prices has narrowed down in the case of a large number of crops. There is also evidence to show some amount of synchronization in the movement of domestic and international prices. Manifestation of globalization, however, is not restricted to its impact on price movements or liberalization of trade barriers. It is reflected in domestic policies as well. Policy measures, which were responsible for the wedge between domestic and international markets, such as state intervention to ensure easy credit, fair prices, subsidies, extension services, etc., have also tended to wane.

Running parallel to globalization there has been a process of atomization too of farming in the country. Atomization of farming as we see it has two related dimensions to it. First, the average farm size has come down quite drastically in most regions as well as crops. Second dimension of atomization is seen reflected in destruction or weakening of possible cooperation and collective action by farmers, such as farmer's cooperatives. Farms have been virtually reduced to atomistic units devoid of any power of cooperative action or collective bargaining in various markets they engage in such as those of products, inputs, credit, etc. It is not that farmers, even the bigger ones, enjoyed much market power during the pre-globalization period. But, collective action of various types, when adequately backed up by state intervention, used to help farmers gain fair deals in various markets they entered into.

The combination of the two processes, viz. globalization of agriculture and atomization of farming, as we endeavor to argue in the present paper, make Indian agriculture vulnerable to external shocks and hence unsustainable. Globalization exposes agriculture in the country to shocks in the international market, which as we argue in the paper, are qualitatively different from instabilities arising from within the borders of the country. Atomization of farming on the other hand drains the ability of farmers and hence of the system to stand up to the pressure of external competition and instabilities of international trade. The combination of the two processes, therefore, is clear recipe for all round crisis in the agricultural sector, which we have been witnessing for some time now.

It is time therefore for us to confront some pertinent basic questions head on. Is unfettered play of market forces advisable for development of agriculture globally, and particularly for a developing country like India? Will free play of market forces always ensure the most desired outcome in agriculture? Is there any possibility of market failures in agriculture which might lead to inefficient and unjust outcomes? Obviously, there is hardly anything new about these questions. Answers are also known and largely uncontested. Given its specificities, compared to many other sectors, agriculture is more vulnerable to market failures. There is no guarantee whatsoever that unfettered play of market forces would not result in economically unacceptable and unjust outcomes. Yet, Indian agriculture is being pushed into an unregulated international market place. The argument in support of globalization is that it would improve productivity and enhance competitiveness of Indian agriculture and hence usher in an era of higher rates of growth. Attainment of higher levels of productivity might be a necessary condition but not a sufficient one for survival and success in the era of unfettered competition. Unrestrained competition can fail even the best in terms of productivity. It is our contention that sustained development of agriculture would require collective intervention in the market, supported by nation-states, at international, national and local levels. Such a policy posture assumes added significance in the context of the obvious lack of sensitivity of policy in India towards impact of fast moving globalization. The Twelfth Plan approach paper, one of the latest official documents in this regard, for instance, is silent on the impact of globalization on farming in India.

The story of Kerala agriculture is not significantly different. The twin processes of globalization and atomization and the consequent crisis were perhaps more prominent in the Kerala context. Even though the overall performance of the regional economy was exceptionally good over the past two decades, the agricultural sector had lagged far behind and suffered sustained stagnation. In spite of the widely acclaimed welfare network of the state, which reaches every nook and corner, the state had also suffered the ignominy of farmer suicides. The crisis in Kerala agriculture, however, has some state specific reasons too. The migration remittances boom is continuing to have its adverse effects on the goods producing sectors of the economy especially the agricultural sector. The migration remittances boom generates typical symptoms of a 'Dutch disease'. It causes both 'resource movement' and 'spending' effects identified by the 'Dutch disease' literature. The consequent increase in wages and prices of non-tradables tend to work as a drag on the goods producing sectors. Continuous pressure on land prices, especially speculation in the land market, is proving to a major constraint on agricultural development. The Kerala story however affords certain special lessons by way of coping up strategies. The state took recourse to the mantra of 'collective action', a *la* of the Kerala model of development, and fought against many odds to revive paddy production in the state, which had witnessed persistent decline over several decades. Another model of collective action is proving to be enduring in vegetable cultivation. The message emanating is to promote collective action by the farmers and not to leave the atomized farming units to fend for themselves in the face of globalised competition.

## *General Presentations - Oral*

# Effect of Organic Manure and Chemical Fertilizers on Growth of *Pisum sativum*

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## INTRODUCTION

Agriculture is depended on soil to a great extent. Chemical fertilizers are used for high yield of crops. However, the use of chemical based fertilizer and plant protectors give rise to negative environmental effects including water and soil pollution and imbalance in biodiversity. The chemical fertilizers and pesticides are very costly and creates health hazards to human and other living beings all over the world. To avoid these side effects and to provide socioeconomic and ecological benefits biofertilizers are generally recommended. Biofertilizers contains living microorganisms and it is expected that their activities will influence the soil ecosystem and produce supplementary substance for the plants. With this back ground, the present investigation was carried out with the objective to study the effect of NPK with different organic manure on growth parameters, yield attributes and germination index.

## MATERIALS AND METHODS

### Pot Experiment with Garden Pea

A field experiment was conducted in pots with garden pea *(Pisum Sativum)* during May-July, 2011. The soil used for the pot experiment were collected from the experimental sites of St.John's college, Anchal. Here five earthen pots were taken and filled with 5kg red loamy soil having pH 6.3. The control pots were planted without any treatment application. All pots were sowed with ten seeds of pea and irrigated daily with water twice a day. Before sowing the seeds, the soil admired with following manures and fertilizers:

| Pot No. | Treatment |
|---|---|
| $T_1$ | Control (without any treatment) |
| $T_2$ | NPK only (17.5g) |
| $T_3$ | ½ NPK (8.75g) + Vermicompost (8.75g) |

$T_4$ ½ NPK (8.75g) + Neem cake (8.75g)

$T_5$ ½ NPK (8.75g) + saw dust (8.75g)

$T_6$ ½ NPK (8.75g) + cow dung (8.75g)

During the course of the experiment, growth and development of plant in the pot were carefully observed. Germination percentage was taken 15 days after sowing. Yield parameters such as number of pods, pod length etc analyzed 60 days after sowing. On every 15 days after sowing the number of seedlings germinated was counted and the germination percentage was calculated using the following formula (ISTA 1993):

$$\text{Germination percentage} = \frac{\text{No of seeds germinated x 100}}{\text{No.of seeds sown}}$$

## RESULTS AND DISCUSSION

The pH, electrical conductivity, nitrogen, phosphorous and potassium content of experimental soil estimated before sowing the seeds is shown in Table 1.

**Table 1**
**Chemical Properties of Soil**

| Parameters | Result |
|---|---|
| pH | 6.3 |
| Electrical Conductivity(mmhos) | 0.4 |
| Organic Carbon(%) | 0.28 |
| Nitrogen(%) | 2.8 |
| Phosphorous (%) | >33 |
| Potassium (%) | 56 |

### Growth Paramete3rs of *Pisum sativum*

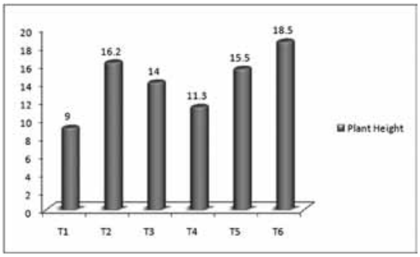
Table 2 and Fig. 1-4 show that the plant height is maximum in $T_6$ pot ( NPK + Cow dung) and is increased successively on 15,30,45 and 60 days after sowing. The height of plant recorded as 18.5, 46.4 , 188 and > 250 cm respectively. Minimum height is observed in the $T_1$ (control) ie, 9.0, 13.6, 22.1cm and 31.0 respectively. The $T_4$ (NPK + Neem cake) and $T_3$ ( NPK + Vermicompost) shows poor growth ie, on 15(11.3) (14.0) on 30(20.2) (27.1) and on 45 (28.0), (44.2) and on 60 (38.0) , (80.0). $T_2$ (NPK) and $T_5$ (NPK + saw dust) also shows better growth. Aduloju *et al* (2010) reported that the plant height of Okra was heights when cow dung was applied. Application of organic manure like neem cake, cow dung, vermicompost, saw dust harboured more microbes in soil than the control. This agrees with the finding of Joshi and Vig (2010).

**Table 2**
**Effect of NPK with different organic manure on plant height and number of leaves of pisum sativum**

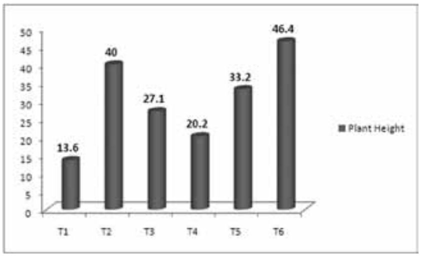
| Treatment | Plant Height | | | | Number of leaves | | | |
|---|---|---|---|---|---|---|---|---|
| | 15DAS | 30DAS | 45DAS | 60DAS | 15DAS | 30DAS | 45DAS | 60DAS |
| $T_1$ Control | 9.0 | 13.6 | 22.1 | 31.0 | 4 | 7 | 12 | 16 |
| $T_2$ NPK | 16.2 | 40.0 | 138.0 | 180.0 | 8 | 14 | 23 | 30 |
| $T_3$NPK+ Vermicompost | 14.0 | 27.1 | 44.2 | 80.0 | 6 | 13 | 17 | 25 |
| $T_4$ NPK+ Neem Cake | 11.3 | 20.2 | 28.0 | 38.0 | 4 | 9 | 16 | 23 |
| $T_5$NPK+Sawdust | 15.5 | 33.2 | 70.0 | 128.0 | 7 | 16 | 20 | 26 |
| $T_6$ NPK+cowdung | 18.5 | 46.4 | 188.0 | >250 | 12 | 30 | 41 | 51 |

*DAS- Days after sowing*

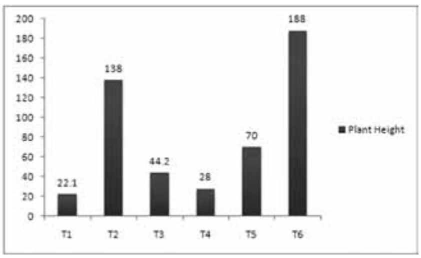
1: after 15 days




2: after 30 days




3: after 45 days




4: after 60 days

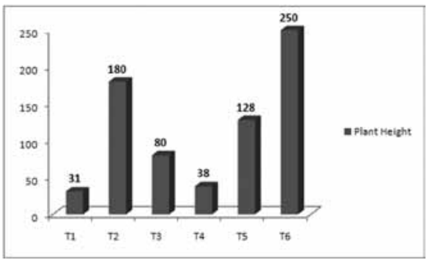



**Fig. 1-4**

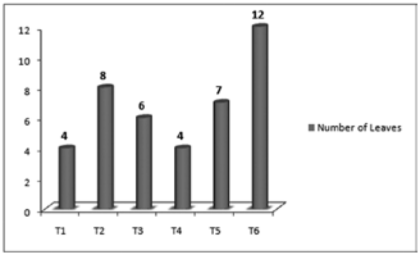
**Effect of NPK with different Organic manure on plant height of *Pisum sativum***

## Number of Leaves

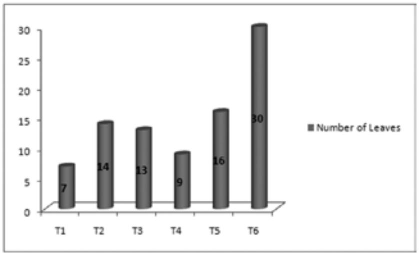
The number of leaves in *Pisum sativum* are shown in Table 2 and Graph 5-8. Among treatments the higher number of leaves observed in $T_6$ (NPK + cow dung) on 15 (12) on 30 (30), on 45 (41) and on 60(51) and lower number of leaves is observed in $T_1$ (Control) on 15(4), on 30(7) on 45(12) and on 60(16). $T_2$ (NPK) that also have maximum number of leaves, on 15 (8), on 30(14) on 30(23) and on 60(30).

Hussain *et al* (2009) reported that application of N,P and K significantly increase number of branches / plant , number of leaves etc.

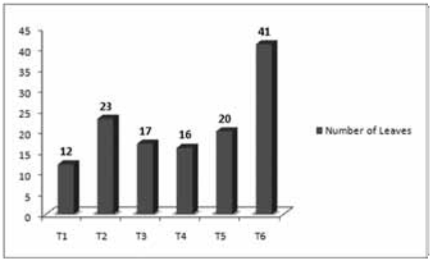
5: after 15 days




6: after 30days




7: after 45 days




8: after 60 days

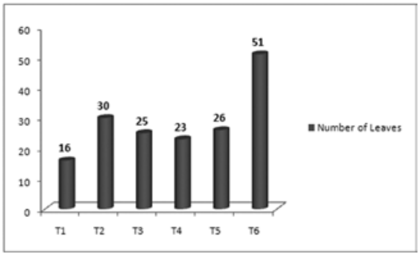



**Fig. 5-8**
**Effect of NPK with different organic manure on no. of leaves of *Pisum sativum***

## Germination Percentage

Germination percentage of *Pisum sativum* 15 days after sown was showed in Fig.9. The result showed that germination percentage is maximum in $T_4$ (NPK + Neem cake ) on 15 (80) and is minimum in $T_1$ (control) and $T_5$ (NPK+ Saw dust) ie 50 in both pots. Ratnoo and Bhatnagar (1993) reported that application of neem cake increased the cow pea seed germination and reduced the disease.

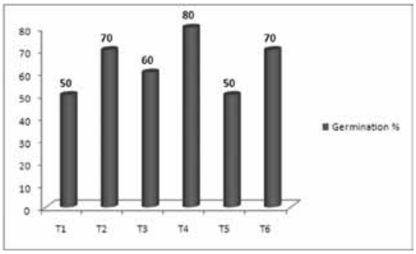



**Fig. 9**
**Effect of NPK with different organic manure on germination percentage of *Pisum sativum* after 15 days**

**Yield Parameters**

Yield parameters of *Pisum sativum* observed 60 days after sowing and results were shown in Fig. 10. The maximum number of pods per plant was observed in $T_6$ (NPK + Cow dung) as 14 and pod length is also high in $T_6$ as 16cm. Minimum number of pods per plant observed in $T_1$ (Control) as 4 and pod length 6.3cm. $T_2$ (NPK) also has large number of pods (9) as compared to control. Reddy et al (1998) reported that constant and optimal supply of nutrients through application of organic manure and recommended dose of NPK influenced better growth and yield parameters and finally the yields. Njoku et al (2008) reported that addition of cow dung to crude oil polluted soil increases the growth, dry weight, chlorophyll content, leaf area and pod production of the crop.

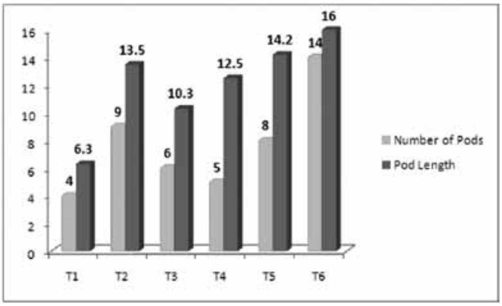



**Fig. 10**
**Effect of NPK with different organic manure on no. of pods and pod length of *Pisum sativum* after 60 days**

The response of pea to the NPK and organic fertilizers showed that the growth of pea is increased by applying NPK and cow dung mixture and growth is less in control, ie, without fertilizer. Number of leaves and number of pods per plant is also high while applying NPK +cow dung mixture. Germination percentage of pea is maximum in NPK+ neem cake mixture. All these result showed that application of fertilizer increases the growth and yield attributes of plants. Besides applying chemical fertilizers alone, it is beneficial to applying chemical and organic fertilizer mixture. Application of chemical fertilizer increased soil pH and reduce soil microbes population. It is recognized that combined source of organic manure and chemical fertilizer play a key role in modern agriculture in increasing the productivity of crops and sustaining soil fertility.

**CONCLUSION**

Plant nutrients are essential for the production of crops and healthy food for the world's expanding population. These are therefore a vital component of sustainable agriculture. Increased crop production largely relies on the type of fertilizers used to supplement essential nutrients for plants. The nature and characteristics of nutrient release of chemical, organic and biofertilizers are different, and each type of fertilizer has its own advantages and disadvantages with regard to crop growth and soil fertility. The sound management of fertilization must attempt to ensure both an enhanced and safeguarded environment; therefore, a balanced fertilization strategy that combines the use of chemical, organic or biofertilisers must be developed and evaluated.

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# Vermicompost as a Seed Inoculant for Reducing the Fertilizer Requirement and Minimising the Environmental Pollution

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## INTRODUCTION

Modern agriculture with its fast growing nature to feed the existing population has resulted in many adverse effects on the dynamic nature of soil by way of negative impact on the most worthy micro organisms and macrofauna. Exhaustive and injudicious use of chemicals including pesticides and fertilizers without adequate organic recycling has not only resulted in much deterioration of soil fertility but also poisoned the natural resources like soil, water and air causing several deformities, inabilities and diseases. Improper dumping of municipal solid waste without proper treatment and proper supervision has further deteriorated the situation leading to widespread contagious diseases. The illegal anthropogenic activities have led to unsustainability in agriculture. Hence, proper maintenance of soil organic matter is one of the major pre-requisites for achieving stability in crop production.

Composting of organic wastes on farms, in households and in rural and urban habitats turns them into valuable agricultural inputs and minimizes environmental pollution. Vermicompost, the organic manure produced due to the activity of earthworms, is a rich source of macro and micronutrients, vitamins, growth hormones and beneficial microorganisms like cellulolytic organisms, nitrogen fixers and phosphorous solubilising bacteria. Hence, the introduction of vermicompost into soil influences the physico-chemical as well as biological properties of soil that in turn improves the fertility status of soil and the efficiency of fertilizers applied to soil. But availability of these organic wastes is restricted due to socio- economic constraints and hence a better option is to introduce these beneficial microorganisms into soil by way of seed coating methods, which is cost effective, ecofriendly and easier to do. Therefore, the present study was undertaken to study the effect of coating seeds with vermicompost on growth parameters and yield and the microbial activity in soil.

## MATERIALS AND METHODS

A pot culture study carried out in Completely Randomised Design in the Instructional Farm of College of Agriculture, Vellayani. Red loam soil having a pH of 5.2, low soil organic carbon (0.18%), cation exchange capacity 4.1 cmol/kg, low available N (222.25 kg/ha), medium available $P_2O_5$ (30.94 kg/ha) and low available $K_2O$ (123.20 kg/ha) utilized for the study. There were nine treatments with three replications. Details of treatments are as follows: $T_1$- uncoated seeds+ full N P K fertilizers. T2 - coating seeds with Bradyrhizobium +N P K. $T_3$- vermicompost coating + N P K. T4- seed coating with combination of Bradyrhizobium & vermicompost. $T_5$- coating seeds with Bradyrhizobium +1/2N,1/2P &K. $T_6$- vermicompost coating + 1/2N,1/2P+K. $T_7$-- seed coating with combination of Bradyrhizobium& vermicompost+1/2N,1/2 P+K. $T_8$- uncoated seeds+ NPK+ vermicompost as organic source(20t/ha). $T_9$- uncoated seeds+ NPK+ 1/2vermicompost as organic source(10t/ha). An additional set of three replications kept apart for carrying out destructive sampling at maximum flowering stage. The test crop used was cowpea, variety Kanakamoni. Earthern pots of 25cm diameter and 30cm height used for raising the crop. The pots were filled with sand and red loam soil in the proportion of 1:1. Seeds were mixed uniformly with Rhizobium culture/ vermicompost @375g for 40kg seeds. Organic manure applied as per the treatment at the time of sowing of seeds. Lime applied in all the pots. A basal dose of 10kg N/ha, 30kg/haP2O5 and 10kg K2O were applied and the remaining half amount of N (10 kg/ha) was applied 20 DAS. N, P and K applied through urea, mussooriephos and muriate of potash. The nutrient status of farmyard manure and vermicompost used in the study was 0.6: 0.20:0.54 and 1.62:0.75:1.84 N: P: K, respectively. Proper plant protection measures were taken. The biometric characters studied include height of plant, number of leaves and girth of plant (two weeks after sowing) number of fruiting branches and number of pods per plant( at flowering and at harvest) and root characters of root length, root spread and number of effective nodules (at maximum flowering stage from the replications kept apart for destructive sampling). Periodical estimation for P solubilisation and N fixation capacity of the soil sample in the pots made at fortnightly intervals up to flowering (Allen, 1953).

## RESULTS AND DISCUSSION

### Effect of Treatments on Biometric Characters

The different treatments did not show any significant influence on the seedling vigour as measured by height of seedling, girth, number of leaves and fruiting characters of plant. However, the highest value for seedling girth obtained for seeds coated with vermicompost. The satisfactory rate of photosynthesis and meristamatic activity may be the main factors causing increased girth. The vegetative growth in vermicompost treated plants enhanced by the release of plant growth promoting compounds by earthworms into their casts (Nielson, 1965). Similar results obtained for vermicompost coating of seeds at maximum flowering stage as revealed by the height of plant and number of leaves. However, the highest mean value for number of fruiting branches observed for the treatment where full dose of organic manure supplemented by vermicompost. At harvest, the maximum value for fruiting branches and number of pods per plant obtained for seed inoculation with vermicompost (Table 1). The positive role of vermicompost on the rate of leaf production and its role in extending the longevity of leaves in cassava are established. Vermicompost significantly improved the yield, biometric characters and quality of cowpea (Prabha et al., 2008). The presence of phytohormones, enzymes, antibiotics and vitamins in vermicompost positively influence the number of fruiting branches per plant. The significant influence of vermicompost in enhancing the biometric characters may be due to the improved plant metabolism resulting in a higher utilization of plant nutrients leading to an increased vegetative growth. Addition of Organic manure conjunctive with inorganic fertilizer could increase the availability of nutrients thereby resulting in positive effect on growth parameters (Dikshit and Khatik, 2002).

**Table 1**
**Effect of vermicompost coating on biometric characters of cowpea**

| Treatments | Two WAS* | | | Flowering stage | | | Harvest | | |
|---|---|---|---|---|---|---|---|---|---|
| | height (cm) | No. of leaves | girth (cm) | height (cm) | No. of leaves | fruiting branches | height (cm) | fruiting branches | pods per plant |
| $T_1$ | 10.27 | 2.33 | .93 | 32.17 | 13.33 | 3.33 | 44.83 | 1.67 | 2.67 |
| $T_2$ | 11.50 | 3.33 | .97 | 40.00 | 15.67 | 4.33 | 51.17 | 4.33 | 6.67 |
| $T_3$ | 11.17 | 2.67 | 1.03 | 40.00 | 19.33 | 3.67 | 51.17 | 5.33 | 7.33 |
| $T_4$ | 10.93 | 2.67 | 0.93 | 39.33 | 15.33 | 3.67 | 53.00 | 4.67 | 4.33 |
| $T_5$ | 10.50 | 2.33 | 0.87 | 35.43 | 13.00 | 3.67 | 48.17 | 4.67 | 5.67 |
| $T_6$ | 10.60 | 2.00 | 0.87 | 34.33 | 14.00 | 3.33 | 48.17 | 4.67 | 6.67 |
| $T_7$ | 10.47 | 2.33 | 0.83 | 34.33 | 11.67 | 4.33 | 48.83 | 4.67 | 5.67 |
| $T_8$ | 9.00 | 2.33 | 0.87 | 34.67 | 14.67 | 4.33 | 47.50 | 4.00 | 5.67 |
| $T_9$ | 9.83 | 2.00 | 0.57 | 29.67 | 12.00 | 2.33 | 42.00 | 3.33 | 4.67 |
| CD | NS | NS | NS | NS | NS | NS | NS | NS | NS |

*(*weeks after sowing)*

**Rooting Pattern as Influenced by Vermicompost Coating**

The results revealed that the root length, root spread and number of effective nodules had significantly influenced by the different treatments (Table 2).Application of vermicompost as an organic source recorded the maximum root length (22.72cm) while seed coating with rhizobium resulted in maximum root spread (14.80cm) and effective nodules (37.00). Application of vermicompost as an organic source as well as a seed inoculants had positive influence on the root -shoot ratio in cowpea. This is in conformity with the findings of Sairam *et al.* (1989) and (Prabha et al., 2008). Inoculation with vermicompost might have increased the bacterial number in the rhizosphere, which in turn might have produced more plant growth promoting substances resulting in better root growth. Roy *et* al. (2000) observed that the activities of dehydrogenase, nitrogenase, phosphatase, arylsulfatase and urease enzymes found to be higher in the process of vermicomposting. The positive benefits of inoculation with vermicompost or Rhizobium may be due to the development and branching of roots, production of plant growth hormones, increased nitrate reductase activity and production of antifungal and antibacterial compounds (Okon, 1985 and Wani, 1990).

**Table 2**
**Effect of vermicompost coating on rooting pattern in cowpea**

| Treatments | Root length (cm) | Root spread (cm) | Effective nodules | Ineffective nodules | Root: Shoot ratio |
|---|---|---|---|---|---|
| $T_1$ | 13.17 | 9.70 | 13.67 | 16.00 | 0.08 |
| $T_2$ | 21.90 | 14.80 | 37.00 | 25.33 | 0.13 |
| $T_3$ | 20.00 | 12.93 | 31.33 | 20.00 | 0.11 |
| $T_4$ | 17.17 | 12.50 | 28.67 | 18.33 | 0.09 |
| $T_5$ | 21.33 | 12.03 | 29.00 | 20.33 | 0.09 |
| $T_6$ | 22.27 | 9.83 | 28.00 | 23.67 | 0.09 |
| $T_7$ | 20.83 | 11.17 | 26.33 | 21.00 | 0.08 |
| $T_8$ | 22.72 | 13.60 | 30.67 | 20.00 | 0.11 |
| $T_9$ | 16.17 | 10.00 | 17.00 | 13.00 | 0.07 |
| CD | 3.248 | 2.876 | 7.937 | ns | 0.016 |

## Yield and yield attributes as influenced by vermicompost coating

The different treatments had a significant influence on total grain yield. Seeds coated with vermicompost (T3) recorded the maximum grain yield, number of pods, weight of pods and number of seeds per pod (Table 3). Application of vermicompost as an organic source or as a seed inoculant stimulates the microbial activity and enhances N fixation (Bohlen and Edwards, 1995). Increase in grain yield in seed treatment with vermicompost may be attributed to the production of humic substances, which improves the physical and chemical properties of soil as well as the release of nutrients and their availability to plants. The higher availability of N and P due to improved physical environment created by worms, N fixing and P solubilising organisms might have contributed to highest yield (More, 1994). Beneficial effect of farmyard manure in increasing nutrient availability and sustaining yield in green gram observed by Rajkhowa el. al, 2000.

**Table 3**
**Effect of vermicompost coating on yield and yield attributes in cowpea**

| Treatments | No: of pods | Weight of pods(g/plant) | No: of seeds per pod | 100 seed weight(g) | Grain yield (g/plant) | Bhusa yield (g) |
|---|---|---|---|---|---|---|
| $T_1$ | 21.33 | 126.60 | 16.33 | 11.00 | 38.19 | 28.05 |
| $T_2$ | 32.33 | 203.21 | 18.00 | 11.35 | 65.31 | 36.27 |
| $T_3$ | 33.33 | 210.32 | 17.33 | 11.48 | 66.20 | 39.25 |
| $T_4$ | 31.67 | 194.48 | 17.33 | 11.71 | 64.26 | 37.29 |
| $T_5$ | 26.33 | 165.24 | 17.67 | 11.03 | 51.25 | 31.57 |
| $T_6$ | 27.00 | 165.08 | 18.33 | 11.07 | 54.73 | 32.48 |
| $T_7$ | 25.67 | 163.85 | 18.33 | 11.04 | 51.86 | 31.41 |
| $T_8$ | 28.33 | 198.35 | 17.33 | 11.33 | 55.16 | 36.83 |
| $T_9$ | 23.33 | 147.64 | 17.33 | 10.71 | 43.19 | 30.63 |
| CD | 7.990 | NS | NS | NS | 14.518 | 5.809 |

### Effect of treatments on N fixation and P solubilisation capacity of soil

Nitrogen fixation capacity of soil at fortnightly intervals up to flowering studied and found that the different treatments significantly influenced the N fixation capacity especially during later stages of crop growth. Vermicompost contain $10^6$N fixers per g of soil (Indira *et al*, 1996). They synthesize nitrogenase enzyme responsible for converting N into plant usable ammonia. Plants fixed considerable amount of N where seeds inoculated with vermicompost ($T_3$- Table 4). The available plant nutrients in vermicompost might have influenced the nodulation and nitrogen fixation, which reflected in increased seedling vigour and growth of the host plant. Further, vermicompost application enhances the soil pH, which is again favourable for N fixation. Even though P solubilisation capacity of soil was not significantly influenced by the different treatments at any stages, the maximum value was obtained for the treatment ($T_3$) where seeds were coated with vermicompost and farmyard manure as the organic source and full NPK fertilizers (9.40, 12.83 and 12.33 $\mu$g 10g$^{-1}$ soil). The mechanism of conversion of insoluble P by P-solubilising organisms to available forms include altering the solubility of inorganic compounds by production of acids and $H_2S$ under aerobic and anaerobic conditions and by mineralizing organic compounds, with the release of inorganic phosphate (Rasal et al., 1988). The solubilisation of P by these microorganisms attributed to excretion of organic acids like citric, glutamic, tartaric, succinic, lactic, oxalic, glyoxalic, maleic, fumaric and butyric acids (Gaur, 1990). These reactions take place in the rhizosphere where the organisms can transfer more P into solution than that required for their own growth and metabolism and thus the surplus is available for plants, thereby increasing the P uptake.

**Table 4**
**Effect of vermicompost coating on N fixation and P solubilisation capacity of soil**

| Treatments | N fixation capacity ($\mu$g g$^{-1}$ soil) | | | P solubilisation capacity ($\mu$g 10g$^{-1}$ soil) | | |
|---|---|---|---|---|---|---|
| | 15 DAS | 30 DAS | 45 DAS | 15 DAS | 30 DAS | 45 DAS |
| $T_1$ | 7.13 | 12.03 | 12.12 | 6.77 | 9.57 | 9.50 |
| $T_2$ | 9.07 | 17.22 | 17.25 | 8.77 | 11.17 | 11.20 |
| $T_3$ | 8.03 | 14.98 | 15.00 | 9.40 | 12.83 | 12.33 |
| $T_4$ | 8.74 | 15.15 | 15.17 | 9.20 | 11.83 | 11.73 |
| $T_5$ | 8.69 | 15.03 | 15.04 | 7.17 | 10.43 | 10.07 |
| $T_6$ | 8.64 | 14.76 | 14.74 | 8.17 | 10.93 | 10.87 |
| $T_7$ | 8.47 | 14.88 | 14.90 | 8.07 | 10.60 | 10.33 |
| $T_8$ | 8.71 | 16.02 | 16.00 | 8.97 | 12.07 | 12.10 |
| $T_9$ | 7.70 | 13.06 | 13.13 | 7.53 | 10.27 | 10.17 |
| CD | NS | 2.242 | 2.043 | NS | NS | NS |

## CONCLUSION

Use of vermicompost either as a seed inoculant or as an organic source gives better results in terms of yield as well as biometric characters. The use of vermicompost as a seed inoculant resulted in increased availability of N and P due to enhanced N fixation and P solubilisation capacity of soil. Since vermicompost coating of seeds with half N ($T_6$) produced 30 % increase in yield over control ($T_1$), it is quite evident that the application of vermicompost as a seed inoculant could reduce the quantity of fertilizers to half of its requirement. Hence, the reduced consumption of inorganic fertilizer possible due to the introduction of eco friendly organic manure in the form of vermicompost could minimise the ill- effects on soil health largely and can thus safeguard our environment from pollution.

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# Synergistic Effects of Earthworms and Effective Microorganisms on Vermicomposting

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## INTRODUCTION

Microorganisms are largely responsible for organic matter decomposition, but earthworms may also affect the rate of decomposition directly by feeding on and digesting organic matter, or indirectly through their interactions with the microflora. Basically this involves stimulation or depression of the microflora biomass and activity. The earthworms, the drivers of many processes in soil, apart from the known vermicomposting, are also found to enhance phytoextraction of metals from contaminated soils (Sinha,, et. al., 2010). In addition, vermicompost, produced by the joint action of earthworms and microbes, contains nutrients in available form with increased microbial activity (Aira, et. al., 2007). The use of biofertilizers and biocontrol agents is nowadays known to bring out several benefits to soil: solubilization of essential minerals, get hold of nutrients, offering micronutrients in more utilizable form for plants, taking part in biological nitrogen fixation, and protection against disease and pests. Psuedomonas and Trichoderma are very effective bio control agents. The Plant Growth Promoting Microbes are capable of putting forth advantageous properties on growth and yield characteristics of several cultivable crops in different parts of the world (Barassi, et. al., 2007; Abo-Baker and Mostafa, 2011; Geetha and Balamurugan, 2011). Recently, Raja Sekar and Karmegam (2010) reported that the vermicasts are able to increase the survival rate of bioagents for more than a year when used as carrier material. Since vermicomposting is a biological process, microorganisms play a key role in the evolution of the organic materials and in the transformations of wastes to safe organic amendments or fertilizers (vermicompost). Therefore, the effects that earthworms have on the microorganisms and the effect of microbes on earthworms must be established. They would have different effects on the decomposition of organic matter, and in turn on the quality of the final product. To address these questions we conducted some experiments, with the objective to investigate whether and to what extent the earthworm *E. eugeniae* and the microbial inoculants are capable of altering the structure and activity of communities each other.

## MATERIALS AND METHODS

### Collection of Earthworms

The earthworms collected from Kerala Agricultural University, was mass multiplied in cowdung and used for the study. African night crawler, *Eudrilus eugeniae* (Kinberg) was used in the experimentation to asses the “worm effect” on microbial activity in vermicompost. The cultures of Psuedomonas, Trichoderma, PGPR Mix II, Phosphate solubulizer and Azospirillum were procured from Department of Microbiology, College of Agriculture, Kerala Agricultural University.

### Enrichment of Vermicompost with Microbes

For enrichment studies, seven different vermicomposting trials, each with thee replicates, were carried out by preparing the vermibeds and *E. eugeniae* was introduced in all the vermibeds at the rate of 10 nos. for 10 kg of bio waste. Banana psuedostem was used as substrate. The vermibeds were prepared in the standard method. The mass multiplied microbes was inoculated to the vermibed at the rate 10 %. The different treatments applied are Azospirillum, Psuedomonas, Trichoderma, Phosphate solubulising bacteria, PGPR Mix II and Neem cake. Three replications were maintained for each treatment.

The vermicompost was collected from all the vermibeds after 40 days. The enumeration of the total bacteria, fungi and actinomycetes in vermicompost samples was carried out by following “serial dilution plate count technique”. About 10g sample is mixed with 100ml sterile water to make solution sample. This solution sample is diluted up to $10^{-5}$ serial dilution. After that 1ml of $10^{-5}$ of serial dilution is transferred into nutrient agar plate for assessing the bacterial population and Kenknights media for actinomycete count. For assessing the fungal population, $10^{-3}$ of serial dilution is transferred into Martin’s Rose Bengal Streptomycin Agar. The earthworm count was also taken for assessing the rate of multiplication of earthworm in combination with different microbes. Number of earthworms per kilogram of vermicompost is recorded.

### Statistical Analyses

Data were subjected for analysis of variance (ANOVA) followed by Duncan’s multiple-range test to differentiate the significant difference between different treatments using SPSS computer software for Windows (version 9.05).

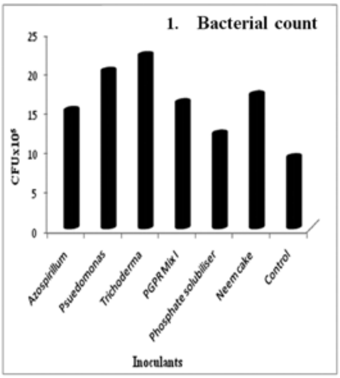
## RESULTS AND DISCUSSION

Vermicompost samples were analyzed for the microorganisms such as bacteria, fungi and actinomycetes. Maximum bacterial population was registered in vermicompost inoculated with *Trichoderma* (22x $10^5$ cfu/g) and *Psuedomonas* (20x $10^5$cfu/g) followed by neem cake (17x $10^5$cfu/ g) and PGPR Mix II (16x $10^5$cfu/g) (Table 1) (Fig. 1). Whereas, bacterial population was minimum in check (9x $10^5$cfu/ g).

**Table 1**
**Microbial count and earthworm population in enriched vermicompost**

| Sl. No | Treatments | Bacteria (CFUx10$^5$ g$^{-1}$ of dry soil) | Fungi (CFUx10$^3$ g$^{-1}$ of dry soil) | Actinomycets (CFUx10$^5$ g$^{-1}$ of dry soil) | Earth worms (Nos.) |
|---|---|---|---|---|---|
| 1 | *Azospirillum* | 15 | 47 | 20 | 112 |
| 2 | *Psuedomonas* | 20 | 49 | 33 | 128 |
| 3 | *Trichoderma* | 22 | 56 | 26 | 283 |
| 4 | PGPR Mix I | 16 | 27 | 25 | 177 |
| 5 | Phosphate solubiliser | 12 | 23 | 18 | 139 |
| 6 | Neem cake | 17 | 22 | 12 | 161 |
| 7 | Control | 9 | 12 | 11 | 108 |
| | CD Value | 4.29 | 4.34 | 3.76 | 39.47 |

The data pertaining to the observation on fungal colonies revealed that, it varied from 12 x10$^3$ to 56 x10$^3$ cfu/g. Fungal population was maximum in vermicompost inoculated with Trichoderma + *E. eugeniae* (56x 10$^3$ cfu/g) followed by Psuedomonas + *E. eugeniae* (49x104 cfu/g) and Azospirillum + *E. eugeniae* (47x104 cfu/g). Vermicompost obtained from control i.e., without inoculation of microbes put minimum fungal population (12 x 10$^3$ cfu/g) (Fig.2). The population of actinomycetes in vermicompost ranged from 11x 10$^5$cfu/g (control) to 33 x 10$^5$ cfu/g (Psuedomonas + *E. eugeniae*). Colony of Actinomycetes in Trichoderma was (26 x 10$^5$ cfu/g) and that of PGPR Mix I was 25 x 10$^5$ cfu/g (Fig. 3). The rate of multiplication of earthworms is greater in vermibeds inoculated with Trichoderma+ *E. eugeniae* followed by PGPR Mix I and neem cake(Fig. 4).



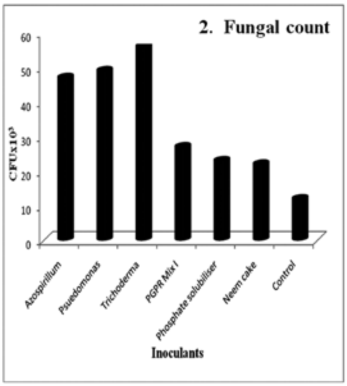




**Fig. 1 & 2**
**Microbial count and earthworm population in enriched vermicompost**

There are little reports about the microbial load of vermicompost, and that with respect to microflora and earthworm species in vermicompost to indicate their combined effect is very little. Giraddi (2007) reported the beneficial microflora in vermicompost such as fungi, bacteria and actinomycetes ($2.65x10^4$, $11.37 \times 10^7$ and $10.43 \times 10^4$ cfu/g, respectively). Ghosh *et al*. (1999) isolated 10 species of microfungi from the gut of *P. excavatus* and the results revealed that *Blastomyces sp, Curvularia lunata* and *Geotrichum candidum* as the organisms which prevailed in large numbers. However, the present results will act as baseline information for future study to throw much light on this aspect. The biochemical decomposition of organic matter is primarily accomplished by microorganisms, but earthworms are crucial drivers of the process as they may affect microbial decomposer activity by grazing directly on microorganisms (Aira et al., 2009), and by increasing the surface area available for microbial attack after breaking of organic matter (Domínguez et al., 2004).

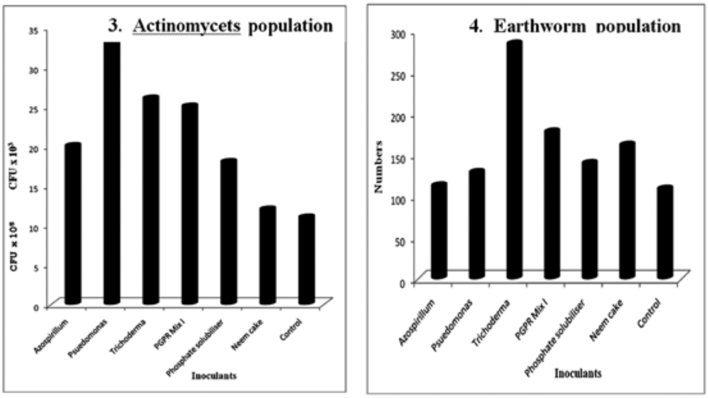



**Fig. 3 & 4**
**Microbial count and earthworm population in enriched vermicompost**

## CONCLUSION

The synergy of earthworms and EM bacteria can accelerate the composting and improve the mineralization and stability of products. The microbial count and the rate of multiplication of earthworms were also accelerated by the application of microbial inoculants at the time of vermicomposting. These activities may enhance the turnover rate and productivity of microbial communities, thereby increasing the rate of decomposition. The presence of increased amount of bio control agents and biofertilizers will provide protection against pest and disease, better growth and ultimately good yield in eco friendly way.

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# The Impact of Lime Application on Lime Requirement of Soil Under Long Term Fertilizer Experiment

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## INTRODUCTION

Long term fertilizer experiments provide an opportunity to evaluate the sustainability of agricultural practices (Jenkinson, 1991). The evidence of sustainability in continuous rice production systems would include sTable or increasing productivity over time as indicated by crop yields and maintenance or enhancement of key soil fertility factors which include soil organic carbon, nutrient availability etc. As Rice-rice cropping system is the predominant crop sequence in the lateritic belts of Kerala state, the changes in physical, chemical and biological properties of soil and nutrient uptake occurring due to continuous use of fertilizers or manures assume great significance for the sustainability of this cropping system.

Soils of Kerala are generally acidic in reaction. A large chunk of land in our state is acidic thus limiting the food grains production. Lack of proper understanding and perspective keeps these soils perpetually less productive. Suppressing hydrogen ions by applying lime is the best possible remedy of soil acidity though organic matter addition also contribute (Manna *et al*., 2007). Soil testing for pH and lime requirement is essential for finding out approximately correct dose of liming material.

In this paper an attempt is made to analyze the long term effects of lime on changes in active acidity measured in terms of soil pH and total acidity measured in terms of lime requirement after a continuous application of lime for fifteen years in the Long Term Fertilizer Experiment (LTFE) maintained at Pattambi centre of AICRP.

## MATERIALS AND METHODS

The present analysis was carried out to monitor the long term effects of fertilizer and organic manures on soil organic carbon content and NPK balance sheet of the soil after completion of 13 cycles of rice-rice system in an acidic lateritic soil at Regional Agricultural Research Station, Pattambi, Kerala agricultural University. Long Term Fertilizer Experiment (LTFE) Pattambi centre, Kerala started in 1997 as one of the 18 centers of LTFE at national level. This experiment started with an objective of assessing the impact of different nutrient management practices on crop yield, soil health and sustainability. It follows a rice- rice cropping system with rice variety Aiswarya in RBD with 12 treatments such as T1-50% NPK of 90:45:45 (KAU recommendation), T2-100%NPK, T3-150% NPK, T4-100%NPK +600 kg lime, T5-100%NPK, T6-100%NP, T7-100%N, T8-100%NPK +FYM@5 t/ha in Kharif season, T9-50%NPK + FYM@5 t/ha in Kharif season, T10-100%NPK+ in situ green manuring in Kharif , T11-50%NPK + in situ green manuring in Kharif and T12-Control and 4 replications. After the harvest, soil samples were collected and subjected to analysis for pH and lime requirement (SMP buffer method) along with other observations.

**RESULTS AND DISCUSSION**

The pH in soil measured using pH meter did not show any significant difference between treatments over fifteen years and the pH of soil samples collected from individual plots of the 12 treatments after fifteen years of continuous crop cycle is given in the Table (Table1).

**Table 1**
**pH in soils collected from different plots of LTFE at Pattambi centre KAU after fifteen years of continuous crop cycle**

| Treatments | Soil pH |
|---|---|
| T1 -50 % NPK of 90:45:45 | 5.06 |
| T2 – 100 % NPK | 5.16 |
| T3 – 150 % NPK | 5.01 |
| T4 - 100%NPK +600 kg lime | 5.14 |
| T5 – 100 % NPK | 5.13 |
| T6 – 100 % NP | 5.13 |
| T7 – 100 % N | 5.15 |
| T8- 100 % NPK+ FYM n kharif | 5.11 |
| T9 – 50 % NPK +FYM in kharif | 5.04 |
| T10-100%NPK+ in situ green manuring in Kharif | 5.01 |
| T11-100%NPK+ in situ green manuring in Kharif | 5.05 |
| T12 - Control | 5.1 |

The lime requirement values measured using SMP buffer method exhibited clear difference between the treatments which indicate the role of lime in correcting total acidity.

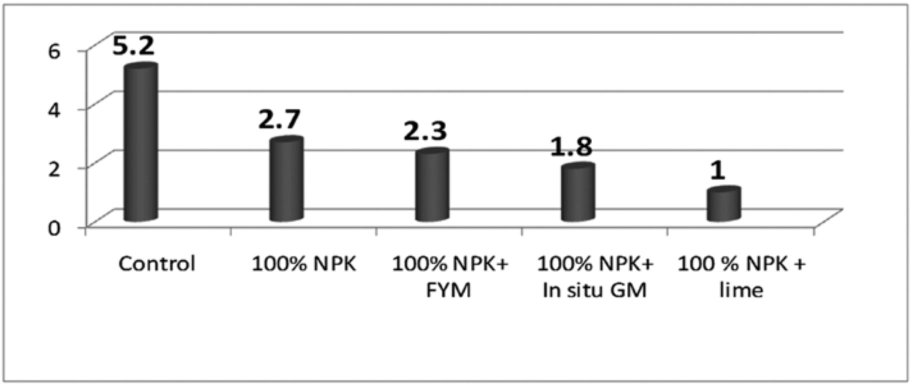


**Fig 1**
**Lime requirement in tons/acre of the soils collected from plots receiving different treatments of LTFE**

The lime requirement (kg/ha) of soil in 100% NPK+ lime plot is 1000 kg/ acre and that is much lower than that of 100% NPK and control plots. This clearly depicts the role of lime in correcting the total acidity of soil, though the beneficial effect of liming was not visible in correction of active acidity. Moreover, the lime requirement of soil from plots which received farm yard manure is found to be 2.3 tons/ acre while that from in situ green manured plot is 1.8 tons/acre. Hence it is clear that organic manures improve soil quality through buffering action on soil pH. However the buffering effect of organic manuring is more in 100% NPK+ in situ green manured plot than 100% NPK+ FYM plot. This can be attributed to the increased addition of organic matter through biomass in in situ green manured plots.

Low soil pH (high acidity) and resultant problems like iron toxicity and low availability of other nutrients are the most important soil related yield limiting factor in rice soils of Kerala. Due to low response to added nutrients in acid soil, farmers will resort to addition of more nutrients in the form of inorganic fertilizers for increase in yield which not only affect the economics of crop production but also environmental safety of the production system. Though different soils have same pH the requirement of liming material to correct the acidity to get desired soil environment for crop production will vary depending on soil. The quantification of lime requirement is a priority area for nutrient management in rice. Instead of soil pH lime requirement using SMP (Shoemaker, McLean and Pratt) buffer is more suiTable for identifying and correcting soil acidity.

Soil acidity is of two types namely active acidity and reserve acidity. Hydrogen ions in soil solution contribute active acidity while those adsorbed on soil particles along with aluminium ions constitute reserve acidity. The groups of hydrogen ions are always in equilibrium, the absorbed ions being greater in number than those present in the soil solution.

Neutralization of the hydrogen ions present in the soil solution (active acidity) is not enough and hence the amount of amendment should be enough to neutralize hydrogen ions swarming around the soil particles also (reserve acidity). Soil testing for lime recommendation must take this point into account. Reserve acidity is sometimes thousand times greater than active acidity In clay soils, reserve acidity is very high, whereas in sandy soils it is comparatively low. The amount of liming material required to neutralize total acidity (active + reserve), therefore, varies greatly according to soil texture also. Thus the results of the experiment provide an indication towards the need of estimation of lime requirement of soil for correct assessment of soil acidity and quantification of lime application rate for getting better response for other nutrients.

## CONCLUSION

Increase in soil acidity is a natural phenomenon in humid tropics and removal of basic cations by crops and use of chemical fertilizers aggravate this problem. Regular application lime is necessary even if a soil is in near neutral condition and the situation will be more critical in an acidic soil environment. Soil pH is the indicator of soil acidity which determine the amount of liming material to be added to the soil. The results from the experiment indicate, though there is no significant change in soil pH, lime requirement vary considerably among the soils studied. Thus, the amount of the liming material should be determined on the basis of lime requirement rather than pH for better crop response in an acidic soil environment.

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# Plant Growth Promoting Rhizobacteria for Reducing the Use of Chemical Fertilizers in Transplanted Rice (*Oryza sativa L*)

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## INTRODUCTION

In India, the use of chemical fertilizers has increased 170 times in last 50 years (Datta *et al.,* 2011). The dependence on chemicals fertilizers created problems such as environmental pollution, health hazards, and interruption of natural ecology and destruction of biological communities that support crop production. This necessitates the need of adoption of practices that maintain soil health and keep the production system more sustainable. Bacteria that colonize the rhizosphere and plant roots and enhance the plant growth by direct and indirect mechanism are referred to as plant growth promoting rhizobacteria (PGPR) (Ashrafuzzaman *et al*., 2009). In the present context of increasing international concern for food and environmental quality, the use of plant growth promoting rhizobacteria are often considered as a potential tool for reducing the use of chemical inputs for sustainable production and productivity in agriculture. The present investigation was undertaken with an objective to study the beneficial effects of plant growth promoting rhizobacteria, PGPR Mix 1 (a consortium of nitrogen fixer, phosphorous and potassium solubilizing bacteria developed by Kerala Agricultural University) in reducing the use of chemical fertilizers and their influence in sustaining the yield of transplanted rice.

## MATERIALS AND METHODS

The field experiment was conducted during Rabi (Punja) season 2011-12 at Rice Research Station, Moncompu (geographically situated 9 °5'N latitude and 76° 5' E longitude and at an altitude 1 m below MSL).The Soil belongs to silty clay textural class with pH 6.4 (wet) and organic carbon content 3.53 %, available P 26.8 kg/ha and available K 263 kg/ha.The experiment was laid out in randomized block design in three replications in plots of 50 $m^2$ size.The treatments included NPK @ 90-45-15 kg/ha +FYM 5 t/ha+ lime top dressing 250 kg/ha + $MgSO_4$ @ 20 kg/ha (best management practice) (T1), NPK @ 45-22.5-7.5 kg/ha +FYM 2.5 t/ha+ PGPR Mix 1 @ 2 kg/ha+ lime top dressing 250 kg/ha (T2), NPK @ 45-22.5-7.5 kg/ha + PGPR Mix 1 @ 2 kg/

ha+ lime top dressing 250 kg/ha (T3), NPK @ 90-45-15 kg/ha + FYM 5 t/ha+ lime top dressing 250 kg/ha (package of practice recommendations) (T4), NPK @ 90-45-45 kg/ha (farmers practice) (T5), NPK @ 45-22.5-7.5 kg/ha + FYM 2.5 t/ha + PGPR Mix 1@ 2 kg/ha (T6) and FYM 2.5 t/ha + PGPR Mix1 @ 2 kg/ha+ lime top dressing 250kg/ha (T7). FYM was applied as basal at the time of final ploughing. PGPR Mix 1, the consortium of nitrogen fixer, P and K solubilizing bacteria developed by College of Agriculture, Vellayani (Kerala Agricultural University) was used as the plant growth promoting rhizobacterial inoculant. PGPR Mix 1 after mixing with dried powdered FYM in the ratio of 1:50 was applied on four days after transplanting (DAT). Eighteen day's old seedlings of medium duration variety "Uma" was transplanted at a spacing of 20 x 10 cm.The fertilizers were applied as per treatment schedule as $1/3^{rd}$ N and K and 1/2 P at 12 DAT, $1/3^{rd}$ N and K and 1/2 P at 35 DAT and remaining $1/3^{rd}$ N and K at 55 DAT. $MgSO_4$ was applied on four DAT. Lime was top dressed one week before the second split application of fertilizers. All the other agronomic and plant protection measures were adopted as per package of practice recommendations (KAU, 2011). Observations on plant growth attributes were recorded at flowering stage and yield attributes and grain yield were recorded at harvest stage. The LAI was worked out as per the method proposed by Ponnuswamy and Gomez (1974). Growth and yield attributing characters were recorded from 10 randomly selected hills in each plot. The grain yield was recorded at 13 % moisture. Soil samples were taken at flowering stage for estimating soil pH and EC (ds/m), organic carbon (Walkley and Black, 1934), soil available phosphorous (Bray and Kurtz, 1945) and available potassium (Knudsen *et al.* 1982). All the data except soil pH and EC were analyzed using ANOVA, and the least significant difference (LSD) values at 5% level of significance were calculated and used to test the significant difference between treatment means.

## RESULTS AND DISCUSSION

### Effect on Crop Growth

Data on growth attributes at flowering stage revealed that the plant height was not significantly influenced by the treatments (Table 1). However, best management practice (BMP) recorded taller plants (80.1 cm) and treatments with FYM, PGPR MIX 1 and lime top dressing recorded plants with minimum plant height (72.1 cm). Package of practice (POP) recommendations recorded higher tiller production and were on par with BMP and treatment with half the recommended dose of chemical fertilizers, PGPR Mix1 and lime top dressing. LAI was found to be more in BMP. This was followed by the treatment with half the recommended dose of chemical fertilizers, PGPR Mix1 and lime top dressing, which was on par with POP recommendations, farmers practice and PGPR Mix 1with half the recommended dose of chemical fertilizers, basal FYM and lime top dressing. Dry matter production (DMP) was also significantly influenced by the treatments. Best management practice recorded plants with more DMP.The treatment receiving half the recommended dose of chemical fertilizers, PGPR Mix1 and lime top dressing recorded DMP of 8155 kg/ha which was on par with farmers practice of applying chemical fertilizers alone (8328 kg/ha) and POP recommendations (8095 kg/ha). Higher LAI and DMP of BMP might be due to the favourable influence of Mg on photosynthetic $CO_2$ fixation and partitioning of carbohydrates and dry matter production between roots and shoots (Cakmak and Kirkby, 2008). The growth enhancement in the treatment with half the recommended dose of chemical fertilizers, PGPR Mix1 and lime top dressing was due to the auxins produced by the rhizobacteria, which influences the plant growth including the root development resulting in the improved uptake of essential nutrients (Vikram, 2007). PGPR Mix 1 with basal application of FYM and with and without lime top dressing recorded lesser LAI, DMP and tillers per square meter than without basal application of FYM. The reason attributed was organic acids produced during the decomposition of FYM increasing the acidity of the soil that will repress the growth and activities of soil organisms like nitrogen fixing and nitrifying bacteria. Then nitrates are not produced in adequate quantities and atmospheric nitrogen is also not fixed and thus the plants do not get enough nitrogen causing the slowdown of crop growth in the initial stages of crop development (Sankaran and Muddaliar, 1993).

**Table 1**
**Effect of treatments on the growth attributes of transplanted rice at flowering stage**

| Treatments | At flowering stage | | | |
|---|---|---|---|---|
| | Plant height (cm) | Tillers/ $m^2$ | LAI | DMP (kg/ ha) |
| NPK @ 90-45-15 kg/ha +FYM 5 t/ha+ lime top dressing 250 kg/ha + $MgSO_4$ @ 20 kg/ha (best management practice) (T1) | 80.1 | 342 | 4.94 | 9827 |
| NPK @ 45-22.5-7.5 kg/ha +FYM 2.5 t/ha+ PGPR Mix 1 @ 2 kg/ha+ lime top dressing 250 kg/ha (T2) | 76.8 | 314 | 3.35 | 7147 |
| NPK @ 45-22.5-7.5 kg/ha + PGPR Mix 1 @ 2 kg/ ha+ lime top dressing 250 kg/ha (T3) | 77.4 | 336 | 3.66 | 8155 |
| NPK @ 90-45-15 kg/ha +FYM 5 t/ha+ lime top dressing 250 kg/ha (package of practice recommendations) (T4) | 76.1 | 347 | 3.34 | 8095 |
| NPK @ 90-45-45 kg/ha (farmers practice) (T5) | 77.3 | 320 | 3.22 | 8328 |
| NPK @ 45-22.5-7.5 kg/ha + FYM 2.5 t/ha + PGPR Mix 1@ 2 kg/ha (T6) | 75.9 | 317 | 2.92 | 6972 |
| FYM 2.5 t/ha + PGPR Mix1 @ 2kg/ha+ lime top dressing 250kg/ha (T7) | 72.1 | 311 | 3.03 | 6207 |
| SE m ± | 3.8 | 10.7 | 0.39 | 339 |
| CD | NS | 18 | 0.67 | 580 |

*DMP-Dry Matter Production, LAI-Leaf Area Index*

**Effect on Yield Attributes and Yield**

Highest number of panicles per meter square and panicle weight were recorded in BMP and it was followed by treatment with half the recommended dose of fertilizers, PGPR Mix 1and lime top dressing (Table 2). 1000 grain weight was not significantly influenced by the treatments. Fertile grains per panicle was found to be highest in treatments with 5t/ha FYM as basal dose. Bhattacharya *et al.* (2003) reported the beneficial effects of FYM on the yield parameters of rice. Best management practices recorded the highest grain yield of 3883 kg/ha followed by POP recommendations (3533 kg/ha). This might be due to the production of more number of panicles per square meter and fertile grains per panicle.

**Table 2**
**Yield attributes and grain yield as influenced by Plant growth promoting rhizobacteria**

| Treatments | At harvest stage | | | | |
|---|---|---|---|---|---|
| | Panicles/ $m^2$ | Panicle weight (g) | 1000 grain weight (g) | Fertile grains per panicle | Grain yield (kg/ha) |
| NPK @ 90-45-15 kg/ha +FYM 5 t/ha+ lime top dressing 250 kg/ha + $MgSO_4$ @ 20 kg/ha (best management practice) (T1) | 339 | 2.69 | 2.22 | 98.7 | 3883 |
| NPK @ 45-22.5-7.5 kg/ha +FYM 2.5 t/ha+ PGPR Mix 1 @ 2 kg/ha+ lime top dressing 250 kg/ha (T2) | 300 | 2.52 | 2.17 | 91.1 | 3253 |
| NPK @ 45-22.5-7.5 kg/ha + PGPR Mix 1 @ 2 kg/ha+ lime top dressing 250 kg/ha (T3) | 321 | 2.52 | 2.28 | 90.3 | 3520 |
| NPK @ 90-45-15 kg/ha +FYM 5 t/ha+ lime top dressing 250 kg/ha (package of practice recommendations) (T4) | 318 | 2.28 | 2.18 | 94.7 | 3533 |
| NPK @ 90-45-45 kg/ha (farmers practice) (T5) | 307 | 2.35 | 2.24 | 83.7 | 3393 |
| NPK @ 45-22.5-7.5 kg/ha + FYM 2.5 t/ha + PGPR Mix 1@ 2 kg/ha (T6) | 300 | 2.23 | 2.08 | 79.9 | 3203 |
| FYM 2.5 t/ha + PGPR Mix1 @ 2kg/ha+ lime top dressing 250kg/ha (T7) | 292 | 2.1 | 2.32 | 81.5 | 2967 |
| SE m ± | 8.7 | 0.15 | .09 | 4.6 | 173.7 |
| CD | 15 | 0.26 | NS | 7.9 | 297 |

PGPR Mix 1 with recommended half the dose of chemical fertilizers and lime top dressing recorded a grain yield of 3520 kg/ha which was on par with POP recommendations (3533 kg/ha), farmers practice (3393 kg/ha) and PGPR Mix 1 applied with recommended half the dose of chemical fertilizers, basal FYM and lime top dressing (3253 kg/ha). PGPR Mix 1 application with basal application of FYM and lime top dressing without chemical fertilizers recorded the grain yield of 2967 kg/ha. The reason was that plant growth promoting rhizobacteria stimulates the plant growth by the production of growth promoting substances like auxins, increasing the availability of nutrients by nitrogen fixation and solubilization of P and K and promotes the uptake of mineral nutrients by the plant (Kaushal, et *al*., 2011).

**Effect of Treatments on Available Nutrients, Soil pH and EC**

There was not much variation in soil pH and EC observed among the treatments (Table 3). The results revealed that PGPR Mix 1 application has profound influence on the availability of mineral nutrients. The availability of $P_2O_5$ and $K_2O$ was found to be more in PGPR Mix 1 applied plots than the plots receiving POP recommendations of chemical fertilizers. This clearly indicated the ability of plant growth promoting rhizobacteria's in the PGPR Mix 1 in solubilizing the insoluble form of P and K in the soil and enhance their availability (Saharan and Nehra, 2011). PGPR Mix 1 with basal application of FYM enhances the organic carbon content of the soil. The treatment with half the recommended dose of fertilizers, PGPR Mix 1 and lime dressing recorded 3.9 % organic carbon content in the soil. However the treatments receiving basal application of FYM and PGPR Mix 1 recorded organic carbon content of 4.6 to 5.0 %. This showed the favourable influence of FYM in enhancing the organic carbon content of the soil.

**Table 3**
**Soil pH, EC and availability of nutrients as influenced by the treatments at flowering stage**

| Treatments | At flowering stage | | | | |
|---|---|---|---|---|---|
| | Soil pH | EC (dS/m) | OC % | Available $P_2O_5$(kg/ha) | Available $K_2O$ (kg/ha) |
| NPK @ 90-45-15 kg/ha +FYM 5 t/ha+ lime top dressing 250 kg/ha + $MgSO_4$ @ 20 kg/ha (best management practice) (T1) | 5.77 | 0.09 | 4.9 (12.79) | 33.6 | 82.36 |
| NPK @ 45-22.5-7.5 kg/ha +FYM 2.5 t/ha+ PGPR Mix 1 @ 2 kg/ha+ lime top dressing 250 kg/ha (T2) | 5.97 | 0.11 | 4.6 (12.39) | 33.97 | 123.39 |
| NPK @ 45-22.5-7.5 kg/ha + PGPR Mix 1 @ 2 kg/ha+ lime top dressing 250 kg/ha (T3) | 6.14 | 0.18 | 3.9 (11.39) | 29.47 | 94.27 |

| | | | | | |
|---|---|---|---|---|---|
| NPK @ 90-45-15 kg/ha +FYM 5 t/ha+ lime top dressing 250 kg/ha (package of practice recommendations) (T4) | 5.65 | 0.10 | 4.4 (12.11) | 23.52 | 60.41 |
| NPK @ 90-45-45 kg/ha (farmers practice) (T5) | 5.68 | 0.14 | 4.3 (11.97) | 31.36 | 104.23 |
| NPK @ 45-22.5-7.5 kg/ha + FYM 2.5 t/ha + PGPR Mix 1@2 kg/ha (T6) | 5.74 | 0.09 | 5.0 (12.92) | 32.11 | 122.94 |
| FYM 2.5 t/ha + PGPR Mix1 @ 2kg/ha+ lime top dressing 250kg/ha (T7) | 6.05 | 0.08 | 4.6 (12.39) | 36.96 | 91.46 |
| SE m ± | | | 0.60 | 5.64 | 31.48 |
| CD | | | NS | NS | NS |

*(Values in parenthesis are transformed values)*

## CONCLUSION

It may be concluded from the study that plant growth promoting rhizobacteria was found effective in reducing the use of chemical fertilizers and favorably influence the growth and yield attributes of transplanted rice. Application of PGPR Mix 1 @ 2kg/ha with recommended half the dose of chemical fertilizers (45-22.5-7.5 kg/ha of NPK) and lime top dressing @ 250kg/ha gave on par yield with POP recommendations of applying manures, lime and chemical fertilizers and farmers practice of applying chemical fertilizers alone @90-45-45 kg/ha of NPK.

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# Quality Assessment of a Single Cell Protein from Vegetable Waste

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## INTRODUCTION

Microorganisms can be cultivated on agro-industrial products with production of large amounts of cells rich in proteins that commonly contain all the essential amino acids, in addition to favorably high vitamin and mineral levels (Kuhad *et al.*,1997). It has been reported that Solid Sate Fermentation (SSF) is the most appropriate process in developing countries for the production of Single Cell Protein (SCP), due to the advantage it offers (Carrizales, 1986.). SSF resembles the natural habitat of microorganism and is, therefore, preferred choice for microorganisms to grow and produce useful value added products (Singhania *et al,* 2009). Of the fungal cultures, members of the Basidiomycetes and Acsomycetes family are supposed to be most efficient lignocelluloses converters in SSF (Moo –Young *et al.*, 1983). Hence a novel fungal culture indigenous to the system was selected for the present study, which aims at the best possible conversion of the substrate in the SSF system. SSF adopted in the present study can be appreciated as a very economical method for the conversion of vegetable waste into a value added product, Single Cell Protein. While considering the quality of SCP, the amount of protein and amino acid extracted from it needs to be determined, in order to verify it as a productive protein (Ahmadi *et al.*, 2010). Since the reports regarding the amino acid profile analysis of SCP are limited, the present study is also significant in evaluating the amino acid composition of the final product

## MATERIALS AND METHODS

### Solid State Fermentation and Data Analysis

A random survey was conducted and vegetable waste samples were collected from various vegetable markets in Thiruvananthapuram city. The vegetable waste samples were subjected to isolation and pure culture preparations for obtaining the fungal culture of interest. The fungal culture isolated was molecularly identified and used for SSF with vegetable waste as the substrate. SSF was carried out using 50gm of vegetable waste taken in a 500ml conical flask. The fermentation was carried out for a period of 12 days under an optimized condition of pH 5.5, temperature $30^0$C, with 0.5% urea as the nitrogen source , at a moisture content of 40% and with an inoculum size of 205 x $10^4$ spores/ml . The effects of different growth factors were studied for the maximum production of Single cell protein and all the experiments were performed based on three replications. Data were analyzed using analysis of variance (ANOVA) and the differences between treatment means were determined with Duncan's multiple range test. (Duncan ,1955). Differences were considered to be significant at $P<0.05$ throughout this study. After fermentation the crude protein content of the fermented substrate was analyzed by the Micro- Kjeldahl method. The total nitrogen content of the sample was multiplied by 6.25 to arrive at the value of the crude protein (Sadasivam, 2008.). This was followed by the determination of the amino acid profile of the Single cell protein.

**Amino acid Characterization of the SCP**

Amino acids in the Single cell protein was determined as per the procedure of Ishida et al *(*1981). The amino acid analyzer (HPLC- LC 10 AS) was equipped with Shimadzu FL 6A fluorescence detector and Shimadzu CR 6A Chrompac recorder. Gradient system was followed for the effective separation of amino acids. The amino acid analysis was done with non-switching flow method and fluorescence detection after post-column derivatization with o-phthaldehyde. In the case of proline and hydroxyl proline, imino group is converted to amino group with hypochlorite. Amino acid standard (Sigma chemical Co., St. Louis, USA) was also run to calculate the concentration of amino acids in the sample. The amount of each amino acid is expressed as g/100g protein.

**Calculation of Essential Amino Acid Index, Biological Value, Nutritional Index and Computed –Protein Efficiency Ratio of the Single Cell Protein**

Essential amino acid index (EAA index) was calculated according to the procedure of Oser (1951), ,taking into account the ratio of EAA in the test protein relative to their respective amounts in whole egg protein. The biological value (BV) was calculated using the formula of Oser (1959). Nutritional index (NI) was calculated using the formula of Crisan and Sands(1978 ). The Computed –Protein efficiency ratio (C-PER) was calculated according to the method of Satterlee (1979) .

**RESULTS AND DISCUSSION**

The fungal culture selected for the production of SCP was molecularly identified to be *Penicillium oxalicum NFCCI 2136*. The crude protein content of the substrate (vegetable matter), before fermentation was found to be 12.8 % and it increased to 38% after SSF, showing a percentage increase of 197% from the initial value.

**Amino Acid Characterization of the SCP**

An ideal protein is one which has a good balance of essential amino acids and can provide necessary nutrition for the animals. This protein should also in the mean time contain sufficient Nitrogen for the production of non essential amino acids by itself (Keshavarz , 2004). The results showed that the concentration of essential amino acids in SCP from *P.oxalicum* was equal to or greater than those in the FAO reference protein, suggesting that it can be used as a good protein supplement for animals .In Table 1, the amino acid composition of the SCP from *P.oxalicun* is compared with that of the FAO reference protein ( FAQ/WHO/UN, 1985), whey protein concentrate (WPC80, 80% protein based on dry weight), sodium caseinate (88.03% protein based on dry weight) (Severin, 2006), human milk (Hambraeus, 1982.) and conventional foods (Erdman, 1977). Amino acid profile of Single cell protein, whey protein concentrate, sodium caseinate, egg, beef_protein, human milk and the FAQ/WHO.UN (1985) ref standard are shown in the Table 1.

**Table 1**
**Amino acid profile of Single cell protein, whey protein concentrate, sodium caseinate, egg, beef protein, human milk and the FAQ/WHO.UN (1985) ref standard**

| Amino acid | SCP | WPC80[a] | SC[b] | Egg [c] | Soya [d] protein | Beef [e] protein | Human[f] milk | FAQ[g] ref std |
|---|---|---|---|---|---|---|---|---|
| **Essential** | | | | | | | | |
| Ile | 3.8 | 4.97 | 4.59 | 5.9 | 5.8 | 5.3 | 4.9 | 2.8 |
| Leu | 10.1 | 10.66 | 8.89 | 8.8 | 7.6 | 8.2 | 9.1 | 6.6 |
| Lys | - | 8.81 | 7.75 | 7.8 | 6.6 | 8.6 | 6.5 | 5.8 |
| Met+Cys | 5.8 | 7.97 | 3.2 | 5.18 | 2.7 | 3.6 | 3.7 | 2.5 |
| Phe+Tyr | 9.7 | 5.82 | 10.14 | 9.39 | 8 | 7.5 | 7.6 | 6.3 |
| Thr | 3.9 | 6.87 | 4.05 | 4.9 | 3.9 | 4.4 | 4.4 | 3.4 |
| Val | 4.8 | 1.84 | 5.64 | 7.1 | 5.2 | 5.5 | 5.2 | 3.5 |
| Trp | 3.76 | 1.73 | 1.04 | 1.33 | 1.4 | 1.2 | NA[h] | 1.1 |
| **Non-Essential** | | | | | | | | |
| His | - | 0.78 | 2.54 | | | | | |
| Ala | 6.5 | 5.55 | 2.76 | | | | | |
| Arg | - | 2.71 | 3.35 | | | | | |
| Asp | 11.8 | 9.18 | 7.57 | | | | | |
| Glu | 17.2 | 15.84 | 21.84 | | | | | |
| Gly | 4.9 | 5.32 | 1.73 | | | | | |
| Pro | - | 6.66 | 9.33 | | | | | |
| Ser | 5.2 | 5.3 | 5.54 | | | | | |

*[a&b] From Severin (2006), [c,d&e] Erdman(1977), [f] Hambraeus(1982),[g] FAQ/WHO/UNU (1985), [h]Not Analyzed*

Leucine and methioine in SCP were having high values of 10.1 and 5.8g/100gm protein respectively, when compared with FAQ ref proteins. Phenyl alanine (9.7g/100gm) showed comparable value with whole egg while Threonine (3.9gm/100gm) showed same value with soy protein suggesting the SCP as being valuable in terms of nutritional value. Percentage of Valine (4.8gm/100gm) was slightly lower than other ref proteins except WPC80 and FAQ ref protein. The Leu, Met, Phe and Trp levels of the SCP shows higher values than soy protein. Since soy protein is widely used in animal diets, this finding is highly advantageous in terms of the economic aspects of formulating animal feed. Lysine one of the most limiting essential amino acid in cereals, but present in higher concentration in animal protein sources, was found to be lacking in this SCP. So, in the present study lysine was not reported in the amino acid profile, which is one of the disadvantages of this SCP. This disadvantage of lysine deficiency in the present study can be better overcome by supplementation with synthetic amino acids and other cheaper protein sources rich in lysine.

### Essential Amino Acid Index, Biological Value, Nutritional Index and Computed – Protein Efficiency Ratio

The EAAI and BV of SCP were found to be higher than WPC80 and SC, suggesting its good nutritional quality. The C-PER value was of SCP found to be closer to SC while NI value was lower than WPC80 and SC,since the protein content of the SCP was lower than SC and WPC80. The results are tabulated in Table 2.

**Table 2**
**Nutritional indices (%) of SCP, WPC80 and sodium caseinate**

| Parameters | SCP | WPC80[a] | SC[b] |
|---|---|---|---|
| EAA index | 83 | 72.28 | 77.80 |
| Predicted BV | 78.77 | 67.09 | 73.10 |
| NI | 31.54 | 58.42 | 69.34 |
| C-PER | 2.164 | 4.85 | 3.06 |

[a&b] *From Severin (2006)*

## CONCLUSION

The results of the present study suggested that the fungal strain *P.oxalicum* isolated from vegetable waste was very efficient in converting the substrate into Single Cell Protein by SSF technique and the SCP showing high protein content and amino acid profile will make an ideal supplement in animal feed formulations.

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# Distribution and Diversity of Bacterial Population in some Agricultural Fields of Kuttanad

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## INTRODUCTION

The present trend of application of huge quantity of fertilizers, pesticides, herbicides and other soil conditioners for increasing the crop yield has contaminated the environment; especially soil and water to a large extend in low land ecosystem. Agricultural activities result in elevated levels of metals in soils. Long term addition of inorganic fertilizers and pesticides can increase total and available metal contents in agro ecosystems. These will come directly to the soil as the ultimate sink is the soil. Usually contaminated soils have reduced microbial activities, biomass and diversity due to stress of contamination. van-Elsas et al. (1992) studied the effect of fertilizer and pesticide application in an agricultural land of Kazakistan, observed that the contamination adversely affected the diversity and interactions of bacteria, actinomycetes and fungi. Gadd (1993) and Zafer and Ahamad (2005) also obtained results in line with this. Soil microbial communities are useful as indicators to determine contamination and remediation due to its sensitivity to most contaminants. Bacteria, actinomycetes, fungi including arbuscular mycorrhiza, and microalgae are also used as biosensors of soil contamination. Microbial bioindicators could be based on functional and structural diversity of the bacterial community. Several indices such as the species richness, diversity and evenness are used to describe the diversity of a community and to monitor the changes in microbial diversity due to environmental fluctuations, land management practices and pollution (Øvreås, 2000).The present study reports the diversity and distribution of bacterial species in five agricultural locations of Kuttanad.

## MATERIALS AND METHODS

The study area was located in the paddy fields of Kuttanad, Alappuzha District. The major crop of the area is rice and that too rice - rice- fallow, rice - fallow under below sea level farming where there is every chance for the acute contamination of the paddy fields with pollutants from agro chemicals, coir industry and inland tourism.

Soil samples were collected from five paddy fields of Kuttanad. Ten replicated soil samples of surface layer were drawn from each site up to a depth of 10 cm using a soil auger to analyse the microbial and physio chemical parameters from the active rooting zone of paddy. Analyses of the wet samples were done on storing the labelled samples at $4^0$C. The physicochemical characteristics of the soils were analysed as per standard procedure (Byju, 2001). The density of cultivable bacterial species was estimated using dilution plating procedure (Wollum, 1982). Bacteria were quantified on nutrient agar, supplied with cycloheximide and identified based on morphological, physiological and biochemical characteristics according to Bergey's Manual of Determinative Bacteriology (Buchanan & Gibbons, 1974). Morphological characteristics such as colony morphology, Gram's reaction, spores motility and fluorescence (UV) were studied. Physiological tests included growth temperature, growth pH, growth on NaCl (%) and growth under anaerobic condition and biochemical tests performed included growth on Mc Konkey agar, indole test, methyl red test, citrate utilization, gas production from glucose, casein hydrolysis, starch hydrolysis, urea hydrolysis, nitrate reduction, $H_2S$ production, catalase, lysine decarboxylase, arginine dehydrolase, tween 20 hydrolysis, lipase test and acid production from carbohydrates. Bacterial diversity has analyzed using species richness (S), the total number of different organisms present, and the Shannon-Wiener index (H) subspecies richness and proportion of each subspecies within a zone (Odum, 1985, Shannon and Wiener, 1942)

## RESULTS AND DISCUSSION

### Physico-chemical Characteristics of the Soil Samples

Wide variations were found in the physicochemical characteristics of the soils under study (Table 1).

**Table 1**
**Physico-chemical characteristics of the soil samples**

| Sl. No | Location | Temperature (ºC) | Moisture (%) | pH | Organic Carbon (%) | Nitrogen (kg/ha) | Phosphorous (kg/ha) | Potassium (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| 1 | L1- Upper Kuttanadu | 27.43±1.38 | 23.40±9.53 | 4.93± 0.51 | 1.19±0.95 | 431.9±04 | 14.46±0.84 | 24.94±2.0 |
| 2 | L2 -Kayal Lands | 27.77±1.05 | 26.16±3.76 | 4.49± 0.65 | 1.27±0.44 | 452±1.32 | 26.67±1.62 | 28.04±2.1 |
| 3 | L3- Lower Kuttanadu | 26.87±1.00 | 32.67±2.63 | 4.80± 0.51 | 1.28±0.36 | 425.6±86 | 34.56±1.96 | 30.37±2.3 |
| 4 | L4- North Kuttanadu | 28.10±0.40 | 32.24± 5.02 | 4.98± 1.28 | 1.03±0.16 | 412±83.0 | 25.13±1.1 | 28.43±2.0 |
| 5 | L5- Kari Lands | 28.23±0.53 | 18.37±1.64 | 4.87± 0.47 | 1.43±0.56 | 450.8±70 | 16.34±1.0. | 27.24±2.0 |

*(Mean ± SD, n = 10)*

The soils are generally acidic in nature and that from Upper Kuttanad and North Kuttanad showed a slight increase. Moisture content was high in location 3 and in location 5. Irrespective of locations the soils showed high level of organic carbon

(1.2 to 1.4%). The available nitrogen content was high in Kayal and Kari lands and available phosphorus and potassium contents were high in Lower Kuttanad. Soil elements play a vital role in meeting microorganism's body requirements (Allison, 1973). In a field study to evaluate the nutrient status of Kerala (Usha and Varghese, 2002) found a high soil NPK.

**Predominant Bacterial Species and their Distribution**

Soil bacterial distribution and diversity varied significantly between locations. Thirteen bacterial species were isolated and identified from five locations (Table 2) and also shown a more or less even distribution. Maximum number of species were encountered in the locations L3 and L4. *Bacillus* genera had the great prevalence. Ohba et al. (2000) reported that among the bacteria bacillus has the largest number of species present in soil. These are ubiquitous microorganisms found in soil (Murray, et al., 1998). Maximum diversity was recorded in North Kuttanad and least in Kari lands. No variations were observed in other locations and that were on par (Fig.1). The occurrence of the bacteria's in rice fields can be probably due to the abundance of organic material (Reche and Fiuza, 2005). Ratcliff et al. (2006) obtained a result indicating an increase in total bacteria, culturable bacteria and bacterial fungal biomass at higher concentration of glyphosate applied soil.

**Table 2**
**Predominant bacterial species and their distribution**

| Sl. No | Location | Distribution of bacterial species |
|---|---|---|
| 1. | L1 | 1, 2, 3, 4, 5, 7, 8, 10, 11, 12, 13 |
| 2. | L2 | 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12 |
| 3. | L3 | 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13 |
| 4. | L4 | 1, 2, 3, 4, 5, 6, 7, 8,9, 10, 11, 12, 13 |
| 5. | L5 | 1, 2, 3, 5, 6, 7, 10, 11,12 |

1. *Alcaligens denitrificans* sub sp. *denitrificans* (MTCC 6945) 2. *Alcaligens faecalis* (MTCC 6946) 3. *Bacillus brevis* (MTCC 6944 4. *Bacillus cereus*; 5. *Bacillus* sp.1; 6. *Bacillus* sp. 2; 7. *Brevibcterium*; 8. *Flavobacterium multivorum*; 9. *Flavobacterium* sp.; 10. *Pseudomonas fluorescens*; 11. *Pseudomonas* sp. 1; 12. *Pseudomonas* sp. 2; 13. *Serratia marcescens*

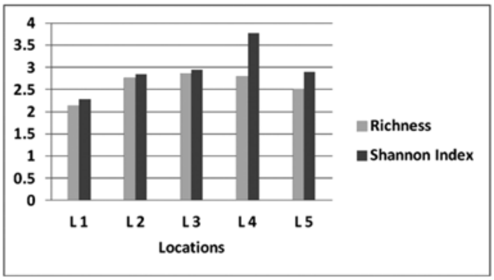


**Fig. 1**
**Diversity of bacterial species in different locations**

## CONCLUSION

The study reveals that bacteria can sustain in various locations of agriculturally contaminated soils and environment, though their distribution and diversity varies. The rice cultivating areas did not significantly affect the bacterial diversity. The study reveals that there is an urgent need for identifying and propagating more environmental friendly species which can survive in the contaminated fields. These species can be effectively utilized for biological remediation of contaminants for a clean environment.

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# Banana Bract Mosaic Virus, A New Threat to Small Cardamom (*Elettaria cardamomum* Maton)

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## INTRODUCTION

India has been acclaimed as the "Land of Spices" from time immemorial. Small cardamom "The Queen of spices" occupies an important position among the foreign exchange earning commodities. Among the Indian states, Kerala accounts for the major share in area and production of cardamom and this phenomenon remained unchanged over the last few decades. The productivity of this crop in Kerala is limited by fungal diseases like capsule rot, clump rot, stem rot and leaf blight. Apart from this the crop is also affected by a viral disease known as Katte / Mosaic disease incited by cardamom mosaic virus (Biju *et al.*,2011). The first visible symptom of Katte appears on the youngest leaf of the affected tiller as slender chlorotic flecks. Later these flecks develop into pale green discontinuous stripes. These stripes run almost parallel to each other from the mid-rib to the margin of the leaves, which form mosaic pattern symptoms. Such stripes are also seen on the leaf sheaths and young shoots. The infected clumps will be smaller in size with fewer tillers. Plants of all stages are susceptible to virus infection and the infection is systemic in nature and gradually spreads to all the tillers in the plant. (Josephrajkumar *et al.,* 2007)

Now a new viral disease quite distinct from Katte disease was noticed in various parts of Idukki district (Rajakkad, Nedumkandam, Vattappara, Vandanmedu and Anachal) of Kerala. Several plantations of the area was found to be affected by this disease. The distinguishing symptoms between Katte and the new virus disease is that, in Katte affected plants mosaic symptoms are seen running parallel between the veins while in new virus affected plants chlorotic streaks are seen along the veins and midrib (fig. 1 & 2). A study was carried out to identify the virus associated with the disease.

## MATERIALS AND METHODS

The disease is noticed in plantations with the variety "Njallani" (Green gold), the popular cardamom variety in highranges of Kerala. The disease is characterized by the appearance of continuous or discontinuous spindle shaped yellow or light green streaks seen along the veins and along the midrib which later coalesce together so that the veins turns into yellow or light green in colour (fig.3). Discontinuous spindle shaped streaks are also noticed along the petioles and tillers (fig. 4). In advanced stages, size of the leaves and yield of the infected plants were reduced. Some of the infected plants showed traveler's palm appearance as in the case of banana bract mosaic virus infection on banana (Bateson and Dale, 1995). In severe cases, suckering in the infected plant is also suppressed (fig. 5).

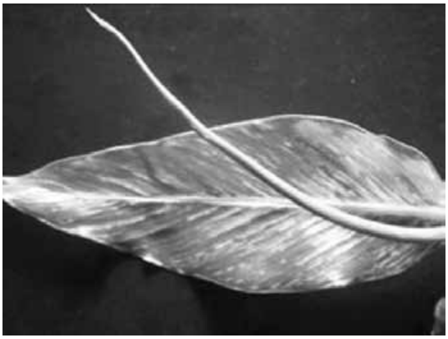

**Fig. 1**
**BBrMV infected leaf**

**Fig. 2**
**Katte infected leaf**

**Fig. 3**
**Symptoms on older leaves**

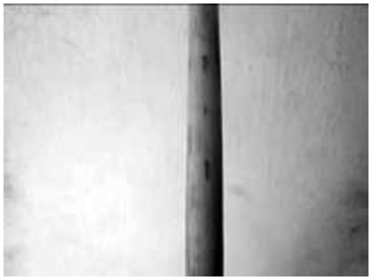

**Fig. 4**
**Chlorotic streaks on tiller**

**Fig. 5**
**Infected sucker**

The infected Njallani plants collected from farmers field at Anachal (near Chenkulam dam) of Idukki District were used in the study. The samples from both infected and healthy plants were analyzed through Direct Antigen Coating Enzyme Linked Immuno Sorbent Assay (DAC ELISA) in the virus indexing lab of College of Agriculture, Vellayani,Thiruvananthapuram.The procedure described by Huguenot *et al.,* (1992) was followed for the detection. Mature leaves, spindle leaf and panicle of the infected plants were used in the study. Plant extracts of the healthy Njallani plant was used as control. Infected and healthy plant tissues were triturated at 1:5 dilution in carbonate buffer(pH 9.6).The extracts were centrifuged at 5000 rpm for10 minutes at 4°C and the resulting supernatant (100$\mu$l) was added into two wells/ sample and incubated for 1 h at 37°.

Katte disease is the common virus disease of cardamom incited by a potyvirus called cardamom mosaic virus. Therefore the antiserum for the potyvirus was included in the study. Since the symptoms of the disease resemble viral infection of banana, antiserum to viruses infecting banana ie., banana bract mosaic virus (BBrMV), banana streak virus (BSV) and cucumber mosaic virus (CMV) were also included in the study. (Table 1). Antirabbit immunoglobulin alkaline phosphatase conjugate was used as secondary antibody. Absorption values at 405 nm were recorded using a microplate reader (ECIL, MS 5608), 1h after adding the p-nitro phenyl phosphate(0.5mg/litre of substrate buffer).

**Table 1**

**Elisa plate with details of sample**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | BSV | | | BBrMV | | | CMV | | | POTY | |
| B | | ML | ML | | ML | ML | | ML | ML | | ML | ML |
| C | | SL | SL | | SL | SL | | SL | SL | | SL | SL |
| D | | PAN | PAN | | PAN | PAN | | PAN | PAN | | PAN | PAN |
| E | | B | B | | B | B | | B | B | | B | B |
| F | | H | H | | H | H | | H | H | | H | H |
| G | | | | | | | | | | | | |
| H | | | | | | | | | | | | |

*Banana streak virus (BSV), Banana bract mosaic virus (BBrMV), Cucumber mosaic virus (CMV), Potyvirus ( POTY). ML-Infected mature leaf, SL-Infected spindle leaf, H- Healthy , B-Buffer , PAN- Infected Panicle*

## RESULTS AND DISCUSSION

ELISA readings were considered positive when the absorbance of the sample wells was at least three times greater than the mean absorbance reading of healthy control. The results of the experiment (Table 2) revealed that the BBrMV specific antiserum gave high reactivity towards the virus isolate. For infected mature leaf the absorbance value (0.08) was four times that of healthy (0.02) where as for spindle leaf it is six times that of healthy(ie., 0.12). Results also showed that the concentration of virus was higher in infected spindle leaves followed by mature leaves and it was least in the panicle of infected plant. None of the other virus antiserum gave good response to the infected plant extract. Based on this the etiology of the disease was confirmed as banana bract mosaic virus.

**Table 2**
**Absorbance value of samples read at 405 nm.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | | BSV | | | BBrMV | | | CMV | | | POTY | |
| B | | 0.040 | 0.026 | | 0.078 | 0.086 | | 0.088 | 0.060 | | 0.016 | 0.023 |
| C | | 0.015 | 0.012 | | 0.120 | 0.120 | | 0.031 | 0.029 | | -0.006 | 0.023 |
| D | | 0.003 | 0.001 | | 0.041 | 0.015 | | 0.038 | 0.034 | | -0.001 | -0.002 |
| E | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| F | | 0.011 | 0.093 | | 0.027 | 0.020 | | 0.053 | 0.079 | | 0.039 | 0.015 |
| G | | | | | | | | | | | | |
| H | | | | | | | | | | | | |

Since the spread of the disease is through infected suckers this seems to be an important emerging viral disease affecting cardamom cultivation in Kerala and other parts of India.

Many workers successfully detected BBrMV in infected banana by ELISA (Thomas *et al*., 1997, Geering *et al*., 1997 and Sundararaju *et al.,* 1999). According to Singh *et al*.,1996 BBrMV concentration was more in the floral part (bract) where as in cardamom it was more in tender leaves of the plant. The result of the study is in agreement with Siljo et al., 2012. They detected BBrMV in cardamom through leaf dip electron microscopy and RT-PCR. In their study sequencing and BLAST analysis of the RT-PCR product showed BBrMV as the closest virus. Sequence analysis of the coat protein gene showed an identity of more than 94% with BBrMV isolate while identity with other distinct potyvirus species was less than 60% indicating that the causal virus is a strain of BBrMV. The survey conducted by them in plantations of Karnataka and Kerala in 2009-2010 revealed the occurrence of the disease in both the states with an incidence ranging from 0-15%. But now it was found that the disease is present in various parts of the Idukki which is the district contributing about 80 % area and 91 % production of small cardamom in Kerala. Considering the nature of spread and potential damage, which can be caused in future, it is highly essential that adequate preventive measures may be taken up to control the disease.

## CONCLUSION

Unlike fungal and bacterial diseases, viral diseases are always systemic in nature and cannot be cured by using chemicals. Hence maximum care should be taken to minimize or check their spread. The following measures are recommended to manage the disease. Use of virus-free planting material is the primary requirement to check spread of the virus. Based on our study ELISA was found to be the efficient test for the early detection of the virus in the planting material. Regular inspection of the plantations and removal of infected plants and replanting with healthy plants are also needed. The removed plants may be buried deep in the soil. Insects such as aphids mainly banana aphid *(Pentolonia nigronervosa)* may act as vector for different viruses in cardamom. Therefore the cultivation of banana in cardamom plantation should be avoided. Whenever these vectors were noticed on plants ,suitable control measures are to be undertaken aginst the insects.

**ACKNOWLEDGEMENTS**

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# Evaluation of Temperature Tolerant Tropical Cauliflower Varieties in the Plains of Kollam District

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## INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*), an important cole crop belongs to the family Brassicaceae. Its centre of origin is Western Europe. Cauliflower was introduced in India in 1822 (Swarup and Chatterjee, 1972). Indian cauliflower has undergone fast diversification within a short period of two centuries of its introduction (Seshadri and Chatterjee, 1996). India developed tropical cauliflower varieties resistant to hot weather and high rainfall and the cultivation has spread to the non traditional areas in South India.

Among the winter vegetables in India, cauliflower is the most popular one. It is an important vegetable crop and is widely cultivated for its white tender head (curd). It is highly nutritious and contains good amount of Vitamin B and a fair amount of protein, minerals and vitamin A and C. Its consumption is increasing because of its anti cancerous properties. Cauliflower in general is very sensitive to its climatic requirements, particularly temperature. Hitherto, cultivation of cauliflower was possible in Kerala only in high ranges. But, now with the development of tropical hybrids it can grow well under high temperature conditions in plains of Kerala (Pradeepkumar and George, 2009). Cauliflower can be grown on a variety of soils from sandy loam to clayey loam, which are well-drained and rich in organic matter and nutrients. It comes up well in pains during October – March under Kerala conditions. The present study was conducted to find out the suitability of varieties for cultivation with limited use of pesticides in plains of Kollam district of Kerala.

## MATERIALS AND METHODS

Two cultivars of cauliflower, Pusa Meghana from IARI, New Delhi and Basant from private seeds were evaluated in the plains (comprising Southern mid lands and *malayoram* zones up to an altitude of 500m above MSL) of Kollam Dist. at different locations of Chadayamangalam,Vettikavala, kottarakkara and Anchal blocks during November 2009 to March 2010. Seedlings were raised and transplanted in the main field at a spacing of 60 x 45 cm. All cultivation practices were followed as per package of practices recommendation of Kerala Agricultural University. Pest management practices were done organically with only need based use of chemicals. Neem oil garlic emulsion, neem cake and pseudomonas were used during cultivation to reduce pest incidence. Cauliflower is harvested when curds remain compact smooth and attain proper size. The data on days to maturity, leaf number, and curd weight were subjected to statistical analysis (Panse and Sukhatme, 1984). Temperature experienced during the period of growth is given in Table 1.

**Table 1**
**Weather data for Kollam district in 2009-2010**

| Month | Rainfall (mm) | Temperature ($^0$C) | | Mean of Maximum and Minimum temperature |
|---|---|---|---|---|
| | | Maximum | Minimum | |
| September 09 | 382.9 | 31.3 | 23.0 | 27.15 |
| October 09 | 575.1 | 30.5 | 23.1 | 26.80 |
| November 09 | 306.2 | 31.7 | 22.3 | 27.00 |
| December 09 | 5.2 | 31.0 | 21.8 | 26.40 |
| January 10 | 11.5 | 34.7 | 21.8 | 28.25 |
| February 10 | 0.0 | 37.0 | 22.7 | 29.85 |
| March 10 | 59.1 | 37.90 | 23.8 | 30.85 |
| April 10 | 221.1 | 33.0 | 24.9 | 28.95 |

*Source: Farm Guide 2012*

## RESULTS AND DISCUSSION

The results (Table 2) showed that both tropical varieties yielded good quality curds and are suiTable for cultivation in the plains of Kollam. Good quality curd refers to firm and compact head of white to cream white curds surrounded by a crown of well-trimmed, turgid green leaves. Additional quality indices are size of curd and freedom from severe yellowing of curd due to sunlight exposure.

The yield was more for variety Basant. IARI variety Pusa Meghna yielded an average curd weight of 626 g where Basant yielded 862 g (Fig. 1). Days required for maturity was 37.80 days and 55.92 for Pusa Meghna and Basant respectively (Fig. 2). Leaf number was more in Pusa Meghna (17.70) as compared to Basant (14.00) (Fig. 3).

**Table 2**
**Performance of tropical Cauliflower varieties for curd weight, days to maturity and leaf number**

| Variety | Curd weight (g) | Days to maturity | Leaf number |
|---|---|---|---|
| Pusa Meghna | 626 | 37.8 | 17.70 |
| Basant | 892 | 55.92 | 14.00 |
| CD* | 22.93 | 2.52 | 1.10 |

**Significant at 5% level*

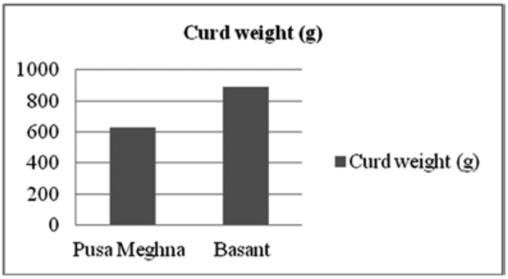


**Fig. 1**
**Varietal influence on curd weight**

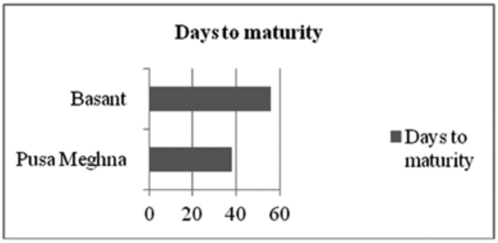


**Fig. 2**
**Varietal influence on days to maturity**

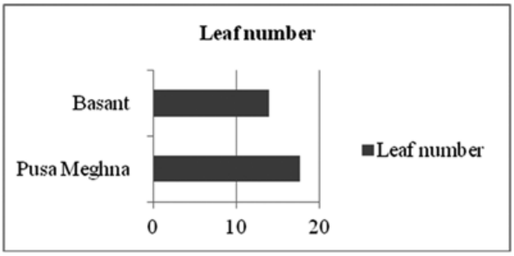


**Fig.3**
**Varietal influence on leaf number**

The variety Pusa Meghna was early type and required only 37.8 days for maturity. It shows that this early type can be cultivated with in short period where Basant was late and needed 56 days to reach maturity.

Weibe(1975), Booij (1987) and Nathoo *et al*. (1997) have reported that curd initiation in cauliflower is favoured by low temperature while at high temperature the crop develops vegetatively. This may be the reason that variety Pusa Meghna yielded comparatively less curd weight and more leaves. This early variety need more low temperature for curd formation and planting should be completed during late of October to first week of November. Basant showed the ability to withstand slightly higher temperature as compared to Pusa Meghna. Studies by Pradeepkumar *et al*.

(2002) revealed curd yield in cauliflower is greatly influenced by planting time and opined that early planting (first week of October) is ideal for realizing potential yields in cauliflower under high range situations of Kerala.

## CONCLUSION

The present investigation revealed that tropical cauliflower varieties can be successfully cultivated in the plains of Kollam by properly adjusting the planting time and variety. Pest incidence was less with proper preventive measures using organic pesticides like neem oil garlic emulsion, neem cake and use of bio control agent, pseudomonas. However, the crops raised in the plains are found to be relatively free from pest and disease incidence. In our market truck loads of cauliflower are coming from neighbouring States which are often drenched with toxic pesticides. Once the potential of the tropical hybrids are exploited in the State, we can produce safe anti cancerous nutritious vegetable commercially as well as in homesteads that will ensure food security and environmental safety.

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# Assessing the Vulnerability of Farmers to Water Stress: A Methodological Excercise

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## INTRODUCTION

Over the last century, there are empirical records of widespread increase in observed air and sea temperatures, sea-level rise, melting sea-ice and glaciers, and reduction of snow cover (Solomon *et al*., 2007). The developing economies are predicted to be more vulnerable to these changes because of the high dependence on primary sector and the low resource base. Watson *et al*. (1996) defined vulnerability as the extent to which a natural or social system is susceptible to climate change, and is a function of the magnitude of climate change, the sensitivity of the system to changes and the ability to adapt. Generally, vulnerability is seen as the outcome of a mixture of environmental, social, cultural, institutional and economic structures and processes related to poverty and health risk and not a phenomenon related to environmental risk only. Thus assessment of vulnerability status is very important when policy decisions involving resource allocation is to be made. This study attempts to develop an index to assess the level of vulnerability and its changing status, taking the case of water stress in agriculture in a relatively backward area in the state of Kerala. Through this, the most vulnerable regions and farmers are identified.

## MATERIALS AND METHODS

The study was conducted in Wayanad, the only one backward district of Kerala, traditionally known to be rich in water resources. The impact of climate change, as water stress in Wayanad, is predicted to be more severe, in the years to come (Sunil *et al.,* 2012). A multistage random sampling method was adopted for the study. The total sample size was 135. Data was gathered through the method of personal interview using pretested structured interview schedule during the months of January – March, 2012.

Balasubramanian *et al*. (2007) has developed an index based on the concept suggested by Olmos, (2001) and Brook *et al*. (2005). In this study, Vulnerability Index has been calculated based on the method developed by Balasubramanian *et al.* (2007) with appropriate changes. In this, the indicators of vulnerability were grouped under three major groups as social, economic and agronomic factors. Based on the range of values of the variables (indicators), as well as scientific consultation, the farmers were grouped into three groups, Severe (S), Moderate (M) and Low (L) as detailed in Table 1.

**Table 1**
**Criteria for Vulnerability Scale**

| Sl.No. | Indicator | Scales | | |
|---|---|---|---|---|
| | | **Severe (S)** | **Moderate (M)** | **Low (L)** |
| **I.** | **Social Factors (SoF)** | | | |
| 1. | Literacy | Up to 4 class | 5- 10 | >10 |
| 2. | Crop insurance | Not insured | Insured 1 – 2 crops | Insured >2 crops |
| 3. | Land ownership status | Leased | Leased + owned | Owned |
| **II.** | **Economic Factors (EF)** | | | |
| 1. | Sources of income | 1 | 2-3 | >3 |
| 2. | Total Household Income | ≤1 lakh | 1.01 – 2 lakh | > 2 lakh |
| 3. | Proportion of livestock income to total income | 0-31% | 31-61% | 61-90% |
| **III.** | **Agronomic Factors (AF)** | | | |
| 1. | Cropping intensity | ≤166 % | 167-273 % | >273% |
| 2. | Diversity index | >0.362 | 0.226-0.362 | <0.226 |
| 3. | Variety tolerance | Non-drought tolerant varieties | If any one – drought tolerant | Both drought tolerant |
| 4. | % of Gross Irrigated area to Gross Cropped Area | >45% | 24-45% | <24% |
| 5. | Water & Soil conservation practices | No Conservation practices | Mulching | Mulching + contour bunds/& rain pits |
| 6. | Sources of water | 1 | 2-3 | >3 |
| 7. | Ownership of source of water | External | External + owned | Owned |
| 8. | Percentage of deviation from normal water Table in Summer | No well | ≥50 % | <50 % |

Based on the frequency of farmers belonging to the three categories (Severe, Moderate and Low), for each indicator under any particular group (SoF, EF, AF) points were awarded. Thus, the points were estimated for SoF, EF and AF under three categories of sensitivity of vulnerability. This was considered as the Main Factor Effect, which gives the effect of each and every variable on vulnerability independently. The interaction effect helps to determine the effect of various combinations of variables (combined effect) on vulnerability. Based on the direct and interaction points obtained, the farmers were grouped under two categories, high and low vulnerability status.

## RESULTS AND DISCUSSION

Small farmers (holding size between 1-2 ha) constituted about 47 per cent with average holding size of 1.34 ha. 37 per cent were Marginal Farmers (MF) with average holding size of 0.57 ha and the remaining were large farmers (LF) with holding size of 3.39 ha. For nearly 14 per cent of the respondents, agriculture was the sole occupation whereas for 59 per cent agriculture was the main occupation and for the remaining 27 per cent, agriculture was a subsidiary occupation. Average household income was found to be Rs 2.14 lakh out of which 60 per cent is contributed by agriculture alone.

The results of the analysis as detailed in the methodology are furnished in Table 2 and 3. The total points were quantified as 688871, 332415 and 95657 respectively for severe, moderate and low vulnerable group. The point 688871 is the maximum value for the most vulnerable farmer in the sample and 95657 is the value for the least vulnerable. Thus, farmers were categorised into two groups as low and highly vulnerable, taking the middle point of 332415 (Table.4).

**Table 2**
**Basis for Main Effects Points (2010)**

| Sl.no | Criteria | Servere (S) | Moderate (M) | Less (L) |
|---|---|---|---|---|
| **I** | **Social Factors (SoF)** | | | |
| 1 | Literacy | | | |
| 2 | Crop insurance | 263 | 183 | 104 |
| 3 | Land ownership status | | | |
| **II** | **Economic Factors (EF)** | | | |
| 1 | Sources of income | | | |
| 2 | Total Household Income | 247 | 204 | 160 |
| 3 | Proportion of livestock income to total income | | | |
| **III** | **Agronomic Factors (AF)** | | | |
| 1 | Cropping Intensity | | | |
| 2 | Diversity Index | | | |
| 3 | Variety Tolerance | | | |
| 4 | % of Gross Irrigated area to Gross Cropped Area | | | |
| 5 | Water & Soil conservation practices | 476 | 324 | 172 |
| 6 | Sources of water | | | |
| 7 | Ownership of source of water | | | |
| 8. | Percentage of deviation from normal water availability in Summer | | | |
| | Total Direct Points (Main Effects) | 5339 | 3753 | 2167 |
| | Total Interaction Points | 683532 | 328662 | 93490 |
| | **Grand Total** | **688871** | **332415** | **95657** |

Farmers often try to develop own adaptive strategies to address the stress, within their socio-economic and climatic environment. Often these adaptive strategies are capable of minimising the shock or even tiding over the undesirable outcome. We tried to assess this aspect, through quantifying the level of vulnerability at two points of time 2005 and 2010 based on farmer responses. However, this index does not include the social and economic factors due to paucity of reliable data. Besides, social factor 'crop insurance' became popular in the district recently only (after 2006). Hence a Vulnerability Index for these years was constructed by taking into consideration of the agronomic factors alone using the methodology previously explained.

**Table 3**
**Basis for Interaction Points (2010)**

| Interaction in between | SoF& SoF | SoF& EF | SoF& AF | EF& SoF | EF& EF | EF& AF | AF& SoF | AF& EF | AF& AF |
|---|---|---|---|---|---|---|---|---|---|
| **SXS** | 700 | 1880 | 3653 | 1880 | 933 | 5120 | 3653 | 5120 | 3907 |
| **SXM** | 227 | 1502 | 2809 | 1502 | 849 | 3551 | 2809 | 3551 | 2729 |
| **SXL** | 33 | 482 | 1453 | 482 | 140 | 1384 | 1453 | 1384 | 2093 |
| **MXS** | 227 | 1502 | 2809 | 1502 | 849 | 3551 | 2809 | 3551 | 2729 |
| **MXM** | 68 | 861 | 2335 | 861 | 385 | 2767 | 2335 | 2767 | 1170 |
| **MXL** | 40 | 360 | 1227 | 360 | 67 | 843 | 1227 | 843 | 1495 |
| **LXS** | 33 | 482 | 1453 | 482 | 140 | 1384 | 1453 | 1384 | 2093 |
| **LXM** | 40 | 360 | 1227 | 360 | 67 | 843 | 1227 | 843 | 1495 |
| **LXL** | 33 | 95 | 656 | 95 | 9 | 245 | 656 | 245 | 862 |

**Table 4**
**Vulnerability of Respondent Farmers to Water Stress (2010)**

| Particulars | MF | SF | LF | Total |
|---|---|---|---|---|
| High Vulnerability | 37 (75.51) | 26 (41.27) | 8 (34.78) | 71 (52.59) |
| Low Vulnerability | 12 (24.49) | 37 (58.73) | 15 (65.22) | 64 (47.41) |
| Total | 49 (100) | 63 (100) | 23 (100) | 135 (100) |

*Note: figures in bracket show the percentage to total.*

The results show more than half of the respondents as highly vulnerable to water scarcity. An inverse relationship is observed between the land holding size and vulnerability, three- fourth of the MF were vulnerable while most of the SF and LF (41.27 % and 34.78 % respectively) belonged to the other group. Land holding size taken as a proxy for economic status, thus, confirms the capability of resource rich farmers to manage risk. Similarly, total household income, which may be from farm or non-farm activities have a direct bearing on the vulnerability.

Though vulnerability of the farmer cannot be attributed to a single factor, some observations reflect interesting associations. Generally livestock rearing is considered as a time tested risk management tool, among SF/MF farmers. They, consider subsidiary livestock rearing as a complimentary and supporting enterprise to farming. The influence of this indicator on the level of vulnerability was very strong. Nearly 80 per cent of farmers were realising only less than 30 per cent of their household income from livestock farming. Most of the LF were not rearing livestock.

People often prefer to ensure own sources of water, especially when there is an indication of supply shortage. Moreover, they try to ensure access to more than a single source. It was noticed that about two-third of the respondents were having only one source of water which make them highly vulnerable. Most of the LF (60.87 %) were found to have more than one source of water, whereas about 70 per cent of MF and SF had only a single source. This factor thus acts a strong point in deciding the level of vulnerability.

The factors, total household income and adoption of soil and water conservation practices were also found to be highly relevant. About 37 per cent were not adopting any of the conservation practices. More than half of MF were under this category while it was only a quarter in SF and LF. Adoption of conservation practices has a direct link with moisture conservation and resultant farm income. Thus, share of livestock income, total household income, number of sources of water and soil conservation measures are the major factors that influence the vulnerability status.

A specific trend in vulnerability level of farmers could be observed over the years. It is clear that the chances of the farmer becoming vulnerable to water scarcity increased over time. Increase in proportionate area under irrigation and decline in cropping intensity were found as the major factors for this. The practise of shifting to irrigated farming is reported as the immediate short term response of the farmers to erratic rainfall and reduced soil moisture. However, this practice in the long run makes the framer more vulnerable. Wayanad agriculture shows a gradual shift towards crops like rubber, arecanut, banana and turmeric, which during this period have shown an increase. These crops limit the scope of crop rotation. Moreover, most often paddy lands (which act as water conservation bodies) are converted for the cultivation of these crops. All sample respondents were in the highly vulnerable category in 2010 irrespective of their geographical location or land holding size, which was only 48 per cent in 2005 (Table 5).

**Table: 5**
**Change in Vulnerability Status during 2005 and 2010**

| **Particulars** | **2005** | | | | **2010** | | | |
|---|---|---|---|---|---|---|---|---|
| | **MF** | **SF** | **LF** | **Total** | **MF** | **SF** | **LF** | **Total** |
| High Vulnerability | 32 (65.31) | 22 (34.92) | 11 (47.83) | 65 (48.15) | 49 (100.00) | 63 (100.00) | 23 (100.00) | 135 (100.00) |
| Low Vulnerability | 17 (34.69) | 41 (65.08) | 12 (52.17) | 70 (51.85) | 0 (0.00) | 0 (0.00) | 0 (0.00) | 0 (0.00) |
| Total | 49 (100.00) | 63 (100.00) | 23 (100.00) | 135 (100.00) | 49 (100.00) | 63 (100.00) | 23 (100.00) | 135 (100.00) |

This is mainly due to the increased dependence on irrigation coupled with decreased cropping intensity. The decline in cropping intensity was due to the shift towards commercial monoculture farming, supported by irrigation. This naturally leads to higher level of vulnerability. The number of sources of water has increased over the years and more farmers were focusing on water conservation methods. However, the present level of conservation efforts is not enough to compensate the damage.

## CONCLUSION

Over the years vulnerability of the farmers are increasing. Majority of the marginal farmers were found to be more vulnerable. Increased dependence on irrigation for farming along with the decreased cropping intensity might have resulted in increased vulnerability. So special packages should be developed for resource poor farmers (Marginal farmers) and the rich farmers should be supported with extension and technology support. This will help in improving their adaptive capacity and thus vulnerability can be reduced.

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# Valuation of Wetlands and Ecosystems: A Concept Note

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## INTRODUCTION

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres (MEA, 2005). Wetlands are very important ecosystems, providing human societies with essential and highly valuable life supporting functions. They directly support millions of people and provide goods and services to the world outside the wet land also.

An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems. A well-defined ecosystem has strong interactions among its components and weak interactions across its boundaries (MEA, 2003). Wetlands provide many services and commodities to humanity(Prasad, *et al.*, 2002., Morris and Camino, 2011 ). Ecosystem services are the benefits people obtain from ecosystems (Zhao *et al.*, 2004). These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious,and other nonmaterial benefits (Turner *et al.*, 2010).

## ECONOMIC VALUE OF WETLAND SERVICES

The economic value of wetland, as an important environmental good, is considered within framework of Total Economic Value (TEV). The TEV is defined as the sum of the values of all service flows that the natural capital generates both now and in the future appropriately discounted. It consists of use value and non use value (Turpie,2010). The concept of TEV has become a widely used framework for assessing the utilitarian value of ecosystems. This framework typically disaggregates

TEV into two categories: use values and non-use values. Use values are the benefits which people derive from the actual use of the environmental goods or services (for example, the benefits from burning firewood, using herbs for medicinal purposes, food items like fish). Use values are composed of three elements: direct use, indirect use, and option values. Direct use value is also known as extractive, consumptive or structural use value, and mainly derives from goods which can be extracted, consumed or enjoyed directly. Indirect use value is also known as non extractive use value, or functional value, and mainly derives from the services the environment provides. Option value is the value attached to maintaining the option to take advantage of something‘s use value at a later date (Brander *et al.*, 2006).

Non use values are the benefits some individuals might derive from wetland ecosystems without even benefited either directly or indirectly from the wetland services and components (Barbier,1989). It is derived by individuals from the benefits the environment may provide and it do not involve using it in any way, whether directly or indirectly. The non use value consists of bequest value and existence value. The existence value is the value that people derive from the knowledge that something exists, even if they never plan to use it. Bequest value, finally, is the value derived from the desire to pass on values to future generations, that is, our children and grandchildren (Groot *et al.*, 2006).

**VALUATION OF ECOSYSTEM SERVICES**

The economic value of any good or service is generally measured in terms of what we are willing to pay for the commodity, less what it costs to supply it. Where an environmental resource simply exists and provides us with products and services at no cost, then it is our Willingness to Pay (WTP) alone which describes the value of the resource in providing such commodities, whether or not we actually make any payment (Barbier et al.,1997). The basic aim of valuation is to determine the peoples preferences ie. how much they are willing to pay for and how much better or worse off they would consider themselves to be as a result of changes in supply of different goods and services (Emerton ,1998). The sustainable, multi-functional use of an ecosystem is usually not only ecologically more sound, but also economically more beneficial, both to local communities and to society as a whole (Balmford *et al.*, 2002).

**Monetary or Financial Valuation Methods**

Monetary valuation is broadly classified into, revealed preference method and stated preference method (Anon., 2007).

***Revealed Preference Technique***

In the revealed preference methods the value of an environmental amenity is estimated indirectly from the purchase price of a commodity whose market value at least partly depends upon the quality of the environmental amenity in question(Verma,2001). The methods are :

1. Market price
2. Cost based approaches
3. Travel cost method
4. Hedonic pricing method

**Market prices:** It is a simple accounting procedure to value environmental goods and services which are traded in markets(Turner *et al*., 2010). Market prices are used to value the costs/benefits associated with changes in quality and quantity of environmental goods that are traded in perfectly functioning markets. Market price is the most widespread method used for evaluating marketed ecosystem services (Korsgaard and Schou,2010). It is based on the observable data from actual choices in markets or other negotiated exchanges (Birol et al., 2006). Market valuation approach can be employed to estimate the value of direct use benefits.

**Cost Based approaches:**

(a) **Opportunity Cost Approach:** Using opportunity cost approach, the value of non-priced goods and services can be estimated by considering foregone benefits of using the same resource for other alternative objectives. It is a very useful approach to estimate the value of non-marketed goods. This is, because the benefits of certain uses such as preservation, protection of habitats, cultural or historical sites, cannot be directly estimated (Binilkumar, 2009).

(b) **Cost of avoidance or Preventive Cost:** Cost of avoidance (COA) or Preventive Cost approach takes into account the expenditure incurred by individuals to avoid illness. For example to avoid the incidence of water borne diseases people resort to water treatment devises like filters, to prevent themselves from water borne diseases Many a times it is observed that the cost of averting illness is much less than the expenses incurred on curing illness and thus this expenditure is preferred by consumers over the cost of curing the illness (Verma, 2001).

(c) **Replacement cost or Substitution Cost:** Wetland services could be replaced with human made systems; an example is natural waste treatment by marshes which can be (partly) replaced with costly artificial treatment systems.(Groot *et al*.,2002., Farber *et al*., 2002). This approach uses the cost of available substitutes for the particular non-priced service or good to estimate the value of latter (Binilkumar, 2009).

(d) **Mitigation or restoration cost:** It refers to the cost of mitigating the effects caused by the loss of ecosystem services or the cost of getting those services restored (Korsgaard and Schou, 2010). Eg: Cost of construction of artificial flood barrier to prevent flood in the absence of wetland service.

(e) **Cost-of-illness (COI) method:** Another approach is the cost-of-illness (COI) method (Birol,2006) in which the benefits of pollution reduction are measured by estimating the possible savings in direct out-of-pocket expenses resulting from illness (e.g medicine, doctor and hospital bills) and opportunity costs. Eg: Lost earnings associated with the sickness.

**Travel Cost Method:** The Travel Cost Method (TCM) is a method which is widely used to estimate the recreational value of natural resources. In TCM approach, the individual incurs two types of expenses, cash expenditure and value of time. Cash expenditure is required to pay fuels, ticket fee, accommodation, and to buy foods. Valuation of time used to enjoy sights and adore the tourism object, starts from the places of stay until back to origin place before going to tourism object. The time used in this model is an opportunity cost for the individual being unable to perform other activities while the individual decides to visit a tourism attraction. According to Bulov and Lundgren (2007) the individual trip generating function for the resource under study can be derived as expressing no of visits made by the visitor i to the site j as a function of travel cost incurred by individual i when visiting site j, time cost incurred by individual i when visiting site j, other perceived qualities for the individual i and of the characteristics of available sites. The trip generating function can now be subjected to regression analysis. The recreation value of the wetland can be estimated as the consumer surplus of the tourists.

Consumer surplus $=1/\beta$

Where $\beta$ is the estimated coefficient of travel cost ( Anoop *et al.*, 2008).The consumer surplus has to be multiplied by the total amount of visitors to the site during the specific period. The total aggregated consumer surplus will be used as a measurement of recreational value.

**Hedonic pricing method:** The word hedonic means pertaining to pleasure; the hedonic pricing method estimates the pleasure or utility associated with an improved environment. The value of a piece of land is related to the streams of benefits to be derived from the land. Home prices are likely to embed values of amenities supplied at or near the home. This corresponds to hedonic pricing (Nauges *et al*., 2009 ). The hedonic pricing method is based on the premise that the observed market price of a marketed good is a function of the prices of the numerous attributes of that good. For example, the incremental value of owning a house with a scenic view is the price of a house with a scenic view minus the price of a house without a scenic view, provided all other attributes of the two houses are similar. It is well known that differences in residential property values can arise from any sources, such as the amount and quality of accommodation available, the accessibility of the central business area, the level and quality of taxes that have to be paid on the property, and the environmental characteristics of the neighbourhood, as measured by the levels of air pollution, traffic and aircraft noise, and access to parks and water facilities. In order to pick up the effects of any of these variables on the value of a property, they all have to be included in the analysis. Hence such studies usually involve a number of property variables, a number of accessibility variable and finally the environmental variables of interest. The property prices can be examined to detect any premium paid for location with the desired amenity. The premium can be taken to reflect the value of the amenity. The hedonic price function is typically estimated using regression analysis.

***Stated Preference Method***

Stated preference methods (SPM), have been developed to solve the problem of valuing those environmental resources that are not traded in any market, including surrogate ones. In addition to their ability to estimate use values of any environmental good, the most important feature of these survey based methods is that they can estimate the non use values, enabling estimation of each component of TEV. Since many of the outputs, functions and services that water resources generate are not traded in the markets, SPM can be used to determine the value of their economic benefits (Birol 2006). An important tool under this method is Contingent Valuation Technique.

**Contingent Valuation Technique (C V M)**

The CVM method is a widely used nonmarket valuation method especially in the areas of environmental cost–benefit analysis and environmental impact assessment. Its application in environmental economics includes estimation of non-use and nonmarket use values. In recent years, this method is commonly used in developing countries to elicit the individual's preferences (Venkatachalam,2004). The purpose of the contingent valuation method (CVM) is to elicit individuals' preferences, in monetary terms, for changes in the quantity or quality of nonmarket environmental resources. Unlike revealed preference methods, CVM is also able to measure the option use values. With CVM, valuation is dependent or contingent upon a hypothetical situation or scenario whereby a sample of the population is interviewed and individuals are asked to state their maximum WTP or minimum willingness to accept (WTA) compensation for an increase, or decrease, in the level of environmental quantity or quality. To conduct a CVM, special attention needs to be paid to the design and implementation of the survey. Focus groups, consultations with relevant experts, and retesting of the survey are important pre-requisites. Decisions need to be taken regarding how to conduct the interviews (in-person, via mail or via telephone surveys); what the most appropriate payment bid vehicle is (e.g., an increase in annual taxes, a single-one-off payment, a contribution to a conservation fund etc (Champ *et al.*, 2002) as well as the WTP elicitation format. Ultimately, the mean WTP bids that have been obtained from the sample can then be extrapolated across the population to obtain the aggregate WTP or value of the environmental resource.

**ECONOMIC VALUATION OF WETLANDS IN KERALA**

In Kerala only a few valuation studies had been conducted on wetland ecosystems. Two major valuation studies are the following.

**Economic Valuation of Use Benefits of Ashtamudi Estuary**

The study was conducted in Ashtamudi estuary in Kollam district of Kerala (Anoop *et a*l.,2002). Market valuation approach was employed to estimate the value of the direct use values. In case of recreation, the standard travel cost model was employed. The value of Ashtamudi lake was estimated to be 77.16 million Rs per annum. The results of the study have clearly shown that fishery is the major direct use value of the Ashtamudi estuary. Hence they recommended that fisheries should be the focal point in the attempt for the sustainable management of the estuary since the majority of local community earns their livelihood from fishing. Based on the valuation studies they have concluded that, the concentrated efforts with active participation of stake holders to conserve the fish stock are necessary for sustainable extraction of fish. The value of coconut husk retting is low. There is ample scope for expansion of inland navigation. The high net present value (Rs. 1923.57 million) of use benefits of the estuary throws light on need for initiating sustainable management practices for the conservation of the estuary with active participation of local community.

**Economic Valuation of Wetland Attributes: A Case Study of Kol Wetlands in Kerala**

A study was conducted at Kol wetlands to assess the economic value (Binilkumar, 2010 ). CVM was adopted to asses the willingness to pay. The results revealed that almost all of the respondent households expressed their approval and willingness to participate for the better conservation of the wetland. Ninety seven per cent of the respondents of CVM study were willing to contribute a part of their income annually for the better conservation of the wetland. This point, invariably, indicates that the stakeholders assign high value for the wetland resource. Gross annual WTP was estimated to be INR 13,365,400 for the all the stakeholders in Thrissur Municipal Corporation put together. The amount, indicated high perceived monetary value placed on the improved conservation of Kol wetland by the urban households.

**ONGOING RESEARCH ON ECOSYSTEM VALUATION OF VELLAYANI LAKE**

Vellayani lake lying on the south east of the Thiruvananthapuram city is one of the three unique fresh water lakes of Kerala. This lake lying in Kalliyoor and Venganoor Panchayats has got an important role in socio economic conditions of people. Over the years because of indiscriminate and unsustainable use, there had been reduction in the area of the lake and the quality of water in the lake had deteriorated considerably which adversely affected the life of people and caused ecological imbalance. The knowledge on benefits provided by the ecosystem and its value are very important to adopt appropriate policies for a wise use of the wetland. It is in this context a study is being proposed to evaluate the benefits of Vellayani wetland ecosystem.

The study will be based on both primary and secondary data. The secondary data pertaining to the study will be collected from various government and nongovernmental agencies. The primary data will be collected based on survey, Participatory Rural Appraisal (PRA), focus group discussions etc. For conducting the survey pre tested structured schedules will be prepared separately for each class of stakeholders. A combination of valuation methods will be used for estimate the TEV. Direct Valuation based on existing market prices will be used to value the use values like fishing, drinking water etc. Stake holders will be selected from the immediate periphery of the lake for estimating the direct valuation. Non use values will be estimated using CVM, Hedonic Pricing and TCM. Various statistical tools like regression analysis, principal component analysis will be attempted for statistical analysis.

It is expected that the outcome of the research will be useful for planners and policy makers to develop a socially acceptable, environmentally sound and economically feasible strategy for interventions in wetland management.

## CONCLUSION

The wetlands constitute a resource of great economic, cultural scientific and recreational services, the loss of which would be irreparable. It provides livelihood to the residents in the areas, in the forms of agricultural produce, fish, fuel, fibre, fodder, and a host of other day-to-day necessities. The conversion of agricultural wetlands for change of crops as well as developmental purposes is a major concern in Kerala now. Economic evaluation plays a major role in convincing the people as well as decision makers. The true value of wetlands and the services they provide to people should be recognized and it should be communicated to decision makers and general public. There are not many researches on economic value of wetlands and perceptions of stake holders in India and especially in Kerala. So there is a need for studies on this line to reveal the unique value of wetland ecosystems. Such research information will assist the policy makers to come up with more sustainable plans for the conservation with a multi-stakeholder approach.

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# Agricultural Land use Pattern and the Flowering Plant Diversity of Cardamom Hill Reserve (CHR), Southern Western Ghats, Kerala, India

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## INTRODUCTION

High Ranges of Kerala State, with deeply dissected valleys and camel-hump peaks, is one of the noTable parts of the southern Western Ghats. Large scale encroachments during last two centuries for raising commercial plantations resulted the division of this biodiversity-rich area into three distinct regions: (1) Protected Areas (PAs), (2) Tea plantations and (3) areas of extensive cardamom cultivation. In addition to the five Protected Areas, there are 35 tea estates spread over Munnar and Peermade of the High Ranges (Anonymous, 1970). The rest of the High Ranges, were opened since early 1800s to establish cardamom cultivation. This area, mostly of evergreen forests, is known as Cardamom Hill Reserve (CHR). It was reserved in 1897 as Government Reserved Forest and had an area of 870 $km^2$ and comes under Udumbanchola Panchayat (old) of Idukki District. From early 1800s, the area has undergone severe deforestation due to extensive planting of cash crops especially, cardamom. Originally ethnic Tamilians of Bodinaikannoor, Cumbum and Cattabomman areas of Tamil Nadu were allowed to cultivate cardamom in High Ranges with a state monopoly in the trade of cardamom. The very liberalized land registration of Government land (Revenue Reserved Forest) till the implementation of Cardamom Rules in 1905 and leasing out of forest for cardamom cultivation to everyone resulted in the rapid expansion of cardamom estates in the CHR, followed by severe and indiscriminate forest destruction. It also changed the biodiversity of cardamom belt of the High Ranges. The dual control of this Cardamom Hill Reserve i.e., land controlled by the Revenue Department and trees by the Forest Department of Kerala (Anonymous, 1978) State became an encouraging factor to cultivate other crops in this area and to fell trees for starting new crop cultivation. During the post independence period, new immigrants mostly resorted to encroachment into forests and conversion of cardamom forests to coffee, pepper, rubber and even annual crops (Anonymous, 1984). These new crops require less or no tree shade and some of them are even monoculture plantations. Now there are only 30,000 ha of land under cardamom cultivation (Anonymous, 1998) whereas, in 1950s, it was above 86000 ha. At present, the forested areas in CHR are confined mostly to Mathikettan Chola that possess rich biodiversity. Mathikettan Chola is in fact an island of original forest in the CHR, which represents the original flora that existed in the entire CHR before the 'Plantation era'. According to Champion and Seth (1986) and Chandrasekharan (1962), the vegetation of CHR is classified as South Indian Subtropical Hill Evergreen Forest. The forest is interspersed with rocky openings and sheer cuttings (Bassett, 1964).

**REVIEW OF EARLIER WORKS**

A systematic work added with phytogeographical information was started in India when Hooker and Thomson (1855) divided the flora of India into 17 botanical provinces and started the preparation of Flora of British India, which was completed within a span of 25 years (1872-1897,1904). Around the same period, Sir George King started the Botanic Survey of India in 1890. Subsequent floras are Flora of the Presidency of Bombay (Cooke, 1901-1908) and Flora of the Presidency of Madras (Gamble and Fischer, 1915-1936). Other noTable works on the flora of South India are Flowering Plants of Travancore (Rama Rao, 1914), Flora of Anamalais (Fischer, 1921), Flora of South Indian Hill Stations (Fyson, 1932). Other noted works on South Indian flora are by Aiyar (1932), Champion (1935), Bor (1938), Meher Homji (1967, 1969, 1978), Blasco (1970), Joseph (1977, 1982), Gupta (1962) and Pascal (1988). Karthikeyan *et al*. (1983) compiled the names of new taxa and new records published since the publication of the Flora of the Presidency of Madras. The Botanical Survey of India launched a scheme to prepare the District floras of various botanically rich districts and several district floras have been worked out.

Unlike other districts of Kerala, the flora of Idukki has not yet been completely explored and the available scattered and fragmentary floristic studies of the Idukki district are not enough to elucidate the actual picture of the floristic structure of this highly undulating area. The first botanical collection from the district was made by Beddome in 1882 from Peermade and adjacent Anamudi, which were part of the erstwhile princely state of Travancore (Iyuppu, 1955). Barnes (1939), Beddome (1883), Bourdillon (1908) and Rao (1914) made collections in the late 19$^{th}$ century and early 20$^{th}$ century and their collections were cited by Hooker (1872-1897) and Gamble (1915-1936). Barnes (1939) had studied the Gesneriaceae of High Ranges. Rama Rao (1914) cited various places of this area. Iyppu (1955) and Chandrasekharan (1962) have studied the forest types of Idukki district. Sebastine and Vivekananthan (1967) and Shetty and Vivekananthan (1971) published brief accounts on the flora of Anamudi and Devikulam. Vivekananthan (1978) studied the vegetation of Periyar Tiger Reserve and also enumerated 12 rare and threatened plants of the area. Studies by Shetty and Vivekananthan (1968, 1969, 1970, 1972, 1973, 1975, 1991), Sharma *et al.* (1974,1978), Nayar (1974), Sreekumar *et al.* (1983a, 1983b), Nair and Sreekumar (1985), and Pandurangan and Nair (1993, 1995) resulted in the discovery of several new taxa from the district. Shetty and Vivekananthan (1972) reported the occurrence of some rare and little known taxa. Nagendran *et al.* (1976-77) and Bhaskar and Razi (1978, 1981) made collections and studied Podostemaceae and Balsaminaceae respectively. Mohanan *et al.* (1984) reported some rare and interesting plants from the Idukki Hydro-electric Project area. Balasubramanyam *et al.* (1989) in their ecological studies of the proposed Pooyamkutty Hydro-electric Project Area listed out some rare and interesting plants.

Though the protected areas of the High Ranges were studied for the floristic wealth and ecological aspects by various workers (Jomy, 2000; Sasidharan, 1996, 2000; Karunakaran, 1998; Biju, 2004; Shetty and Vivekananthan 1968, 1969, 1970, 1973, 1975), forested and cultivated but potential areas outside the Protected Areas were left unexplored. The ecological significance of the High Ranges were studied by various workers like Chattopadhyay (1985), Gadgil & Meher-Homji (1982 &1990) Karunakaran (1986), Mani (1974), Menon (1982), Sathis (1991 &1994)and Subhash (1997). . The unique floristic components were partly exposed by the works like Nair & Daniel (1986), Nayar (1996 &1997), Pascal (1988) and Ramesh and Pascal (1991).

Ward and Corner (1827) studied the starting of the depletion of vegetation especially of tree species in the High Ranges of Kerala. Munro, the then Conservator of Forests (1837) hinted the danger of throwing virgin forests by the Travancore Government to anybody who wishes to cut trees. The timber trade of High Ranges controlled by the Travancore Government was reported by Bourdillon (1893). The method of early cardamom cultivation and its Government controlled trade was beautifully reported by Aiya (1906). He added the rise of coffee plantations also in the High Ranges in his report. Playne (1914 -1915) reported the establishment of tea estates under the ownerships of Europeans in the High Ranges. Lovatt (1972) commended the Travancore Government's attitude towards the opening of evergreen forests in the High Ranges for plantation crops, as it was a source of revenue to the government. Early settlement and associated issues were studied by Pillai (1940). Chandrasekharan (1973) has reported the pattern of short term lease (kutthakapattam) for cardamom cultivation observed in the High Ranges under the Grow More Food Programme. Karunakaran (1986b), Gopalan (1973) and Nayar (1986) studied the problems associated with the encroachment and subsequent eviction taken place in CHR during 1958-1970. Sivanandan *et al*, 1986 studied the new encroachment and their impacts in the floristic aspect of the CHR. It was Marcus Moench (1991) who explained the involvement of politics and government's policies in the deforestation process of CHR.

## RESULTS AND DISCUSSION

### Vegetation and Floristic Richness of the CHR

Many exploratory studies were conducted to various places of the Cardamom Hill Reserve *Koomban Mala, Kailasapparametttu, Suppukandam Para, Neyyandi Mala, Chundelimettu, Anakkarametttu, Soolapparametttu, Chathurangapparametttu, Vellakkaltheri, Koodampara, Kathakalimettu, Senapathi, Matthappu, Pallikkunnu, Rajappara, Ramackalmedu, Mankuthimedu, Meesappuli Mala, Koluckan Mala,* *Lockheart Hill* and *Mathikettan Chola* were recorded as floristically rich. These so called 'Hot Spots' are in fact the clear representations of the flora and vegetation of the entire CHR. The vegetation and floristic composition of these areas share the plant community of the other Protected Areas of the High Ranges. All of them are grassy hilltops with sheer rocky cuttings and primary forest is not found in any of the above said areas except Mathikettan Chola. Tracts of grasslands with scattered trees and small thickets of *Strobilanthus* and *Psychotria* were the vegetation in most of the areas. They were visited for floristic studies but Mathikettan Chola was subjected to detailed floristic exploration due to its immense biodiversity richness.

The vegetation of Mathikettan Chola is of Evergreen Shola-grassland association. This is the largest forested area in the CHR. About 740 species of flowering plants were collected and identified from this small but beautiful area. Of these, 346 are southern Western Ghats Endemics, 48 species fall under various threat categories. There is a good representation of Orchids (40 species) with 20 endemics. Twenty species of Balsams (Genus *Impatiens*) were recorded of 16 species are endemic to southern Western Ghats. Mankuthi medu, another area in the CHR, is noTable for a good population of the "possibly extinct" epiphytic orchid *Taeniophyllum scaberulum*. Ramackalmedu, a famous tourist place at the state border of Kerala and Tamil Nadu, is noteworthy for the presence of *Utleria salicifolia*, one of the few endemic monotypic genera in South India.

The present study was extended to other areas including cardamom plantations in the High Ranges though not in a systematic way. However, during the short-term effort, 1044 species of flowering plants were identified in the Cardamom Hill Reserve. These include 395 species endemic to the southern Western Ghats and 38 species that are rare or facing the threat of extinction.

The dominant tree species of the CHR are *Palaquium ellipticum, Mesua ferrea, Prunus ceylanica, Myristica beddomei, Calophyllum polyanthum, Syzygium hemisphericum, S. ceylanicum, S. gardnerii, S. cumini, Bhesa indica, Acrocarpus fraxinifolius, Cullenia exarillata, Toona ciliata, Elaeocarpus oblongus, Gordonia obtusa, Persia macrantha, Dysoxylum binectariferum, D. beddomei, Vateria indica, Canarium strictum, Bombax ceiba, Canthium umbellatum, Cryptocareya beddomei, C. bourdillonii, Actinodaphne bourdillonii, A. malabarica, Litsea insegnis, L. oleoides, L. coriacea, L. floribunda, Hydnocarpus alpina, Garcinea cambogea, Ligustrum perrottetii, Vernonia arborea, Chionanthus mala-elengi*, *Celtis cinnamomea, Mallotus tetracoccus, M. phillippinensis,* etc. The top canopy is about 40-60 m high and the emergent trees may reach higher. In many areas there are trees of exotic nature like *Macaranga peltata, Grevellia robusta, Erythrina stricta, Erythrina sumumbrans,* etc.

The shrub layer is composed of *Debregeasia longifolia*, *Psychotria* spp. *Strobilanthus* spp, *Maesa indica, Elatostemma lineolatum, Allopohyllus cobbe, Chasalia ophioxyloides, Pavetta brevifolia, Ixora* spp, *Pogostemon benghalensis, Rauvolfia densiflora, Sarcococca trinervia, Solanum* spp., *Lantana camara* and *Clerodendron viscosum* were seen to be widely distributed.

The riversides and stream banks have Balsams *like Impatiens maculata, I. verticillata* and *I. cordata.* Though there are more than 60 species of Impatiens in the High Ranges, only a few are present in the cardamom plantations. The decrease in shade by intensive cultivation of cardamom may be the reason for their considerable absence here. Cardamom plantations are usually maintained with trees only and in many plantations the canopy cover is only 50-70 %. Shrubby species are very meager or absent. Exotic weeds like *Ageratum conyzoides, Bidens pilosa, Seigesbeckia orientalis, Eleutheranthera rederalis,* etc dominate the ground layer. Epiphytic flora is also much reduced due to the thinning of the trees which considerably decrease the moisture content in the atmosphere. Many exotic fast growing trees are also planted in the Cardamom plantations. These trees are not suiTable for the growth of epiphytic species.

**Threats to the Biodiversity of CHR**

During 1950s to early 1960s the new immigrants from central Travancore, came to The High Ranges with the cultivation of other crops like rice, pepper, rubber, tapioca, coconut, areca nut, etc. as well as cardamom. These new crops and new methods of cultivation changed the vegetation of the Cardamom Hill Reserve. The cropping pattern adopted by the new immigrants, were not suiTable to the evergreen forest ecosystem of the CHR. The dual control of the CHR, ie, land by the Revenue Department, and trees by Forest Department, in effect paved way for massive tree felling in the leased or encroached areas. The Kuthakapattam was for the cultivation of Cardamom only and by this the forests trees were protected well by the cultivators because cardamom needs this evergreen habitat. But large scale conversion of cardamom estates to the cultivation of other crops by new immigrants and the thinning of trees in the cardamom estates for better yield degraded or even deforested the CHR considerably. Presently there are very few areas like Mathikettan Chola, which became an issue in recent times, where original forests of CHR can be found. These areas have very high plant diversity. It is known that more than 10% of the world biodiversity is in the way of extinction and that will be accelerated by the destruction of forests outside the protected areas. Conversion of these lands for non-forest purposes will definitely cause mass extinction of endemic organisms.

**CONCLUSION**

Cardamom Hill Reserve, though subjected to various kinds of land use still has a considerable extent of plant diversity. The early planters and the recent immigrants from the plains left certain areas of the CHR due to its inaccessibility or due to failure of cardamom cultivation in early decades of 20$^{th}$ century. Rich plant diversity exists in such areas with many rare and threatened species. These areas are under the dual control of the Kerala Revenue and Forest Departments and poses hurdles in the conservation of the species diversity. The existence of such a large number of species with a high percentage of endemism (about 39%) in CHR clearly indicates the immense value of the original vegetation of the CHR. The richness is comparable to any Protected Areas in Kerala. A recent study (Jha *et al.*, 2000) shows that the forest loss in the southern Western Ghats during the last quarter of the 20$^{th}$ century was about 25.6%. They attributed the loss to the conversion of dense forests to plantations. The observation is more relevant to Idukki district where plantation areas increased by 5.62 %.

Moreover, cardamom is a spice, which requires a considerable amount of shade and moisture. The reduction of the canopy cover by thinning may give more yields for a short period but in the long run it may make the soil unsuiTable for any crop including cardamom. The unsuitability of some of the areas of the High Ranges for cardamom cultivation, the dynamic nature of the price of cardamom in the market coupled with the high price for other cash crops, and/or the attitude of the new immigrants from the plains might have been the reasons for the large-scale conversions of cardamom to other crops. It is the flora of the CHR, which determines the survival of the cardamom cultivation in the High Ranges. Hence any destruction, even the least, will definitely be detrimental to the future of cardamom in Cardamom Hill Reserve.

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# Scientific Rationalization of Indigenous Technology Knowledge on Environmental Resource Management in Palakkad District of Kerala

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## INTRODUCTION

The importance of indigenous technology and practice to sustainability is being brought through pooling of traditional knowledge, short listing and evaluating them in the context of modern scientific and technological environment and harnessing it for sustainable agriculture growth. A blend of indigenous knowledge and modern technology may be most appropriate for sustainable development (Radhakrishnan *et al*., 2009, Kumar, 2008). The capital and technological skill requirements in the use of traditional technologies are generally low and their adoption often requires little restructure of the traditional societies. Indigenous practices in agriculture are organic in nature; never causes any damage to the air, water and soil, free from environmental pollution and safe to mankind. These practices are dynamic, region specific, depending upon soil type, rainfall, topography etc., and are often modified by the local farmers.

Indigenous knowledge is Unique, traditional, local knowledge existing within and developed around the specific condition of women and men indigenous to a particular geographic area (Grenier, 1998). International Institute for Rural Reconstruction (IIRR, 1966) defines Indigenous knowledge as the knowledge that the people in a given community have developed over time and contribute to develop which is based on the experience, often tested over centuries of use, adapted to local culture and environment and is dynamic and changing. Most ITK systems are eco-centric, objective as well as intuitive, and derived from the practical and innovative life of generations of indigenous people (Rajagopalan, 2003). These are also readily available, socially accepTable, economically affordable, and sustainable, besides involving minimum risk to farmers and consumers, and above all, resource conserving (Grenier, 1998). However, with the passage of time and with the advent of modern scientific knowledge systems, most of these useful traditional practices are continually being lost. Hence, there came an urgent need to document the indigenous practices systematically in agriculture and validate them, before they become extinct. This is relevant in the present context of Intellectual Property Rights (IPR) regime and up scaling ITKs in agriculture along with modern agricultural practices. In view of this, the present study was being undertaken with the specific objectives of collecting information on ITK related to resource management in different crops of Palakkad district of Kerala and documenting the same, and analyzing the scientific rationale of selected ITKs.

## MATERIALS AND METHODS

The investigation was undertaken with the main objective of rationalization of ITK in production management systems of Palakkad district in 2002. Keeping in view of the objectives of our study, expost facto research design was considered as the appropriate design for the investigation. The locale of the study was Palakkad district, the Rice bowl of Kerala which has wide crop diversity and encompasses five agro eco zones out of the 13 agro eco zones of Kerala and occupies the central east position in the state. Multistage sampling was followed for selection of samples for the study. Out of the 13 developmental blocks, 5 were selected based on the criteria of highest agricultural predominance and presence of at least three production systems out of the five envisaged in the study namely rice based, homestead based mixed farming system, plantation including spices, seasonal crops and annual crops. One of the blocks was selected to represent one agro ecozone and four panchayaths were selected within each block based on the same criteria thus making the involvement of 20 panchayaths in the district

The objectives of the study necessitated the involvement of 3 types of respondents viz., farmers, extension personnel and scientists, the groups referred as Farmers subsystem (FSS), Extension sub system (ESS) and Research subsystem (RSS) respectively. Hundred key informant farmers (KIF) representing different farming systems were selected for the study under FSS and under ESS 40 respondents were selected which included agricultural officers, veterinary doctors and agricultural assistants of different panchayats in the district. The scientists of both agriculture and veterinary discipline from Kerala Agricultural University who formed the researcher respondents of the study constitute the RSS. Various categories were delineated under the production system and 100 KIF were interviewed with the help of interview schedule to collect various ITK s under each category. The list of ITKs collected under various categories of production system were categorized and circulated among the multidisciplinary team of RSS for scientific reasoning so as to rationalize the ITKs.

Evaluation of ITK by KIF was also done by presenting the collected list of ITK to the KIF in order to get the response in range of 0-10 based on their belief and willingness of adoption. For this purpose, key informant workshops were conducted in different locations. Evaluation of ITK by ESS was done by circulating the list among the extension personnel in the form of a questionnaire to assign a score in range of 0-5 based on their perceived effect and scientific rationality. Correlation analysis was performed to find the relationship between the scores of FSS and ESS assigned for the ITKs under each crop.

## RESULTS AND DISCUSSION

A suite of 164 ITKs were documented in different farming systems as a part of this study and a crop-wise summary is presented in Table 1. Out of this, 25 were purely dealing with practices of soil management in different crops.

**Table 1**
**Crop wise classification of the documented indigenous technical knowledge (ITK) in Palakkad**

| Crop | ITKs collected under each crop |
|---|---|
| Plantation crops and spices | 49 |
| Seasonal crops | 46 |
| Rice based cropping system | 33 |
| Homesteads | 23 |
| Annual crops | 13 |
| Total | 164 |

Rationality analysis revealed that out of the 25 practices evaluated, 21 were rational and the remaining four irrational (Table2). The ITKs on environmental resource management in various production systems include the management of resources such as water, sunlight, day length, soil resources etc. Rationality analysis revealed that out of the 31 practices evaluated, 25 were rational and the remaining six irrational. The underlying scientific rationale of the rational practices is presented in Table 2.

**Table 2**
**Scientific rationale of the indigenous technical knowledge (ITK) on resource management in Kerala**

| No. | ITK | Rationalization |
|---|---|---|
| **Coconut** | | |
| 1 | Transplanting during 'Karkkidaka vaarcha' | This is the period when south west monsoon was ceased and north east monsoon is yet to begin. At this time soil will be so wet that irrigation is not required |
| 2 | Transplanting in 'Kumbha bharani' | Second half of February and first half of March. So seedling will establish before heavy monsoon |
| 3 | Plant banana around coconut seedling | It will prevent direct sunlight and give moist atmosphere |

| | | |
|---|---|---|
| 4 | Drip irrigation using clay pot and thread | Water loss will be decreased and ensures continuous availability of water |
| 5 | Burial of pseudo stem of banana in the basin of the palm | The water holding capacity and organic matter content of soil increase |
| 6 | Burial of salvinia and Eichornia in the basin | It increases water holding capacity |
| 7 | Arranging coconut husk inside planting pit | It increases water holding capacity and supplies potassium |
| 8 | Dig the coconut basin to a depth of 30 cm and 1 m diameter and fill the pit with chaff rice grains @ 10 baskets per plant per year | Rice chaff grain reduces soil bulk density and thus increases water holding capacity. Moreover addition of silica rich materials increases productivity |
| 9 | Application of decomposed hay in the basin increases yield of the palm | It increases water holding capacity and hence the yield |
| 10 | Cultivation of betel vine in coconut gardens increases yield of coconut | Betel vine roots add organic matter to the rhizosphere |
| **Cowpea** | | |
| 11 | Neem cake application has fertilizer and plant protection effect | It supplies plant nutrients. Azadiractin in the neem repels pests and nematodes |
| 12 | Green leaf manuring with thick leaves of mango, jack, cashew etc more preferred because of the long lasting residual effect | The leaves decompose slowly releasing the nutrients in a slow manner. It improve soil aeration and soil structure to a more extent |
| 13 | Add fresh cow dung at the time of flowering | Good organic manure |
| **Vegetables** | | |
| 14 | Land kept as such for three days after land preparation | If done in summer it help to destroy the weed seeds, resting stages of insects and pathogens on exposure to sunlight |
| 15 | Green leaf manuring with thick leaves of mango, jack, cashew etc preferred | The leaves disintegrate slowly releasing nutrients very slowly and improve soil aeration and soil structure |
| 16 | Liming at first digging reduces fungal diseases | Liming adjusts the pH of the soil to neutral range. This will avoid the growth of fungi which prefer acidic environment |
| 17 | Burning basins before sowing | Field sanitation practice. It also gives ash which is a rich source of potassium |
| **Rice** | | |
| 18 | Application of ash increases grain yield while application of cow dung increases straw yield | Ash supplies potassium which improves grain yield and filling percentage<br>Cow dung supplies nitrogen which is the main principle of vegetative growth |

| | | |
|---|---|---|
| 19 | In areas of iron toxicity add mango leaves and twigs as green manure | Green manure reduces iron toxicity through chelation |
| 20 | Add cowpea seeds along with rice seeds while sowing in water scarce conditions @12.5 kg/ha | It increases the availability of green manure (In situ green manuring) |
| 21 | Add calotropis as green manure | Pest repellant properties |
| 22 | Sprinkling common salt in nursery beds @2 kg/cent makes the uprooting of seedlings easier | Deflocculation of soil occurs making the soil loose for easy uprooting of seedlings |
| 23 | Sowing seeds in karutha paksham decrease the incidence of rice bug | It synchronises the milking stage of grains and life cycle of pests |
| 24 | Avoid planting during pooyam njattuvela (July 18 – August 2) to decrease the incidence of gall fly and shoot borer | It asynchronises the most susceptible stage of rice with the most damaging stage of insect |
| 25 | Sprinkling of salt at the rate of 2 kg/cent in the nursery makes the uprooting of seedlings easier | Deflocculation of soil take place hence soil loosens and it help in easy uprooting of seedlings |

Various ITK practices associated with resource management options are still in use and this depicted the confidence of the farmers regarding the technologies developed by their forefathers through trial and error. Many of the practices are still in use while some are mere recollection of farmers and still a certain category of ITK practices have blended, modified or attained newer uses through technology advancement. Correlation analysis was performed to find the relationship between the scores of FSS and ESS assigned for the ITK and presented in Table 4

**Table 4**
**Correlation coefficients between the scores of FSS and ESS for the ITKs**

| Perceived effects (PE) | Scientific rationality (SR) |
|---|---|
| 0.514 | 0.512 |

The positive and significant correlation obtained for the PE and SR by the farmers and extension personnel indicate the continued adoption of those ITK practices extensively. The farmers might be practicing the ITK techniques widely without being aware of their scientific reasoning. It can be inferred that the farmers and the extension personnel were in agreement regarding their opinion about various items included in the study. This was in concurrence with the results of Kashem & Islam (1999) who revealed that farmers attitude towards ITK was positively related to their rationality at one per cent level of probability

## CONCLUSION

The present study documented 164 Indigenous Technical Knowledge of which 31 was related to environmental resource management practices. Majority of the ITK analyzed for their rationality were adjudged as rational by experts. Such rational and effective ITK may directly be recommended by the extension system for adoption. Unlike modern technologies, indigenous practices do not involve hazardous chemicals as they generally utilize locally available resources. Thus, indigenous practices may be promoted not only for the benefit of the people but also for maintaining agricultural sustainability and ecosystem integrity through integration with the modern science.

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## *General Presentations - Poster*

# Effect of Bio-inoculants on Composting and its Effect on Soil Chemical and Biological Regimes for Sustaining Soil Health

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## INTRODUCTION

With the advent of green revolution, substantial increase in production of food grains was achieved through the use of improved crop varieties and higher levels of inputs of fertilizers and plant protection chemicals. But it has now been realized that increase in production was achieved at the cost of soil health and that sustainable production at higher levels is possible only by the proper use of factors which will help to maintain the fertility of soil. About 60 % of our agricultural land currently under cultivation suffers from indiscriminate use of chemical fertilizers. The gravity of environmental degradation resulting from these faulty agricultural practices has caused alarm among the scientific community and conservationalists.

Soil fertility is a prerequisite to productivity. From the stand point of crop yield and quality , nutrient supply both from organic and inorganic sources are important. One of the alternative strategy to overcome the problems of soil degradation and declining soil fertility is organic farming and ecological agriculture. A number of diverse organic sources are available for use in agriculture. These sources can reduce the mining of soil nutrients and improve overall soil productivity. Recycling of wastes and their conversion into easily available transporTable and usable forms is the ultimate aim of any soil fertility management programme. Use of bioinoculants and biofertilizers in soil fertility offers a great scope in management programmes in order to achieve long term sustainability of the ecosystem.

Organic farming thus depends on waste recycling. Harnessing the nutrients from biological and farm wastes is of prime importance for maximizing production. When these wastes are recycled as manure for crop production , the manurial value and quality of these wastes can be improved by composting and enriching these organic sources with bioinoculants etc. The use of organic manures as amendments to improve soil organic matter level and long term soil fertility and productivity is gaining importance now a days . The benefits of composted organic wastes in improving soil structure, fertility as well as plant growth have been increasingly emphasized. Thus the proper management of these biodegradable wastes is a growing concern of Pachayaths of Kerala in view of the rising environmental, health problems arising from its disposal without proper treatment or processing. Composting is a widely and popularly used method for disposal of organic wastes and a cheap means of waste management.

*Okra (Abelmoschus esculentus L. Moench*) is widely grown in tropics and subtropics for its tender green pods. The crop is grown in Kerala during monsoon seasons and its average yield is 8 to 10 tons $ha^{-1}$ only. Further increase in yield and improvement in quality of the produce can be exploited by use of high yielding cultivars and manipulation of improved cultural practices. Among the cultural practices, application of fertilizer and proper crop geometry are the most important factors, which influence both yield and quality of green pods.Of which application of fertilizer and manures the most important factors, which influence both yield and quality of green pods. It is well known that Okra is highly responsive to fertilizer application. Hitherto with these back ground, the present study was carried out with objective of assessing the effect of biofungicides such as *Pseudomonas* and *Trichoder*ma as a potential source for accelerating the composting of pseudostem of Banana using Okra as test crop , the present study was undertaken.

## MATERIALS AND METHODS

An investigation was carried out in a typical laterite soils at in the farmers field at Chengamandu Village of Kottarakkara Taluk Kollam District during the year 2010-11 to study the effect of biofungicides such as *Pseudomonas* and *Trichoderma* as a potential inoculants for composting and the yield and growth of Okra.

The soil of the experimental site was a typical laterite type with a pH of 5.3. Electrical conductivity of 0.01 d $Sm^{-1}$, available N 217.6 Kg $ha^{-1}$, available $P_2O_5$ 20.58 kg $ha^{-1}$ and available $K_2O$ 165.34 kg $ha^{-1}$.The experiment was laid out in Randomized block design with 8 treatments replicated thrice. Pits of size 3 X 3 feet were taken according to the treatments in to which 100 kg of Pseudostem was dumped to which the bio fungicides were inoculated as per the treatments. The treatment details are furnished in Table 1.

**Table 1**
**Treatment details**

| | **Treatment Details** |
|---|---|
| **$T_1$** | Pseudostem +cowdung+ Pseudomonas (1% dose) + NPK fertilizer |
| **$T_2$** | Pseudostem+cowdung+ Pseudomonas (0.5 % dose) + NPK fertilizer |
| **$T_3$** | Pseudostem+ cowdung+Trichoderma (1% dose) + NPK fertilizer |
| **$T_4$** | Pseudostem + cowdung+ Trichoderma (0.5 % dose) + NPK fertilizer |
| **$T_5$** | Pseudostem + cowdung + Azosprillum (1% dose) + NPK fertilizer |
| **$T_6$** | Pseudostem + cowdung + Azosprillum (0.5 % dose) + NPK fertilizer |
| **$T_7$** | Pseudostem+ cowdung alone + NPK fertilizer |
| **$T_8$** | Pseudostem alone ( Absolute control) |

The test crop was Bhindi (Var. *Varsha Upahar* ) sown in a spacing of 60 x 30 cm at the seed rate of 7 kg ha$^{-1}$.the experimental plots were of the size 1m x 1m. The wastes were inoculated with the bioinoculants *Pseudomonas, Trichoderma* and *Azosprillum* @ 15 and 0.5 % rates. The resultant composts were applied to the crop as basal as per the recommendation of Package of Practises .Soil Samples were collected before and after the experiment for chemical analysis. The soil samples were then analyzed for N, P, and K using the standard procedures as outlined by Jackson,1973. The plant samples collected from each plot after harvest were processed and stored for further chemical analysis.

**RESULTS AND DISCUSSION**

The results of the analysis of soil chemical characters and nutrient content are presented in the Table 1, 2, 3, 4 and 5. A close scrutiny of the data from the Table 2. revealed that yield was considerably influenced by various treatments. A higher fruit yield was realized when compost enriched with *Pseudomonas* as in $T_1$ (*Pseudomonas* @ 1 % ) + NPK fertilizer was applied (15.74 t ha$^{-1}$). This was followed by the treatments involving the application of compost enriched with *Pseudomonas 0.5 % dose with* a supplemental dose of N, P & K fertilizers. The release of growth promoting trigger molecules by the decay of organic amendments due to the application of compost enriched with microbial inoculants especially *Pseudomonas* might *have* resulted in the increased in yield of the crops.

**Table 2**
**Effect of treatments on the yield and uptake of nutrients**

| Treatments | Yield (t ha$^{-1}$) | Uptake of Nutrients (%) | | |
|---|---|---|---|---|
| | | N | P | K |
| $T_1$ | 15.74 | 54 | 9.73 | 33.21 |
| $T_2$ | 13.39 | 44.57 | 7.71 | 19.87 |
| $T_3$ | 14.80 | 52.97 | 9.74 | 25.13 |
| $T_4$ | 12.31 | 42.26 | 11.1 | 31.18 |
| $T_5$ | 12.76 | 61.80 | 9.64 | 32.80 |
| $T_6$ | 11.48 | 37.00 | 7.74 | 21.1 |
| $T_7$ | 10.59 | 44.15 | 7.97 | 23.04 |
| $T_8$ | 9.22 | 22.42 | 5.26 | 18.99 |
| S.Em+ | **0.16** | **1.73** | **0.07** | **0.65** |
| C.D (0.05) | **0.34** | **3.70** | **0.14** | **1.39** |

The highest yield of in Treatment $T_1$ with the conjunctive use of enriched compost using *Pseudomonas* in combination with inorganics could be also ascribed to slow and steady rate of nutrient release in the soil to match the required absorption pattern of the crop (Lakshminarayana and Patiram, 2005). The role of *Pseudomonas* in this case is predominant over the other inoculants viz.*Trichoderma* and *Azosprillum.* The release of growth promoting trigger molecules by the decay of organic amendments due to the application of compost enriched with microbial inoculant Pseudomonas have resulted in the increased in yield of the crops. The availability of nutrients in organic manures is stimulated by increased microbial activity .Similar results have been reported by Bidanchandra (1992 ) in green gram and in onion by Reddy et al (2010).

Thus it is evident from the study that the availability of nutrients in organic manures is stimulated by increased microbial activity and complementary through chemical fertilizers. It is also inferred that the quantity of inorganic chemical fertilizers can be added as complementary with the organic sources preferably with compost enriched with various microbial inoculants. The sustained use of organics in crops also increases higher uptake of all nutrients when used along with inorganic fertilizers. Similar results have been reported by Anjum and Amjad,(1999).The lowest yield in the control plot might have been due to low or insufficient availability of nutrients for an enhanced yield as observed from the data presented in Table 2.

With regard to the uptake of nutrients as observed from Table 2, the treatments imposed significant effects on the uptake of nutrients. The highest uptake of nitrogen was noticed in the treatment $T_5$ with the application of compost prepared using pseudostem enriched with Azosprillum (1 % dose). The higher uptake of the nutrients in the plots treated with compost enriched with microbial sources might be due to the triggered microbial action resulting in solubilization and the uptake of nutrients. In this context, we could speculate that inhabiting the interior of leaves, these bacteria are thought to stay away from competition with bacteria of the rhizosphere and obtain nutrients directly from host plants. This might have also been due to conditions favorable to $N_2$-fixation, allowing the bacteria to transfer fixed N products efficiently to the host .Besides, considering that the bacteria associated to inner tissues of crop leaves could have contributed with part of the amount of fixed nitrogen in the N-content, under our experimental conditions the beneficial effect of inoculation could be due to the type of plant growth promotion associated with the strains inoculated. *A. brasilense* which produces more phytohormones thus stimulating differentially the development of roots to explore a wider soil volume for obtaining nutrients, whether the soil was fertilized. (Bodelier 2003)

The uptake of P content was significantly affected by the application of *Trichoderma* as in treatment $T_4$ which was on par with the treatment $T_1$ with the application of compost ( *Pseudomonas* 1%) and treatment $T_5$ pseudostem + cowdung+ *Azosprillum* (1 % dose) + NPK fertilizer. These treatments were statistically on par and are significantly superior to phosphorus content of the pods from the plants received only pseudo stem (Table 2). This indicated that the application of *Trichoderma* increases the uptake of phosphorus in the crop. This might be due to the solublization of phosphorus due to the formation of organic acids by the addition of these microbes. The mechanism of increased uptake of phosphorus is still ambiguous and needs to be elaborated. While in the case of K uptake , the highest value was recorded in $T_1$ (33.21%) with the application of compost enriched with *Pseudomonas* @ 1 % significantly superior than other treatments except Treatment $T_5$ ( Pseudostem + cowdung + *Azosprillum* 1 %).

**Table 3**
**Data on the nutrient content of various compost,composting period and pH**

| Treatments | N (%) | P (%) | K(%) | pH | Composting period |
|---|---|---|---|---|---|
| $T_1$ | 2.11 | 1.92 | 1.16 | 7.8 | 54 |
| $T_2$ | 2.05 | 2.4 | 1. 37 | 8.1 | 70 |
| $T_3$ | 2.01 | 1.15 | 1.44 | 7.9 | 76 |
| $T_4$ | 1.45 | 0.62 | 1.14 | 7.7 | 82 |
| $T_5$ | 2.55 | 0.56 | 1.25 | 8.2 | 85 |
| $T_6$ | 2.13 | 0.71 | 1.64 | 7.7 | 86 |
| $T_7$ | 0.84 | 0.36 | 1.08 | 7.9 | 121 |
| $T_8$ | 0.90 | 0.53 | 1.1 | 6.8 | 133 |
| SE m+ | **0.11** | **0.04** | **0.06** | **0.17** | **2.24** |
| CD (0.05) | **0.24** | **0.08** | **0.146** | **0.38** | **4.80** |

The data on the nutrient content of the resultant compost as observed from the Table 3 with respect to nitrogen content revealed that treatment involving the addition of pseudostem along with *Azosprillum* (1 % dose) was found to be significantly higher than the other treatments. Followed by the treatment involving the application of *Pseudomonas* at the rates of 1 % & 0.5 % dose along with NPK fertilizer. With respect to phosphorus content of the resultant compost, the predominance of *Pseudomonas* can be observed as inferred from Table 3. While in the case of K content, treatment involving the addition of Pseudostem along with *Azosprillum* (0.5 % dose) was found to be significantly higher. However, the lowest value was observed with the treatment involving the application pseudo stem alone.

The soil pH was found to be considerably influenced with the application of these manures in combination with chemical fertilizers. Treatment involving the application of Pseudomonas ( 0.5 %) was found to be significantly higher than the control treatment with the application of pseudostem alone. All the other treatments imposed a similar effect on the pH of the compost samples. A pH of 6.7–9.0 supports good microbial activity during composting. This might be attributed to the fact that release of some alkaline substances during the process of composting, which in turn, increased the alkaline nature of composts. (Bangar *et al*. 1989).

Composting of organic wastes is a bio- oxidative process involving the mineralisation and partial humification of the organic matter, leading to a stabilised final product, free of phytotoxicity and pathogens and with certain humic properties.With respect to the time taken for attaining maturity, the role of *Pseudomonas* and *Trichoderma* @ 1% and 0.5 % doses needs to be mentioned . The time taken for bio conversion was significantly less with the application of *Pseudomonas* @ 1% and.5 % rates followed by *Trichoderma* as evident from Table 3. Production of hydrolytic enzymes such as cellulase and chitinases by microorganisms might be the reason for the rapid composting of organic wastes.

**Table 4**
**Data on soil available nutrient status ( kg ha-1)of the post harvest soil sample**

| **Treatments** | **Nitrogen** (kg $ha^{-1}$) | **Phosphorus** (kg $ha^{-1}$) | **Potash(** kg $ha^{-1)}$ |
|---|---|---|---|
| $T_1$ | 136.65 | 51.537 | 70 |
| $T_2$ | 121.02 | 59.11 | 112 |
| $T_3$ | 124.14 | 65.31 | 89.60 |
| $T_4$ | 124.13 | 73.47 | 123.20 |
| $T_5$ | 122.58 | 72.57 | 106.40 |
| $T_6$ | 130.00 | 84.22 | 134.40 |
| $T_7$ | 144.14 | 76.78 | 140 |
| $T_8$ | 135.56 | 85.11 | 154 |
| S.Em+ | NS | NS | 5.82 |
| C.D (0.05) | NS | NS | 17.14 |

The soil of the experimental site was a typical laterite type with a pH of 5.3.The pre harvest soil samples recorde the values for electrical conductivity of 0.01 d $Sm^{-1}$, available N 217.6 Kg $ha^{-1}$, available $P_2O_5$ 20.58 kg $ha^{-1}$ and available $K_2O$ 165.34 kg $ha^{-1}$From the Table 4 , an increase in the soil nutrient status with respect to available, N P and K was noticed . But the treatment effects were not significant with respect to the available nitrogen and phosphorus status of the post harvest soil samples. But with respect to available potassium status the treatment $T_7$ was found to be significantly superior compared to other treatments which were found to be on par with the treatment $T_7$.

**Table 5**
**Effect of treatments on soil enzyme status**

| **Treatments** | **Urease (ppm of urea hydrolysed g-1 of soil hr-1)** | **Phosphatase ($\mu$g of p-nitrophenol released $g^{-1}$ of soil $hr^{-1}$)** | **Protease (micromoles of amino nitrogen hydrolysed $g^{-1}$of soil $hr^{-1}$)** | **Dehydrogenase ($\mu$g of TPF hydrolysed $g^{-1}$ of soil 24 $hrs^{-1}$)** | **Cellulase (ppm of glucose hydrolysed $g^{-1}$ of soil per 24 $hrs^{-1)}$** |
|---|---|---|---|---|---|
| $T_1$ | 107.6333 | 65.23 | 127.6667 | 137.64 | 36.13333 |
| $T_2$ | 144.9 | 82.63 | 167.6667 | 114.16 | 41.02 |
| $T_3$ | 154.4367 | 93.48667 | 161.6667 | 97.77 | 80.33333 |
| $T_4$ | 195.1 | 92.92333 | 158.3333 | 93.60 | 51.67667 |
| $T_5$ | 211.9397 | 99.68667 | 210 | 58.19 | 51 |
| $T_6$ | 199.6667 | 116.64 | 188 | 111.66 | 70.33333 |
| $T_7$ | 208.88 | 113.7233 | 206.6667 | 78.90 | 71 |
| $T_8$ | 162.63 | 110.4767 | 181. | 76.98 | 70.33333 |
| S.Em+ | **0.83** | **0.58** | **2.89** | **0.69** | **0.67** |
| C.D (0.05) | **1.77** | **1.24** | **6.18** | **1.47** | **1.43** |

A close scrutiny of the data presented in Table 5 revealed significant effects due to the application of fertilizers, and manures on the activity of urease The highest value recorded for Treatment $T_5$ with the application of *Azosprillum* 1 % dose followed by the application of compost along with NPK fertilizers. This study also indicated the significant effect of fertilizers and manures on urease activity. This increase in urease with the addition of manures in the form of vermicompost may be attributed to incorporation and promotion of urease enzyme fraction upon increasing the soil nutrient status, carbon and energy sources and humus. The low values in the control plots may be due to the limited supply of subtrate, nutrients and energy sources. Similar results were reported by Skogland et al. 1998.

Phosphatase is an enzyme of agronomic value because it hydrolyses compounds of organic phosphorus and transforms them into different forms of inorganic phosphorus, which are assimilable by plants. The phosphatase activityis due to the presence of phosphorylated compounds,which act as a substrate for the microorganisms to synthesize phosphatase and is considered as a general microbial indicator (Spier and Ross, 1978). It is a key enzyme in the phosphorus cycle, which is induced by the carbohydrate-derived structures (including cellulose) that are degraded by enzymatic hydrolysis to cellobiose, which in turn degraded to glucose by B-glucosidase . Phosphatase a relevant enzyme for the characterization of the composting process, since it is synthesized by microorganisms only and does not originate from plant residues. The high activity was reported with the application of compost enriched with 0.5 % *Azosprillum* could be related to the amount of organic phosphate compounds formed in the composting mixture which may have served as a potential substrate .

Protease activity is closely related to the N cycle and catalyses the hydrolysis of proteins to ammonia, acting on the short-chain poly peptide substrates. The activity of protease and degradation of proteins increased in rapid composting due to the removal of ammonia through aeration. Otherwise, ammonia can act as an inhibitor since it is the product of the hydrolytic reactions catalysed by urease and proteases (Ross *et al*., 2006).A close scrutiny of the data presented in Table 1.clearly indicates highly significant effects of treatments on protease activity. The highest activity with respect to protease activity was reported in the treatment $T_5$ with the application of compost (*Azosprillum@* 1%). This might have been due to the treatment in which Nitrogen fixed by the organism might have served as a substrate to the growing microbes resulting in the synthesis of protease intracellularly as well as extracellularly during the lysis of these cells .

Dehydrogenase activity is a basic index of intensity of oxidation processes conducted by microorganisms and it is positively correlated with their respiratory activity as measured by the amount of emitted $CO_2$ .As presence of dehydrogenases, which are intracellular to the microbial biomass, is common throughout microbial species and they are rapidly degraded following the cell death, the measurement of microbial dehydrogenase activity (DHA) in soils and sediments has been used extensively. In the case of dehydrogenase activity the superiority of compost enriched with Pseudomonas

@ 1 % was noticed (Table 5).This treatment was found to be significantly superior to other treatments. Application of *Pseudomonas* might have evoked responses similar to that of Auxins or Gibberllins. Application of compost ( *Pseudomonas* @ 1 %) might have also resulted in the increased activity of microbes ultimately reflecting on dehydrogenase activity an index of active microbial mechanism and dynamics. Generally, stimulatory effects of *pseudomonas* addition on dehydrogenase activity in the soil among all treatments were observed The stimulation of DHA by this bio inoculant in soils is principally attributed to spurt of microbial populations.. In contrast,lower rate of dehydrogenase activity in the control plot might be due to reduced microbial numbers and the source of this enzyme is purely intracellular in various organisms.

Cellulases are the enzymes involved in the degradation of cellulose. Cellulose decomposition limits the rapid production of compost more than any other substrates (Poincelot and Day, 1973). Cellulase activity is dependent on the types of cellulolytic microorganisms that develop on the organic waste. Mostly, fungi are involved in the decomposition of cellulose, hemicellulose and lignin present in the organic matter. From the Table 5, it is inferred that, the cellulase activity was found to be higher in treatment involving the application of compost enriched with *Trichoderma* @1 %.This could have attributed to the addition of fungal cultures in this treatment which might have promoted the formation of cellulase and hemicellulase. Low cellulase activity in the control may be attributed to the of the insufficient growth of cellulolytic fungus during composting because of the low availability of nutrients..

**Table 6**
**Effect of treatments on the uptake of secondary and micronutrients at harvest stage**

| Treatments | Ca (Kg ha$^{-1}$) | Mg (Kg ha$^{-1}$) | Fe (g ha-1) | Mn (g ha-1) | Zn (g ha-1) | Cu (g ha-1) |
|---|---|---|---|---|---|---|
| $T_1$ | 21.43 | 5.31 | 427.95 | 61.41 | 92.32 | 46.73 |
| $T_2$ | 12.47 | 5.29 | 427.87 | 32.95 | 58.45 | 33.55 |
| $T_3$ | 16.52 | 7.37 | 335.66 | 52.77 | 83.46 | 47.09 |
| $T_4$ | 15.53 | 6.39 | 341.66 | 58.11 | 81.73 | 37.10 |
| $T_5$ | 19.74 | 6.31 | 319.55 | 63.43 | 75.79 | 37.06 |
| $T_6$ | 18.53 | 6.12 | 316.54 | 56.35 | 73.84 | 42.75 |
| $T_7$ | 18.99 | 5.78 | 348.41 | 48.66 | 71.8 | 42.41 |
| $T_8$ | 11.3 | 3.64 | 231.64 | 35.22 | 48.58 | 24.22 |
| S.Em+ | **0.32** | **0.08** | **10.09** | **1.04** | **0.86** | **0.84** |
| C.D (0.05) | **0.68** | **0.174** | **21.5** | **2.24** | **1.84** | **1.81** |

From the data on the uptake of secondary and micro nutrients as given in Table 6, it was observed that maximum calcium magnesium and Zinc uptake was noticed in the plots treated with enriched compost ( *Pseudomonas and Trichoderma* @ 1 % dose ) as per the treatment $T_{1\ \&}\ T_4$.The higher content of these cations present in plants treated with enriched compost may be due to increased uptake through enhanced availability in soil. Similar results have been reported by Sailajakumari and Ushakumari, 2002. Significant difference in the case of Fe,Mn & Cu was noticed with the application of composing enriched using *Pseudomonas and Trichoderma* @ 1 % dose which were significantly superior.

## CONCLUSION

Taking to consideration of the environment , this study highlights the benefits of recycling of wastes and use of inoculants to enrich the composts**.**This study clearly showed that the judicious use of bioinoculants such as *Pseudomonas, Trichoderma* and *Azospirillum* as potential source of enrichment which improves the soil parameters as well as yield of the crops to meet the present day requirement. The present study needs elaboration will go a long way in achieving the much desired increase in yields of the crops and meet the requirements of an ever growing world population without affecting the production base – the soil.

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# Ecologically Sustainable Intercropping System for Summer Fallows of Onattukara Tract

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## INTRODUCTION

Sesamum is mainly grown in our state as a sole crop in the summer rice fallows of Onattukara tract spread over Kollam and Alappuzha districts. The soil in this area is sandy loam with low nutrient status. The crop grows in this tract utilizing the residual moisture available in rice fields. The establishment of the crop is often poor resulting in low productivity. It is very sensitive to heavy or scarce rains, which often occurs during this period leading to instability in its production and economic returns. Under these adverse circumstances an intercropping system provides an insurance against failure of any one crop. Besides in a normal season it increases the income of the farmer.

Sesamum being a soil exhausting crop, the inclusion of leguminous crops like Green gram and Black gram may benefit the companion crop through current nitrogen transfer and to the succeeding rice crop through the residual effect. By biologically fixing nitrogen levels in the soil, legumes provide a relatively low cost method of replacing nitrogen in the soil, enhancing soil fertility and boosting subsequent crop yields. Besides legumes are one of the most ecologically sustainable agricultural solutions on the planet as it naturally rejuvenate the soil. The use of low carbon-to-nitrogen organic residues to maintain soil fertility, combined with greater temporal diversity in cropping sequences, significantly increases the retention of soil carbon and nitrogen, which has important implications for regional and global carbon and nitrogen budgets ,sustained production, and environmental quality (Drinkwater, *et al*. 1998).

Now a days climate change is a subject of great concern. Gregory and Ingram (2000) observed that the farmers may combat the effect of climate change by reverting to more natural systems which provide beneficial ecological functions. To increase and stabilize the productivity of Sesamum, suiTable intercropping systems have to be developed for Onattukara region. The present investigation was undertaken with the objective of developing suiTable intercropping systems in Sesamum for stabilizing its productivity in the Onattukara region.

## MATERIALS AND METHODS

The experiment was conducted in the summer rice fallows of Onattukara Regional Agricultural Station, Kayamkulam during the period from February 1998 to August 1998. The soil of the experimental site is loamy sand and acidic in nature. The experiment was laid out in Randomised block design with 9 treatments viz Sesamum sole ( $T_1$ ), Sesamum + Black gram (1:1) ( $T_2$), Sesamum + Black gram (2:1) ( $T_3$), Sesamum + Black gram (3:1) ($T_4$), Sesamum + Green gram (1:1) ($T_5$), Sesamum + Green gram (2:1) ($T_6$), Sesamum + Green gram (3:1) ($T_7$) with 4 replication. The varieties used were Kayamkulam 1 for Sesamum, Syama for Black gram and PUSA 8973 for Green gram. The gross plot size was 5m X 4m.

Biometric observations, yield and yield attributing characters were recorded for both main crop and intercrops. Soil analysis was done before and after the experiment for finding out the available nutrient status. Bio suitability of the intercropping systems was analyzed using parameters like Land Equivalent Ratio ( LER) ( Mead and Willey,1980), Land Equivalent Coefficient (LEC) ( Adetiloye *et al.,*1983), Relative Crowding Coefficient (RCC), (de Wit, 1960), Aggressivity (Mc Gilchrist,1965). Economic efficiency of the intercropping systems was analyzed by calculating Gross returns, Net returns, Benefit Cost Ratio (BCR) and Net returns per rupee invested. Bio-economic efficiency was analyzed by monetary advantage based on LER and Sesamum Equivalent Yield (SEY) which was calculated by converting the yield of intercrop into yield of base crop considering the market rates.

## RESULTS AND DISCUSSION

The experimental data collected were statistically analysed. The results revealed that the different intercropping treatments did not significantly influence the growth characters of Sesamum. Among the yield characters, the sole crop of Sesamum recorded the maximum seed yield (539 kg $ha^{-1}$) and biological yield (2350 kg $ha^{-1}$) and was significantly superior to all other treatments. The analyzed results indicated that Sesamum did not show any significant superiority in growth characters, when it was raised either as sole crop or as intercrop with Green gram and Black gram .Sole crop of Sesamum gave significantly highest seed yield than when they were grown in intercropping system (Table 1). In all intercropped treatments, there was reduction in Sesamum yield below the expected level on the basis of planted area.

Evaluation of Sesamum-Pulse intercropping system for their biological efficiency (Fig.1) were analyzed. In all intercropping systems except Sesamum and Black gram in 2:1 ratio, LER excelled unity, indicating greater biological efficiency of intercropping. The results on LEC showed that LEC was more than 0.25 in Sesamum and Black gram in 1:1 ratio and Sesamum with Green gram in 1:1 row proportion and they were on par. In all other situations LEC was less than 0.25 which indicated that due to competition between the components crops the yield would be less than the expected yield. The aggressivity values were found to be positive in pulses and negative in Sesamum. The maximum value of aggressivity (0.12) was recorded by Black gram when it was intercropped with Sesamum in 1:1 ratio. Here the intercrops Black gram and Green gram have its coefficient greater than one in all treatments. The product of RCC was greater than one except in Sesamum+ Black gram in 2:1 ratio indicating a definite yield advantage due to intercropping.

**Table 1**
**Seed Yield, Biological Yield and Harvest Index of Sesamum in different Treatments**

| Treatments | | Seed yield (Kg/ha) | Biological Yield (Kg/ha) | Harvest Index |
|---|---|---|---|---|
| $T_1$ | Sesamum sole | 539.53 | 2350.41 | 0.229 |
| $T_2$ | Sesamum + Black gram (1:1) | 262.92 | 1287.76 | 0.204 |
| $T_3$ | Sesamum + Black gram (2:1) | 356.21 | 1537.51 | 0.232 |
| $T_4$ | Sesamum + Black gram (3:1) | 406.85 | 1740.37 | 0.235 |
| $T_5$ | Sesamum + Green gram (1:1) | 262.76 | 1215.36 | 0.216 |
| $T_6$ | Sesamum + Green gram (2:1) | 363.02 | 1522.98 | 0.239 |
| $T_7$ | Sesamum + Green gram (3:1) | 407.72 | 1723.02 | 0.238 |

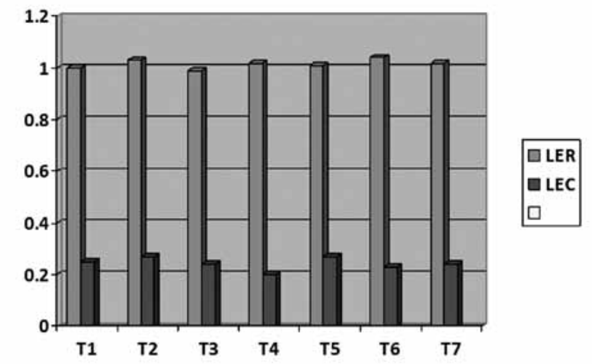


**Fig.1**
**Biological efficiency of sesamum pulse intercropping system**

The results indicated that Sesamum equivalent yield from all intercropping systems were significantly more than sole Sesamum yield and highest equivalent yield was obtained in Sesamum + Black gram in 1:1 row proportion. Highest monetary advantage based on LER was also obtained from the intercropping of Sesamum and Black gram in 1:1 row arrangement. Economic efficiency of intercropping system was analyzed. Significant differences were observed for gross returns, net returns, BCR and net return per rupee invested. The most profiTable intercropping treatment was Sesamum and Black gram in 1:1 ratio which gave a BCR of 1.73 which was significantly superior to other intercropping treatments. The lowest BCR (1.23) was recorded by the sole crop of Sesamum .The other economic parameters also followed the same trend.

To achieve higher productivity from intercropping, the component crops are to be evaluated and selected for better compatibility. Therefore a basic knowledge of techniques of evaluations of competitive relation of component crops and their yield advantages in intercropping situation would be helpful in future for selecting suiTable intercropping system for any specific agro-ecological situation. Jena *et al.* (2009) reported that the canopy temperature of component crops was reduced under intercropping system when compared to the sole stand situation which indicated better moisture utilization under intercropping and the tall crop Sesamum was more benefited with the presence of short stature crop like Green gram.

Total productivity was given in terms of Sesamum equivalent after converting intercrop yield into Sesamum based on market prices .Sesamum equivalent yields from all intercropping system were significantly more than sole Sesamum yield. All the intercropping systems registered significant and appreciable increase in total productivity in terms of Sesamum equivalent yield over sole crop of Sesamum (Sarkar *et al.*2003). Intercropping Sesamum+ Black gram in 1:1 ratio recorded significantly more Sesamum equivalent (812 kg $ha^{-1}$) than sole Sesamum and other intercropping treatments. Among the different intercropping systems with Sesamum ,Sesamum+ black gram(1:1) gave the maximum LER ,Sesamum equivalent yield and net returns (Kumar and Thakur,2006).

Among the intercropping system, Sesamum+ Black gram system was found more economically feasible than Sesamum+ Green gram system. This is due to higher yield and greater market price of Black gram as compared to Green gram .It was also revealed that the planting geometry of 1:1 proportion was economically more feasible than 2:1 and 3:1 row arrangements. The Benefit-Cost Ratio and the net returns per rupee were highest in Sesamum+ Black gram in 1:1 row ratio. Results on the Monetary advantage based on LER revealed that maximum value was obtained when Sesamum and Black gram were grown in 1:1 ratio due to higher values of the produce of both intercrops.

Soil nutrient status before the experiment were analyzed and the results revealed that there was no significant difference in the nutrient content in the various plot (Table2).

**Table 2**
**Average Soil nutrient status before the experiment (kg ha-1)**

| Nitrogen | Phosphorus | Potassium |
|---|---|---|
| 194.3 | 33.24 | 42.57 |

But after the experiment ,the soil nutrients were found to be significantly influenced by the treatments. The soil test data after the experiment indicated a significant positive build up of nitrogen and phosphorus in all plots except in plots of sole crop of Sesamum (Table 3). Chu *et.al.* (2004) reported that there was significant direct transfer of fixed-N by legumes to the associated non legume species.

**Table 3**
**Average Soil nutrient status after the experiment (kg ha-1)**

| Treatments | | Nitrogen | Phosphorus | Potassium |
|---|---|---|---|---|
| $T_1$ | Sesamum sole | 193.03 | 35.68 | 41.17 |
| $T_2$ | Sesamum + Black gram (1:1) | 198.35 | 37.93 | 41.32 |
| $T_3$ | Sesamum + Black gram (2:1) | 197.20 | 37.30 | 40.45 |
| $T_4$ | Sesamum + Black gram (3:1) | 195.73 | 38.18 | 39.06 |
| $T_5$ | Sesamum + Green gram (1:1) | 197.23 | 38.73 | 39.85 |
| $T_6$ | Sesamum + Green gram (2:1) | 198.03 | 38.08 | 40.03 |
| $T_7$ | Sesamum + Green gram (3:1) | 197.10 | 36.98 | 39.48 |

## CONCLUSION

The study revealed that the association of Sesamum had lesser adverse effect on legumes and it was proved that legumes can be grown in a compatible manner with Sesamum. In summer rice fallows of Onattukara tract, instead of growing sole crop of Sesamum, intercropping of Sesamum with Black gram in 1:1 proportion can be recommended as an economically viable, biologically suiTable and a sustainable intercropping system. The monitory returns where higher in inter cropping systems irrespective of pulse crops raised, compared to sole crop of seasmum.

The experiment proved that there was a gain in nitrogen and phosphorus in soil in which legume crop where included in the intercropping system. The legume association with Sesamum could increase the total productivity, enrichment of soil fertility and natural rejuvenation of the ecological system.

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# Physiological Response of Female Workers during Operation of a Rotary Weeder for Paddy

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## INTRODUCTION

The performance of any machine especially manually operated ones could be considerably improved if ergonomic aspects are given due consideration. The application of ergonomics can help in increasing the efficiency and thereby productivity of the workers without jeopardizing their health and safety.

Most technologies developed for small-scale farmers are geared to men with no concern for their appropriateness for women, who possess different physiques and energy capabilities in comparison to men. There is an urgent need to design and develop farm tools specifically for female operators in order to improve overall ease of use, safety, and effective integration of women in farming system innovations (Kaul and Ali, 1992). Systematic efforts to evaluate the energy expenditure of female labourers are generally non-existent. Hence the energy measurements for different operations under different environmental conditions are essential. Here, we analyze the human energy expenditure during operation of a rotary weeder for effective use of women labourers available for rice cultivation.

## MATERIALS AND METHODS

### Selection of Subjects

A preliminary survey was conducted among women agricultural labourers engaged in rice cultivation in southern districts of Kerala. Nine subjects were selected having anthropometric dimensions conforming to statistical requirements from the available anthropometric data base of the study region. The medical and bio-clinical investigations were also conducted to assess the medical fitness of selected subjects which included Electro Cardio Graph (ECG), blood pressure and bio-clinical analysis.

### Calibration of Subjects

To evaluate physiological workload using heart rate, the relationship between heart rate and oxygen uptake for each subject must be determined. Since the relationship between the two variables is linear, a subject's heart rate when it is subsequently measured in the field can be converted into an estimate of oxygen uptake by reference to the laboratory data. The selected nine subjects were calibrated in the laboratory by measuring oxygen consumption while pedalling a standard bicycle ergometer and the corresponding heart rate to arrive at the relationship between heart rate and oxygen consumption. The oxygen consumption was measured using Benedict-Roth spirometer and the heart beat rate was recorded using computerized heart rate monitor (Polar make).

**Field Layout Experiments**

Rotary weeder is a manually operated implement and designed to work in between the rows of 20 cm spacing in wet lands. It works by the push pull action and the weeds were uprooted and buried in the field itself. A float provided in the front portion prevents the unit from sinking into the puddled soil. It disturbs the topsoil and increases the aeration also. All the nine subjects were equally trained in the operation of the Rotary weeder. The trials were conducted two times a day, at different time intervals i.e., before 9 am and after 11 am in order to find out the changes in energy expended and heart rate due to environmental condition. They were asked to report at the work site at 7.30 am and have a rest for 30 minutes before starting the trial. To minimize the effects of variation, the treatments were given in randomized order. All the subjects used similar type of clothing. The subjects were given information about the experimental requirements so as to enlist their full cooperation. The heart rate was measured and recorded using computerized heart rate monitor for the entire work period. Each trial was carried out for 15 minutes of duration and same procedure was repeated to replicate the trials for all the selected subjects.

The physiological response of the subjects while weeding by manually was also assessed to compare the energy expenditure in manual and mechanized operation.

**Data Collection and Analysis**

The recorded heart rate values from the computerized heart rate monitor were transferred to the computer through the interface provided in all the above cases. From the down loaded data, the values of heart rate at resting level and $6^{th}$ to $15^{th}$ minute of operation were taken for calculating the physiological responses of the subjects). The stabilized values of heart rate for each subject from $6^{th}$ to $15^{th}$ minute of operation were used to calculate the mean value for all the selected implements.

From the values of heart rate (HR) observed during the trials, the corresponding values of oxygen consumption rate ($V0_2$) of the subjects were predicted from the calibration chart of the subjects. The energy costs of operation of the selected implements were computed by multiplying the oxygen consumed by the subject during the trial period with the calorific value of oxygen as 20.88 kJ $lit^{-1}$ (Nag *et al.* 1980) for all the subjects. The energy cost of the subjects thus obtained was graded as per the tentative classification of strains in different types of jobs given in ICMR report as shown in Table 1 (Vidhu, 2001).

**Table 1**
**Tentative classification of strains (ICMR) in different types of jobs**

| Grading | Physiological response | | |
|---|---|---|---|
| | Heart rate (beats $min^{-1}$) | Oxygen uptake, lit $min^{-1}$ | Energy expenditure, kcal $min^{-1}$ |
| Very light | <75 | < 0.35 | <1.75 |
| Light | 75-100 | 0.35 - 0.70 | 1.75-3.5 |
| Moderately heavy | 100-125 | 0.70 - 1.05 | 3.5-5.25 |
| Heavy | 125-150 | 1.05 - 1.40 | 5.25-7.00 |
| Very heavy | 150-175 | 1.40- 1.75 | 7.00-8.75 |
| Extremely heavy | >175 | > 1.75 | >8.75 |

### Acceptable Workload (AWL)

Work load can be expressed as percentage of the individual's maximal aerobic power i.e. how much of the individual's maximal aerobic power has to be taxed in order to accomplish the work in question. Saha et al. (1979) reported that 35 % of maximum oxygen uptake (also called maximum aerobic capacity or $VO_2$ max) can be taken as the accepTable work load (AWL) for Indian workers which is endorsed by Nag et al, 1980 and Nag and Chatterjee, 1981. To ascertain whether the operations selected for the trails were within the accepTable workload (AWL), the oxygen uptake in terms of $VO_2$ max (%) was computed.

## RESULTS AND DISCUSSION

### Calibration Process

By using the data on heart rate and oxygen consumption rate, calibration chart was prepared with heart rate as the abscissa and the oxygen uptake as the ordinate for the selected nine subjects. It is observed that the relationship between the heart rate and oxygen consumption of the subjects was found to be linear for all the subjects, which is in close agreement with the results reported by Kroemer and Grandjean, 2000 and Vidhu (2001).

Each subject's maximum heart rate was estimated by the following relationship (Bridger, 1995).

Maximum heart rate (beats $min^{-1}$) = 200 - 0.65× Age in years

The oxygen uptake corresponding to the computed maximum heart rate in the calibration chart gives the maximum aerobic capacity ($VO_2$ max).

### Energy Cost of Operation

Effect of mode of operation and time of operation on energy cost for weeding operation is shown in Table 2. The results of the study show that there was significant difference in physiological cost between the rotary weeder operation and weeding by hand. Energy cost was recorded significantly higher in weeding by hand than rotary weeder operation. The maximum energy cost observed to be 21.58 kJ $min^{-1}$ in hand weeding, whereas with the rotary weeder this value was 13.96 kJ $min^{-1}$. In hand weeding the subjects were bending over work surfaces for targets which are too low. It may be suggested that pain rather than capacity may often be the limiting factor in such task situations. Since the rotary weeder is provided with a long handle, the subjects can comfortably do the weeding in a standing posture.

The energy expenditure after 11 am was increased by 14 % in compared to energy expenditure before 9 am. An increase with time was observed in energy expenditure in high environmental stress (high temperature and solar radiation) among the operators.

**Table 2**
**Energy cost as influenced by mode of operation and time of operation during weeding**

| Treatments | Energy cost, (kJ $min^{-1}$) |
|---|---|
| **Mode of operation** | |
| Weeding with Rotary Weeder | 13.96 |
| Hand Weeding | 21.58 |
| F (32,1) | 208.93** |
| CD ( P=0.05) | 1.08 |
| **Time of operation** | |
| Before 9 am | 16.63 |
| After 11 am | 18.92 |
| F (32,1) | 18.81** |
| CD ( P=0.05) | 1.08 |

## Acceptable Workload (AWL)

The mean oxygen uptake in terms of maximum aerobic capacity of selected operations was calculated and the values are depicted in Table 3. For field operations with rotary weeder the oxygen uptake in terms of $VO_2$ max was varied from 46.94 % to 50.41 % while these values varied from 69.62% to 85.20 % for weedng manually. All values were much higher than that of the AWL limits of 35 per cent indicating that the selected operations could not be operated continuously for 8 hours without frequent rest-pauses.

**Table 3**
**Oxygen uptake in terms of VO2 max for selected operations**

| Selected Operation | Mean $VO_2$ | | $VO_2$max (%) | | AWL (35 % of $VO_2$ max) |
|---|---|---|---|---|---|
| | Before 9 am | After 11 am | Before 9 am | After 11 am | |
| Weeding with Rotary Weeder | 0.6243 | 0.6704 | 46.94 | 50.41 | > AWL |
| Weeding manually | 0.9259 | 1.1414 | 69.62 | 85.2 | > AWL |

The weeding efficiency of rotary weeder was also calculated. It is a ratio between the number of weeds removed by a weeder to the number present in a unit area and is expressed as a percentage. The spots where such counts are taken are randomly selected and a ring covering an area of 1 sq m is used for sampling.

Weeding efficiency (%) = $(W_1-W_2)/W_1$x100

Where $W_1$= weeds before weeding

$W_2$= weeds after weeding

The weeding efficiency was found to be 85%.

## CONCLUSION

There existed a significant difference in the energy expenditure among the subjects for doing the same operation under similar conditions. The subjects expended more energy during manual weeding than rotary weeder operation to the tune of 55%. It is further noticed that the mean energy expenditure before 9 am was 16.63 kJ $min^{-1}$ while after 11 am it was increased to 18.92kJ $min^{-1.}$ The operations were graded as "moderately heavy". The oxygen uptake in terms of $VO_2$ max was above the accepTable workload for both operations. The present investigation concluded that the use of rotary weeder reduced the workload/drudgery of women labourers in rice farming operations and enhancing their opportunities for remunerative employment and income using women friendly equipment.

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# Performance of Rice Varieties under Aerobic Conditions in Kerala

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## INTRODUCTION

Rice deserves a special status among cereals as world's most important wetland crop. About 80% of the fresh water available is now used for irrigation; rice alone consumes more than 50 per cent of this water. By 2025, there will be 10-15 per cent reduction in water for irrigation due to unpredicted weather conditions and climate changes. The looming climate changes and global water crisis threatens the sustainability of irrigated rice, which is the Asia's biggest water user (Martin *et al* 2007). In this scenario to produce more from every drop of water and to meet the food security problems, there is a need to develop and popularize innovative water saving technologies like aerobic rice cultivation (DRR, 2010).

Aerobic rice is a new concept of growing rice in non-puddled and non flooded soil and producing yields equivalent to that of irrigated wetland rice (Singh *et al* 2008). It is a projected sustainable rice production methodology for the immediate future to address water scarcity. To make aerobic rice successful, suiTable varieties should be identified. Hence, the present investigation was carried out to identify suiTable varieties for aerobic rice production in Kerala.

## MATERIALS AND METHODS

A field experiment was conducted in the sandy loam soils of Regional Agricultural Research Station, Pattambi during kharif 2011 to identify suiTable rice varieties for aerobic cultivation. Six rice varieties *viz*., Kanchana, Matta Thriveni, Vaisakh, Samyuktha, Aiswarya and CORH-3 were evaluated on three different dates of sowing starting from 1$^{st}$ June at 20 days interval in a split plot design with three replications. The land was initially ploughed in dry condition 2 – 3 times and pulverized and brought the soil to a fine tilth. The seeds were treated with carbendazim @ 2 g/seed and soaked in water for 10 hours followed by incubation for 12 hours. The seeds were sown@80 kg/ha in lines 20 cm apart. Optimum population was maintained in all plots. Recommended doses of nitrogen, phosphorus and potash were applied as per the package of practices recommendations of Kerala Agricultural University. Observations on growth parameters and yield of rice were recorded and the data were subjected to statistical analysis.

## RESULTS AND DISCUSSION

### Yield of Rice

Aerobic rice cultivation was found to be a successful water saving technology of rice production giving an yield of 3t/ha when grown with suiTable varieties and at correct time of planting.

Among the different dates of sowing, sowing on or before the onset of monsoon was found to be the best. The crop sown on this date got established before heavy rainfall and could fully utilize the South West monsoon resulting in maximum yield (Table 1). No further irrigation was given to the crop. The crops sown later had to undergo a rainless period during the grain filling stage, resulting in poor grain filling and lower yield when compared to earlier sowing.

**Table 1**
**Growth and yield attributes of different rice varieties under aerobic rice cultivation**

| Treatments | Plant Height (cm) | Days to 50% flowering | No. of panicles/m² | 100 seed weight(g) | Grain yield(kg/ha) |
|---|---|---|---|---|---|
| **June 1st sowing** | | | | | |
| Kanchana | 86.8 | 83.3 | 417.3 | 2.89 | 3042 |
| Mattathriveni | 93.8 | 82.0 | 578.7 | 2.84 | 2646 |
| Vaisakh | 103.5 | 82. 7 | 434.7 | 2.17 | 2375 |
| Samyuktha | 103.9 | 84. 0 | 378.7 | 2.02 | 1708 |
| Aiswarya | 93.1 | 87.3 | 612.0 | 2.71 | 3104 |
| CORH-3 | 83. 7 | 78.0 | 390.7 | 2.73 | 2541 |
| **June 3rd week sowing** | | | | | |
| Kanchana | 86.8 | 78.0 | 332.0 | 2.12 | 1438 |
| Mattathriveni | 97.9 | 76.7 | 266.7 | 2.48 | 1167 |
| Vaisakh | 136.3 | 74.7 | 293.3 | 2.53 | 1458 |
| Samyuktha | 135.3 | 82.3 | 302.7 | 2.03 | 990 |
| Aiswarya | 100.4 | 82.7 | 298.7 | 2.48 | 2187 |
| CORH-3 | 94.0 | 83.7 | 360.0 | 1.95 | 2448 |
| **July 1st week sowing** | | | | | |
| Kanchana | 80.4 | 80.3 | 281.3 | 2.53 | 2667 |
| Mattathriveni | 92.1 | 79.3 | 313.3 | 2.51 | 2333 |
| Vaisakh | 130.1 | 74.7 | 289.3 | 2.51 | 2917 |
| Samyuktha | 122.3 | 77.3 | 305.3 | 2.21 | 1708 |
| Aiswarya | 104.9 | 77.7 | 293.3 | 2.39 | 2771 |
| CORH-3 | 77.4 | 84.0 | 356.0 | 2.28 | 2063 |

Significant difference in grain yield was observed among the rice varieties. Among the varieties sown on June 1st, variety Aiswarya recorded the highest yield (3104 kg/ha) followed by Kanchana (3042 kg/ha). The other varieties except Samyuktha were on par. The upland varieties Vaisakh and Samyuktha were susceptible to lodging as the plants were taller and slender. The varieties sown during June third week resulted in poor yield and among the varieties, CORH-3 recorded the highest followed by Aiswarya. When the crop was sown during July 1st week, Vaisakh and Aiswarya recorded the highest yield. Thus it was observed that Aiswarya was found to be producing a higher yield in all the three dates of sowing.

Aiswarya took more days for flowering compared to the other varieties sown on June 1st and this shows that it received more days for heat energy accumulation producing a higher yield. Same is true for CORH-3 sown during third week of June.

The number of panicles per unit area also varied significantly among the varieties. When the crop was sown during first week of June, the highest number of panicles/ $m^2$ was recorded by Aiswarya and with the second sowing CORH-3 recorded the highest number of panicles per unit area. The short duration varieties Kanchana and Matta Thriveni had less number of panicles, but the 100 seed weight was higher, resulting in better yield.

It is to be noted that the number of irrigations was meager for the aerobic rice cultivation to realize the reported yields. The number of irrigations given was nil for the first crop, two for the second crop and four for the third and this shows that the monsoon was effectively utilized during the crop season.

**Cost of Cultivation**

The cost of cultivation for aerobic rice, compared to transplanted rice is also less as it does not involve puddling and transplanting. An amount of Rs.8875 per ha could be saved in this when compared to transplanted rice.

The study showed that aerobic rice cultivation can be an alternative rice production methodology for the immediate future to address water scarcity. Sowing on or before the onset of monsoon was found to be the best season as the crop was completed without any supplemental irrigation. The variety Aiswarya was found to be performing better under aerobic conditions with more panicles per unit area and a higher yield.

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# Eco Friendly Management of Plant Diseases using *Ganoderma* sp., the Medicinal Mushroom

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## INTRODUCTION

The environmental impact of chemical pesticides is drastic. Continuous use of them is found to result in residual toxicity, environmental pollution and high cost of cultivation. Intensive use can have adverse effects on crops, beneficial organisms, predators and parasites. The most serious problem is the development of fungicide resistant strains of pathogens, leading to the failure of disease control (Waard *et al*., 1993). Over 98% of the sprayed insecticides and 95% of herbicides reach a destination other than their target species causing environmental pollution (Miller, 2004). Pesticides can contaminate unintended land and water and can contribute to air pollution (Tashkent, 1998). They are persistent soil contaminants, whose impact may endure for decades and adversely affect soil conservation. The use of pesticides decreases the general biodiversity in the soil. They are also reported to contribute to the depletion of the ozone layer leading to global warming (Reynolds, 1997).

Many alternatives are available to reduce the effects that the chemical pesticides have on the environment. Use of biocontrol agents is one alternative which can be successfully exploited in the frame work of integrated disease management (Knight *et al*., 1997) whereby the chemical use can be minimized to a need basis only. It can avoid environmental pollution as well. It, besides being cost effective is eco friendly and does not leave any residual toxicity.

Mushrooms are proved to be effective biocontrol agents besides being generally used as food and medicine. They are known to possess antifungal, antibacterial, antiviral, insecticidal and nematicidal properties (Wasser, 2002). Several compounds with important pharmaceutical properties have been isolated from medicinal mushrooms which act in modulating our immune system (Chin *et al*., 2012). Several commercial pesticidal formulations from mushrooms are presently available in the market. *Ganoderma lucidum* was discovered to be an antibacterial agent in the development of a new drug for the therapy of urinary tract infections which is caused by bacterial pathogens (Anita and Bhatt, 2012). Strobilurin from *Strobilurus tenacellus* (Anke *et al*., 1977) and Oudemansin from *Oudemansiella mucida* (Musilek *et al*., 1969) are being used as agricultural fungicides. Azoxystrobin (Sendhilvel, 2003) and Kresoxim-methyl (Ammermann *et al*., 1992) are studied to have high potential use in the control of cereal downy and powdery mildew pathogens. Both the compounds are having low mammalian toxicity and get rapidly degraded in soil making them environmentally benign. The present investigation was a novel approach to develop an environmental friendly, commercial pesticidal formulation based on *Ganoderma* sp.

## MATERIALS AND METHODS

*Ganoderma* sp. was tested for its antifungal activity against rice sheath blight pathogen by Dual culture technique (Dennis and Webster, 1971). The active metabolites from the culture filtrate of *Ganoderma* sp. were extracted using the solvent, diethyl ether and was used to develop an emulsifiable concentrate. The presence and nature of antifungal compounds were identified by thin layer chromatography (TLC) at Central Drug Research Institute, Lucknow. Different emulsifiable concentrates (10, 20, 30, 40 and 50 EC) were prepared using the recommended quantities of emulsifying agents, stabilizing agent, solvent and the diethyl ether extract. The formulation was tested against rice sheath blight pathogen both *in vitro* and under glass house conditions. Antiviral activity was tested against *Groundnut Bud necrosis virus* (GBNV) under glass house conditions.

## RESULTS AND DISCUSSION

### *In Vitro* Studies

*Ganoderma* sp. exhibited 82.59 % reduction of the mycelial growth of *Rhizoctonia solani* by dual culture technique Thin layer chromatography using n-butanol: acetic acid: water (5:1:1) showed the presence of purple and blue coloured spots revealing them to terpenes and phenols respectively which exhibited activity against the pathogen. All the emulsifiable concentrates (10, 20, 30, 40 and 50 EC) at one per cent concentration completely inhibited the mycelia growth of *R. solani* and hence 10 EC was standardized as the best concentration (Table 1). 10 EC at 0.25 per cent was the best emulsifiable concentration against *R. solani* and the formulation, Ganosol 10 EC was standardized.

**Table1**
**Effect of various concentrations of Ganosol 10 EC against R. solani**

| Formulation | *Mycelial growth of *R. solani* ($cm^2$) | Per cent reduction over control |
|---|---|---|
| 10 EC 0.1 % | 23.50 | 62.99 |
| 10 EC 0.25 % | 0.00 | 100.00 |
| 10 EC 0.50 % | 0.00 | 100.00 |
| 10 EC 0.75 % | 0.00 | 100.00 |
| 10 EC 1.00 % | 0.00 | 100.00 |
| Control | 63.50 | - |

## Glass House Studies

A glasshouse experiment was conducted to study the effect of Ganosol 10 EC on sheath blight incidence in rice. The formulation (10 EC, 0.25 %) was sprayed on rice plants as pre, simultaneous and post inoculation sprays. The pre inoculation spray of the formulation was observed to cause 63.62 per cent reduction of lesion height followed by simultaneous inoculation (Table 2) and the formulation spray, which recorded a reduction of 9.69 per cent of the lesion height over control. The antiviral effect of the formulation on *Groundnut bud necrosis virus* (GBNV) infection was studied on cowpea (local lesion host cv C-152). Simultaneous spray of the formulation and the virus inoculation was found to be the best treatment, which produced 88.39 per cent reduction of the number of lesions followed by pre inoculation spray (63.67 %) compared to the control (Table 3).

**Table 2**
**Effect of Ganosol 10 EC (0.25 %) on sheath blight of rice under glasshouse condition**

| Treatment | Concen-tration (%) | *Lesion length (cm) | *Mean lesion height (%) | Per cent reduction over control |
|---|---|---|---|---|
| Healthy control | - | 0.00 [a] | 0.00 (1.00) [a] | - |
| Inoculated control | - | 3.89 [h] | 7.12 (15.47) [h] | - |
| Ganosol 10 EC pre inoculation spray | 0.25 | 1.55 [d] | 2.59 (9.27) [c] | 63.62 |
| Ganosol 10 EC simultaneous spray and inoculation | 0.25 | 1.67 [d] | 2.87 (9.75) [d] | 59.69 |
| Ganosol 10 EC post inoculation spray | 0.25 | 1.95 [e] | 3.28 (10.43)[e] | 53.93 |
| *Ganoderma* diethyl ether extract pre inoculation spray | 0.25 | 2.17 [f] | 3.79 (11.22) [f] | 46.77 |
| *Ganoderma* diethyl ether extract simultaneous spray and inocula-tion | 0.25 | 2.33 [g] | 3.94 (11.44) [f] | 44.66 |
| *Ganoderma* diethyl ether extract post inoculation spray | 0.25 | 2.39 [g] | 4.32 (11.99) [g] | 39.33 |
| Carbendazim pre inoculation spray | 0.25 | 1.00 [b] | 2.42 (8.95) [bc] | 66.01 |
| Carbendazim simultaneous spray and inoculation | 0.25 | 1.20 [c] | 2.39 (8.89) [b] | 66.43 |
| Carbendazim post inoculation spray | 0.25 | 1.25 [c] | 2.40 (8.90) [b] | 66.29 |

** Mean of three replications, Means with in the column followed by same letter are not significantly different (P=0.05) by Duncan's Multiple Range Test, Figures in parentheses are arcsine transformed values*

**Table 3**
**Antiviral activity of Ganosol 10 EC (0.25 %) on Groundnut bud necrosis virus (GBNV)**

| Treatment | Concentration (%) | Number of plants observed | *Number of lesions | *Average number of lesions | Per cent reduction over control (%) |
|---|---|---|---|---|---|
| Healthy control | - | 5 | 0 | 0 | 0 |
| Inoculated control | - | 5 | 267 | 53.4 | 0 |
| 10 EC pre inoculation spray | 0.25 | 5 | 97 | 19.4 | 63.67 |
| 10 EC simultaneous spray and inoculation | 0.25 | 5 | 31 | 6.2 | 88.39 |
| 10 EC post inoculation spray | 0.25 | 5 | 237 | 47.4 | 10.67 |

**Mean of three replications, each replication of five plants, two leaves per plant, Means with in the column followed by same letter are not significantly different (P=0.05) by Duncan's Multiple Range Test*

The present study proves that mushrooms can be used as an alternative to chemical pesticides where by environmental pollution can be reduced to a considerable limit. They are proved to exhibit antagonistic effect against human pathogens. In the field of agriculture also, research works carried out with some selected mushrooms have demonstrated their possible effects in controlling phytopathogens. Badalyan *et al*. (2002) established the antagonistic activity of 17 species of mushrooms all of which significantly inhibited the mycelial growth of four phytopathogenic fungi. Thus

Terpenes and phenols were identified to be present in the culture filtrate of *Ganoderma* sp, which exhibited the antifungal effect. Rajasekaran and Kalaimakal (2011) reported that the extracts of *Ganoderma lucidum* contain phenols, flavonoids and ascorbic acid, which confirms this result. The presence of inhibitory substance in the culture broth of *Lentinus edodes* against *Aspergillus ochraceus* after fractionating on TLC was also observed by Komemushi *et al*. (1995). Miyahara *et al*. (1987) isolated triterpene alcohol, triterpene aldehyde and ganoderic acid from the fruiting bodies of *Ganoderma lucidum* and their structures were identified by 13C- NMR and mass spectra which strengthens the results of the present study.

A number of pesticides have been produced from different mushrooms such as *Strobilurus tenacellus, Oudemaniella mucida, and drugs from Lentinus edodes*, *Tremetes versicolor*, *Ganoderma lucidum etc*. from fruiting bodies, mycelia and residual culture broth. These compounds have low mammalian toxicity and a benign environmental profile. In the present study, the formulated product of *Ganoderma* sp was found to be effective against rice sheath blight disease and *Groundnut bud necrosis virus* in cowpea which can be used as an alternative to chemical pesticides reducing environmental toxicity.

## CONCLUSION

Thus the present investigation was a novel approach in developing an environment friendly commercial pesticidal formulation based on the mushroom *Ganoderma* sp. This proves that mushrooms can be a ready source of antimicrobial metabolites which can be formulated and commercialized on a large scale. These metabolites, if commercialized can protect the farming community from the risk of environmental pollution and residual toxicity which are the harmful effects of chemical pesticides.

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# Variability in Flowering and Seeding Behaviour of Neelayamari (*Indigofera tinctoria* L.) Accessions Under Open and Shaded Conditions

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## INTRODUCTION

*Indigofera tinctoria* L. commonly known as Neelayamari in Malayalam, Indian indigo in English and Neelini/ Neelika/ Renjini in Sanskrit is a medicinally as well as commercially useful leguminous plant. It belongs to the family Leguminosae/ Fabaceae and subfamily Papilionoideae. The plant is utilized in ayurveda as an important constituent in several hair growth promoting oils such as Neelibringadhikesathailam. The plant is also utilized in the treatment of hydrophobia, epilepsy, nervous disorders, bronchitis and also as external application for sores, old ulcers and haemorrhoids (Singh and Khan, 1990).

Species of flowering plants are most reliably identified by their flowers, the sexually reproductive organs. The knowledge of floral biology is a prerequisite for genetic improvement of any crop through conventional breeding. Tucker (2003) made a detailed study on the floral development in legumes. Eight commonly occurring species of *Indigofera* were identified in Eastern Nigeria by Nwachukwu and Mbagwu (2006), in which the vegetative and floral morphology characters of *Indigofera tinctoria* has been described.

The present study on variability in flowering and seeding behavior of Neelayamari accessions under open and shaded conditions has been taken up with a view to identify the accessions producing early flowering and pod set and to study the influence of light on flowering and pod set. Inter or mixed cropping in coconut gardens is very popular in important coconut growing states in India. The practice of inter/mixed cropping is followed in order to utilize the natural resources like light, soil nutrients and water efficiently. The transmission of light through the coconut canopy is one of the most important factors affecting the success of intercropping programmes. Maheswarappa and Anithakumari (2002) reported that in coconut plantations of more than 25 years old, 45-50 per cent of the sunlight is infiltrated on to grounds without interception by the coconut.

## MATERIALS AND METHODS

The study was conducted at College of Agriculture, Vellayani, Thiruvananthapuram. Seeds of thirty different accessions of *I. tinctoria* were collected from inside and outside the state. Growth and yield analysis of the accessions as pure crop in open and as an intercrop in shaded situation in a coconut garden was conducted. From the results, best 10 accessions were selected based on leaf yield and indigo content (Table 1). Selected 10 accessions were raised in replicated trial in open and under shade in coconut garden consisting of palms of 35 years of age, with three replications and at a spacing of 45 x 45 cm. Eight plants from each replication was utilised for sampling, the following observations were taken and the mean value recorded.

1. Number of days for flowering: Total number of days required for commencing flowering from the date of sowing in fifty per cent of plants in a plot was recorded in each accession.
2. Total number of flowers produced per plant: The total number of flowers produced per plant was counted and recorded.
3. Percentage of pod set: The total number of pods produced in an inflorescence in each replication in an accession was noted in the observational plants. The percentage of pod set was calculated using the total number of flowers produced per inflorescence.
4. Number of days for seed set: Total number of days required for 50 per cent of plants in a plot to attain seed set from the date of sowing was recorded in each accession.
5. Number of days for seed maturation: Total number of days required for 50 per cent of plants in a plot to attain seed maturation from the date of sowing was recorded in each accession.

**Table 1**
**Particulars of *Indigofera tinctoria* accessions**

| Sl. No. | Accession No. | Source |
|---|---|---|
| 1 | IT-108 | Neyyattinkara market, Thiruvananthapuram. |
| 2 | IT-101 | AICRP on Medicinal& Aromatic plants, KAU, Thrissur. |
| 3 | IT-96 | Seed Bank, TBG&RI, Palode, Thiruvananthapuram. |
| 4 | IT-114 | Pankajakasthuri, Thiruvananthapuram. |
| 5 | IT-106 | University of Agricultural Sciences, Bangalore. |
| 6 | IT-104 | Vrikshabandhu Social Forestry Club, Pala, Kottayam. |
| 7 | IT-105 | Aryavaidyasala, Kottakkal, Malappuram. |
| 8 | IT-111 | Aromatic & Medicinal Plants Research Station, KAU, Odakkali. |
| 9 | IT-97 | Medicinal plant garden, TBG&RI, Palode, Thiruvananthapuram. |
| 10 | IT-99 | Thomas Mathew, Mundakkayam, Idukki. |

## RESULTS AND DISCUSSION

The data on flowering and seeding behavior of selected accessions of *I. tinctoria* are given in Table 2. Flowers of *I. tinctoria* are numerous and sessile, racemes, 5 -10 cm long with 20 to 40 flowers/ inflorescence. The corolla is pink in colour, consisting of a rounded standard petal, brownish and pubescent at the back and two wing petals adherent to the two keel petals which are greenish in colour. Pods are 2-3.2 cm long, linear, straight or slightly curved, pale greenish grey when young and dark brown on ripening with 8-12 seeds.

**Table 2**
**Flowering and seeding behaviour of selected I. *tinctoria* accessions**

| Sl. No. | Accession No. | No. of days for flowering | | No. of flowers/ inflorescence | | Total no. of flowers produced/ plant | | Percentage of pod set (%) | | No. of days for seed set | | No. of days for seed maturation | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Open | Shade | Open | Shade | Open | Shade | Open | Shade | Open | Shade | Open | Shade |
| 1 | IT- 108 | 115 | 124 | 34.82 | 22.92 | 18872.42 | 10171.67 | 21.17 | 19.33 | 139 | 148 | 237 | 252 |
| 2 | IT- 101 | 116 | 121 | 42.07 | 27.25 | 22382.17 | 10764.21 | 18.03 | 14.93 | 141 | 147 | 241 | 246 |
| 3 | IT- 96 | 111 | 120 | 37.56 | 21.08 | 20825.09 | 10104.04 | 19.60 | 19.88 | 136 | 144 | 236 | 242 |
| 4 | IT- 114 | 113 | 124 | 31.65 | 26.60 | 18005.50 | 9824.38 | 22.46 | 21.04 | 136 | 149 | 238 | 258 |
| 5 | IT- 106 | 114 | 126 | 35.07 | 35.56 | 14378.84 | 10016.29 | 23.78 | 16.09 | 142 | 149 | 246 | 252 |
| 6 | IT- 104 | 113 | 117 | 40.50 | 24.00 | 19542.29 | 8625.71 | 20.63 | 18.74 | 136 | 148 | 234 | 251 |
| 7 | IT- 105 | 115 | 124 | 29.13 | 34.63 | 17506.67 | 8977.13 | 21.38 | 15.44 | 142 | 152 | 244 | 260 |
| 8 | IT- 111 | 116 | 123 | 30.06 | 29.38 | 19995.50 | 10225.71 | 21.24 | 13.55 | 143 | 151 | 248 | 257 |
| 9 | IT- 97 | 112 | 126 | 30.00 | 23.22 | 12797.50 | 10545.84 | 21.55 | 20.35 | 133 | 152 | 235 | 259 |
| 10 | IT- 99 | 115 | 122 | 39.00 | 30.75 | 19261.21 | 10403.75 | 18.81 | 16.52 | 136 | 150 | 235 | 258 |

1. Number of days for flowering: Under open condition, IT-96 was found to flower earlier (111 days) than other accessions. IT-101 (116 days) and IT-111 (116 days) took more number of days to flower. Under shade, IT-104 flowered earlier (117 days) than the other accessions, while IT-106 (126 days) and IT-97 (126 days) were late in flowering.
2. Total number of flowers produced per plant: IT-101 produced more number of flowers (22382.17) under open condition followed by IT-96 (20825.09). Least number of flowers (14378.84) was produced by IT-106. In shaded condition also, IT-101 produced more number of flowers (10764.21) followed by IT-97 (10545.84). Lowest number of flowers (8625.71) was produced by IT-104.

3. Percentage of pod set: Highest percentage of pod set (23.78%) was recorded in open condition by IT-106 followed by IT-114 (22.46%). Lowest value (18.03%) was recorded by IT-101. Under shade, IT-114 recorded the highest percentage of pod set (21.04%) followed by IT-97 (20.35%). Percentage of pod set was least in IT-111 (13.55%).
4. Number of days for seed set: Under open condition, seed setting was earlier in IT-97 (133 days) and late in IT-111 (143 days). In shaded condition, earlier seed setting was observed in IT-96 (144 days) and late in IT-105 and IT-97 (152 days).
5. Number of days for seed maturation: Under open condition, IT-104 took 234 days for seed maturation followed by IT-97 (235 days) and IT-99 (235 days), while IT-111 took 248 days. Under shade, IT-96 recorded less number of days for seed maturation (242 days) and IT-105 recorded more (260 days).

*I. tinctoria* flowers open early in the morning, close before noon and fall in the same day. Flowering in *I. tinctoria* was observed about 111 days after sowing (DAS) to 116 DAS in open condition and about 117 DAS to 126 DAS under shade. Profuse flowering occur about 150 DAS, which was fixed as the second stage of plant growth. According to Benvenuti *et al.* (1994), shading caused species dependant delay in the onset of flowering in *Datura stramonium*. *I. tinctoria* accessions IT-101 and IT-96, which dominated in shoot and leaf yield produced more number of flowers under open condition. Early flowering and more number of flowers was obtained in IT-96 under open condition. In a study on the effect of light intensity on plant growth in *Eryngium foetidum*, a medicinal herb, Casey *et al*. (2004) reported that greatest number of flowers was obtained in 0% shade.

In *I. tinctoria*, the flower shedding percentage was high. This led to a poor pod setting percentage of 20.91 and 17.30 per cent respectively under open and shaded condition. Average number of days for pod set was 138 days in open and 148 days under shade. *I. tinctoria* pods are harvested when they turn brown. It will not split longitudinally on attaining maturity. Hence seed dehiscence does not occur. Average number of days for seed maturation was 241 DAS in open condition and 251 DAS under shade. Under open condition early seed set and seed maturation was observed in IT-97. Less pod setting percentage and delay in pod set and seed maturation was observed in shaded condition compared to open. Hence flowering behaviour in *I. tinctoria* was found better under open condition compared to shade under coconut garden. Reduced light intensity of 220 to 700 foot candles have been reported under coconut plantation by Venugopal *et al.* (2008).

**CONCLUSION**

*I. tinctoria* plants grown in open condition exhibited early flowering, more number of flowers, increased pod set percentage, early seedset and early seed maturation when compared to those under shade in coconut plantations consisting of palms of 35 years age. Increased light intensity under open condition favours flowering in *I. tinctoria* . Variation could also be observed among the accessions for these characters.

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# Evaluation of Traditional Mango (*Mangifera indica* L.) Varieties of Southern Kerala

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## INTRODUCTION

Mango (*Mangifera indica* L.) is the most important fruit crop of India and it has been cultivated in India for over 4000 years. Previously, there were vast areas of land under mango cultivation in Kerala. Vellari manga, Karpooram manga, Chenka Varikka, Moovandan, Kotookonam Varikka, Chandrakaran, Koonan, Kalkandamanga, Karakka manga, Chappikudiyan and Kilichundan are some of the traditional mango varieties of Kerala. However, due to the changes in socio-economic situation and land use pattern and the shrinking homesteads, the area under mango cultivation has been reduced. Moreover, there was a shift in the preference of people towards new varieties and grafts, which resulted in the genetic erosion of traditional mango germplasm. In southern Kerala, particularly, Thiruvananthapuram, Kollam, Pathanamthitta and Alappuzha districts, there has been more than 15 per cent reduction in area from 2000-01 to 2003-04 (FIB, 2006). Many of our traditional varieties have become extinct. The remaining few varieties are confined to homesteads and avenues. This is an alarming situation. Therefore, there is an urgent need to catalogue and conserve at least the available traditional genetic resources, which are at the verge of extinction. In the present study, an attempt has been made with the objective to characterize the traditional mango varieties of southern Kerala based on their utility.

## MATERIALS AND METHODS

Publicity about the study was given in different mass media like newspapers, television and All India Radio in order to locate the traditional mango varieties. Field visits and survey were done in order to locate the trees and to collect samples. The standard descriptor prescribed by IBPGR (1989) was used as guideline to describe the vegetative, floral and fruit characters. Fruit pulp was analysed for acidity (Ranganna (1977), ascorbic acid content (Sadasivam and Manikam, 1992), total carotenoids (Jensen , 1978), total soluble solids (TSS), total and reducing sugars and crude fibre content ( Saini *et al.*, 2001). Organoleptic evaluation was done at the laboratory level by ten judges including a group of teachers and students. The sensory analysis was done using a four point score method.

## RESULTS AND DISCUSSION

Results of the experiments on characterization of traditional mango varieties of southern Kerala are discussed below. Fifty varieties / accessions could be located and they were grouped into three as pickling (32%), Table (34%) and dual (34%) types based on the utility of the fruits. The list of mango varieties/accessions, place of collection and district were tabulated (Table 1).

Mango flowering is an important physiological event that sets the start of fruit production (Ramírez and Davenport, 2010).Varietal influence in secondary (off-season) flowering is obvious. In the present study, frequent secondary flowering was reported in Vellari type-1, Thali, Kizhakkan Thali and Ambalathara local (Table 2). Of these varieties, Vellari Type-1 has importance in pickling. Ambalathara Local has good organoleptic qualities also. Hence both are economically very important. Secondary flowering helps to get fruits during off- season.

**Table 1**
**List of traditional mango varieties/ accessions collected from southern Kerala**

| Acc. No. | Local Name | Location | District |
|---|---|---|---|
| **I** | **Pickling types** | | |
| 1 | Karutha Muvandan | Mavelikkara | Alappuzha |
| 2 | Natumavu Type-1 | Karunagapally | Kollam |
| 3 | Vellari Type-1 | Kalliy-oor | Thiruvananthapuram |
| 4 | Kalkanda Vellari | Manacaud | Thiruvananthapuram |
| 5 | Vazhapazhithi | Kalliyoor | Thiruvananthapuram |
| 6 | Pulichi | Plamoottukada | Thiruvananthapuram |
| 7 | Natumavu Type-2 | Eara | Alappuzha |
| 8 | Chadayamangalam Local | Chadayamangalam | Kollam |
| 9 | Komanga | Vallikkal | Pathanamthitta |
| 10 | Puliyan | Cherthala | Alappuzha |
| 11 | Natumav Type-3 | Parakode | Pathanamthitta |
| 12 | Manacaud Local-1 | Manacaud | Thiruvananthapuram |
| 13 | Kalluketty | Vayalar | Alappuzha |
| 14 | Natumav Type-4 | Mavelikkara | Alappuzha |
| 15 | Natumavu Type-5 | Vayalar | Alappuzha |
| 16 | Eara Local | Eara | Alappuzha |
| **II** | **Table types** | | |
| 17 | Muthalamookkan | Karunagapally | Kollam |
| 18 | Nedungolan | Chadayamangalam | Kollam |
| 19 | Vellari Type-2 | Paripally | Kollam |
| 20 | Kolambi | Chadayamangalam | Kollam |
| 21 | Perakka manga | Eara | Alappuzha |
| 22 | Kasthuri | Kalliyoor | Thiruvananthapuram |
| 23 | Inamanga | Varkala | Thiruvananthapuram |

| | | | |
|---|---|---|---|
| 24 | Panchasara Varikka | Plamoottukada | Thiruvananthapuram |
| 25 | Kappa manga | Adoor | Pathanamthitta |
| 26 | Kandiyoor Local | Kandiyoor | Alappuzha |
| 27 | Thenga manga | Chiranikkal | Pathanamthitta |
| 28 | Mylapore manga | Plamootukada | Thiruvananthapuram |
| 29 | Kolimanga | Mavelikkara | Alappuzha |
| 30 | Kundara manga | Thykkal | Alappuzha |
| 31 | Neendakara manga | Cherthala | Alappuzha |
| 32 | Neenda Karpooram | Parakode | Pathanamthitta |
| 33 | Karpooram manga | Eara | Alappuzha |
| **III** | **Dual types** | | |
| 34 | Cheriya Kilichundan | Chadayamangalam | Kollam |
| 35 | Valiya Kilichundan | Karunagapalli | Kollam |
| 36 | Velutha Muvandan | Eara | Alappuzha |
| 37 | Kotookonam Varikka | Vellayani | Thiruvananthapuram |
| 38 | ChampaVarikka | Ambalathara | Thiruvananthapuram |
| 39 | Kallu Varikka | Vellayani | Thiruvananthapuram |
| 40 | Vellamkolli | Karunagapally | Kollam |
| 41 | Vellayani Local | Vellayani | Thiruvananthapuram |
| 42 | Thali | Manacaud | Thiruvananthapuram |
| 43 | Karpoora Varikka | Plamoottukada | Thiruvananthapuram |
| 44 | Kotamanga | Cherthala | Alappuzha |
| 45 | Karimbu mavu | Parakode | Pathanamthitta |
| 46 | Mavelikkara Local | Mavelikkara | Alappuzha |
| 47 | Kizhakkan Thali | Paripally | Kollam |
| 48 | Ponnadan manga | Cherthala | Alappuzha |
| 49 | Manacaud Local-2 | Manacaud | Thiruvananthapuram |
| 50 | Ambalathara Local | Ambalathara | Thiruvananthapuram |

**Table 2**
**Flowering behaviour of the traditional mango varieties/ accessions**

| | Class | Pickling | Table | Dual | Total |
|---|---|---|---|---|---|
| **Season of flowering** | Early | 7(43.75 %) | 5(29.41 %) | 10(58.82 %) | 22(44.00 %) |
| | Intermediate | 9(56.25 % ) | 12(70.59%) | 7(41.18 %) | 28(56.00%) |
| | Late | 0 | 0 | 0 | 0 |
| **Regularity of flowering** | Regular | 13(81.25 %) | 14(82.35%) | 15(88.24%) | 42(84.00 %) |
| | Intermediate | 3(18.75%) | 2(11.76%) | 2(11.76%) | 7(14.00 %) |
| | Irregular | 0 | 1(5.88%) | 0 | 1(2.00%) |
| **Secondary flowering** | Rare | 13 (81.25 %) | 16 (94.12 %) | 13 (76.47 %) | 42 (84.00 %) |
| | Intermediate | 2(12.5%) | 1 (5.88%) | 1(5.88%) | 4 (8.00 %) |
| | Frequent | 1 (6.25%) | 0 | 3(18.75%) | 4 (8.00 %) |

The composition of mango fruit in general differed with cultivar (Table 3).

**Table 3**
**Fruit quality characters of the traditional mango varieties/ accessions**

| Acc. No. | TSS(⁰Brix) | Carotenoids (mg/100g) | Vitamin C (mg/100g) | Titrable acidity (%) | Crude fibre (%) | Total sugars (%) | Reducing sugars (%) |
|---|---|---|---|---|---|---|---|
| **I Pickling types** | | | | | | | |
| 1 | 12.71 | 1.66 | 18.75 | 1.08 | 0.89 | 6.06 | 1.54 |
| 2 | 13.77 | 0.55 | 68.75 | 1.66 | 1.14 | 6.90 | 2.27 |
| 3 | 11.69 | 0.32 | 45.00 | 0.32 | 0.65 | 5.06 | 3.33 |
| 4 | 10.69 | 0.36 | 42.00 | 1.20 | 0.82 | 4.90 | 1.60 |
| 5 | 9.69 | 1.46 | 9.52 | 0.32 | 0.75 | 5.33 | 2.94 |
| 6 | 15.00 | 0.69 | 46.88 | 1.15 | 2.80 | 10.81 | 5.00 |
| 7 | 8.77 | 0.5 | 119.05 | 1.40 | 1.40 | 2.90 | 1.36 |
| 8 | 11.69 | 0.34 | 90.72 | 0.18 | 0.92 | 3.36 | 2.11 |
| 9 | 13.78 | 0.87 | 36.92 | 1.28 | 0.67 | 5.55 | 1.58 |
| 10 | 10.69 | 0.58 | 23.81 | 0.83 | 1.20 | 3.90 | 1.50 |
| 11 | 11.69 | 0.56 | 12.31 | 0.13 | 2.92 | 7.27 | 1.98 |
| 12 | 12.77 | 1.38 | 37.50 | 0.42 | 1.20 | 5.97 | 2.08 |
| 13 | 11.77 | 0.59 | 66.67 | 2.80 | 0.90 | 2.31 | 0.90 |
| 14 | 12.77 | 0.21 | 47.62 | 0.57 | 0.82 | 2.01 | 1.20 |
| 15 | 9.69 | 0.28 | 46.20 | 2.20 | 1.50 | 3.50 | 1.70 |
| 16 | 14.73 | 0.68 | 24.62 | 4.03 | 0.58 | 5.33 | 1.63 |
| Average | 11.99 | 0.69 | 46.02 | 1.22 | 1.188 | 5.07 | 2.05 |
| SE | 0.45 | 0.11 | 7.25 | 0.26 | 0.18 | 0.55 | 0.25 |
| **II Table type** | | | | | | | |
| 17 | 14.61 | 0.98 | 9.23 | 0.30 | 0.61 | 9.11 | 3.45 |
| 18 | 19.00 | 1.10 | 12.50 | 0.12 | 0.40 | 13.90 | 4.10 |
| 19 | 16.61 | 1.88 | 24.62 | 0.26 | 0.47 | 14.29 | 2.50 |
| 20 | 17.78 | 2.69 | 25.00 | 0.96 | 0.63 | 12.69 | 5.71 |
| 21 | 25.71 | 3.84 | 33.33 | 0.19 | 0.52 | 18.40 | 6.10 |
| 22 | 12.18 | 1.29 | 12.50 | 0.40 | 0.90 | 10.26 | 3.64 |
| 23 | 18.66 | 0.88 | 31.25 | 0.26 | 0.60 | 15.10 | 3.08 |
| 24 | 19.79 | 1.58 | 9.52 | 0.38 | 0.76 | 6.45 | 3.45 |
| 25 | 13.78 | 1.12 | 28.57 | 1.00 | 1.61 | 6.56 | 1.69 |
| 26 | 14.77 | 1.50 | 62.50 | 0.26 | 0.45 | 6.15 | 3.85 |
| 27 | 15.69 | 1.36 | 24.62 | 0.23 | 0.50 | 11.11 | 4.17 |
| 28 | 15.78 | 1.69 | 23.80 | 0.13 | 2.40 | 9.10 | 5.41 |
| 29 | 15.67 | 0.62 | 33.33 | 0.52 | 1.30 | 8.70 | 2.60 |
| 30 | 15.78 | 1.38 | 9.52 | 0.13 | 0.88 | 8.82 | 3.17 |
| 31 | 15.78 | 0.98 | 3.08 | 0.25 | 0.64 | 8.88 | 4.17 |
| 32 | 18.66 | 1.11 | 12.31 | 0.20 | 0.60 | 22.20 | 5.40 |
| 33 | 19.71 | 1.25 | 31.20 | 0.41 | 0.46 | 13.70 | 4.33 |
| Average | 17.06 | 1.49 | 22.76 | 0.35 | 0.81 | 11.50 | 3.93 |
| SE | 0.75 | 0.19 | 3.45 | 0.06 | 0.13 | 1.06 | 0.29 |
| **III Dual types** | | | | | | | |
| 34 | 17.78 | 1.83 | 18.75 | 0.19 | 0.71 | 10.26 | 3.20 |
| 35 | 15.70 | 1.45 | 12.50 | 0.72 | 0.80 | 9.09 | 2.82 |
| 36 | 19.71 | 2.65 | 31.20 | 0.31 | 0.75 | 13.92 | 3.70 |
| 37 | 17.68 | 0.69 | 37.10 | 0.32 | 0.97 | 10.88 | 3.77 |
| 38 | 14.67 | 1.88 | 12.31 | 0.35 | 0.59 | 11.11 | 3.03 |
| 39 | 13.67 | 1.12 | 12.50 | 0.68 | 1.00 | 7.41 | 3.64 |
| 40 | 12.77 | 1.36 | 37.50 | 0.25 | 0.76 | 5.63 | 3.33 |
| 41 | 13.77 | 0.67 | 61.90 | 0.62 | 0.80 | 7.20 | 2.00 |
| 42 | 12.71 | 0.93 | 57.14 | 0.50 | 0.47 | 8.08 | 2.33 |
| 43 | 20.66 | 7.97 | 24.62 | 1.20 | 0.84 | 13.79 | 2.67 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 44 | 14.78 | 0.73 | 23.50 | 0.40 | 0.75 | 7.90 | 3.10 |
| 45 | 12.18 | 0.80 | 46.88 | 0.45 | 0.67 | 6.25 | 2.30 |
| 46 | 15.78 | 0.96 | 71.43 | 0.70 | 1.30 | 6.67 | 2.78 |
| 47 | 13.77 | 1.10 | 57.14 | 0.66 | 0.79 | 6.67 | 1.87 |
| 48 | 13.77 | 1.20 | 12.40 | 0.58 | 0.70 | 7.17 | 3.17 |
| 49 | 14.73 | 2.00 | 12.31 | 0.50 | 0.97 | 7.89 | 3.90 |
| 50 | 17.78 | 0.96 | 27.69 | 0.35 | 0.54 | 13.40 | 5.33 |
| Average | 15.41 | 1.66 | 32.76 | 0.52 | 0.79 | 9.02 | 3.11 |
| SE | 0.61 | 0.42 | 4.78 | 0.06 | 0.05 | 0.38 | 0.20 |
| Overall Average | 14.88 | 1.29 | 33.60 | 0.69 | 0.92 | 8.60 | 3.05 |
| SE | 0.46 | 0.17 | 3.29 | 0.10 | 0.08 | 0.59 | 0.18 |

There was remarkable variability in acidity among the varieties. The varieties, Nedungolan, Perakka manga, Chadayamangalam Local, Natumav Type-3, Mylapore manga, Kundara manga, and Cheriya Kilichundan can be designated as varieties with less acidity. Varieties containing high ascorbic acid content were Natumav Type-1, Natumav Type-2, Chadayamangalam Local, Kalluketty, Kandiyoor Local, Vellayani Local, Thali manga, Mavelikkara Local and Kizhakkan Thali. Mango is the richest source of carotenoids among the fruits. In the present study, we could identify a variety, Karpoora Varikka having carotenoid content (7.97mg/100g) higher than most of the leading superior varieties. Perakka manga (3.84), Kolambi (2.69), Velutha Muvandan (2.65) and Manacaud Local-2 (2.00) are some of the varieties rich in carotenoid content. The varieties varied greatly in TSS content. TSS ranged from 8.77 (Natumav Type-2) to 25.71 $^{0}$B (Perakka manga). Perakka manga and Karpoora Varikka can be recommended as varieties having high TSS. Among the fifty mango varieties/ accessions analysed, high content (>4.3%) of reducing sugar was detected in Pulichi, Kolambi, Perakka manga, Mylapore manga, Neenda Karpooram, Karpooram manga and Ambalathara Local.

Variability in fibre content was observed among varieties. The varieties, Nedungolan, Vellari Type-2, Perakka manga, Inamanga, Neenda Karpooram, Kandiyoor Local, Karpooram manga and Ambalathara Local recorded less fibre content. Of the three utility groups, the average crude fibre content was the highest for pickling followed by the Table types.

The overall acceptability depends on the concentration of particular components, nutritional and other hidden attributes of food and its palatability or sensory quality. The variety scored as the best in overall acceptability was Perakka manga, followed by Karpooram manga (Fig.1). Perakka manga, Karpooram manga, Vellari Type-2, Nedungolan, Ambalathara Local, Kotookonam Varikka, Neenda Karpooram, Kandiyoor Local, Muthalamookan, Velutha Muvandan and Inamanga ranked the top positions in overall acceptability. These can be recommended as excellent edible varieties suited for cultivation in tropical environment. Similarly, the physico-chemical quality characteristics of some mango cultivars growing under a Mediterranean subtropical climate in Spain were assessed (Pleguezuelo *et al.*, 2012). Osteen and Tommy Atkins, the cultivars with high-quality fruits were recommended for their performance and sustainable yield in subtropical marginal environment.

Kotookonam Varikka, Kallu Varikka, Champa Varikka, Kasthuri and Vellari Type-1 were more prevalent in Thiruvananthapuram district. Muvandan was distributed mainly in Alappuzha district. Natumanga types were more in Pathanamthitta district. Nedungolan (Karpooram) was distributed from Nilamel, Kilimanoor and nearby regions (Thiruvananthapuram district) up to Chadayamangalam. Mylapore manga is mostly located in southern parts of Thiruvananthapuram district. Vellari Type-2 is found more in Varkala, Parippally and Chadayamangalam regions. Kolambi manga is located mostly Kollam district (Chadayamangalam and near by places). Muthala mookan was mostly located in Chettikulangara, Karunagapalli (Kollam district) and Cherthala (Alappuzha). Mavelikkara and Cherthala of Alappuzha district can be considered as hot spot areas for traditional mangoes in south Kerala, as many of the varieties are concentrated in the area.

Traditional mango varieties flowering throughout the year and those with desirable characters like high TSS, reducing sugar, Vitamin c and carotenoids which can be recommended for growing in tropical environment could be identified by this study.

## CONCLUSION

Considering the importance of these traditional mango varieties possessing rare and desirable qualities and their adaptability to our environmental conditions, they should be conserved. Kerala Agricultural University and the state Department of Agriculture have been promoting the multiplication of local varieties through grafting. More concerted efforts to exploit the genes coding for desirable trait in these genetic resources which are at the verge of extinction through biotechnological interventions is the need of the hour.

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***Young Scientist Award Presentations***

# Aromatic Rices Adapted to Unique Environmental Conditions of Wayanad District

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## INTRODUCTION

Wayanad district in Kerala, having peculiar and unique environmental, geographical and ecological conditions, is suited to the cultivation of aromatic rice. The high altitude (varying from 700-2100m above mean sea level) and the low temperature ($19^0$C to $30^0$C) prevailing in Wayanad are the most suited environmental factors favouring the cultivation of aromatic rice. Wayanad district is gifted with unique germplasm of non-Basmati traditional aromatic fine rice cultivars which include *Gandhakasala, Jeerakasala, Velumbala, Chomala, Kayama, Kothampalarikkayama* and *Pookkilathari*. The aroma in these cultivars is best developed when cultivated during the *Nancha (Kharif)* season when the flowering coincides with ideal low temperature. These aromatic rice cultivars are conserved and cultivated mainly by tribal communities. '*Gandhakasala*' and '*Jeerakasala*' are the most popular traditional cultivars of this district. *Gandhakasala* rice and *Jeerakasala* rice are registered as Geographical Indications from Wayanad district in Kerala. (GOI, 2010)

The uniqueness of Wayanad aromatic rice cultivars is mainly due to the climatic and environmental conditions prevailing in Wayanad district together with the varietal characters. In spite of the market potential of these rices, only limited studies have been conducted about genetic variability and adaptability of these unique germplasm. Also, there is depletion in the area of cultivation of these cultivars leading to the loss of genetic diversity of this valuable germplasm. Hence a study was undertaken to characterize the most popular aromatic rice cultivars of Wayanad district and to find the most suited genotypes for the unique environmental conditions prevailing in Wayanad district.

## MATERIALS AND METHODS

An initial survey was conducted and seed samples of 35 *Gandhakasala* and two *Jeerakasala* types were collected from various parts of the Wayanad district. From these samples, based on grain characteristics, eight *Gandhakasala* genotypes (GT

1 – GT 8) and one *Jeerakasala* genotype (JT 9) were selected and compared with non aromatic check variety, Aiswarya. Field experiments related to the investigation were laid out at Regional Agricultural Research Station, Ambalavayal in Wayanad district during *Kharif* 2011, using organic way of cultivation. Morphological observations were recorded at different stages of plant growth and grains were collected for biochemical and cooking quality analysis.

## RESULTS AND DISCUSSION

*Gandhakasala* and *Jeerakasala* genotypes are cultivated in an area of 327ha and 22ha respectively. *Gandhakasala* is mainly cultivated in Panamaram, Thirunelly and Noolpuzha panachayats of Wayanad district having an area of 78 ha, 60 ha and 38 ha respectively. *Jeerakasala* is cultivated in small patches in different panchayat. From the different localities, 35 seed samples of *Gandhakasala* and two samples of *Jeerakasala* were collected. These samples revealed high level of variability with respect to various grain characters especially for apiculus colour. The samples collected had admixtures of grains having pigmented apiculus (Fig. 1) that indicated the possibility of natural out-crossing of these unique genotypes with other traditional non aromatic genotypes cultivated in Wayanad district. This had resulted in loss of varietal purity of these aromatic genotypes resulting in low aroma and different grain characters.

**Fig. 1**
**Sample containing admixtures of pigmented apiculus grains**

Based on grain characters, these genotypes were characterized for grain shape, lemma palea colour and apiculus colour. Samples with uniform short grains, white kernel colour, golden colour for lemma and palea and straw colour for apiculus were selected as *Gandhakasala* types and samples with slightly elongated grains with partial awns, white kernel colour and golden colour for lemma and palea were selected as *Jeerakasala* type for the present study.

### Morphological Characters

The selected samples were morphologically characterized and the results are presented in Table 1 and 2.

**Table 1**
**Mean performance of aromatic genotypes in Wayanad district during kharif, 2011**

| Sl. No | Genotypes | Seedling height (cm) | Leaf length (cm) | Culm number | Culm length (cm) | Number of productive tillers | Panicle length (cm) | Number of spikelets per panicle | Days from seeding to harvest |
|---|---|---|---|---|---|---|---|---|---|
| 1 | GT 1 | 27.15[bc] | 45.99[bcd] | 6.46[f] | 101.56[a] | 6.46[d] | 26.63[a] | 129.90[d] | 180.0[b] |
| 2 | GT 2 | 26.46[bc] | 45.54[bcd] | 8.25[b] | 97.183[a] | 8.05[b] | 24.27[ab] | 126.30[d] | 180.0[b] |
| 3 | GT 3 | 27.17[bc] | 42.05[de] | 7.00[def] | 87.233[b] | 7.00[cd] | 27.10[a] | 145.37[cd] | 180.33[b] |
| 4 | GT 4 | 27.03[bc] | 52.33[a] | 6.59[ef] | 99.747[a] | 6.55[d] | 26.20[a] | 181.81[abc] | 179.67[b] |
| 5 | GT 5 | 26.18[bc] | 42.89[cde] | 7.43[cd] | 95.273[a] | 7.43[bc] | 24.00[ab] | 195.63[ab] | 180.00[b] |
| 6 | GT 6 | 25.18[c] | 41.57[de] | 7.21[de] | 98.300[a] | 6.77[cd] | 22.13[b] | 157.84[bcd] | 179.67[b] |
| 7 | GT 7 | 26.09[c] | 46.50[bc] | 6.64[ef] | 95.967[a] | 6.34[d] | 24.70[ab] | 216.13[a] | 179.33[b] |
| 8 | GT 8 | 25.73[c] | 40.82[e] | 7.13[de] | 84.227[b] | 6.93[cd] | 24.66[ab] | 124.13[d] | 179.00[b] |
| 9 | JT 9 | 29.31[ab] | 48.98[ab] | 9.34[a] | 88.243[b] | 9.27[a] | 25.87[a] | 187.47[ab] | 182.67[a] |
| 10 | Check | 30.80[a] | 24.24[f] | 7.95[bc] | 48.05[c] | 7.95[b] | 16.38[c] | 64.07[e] | 131.00[c] |
| **Mean** | | **27.11** | **43.06** | **7.39** | **89.58** | **7.28** | **24.19** | **152.92** | **175.17** |

**Table 2**
**Mean performance of grain yield and grain characters of aromatic genotypes in Wayanad district during *kharif*, 2011**

| Sl. No | Genotypes | Grain yield (kg/ha) | Straw yield (kg/ha) | Kernel elongation ratio | Volume expansion ratio | Total carbohydrate (%) | Amylose content (%) | Aroma |
|---|---|---|---|---|---|---|---|---|
| 1 | GT 1 | 1576.89[bc] | 3606.24[cd] | 2.04[c] | 5.62[b] | 85.23[c] | 19.04[g] | Moderate |
| 2 | GT 2 | 1077.09[e] | 4776.26[a] | 2.49[a] | 5.33[c] | 86.63[b] | 26.36[a] | Moderate |
| 3 | GT 3 | 1642.50[b] | 5043.73[a] | 2.23[abc] | 5.62[b] | 73.51[g] | 20.28[d] | Moderate |
| 4 | GT 4 | 1308.89[bcde] | 3801.17[bcd] | 2.45[ab] | 5.30[c] | 72.08[h] | 17.82[j] | Moderate |
| 5 | GT 5 | 1122.77[de] | 2923.97[e] | 2.04[c] | 5.70[b] | 82.07[e] | 19.11[f] | Slight |
| 6 | GT 6 | 1366.45[bcde] | 4093.56[bc] | 2.02[c] | 5.37[c] | 72.04[h] | 18.61[h] | Moderate |
| 7 | GT 7 | 1220.00[cde] | 3216.37[de] | 2.15[bc] | 5.41[c] | 64.89[i] | 17.92[i] | Moderate |
| 8 | GT 8 | 1490.56[bcd] | 3947.10[bc] | 2.12[c] | 5.21[c] | 76.63[f] | 20.16[e] | Moderate |
| 9 | JT 9 | 2735.22[a] | 4483.57[ab] | 1.71[d] | 6.07[a] | 84.66[d] | 21.56[c] | Moderate |
| 10 | Check | 3055.55[a] | 3216.38[de] | 1.95[cd] | 5.78[b] | 87.09[a] | 21.66[b] | Moderate |
| **Mean** | | **1659.59** | **3910.83** | **2.12** | **5.54** | **78.48** | **20.25** | |

## *Plant architecture*

In general aromatic genotypes showed lesser seedling height than check variety. This indicated that these genotypes had less seedling vigour and hence had less competing ability with weed flora in the initial growth phase. The seedling height of genotypes was found to vary from 25.18 cm to 30.80 cm. The non aromatic check variety Aiswarya (30.80 cm) and JT 9 (29.31 cm) recorded the highest seedling height. In general, the aromatic genotypes had longer droopy leaves than check variety which could cause mutual shading. This in turn would have reduced the photosynthetic efficiency and thus would have contributed to reduced grain yield in aromatic types. The leaf length ranged between 24.24 cm (Aiswarya) to 52.33 cm (GT 4).

The check variety Aiswarya was having shortest leaves of 24.24 cm. *Jeerakasala* type exhibited a higher culm number of 9.34. The high culm length of aromatic types could make them more prone to lodging at maturity. The check variety Aiswarya recorded culm length of 48.05 cm and the aromatic types recorded the culm length of 94.19 cm. As in the case of culm number, *Jeerakasala* type produced higher number of productive tillers per hill compared to *Gandhakasala* types and check variety. In general, aromatic genotypes showed less variability for panicle length. Aromatic types recorded more panicle length than the non aromatic check variety. Panicle length ranged from 16.38 cm (Aiswarya) to 27.10 cm (GT 3). In general aromatic types recorded more number of spikelets per panicle than check variety. The mean number of spikelets per panicle was 183.54.

***Phenological characters***

Days from seeding to harvest showed less variability among the aromatic genotypes. The aromatic genotypes recorded more days to 50 per cent flowering compared to check variety Aiswarya. The days to 50 per cent flowering for the aromatic genotypes were more reaching to the maximum of 182.67 days for *Jeerakasala* type.

***Yield***

*Jeerakasala* type recorded comparable yield with that of Aiswarya whereas *Gandhakasal*a types recorded significantly lesser yield than Aiswarya. The mean grain yield ranged from 1077.87 kg/ha (GT 2) to 3055.55 kg/ha (Aiswarya). In general, the grain yield of *Jeerakasala* type was higher than *Gandhakasal*a types. The mean performance of grain yield is presented in Fig. 2. The straw yield was more for aromatic genotypes than the check variety. The higher culm number and culm length in aromatic types resulted in higher straw yield. Straw yield ranged from 2923.98 kg/ha for GT 5 to 5043.73 kg/ha for GT 3.

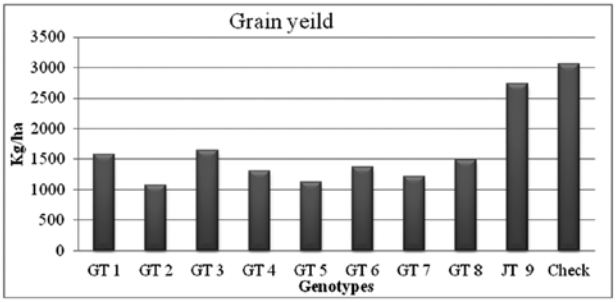


**Fig. 2**
**Mean performance of grain yield for aromatic genotypes**

***Cooking and Biochemical Qualities***

The kernel appearance, size, shape, aroma, nutritional value and cooking characteristics are important for judging the quality and preference of aromatic rice.

Aroma is one of the most valuable traits in grain quality of specialty rices and it helps to fetch a higher premium prize in the market. The biochemical basis of aroma was identified as 2-acetyl-1-pyrroline which is the major volatile component associated with aroma. It was also reported that aroma was best developed when aromatic rice varieties were grown in areas where the weather was cooler during maturity. At Wayanad district, all genotypes except GT 5 were found to be moderately aromatic.

Kernel Elongation Ratio (KER) is the ratio of average kernel length after cooking to average kernel length before cooking. Volume Expansion Ratio (VER) `is the ratio of volume of cooked rice to that of raw rice. Lengthwise expansion without increase in girth is considered most desirable trait in high quality rices. In the study, *Gandhakasala* types showed high KER compared to *Jeerakasala* type and check variety. KER ranged from 1.7 (JT 9) to (2.49) in GT 2 at Wayanad. *Jeerakasala* type had high VER compared to *Gandhakasala* types and check variety.VER ranged from 5.21 (GT 8) to 6.07 (JT 9). In general, *Gandhakasala* types had high KER and low VER, which is one of the preferred qualities of aromatic rices.

Starch is the major component of rice endosperm and composed of linear glucan and amylose and highly branched glucan and amylopectin. In general total carbohydrate content was low for aromatic genotypes than the check varieties. For Aiswarya, total carbohydrate content was 87.09 per cent and mean total carbohydrate content for aromatic types was 77.52 per cent. Amylose content of rice endosperm determines its cooking quality and influences cooked rice firmness. Cooked rice becomes moist and sticky due to low amylose content. Intermediate amylose contents (20-25%) in rice varieties are preferred in most of the rice growing areas of the world since cooked rice with intermediate amylose content becomes moist, tender, non sticky and does not harden upon cooking. In the present study at Wayanad district GT 3, GT 8 and JT 9 expressed intermediate amylose content adding to consumer preference. Amylose content ranged from 17.82 per cent (GT 4) to 26.36 per cent (GT 2).

The genotypes JT 9, GT 3 and GT 8 showed better performance based on the grain yield, straw yield, cooking and biochemical characters. These three genotypes expressed intermediate amylose content and moderate aroma which were the preferred qualities in specialty rice preparations. Among these three types, GT 3 was found to have better flavor, taste and appearance for cooked rice based on the organoleptic test conducted. Hence GT 3 is the best suited genotype for general cultivation in Wayanad district.

***Qualitative characters***

In general, the aromatic genotypes had well exserted panicles, fertile spikelets, moderately difficult panicle threshability, yellow stigma, straw coloured apiculus, golden coloured lemma and palea and white seed coat. *Jeerakasala* genotype showed straw coloured, short and partly awns, whereas *Gandhakasala* genotypes were awnless. The check variety Aiswarya had moderately well exserted panicles, highly fertile spikelets, intermediate threshability, white stigma, straw colour for apiculus, awnless grains, straw colour for lemma and palea and red seed coat colour. Grains and kernels of *Jeerakasala* and *Gandhakasala* are presented in Fig. 3.

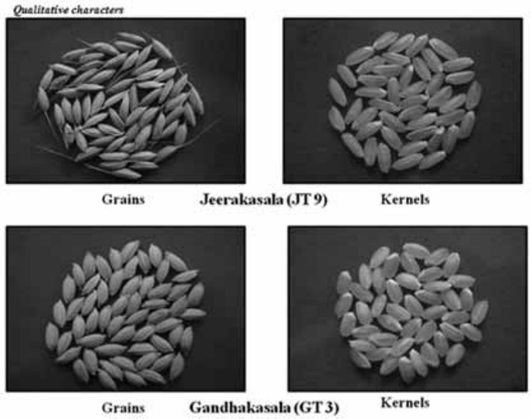


**Fig. 3**
**Grains and kernels of *Jeerakasala* and *Gandhakasala***

## CONCLUSION

The present study revealed that environmental conditions in Wayanad are highly suited for the cultivation of aromatic genotypes. All the genotypes except one produced moderate aroma, which is the most preferred grain character for aromatic rices. Amylose content and other grain characters were also best developed in aromatic types cultivated in Wayanad district.

From the seed samples collected it was revealed that most of cultivated aromatic genotypes at Wayanad district showed low genetic purity caused by out crossing with other cultivars and this contributed to low aroma and low quality characteristics of these precious genotypes from Wayanad district. Hence it is necessary that the aromatic germplasm of this region has to be collected, conserved and improved through purification and selection and raised to varietal status through the intervention of R&D institutions. The *Jeerakasala* (JT9) and *Gandhakasala* types (GT 3 and GT 8) identified as the most promising type in the present study can be further evaluated, purified and popularized for commercial cultivation.

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# Impact of Cuelure Traps in the Reduction of Insecticide Usage in Farmers Field of Malappuram District

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## INTRODUCTION

The dipteran family Tephritidae consists of over 4000 species, of which nearly 700 species belong to Dacine fruit flies (Fletcher, 1987). A major biotic limiting factor in the cultivation of cucurbitaceous vegeTables in India is the incidence of melon fruit fly, *Bactrocera cucurbitae*. The yield loss in various cucurbitaceous vegeTables due to the melon fruit fly varies from 30-100% depending upon cucurbit species and season (Dhillon *et al.*, 2005). In bitter gourd, *Momordica charantia* and snake gourd, *Trichosanthes anguina* the melon fruit fly damage may go up to 27-89% (Lall and Sinha, 1959; Narayanan and Batra, 1960; Kushwaha et al., 1973; Gupta and Verma, 1978; Rabindranath and Pillai, 1986; Mumford, 2006). These fruit flies prefer young, green, and tender fruits for egg laying. The females lay the eggs 2 to 4 mm deep in the fruit pulp, and the maggots feed inside the developing fruits. At times, the eggs are also laid in the corolla of the flower, and the maggots feed on the flowers (Narayanan, 1953). The fruits attacked in early stages fail to develop properly, and drop or rot on the plant. Since, the maggots are concealed inside the fruits, chemical control of melon fruit fly is relatively ineffective and may lead to residual toxicity of insecticides in vegeTables (Dhillon *et al.*, 2005; Laskar and Chatterjee, 2010).

In order to overcome these problems, most of the efforts in fruit fly management have focused on mature adult through the use of bait traps (McQuate *et al.*, 2005) and cuelure (Inayatullah *et al.*, 1991). Two techniques are commonly used for the management of this pest: Bait Application Technique (BAT), in which food baits containing proteins and sugars are mixed with a small amount of insecticide to attract and kill adults; and Male Annihilation Technique (MAT), in which synthetic parapheromones, mainly cuelure (4-4 acetoxy phenyl-2-butanone), are mixed with insecticide, applied to a suiTable substrate to allow slow release, and used to selectively attract and kill male flies so that the flies cannot reproduce (Cunningham, 1989). Cue-lure traps have been used for monitoring and mass trapping of *B. cucurbitae* males (Ramsamy *et al.,* 1987; Zaman, 1995; Liu and Lin, 1993) in bitter gourd (Pawar *et al.*, 1991; Khoo and Tan, 2000, Mumford, 2006). MAT was found to be more effective than food attractant (Pawar *et al.*, 1991) and it reduces the threat to human beings and non-target organisms by direct spray of insecticides on crop (Stonehouse *et al.*, 2002).

Cucurbits are one of the major group of vegeTables grown throughout the year by vegeTable farmers of the district. Traditionally, farmers resort to weekly sprays of toxic and costly insecticides contaminating the environment as well as affecting the health of consumers. The frequent application of insecticides and the harvesting of produce without adopting the waiting period resulted in marketing of the produce laden with pesticide residues to consumers. During monsoon, when insecticide application is difficult, farmers suffer heavy losses due to this pest. Krishi Vigyan Kendra, Malappuram has initiated front line demonstrations (FLDs) and trainings (89 trainings for 4187 farmers) from 2008 onwards to popularize MAT for the management of fruit flies and this paper discuss the impact of MAT in increasing the productivity in fields of bitter gourd and snake gourd farmers and refinements carried out to make this technology more effective.

## MATERIALS AND METHODS

Plywood pieces of size 5 cm X 5 cm X 1 cm were dipped in a 10 ml mixture of ethanol (Otto Inc, Mumbai), 4-4 acetoxy phenyl-2-butanone (Spectrochem, Mumbai) and Malathion 50% EC (Jayakrishna Pesticides Pvt., Ltd) mixed in the ratio 6:4:1 (Mumford, 2006). The plywood pieces dipped in the solution was kept in air tight containers for 5 days. These pieces were then air dried for 3 days. A transparent plastic jar (500 ml) with 4 holes of size 1 cm diameter was prepared and these plywood pieces were hung inside these jars. These traps were then hung below the pandal at the initiation of flowering.

50 farmers or farmer groups participated in these demonstrations and on farm trials and they were selected for the FLDs through line departments like Department of Agriculture, VegeTable and Fruit Promotion Council Keralam and also through KVK activities. Data regarding the cultivation practices, cost of cultivation, insecticides used, no. of sprays, yield etc were collected before and after the usage of pheromone traps. Since the farmers were unable to differentiate between the insecticide and fungicide sprays they had given to their crops earlier, the total no. of pesticide spray is taken into consideration in this study. The observations were also recorded on the period of effectiveness of the traps and no. of traps required for effective reduction in pest population.

## RESULTS AND DISCUSSION

Data collected revealed that farmers were using insecticides like quinalphos, dimethoate, lambda cyhalothrin and imidacloprid for managing this pest before the adoption of MAT. The no. pesticide sprays varied from 13-23 between farmers during a cropping season and the average no. of sprays was 15.2. The cost of insecticides alone was Rs. 500/ha/spray and Rs. 2000/ha/spray was spend as labour charges for spraying. With the use of pheromone traps, farmers recorded a 75.8% reduction in fruit fly infestation. On an average 8 pesticide sprays could be avoided by the farmers

(Fig. 1), there by resulting in a saving of Rs. 20,000/ha/season (Fig. 2). After the adoption of MAT majority of the insecticide sprays were targeted for the management of sucking pests like jassids, whiteflies and aphids and against cucumber moth *Diaphania indica.*

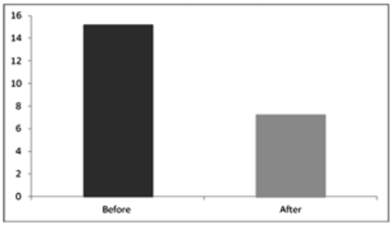


**Fig. 1**
**Reduction in the no. of insecticide sprays before and after the adoption of MAT**

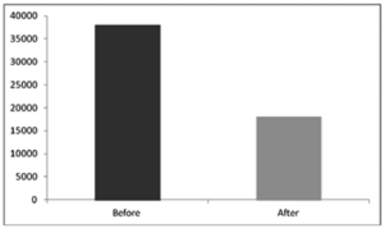


**Fig. 2**
**Reduction in the cost of plant protection before and after the adoption of MAT**

KAU, 2009 has recommended the usage of 10 traps per hectare for the management of this pest. But our trials in farmers fields has shown that an increase in the no. of traps to 15/ha. provides better reduction in pest incidence.

Other than the reduction in cost of insecticide sprays there was an increase in production of 1.32 t/ha. leading to the realization of an additional income of Rs. 25116/ha (fig 3). Earlier, during monsoon, farmers incurred huge crop losses as they were unable to take up spraying operation due to incessant rains. The usage of pheromone traps helped the farmers to do away with spraying of crops during monsoon. Vargas *et* al, 2000; IAEA, 2003; Mumford, 2006; and Khan, *et al,* 2010 has also reported the effectiveness of cuelure traps in the management of *B. cucurbitae*.

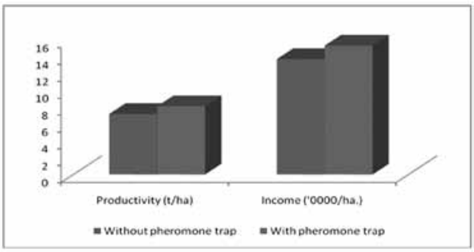


**Fig. 3**
**Increase in the productivity and income of farmers after the adoption of MAT**

The effectiveness of the traps lasted for 3 months on an average. Wetting of plywood lures in rains was found to reduce the period of effectiveness of these traps. We could overcome the wetting of the lures simply by giving a cap of inverted coconut shell over the trap and by sealing the hole on top of the trap lid.

Rakshit *et* al, 2011 studied the beneficial effects of the usage of cuelure traps in Bangladesh and concluded that net economic benefits of using cuelure to manage fruit fly infestation ranges from 2.7 million USD to 6.3 million USD over a period of

15 years and in addition to the reduced cost of pest management as well as pesticide usage, estimated benefits would be even higher if environmental and health effects due to pesticide reduction were included. This will be the same with the current study also.

**CONCLUSION**

Male annhilation technique (MAT) using cuelure traps for the management of *B. cucurbitae* is a simple, highly useful, ecofriendly and effective tool for the management of this pest. The reduction in pesticide usage will help to reduce the load of toxic insecticide residues in the produce as well as in the environment. Further studies on the ecofriendly management of sucking pests and cucumber moth will help us to further reduce the insecticide usage in bitter gourd and snake gourd.

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# Occurrence and Isolation of Organophosphorus Pesticide Degrading Bacteria from the Agricultural Soils of Thiruvananthapuram District, Kerala

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## INTRODUCTION

Chlorpyrifos, monocrotophos and quinalphos are some of the most widely and extensively used organophosphorus insecticides all over India, effective against a broad spectrum of insect pests of economically important crops. Even though most of the organophosphorus pesticides are biodegradable, large concentrations of them in soil adversely influence the growth and activity of beneficial indigenous micro organisms apart from its high mammalian toxicity. The majority of biochemical transformations in soil result from microbial activity and any compound that alters the number or activity of microbes could affect soil biochemical processes and ultimately influence soil fertility and plant growth (Cohen *et al*., 1984). At the same time it has been demonstrated that a fraction of soil biota can develop the ability to rapidly degrade certain soil applied pesticides, a phenomenon, known as enhanced or accelerated biodegradation described by Walker and Suett (1986). Among the soil microflora, bacteria are found to be most abundant with great nutritional and physiological versatility. Both co-metabolic and biomineralisation of organophosphorus compounds by isolated bacteria have been reported. Hydrolysis of organophosphorus compounds by bacteria leads to a reduction in their mammalian toxicity by several orders of magnitude (Singh and Walker., 2006). Several species of bacteria have been isolated and characterized that can degrade these compounds in liquid medium and soil. Singh *et al* (2004) separated *Enterobacter* B-14 a strain that could degrade chlorpyrifos. Li *et al* (2008) reported chlorpyrifos degrading *Stenotrophomonas* sp. from organophosphorus pesticide contaminated soil and water. Bhadbhade *et al* (2002) isolated Monocrotophos mineralizing *Pseudomonas* spp., *Arthrobacter* spp, *Bacillus megaterium* and *Pseudomonas aerugenosa*. Quinalphos resisting and degrading *Pseudomonas* and *Bacillus* sp bacterial strains were isolated from surface soil samples of rice cultivation field by Gengadharan and Ramdas (2009). It has been suggested that cultures of bacteria with the ability to degrade specific compounds can be used for bioremediation of pesticide polluted sites. In view of heavy pesticide usage on agriculture it is essential to characterize more indigenous microorganisms that can degrade organophosphorous compounds by mineralization or co-metabolism, since bioremediation can offer an efficient and cheap option for decontamination of polluted ecosystems. The main objective of the present study is to isolate and characterize chlorpyrifos, monocrotophos and quinalphos mineralizing bacteria from agricultural soil, and to assess the growth response of the isolates in liquid ntrient broth and agar medium containing different concentrations of pesticides.

## MATERIALS AND METHODS

The soil samples were collected following random sampling method from a local agricultural farm (Venganoor, Thiruvananthapuram,Kerala) where cultivation practices are going on for many years and used for laboratory studies. Commercial grade insecticides Chlorpyrifos (20%EC), Monocrotophos (36%SL) and Quinalphos (25%EC) were used for the experimental studies, because it may closely resemble the active compound that micro organisms are likely to be exposed in the soil environment.

### Isolation of Chlorpyrifos, Monocrotophos and Quinalphos degrading bacterial strains

250g soil sample was taken in 500ml Erlenmeyer flask and was treated with aqueous solution of chlorpyrifos, monocrotophos and quinalphos pesticides at concentration of 500ppm, mixed, stoppered and incubated at room temperature. Proper moisture content was maintained by adding sterilized distilled water. After 7 days of incubation 1g of the soil was taken out and by following serial dilution and plating technique (Cappucino and Sherman, 1999), using nutrient agar medium three dominant bacteria were isolated. Pure cultures were obtained by repeated sub culturing.

### Identification of pesticide degrading bacterial strains

The isolates (Strain1, Strain2, Strain3) were tested for their morphological and biochemical characteristics (Cappucino and Sherman, 1999) and are tentatively identified. The 16S rRNA gene of Strain3 was PCR amplified with 27F and 1525R primers. The sequence analysis was carried out using bioinformatics tool BLAST of NCBI (by Scigenome Labs Pvt Ltd, Cochin).

### Growth of isolates in nutrient agar medium supplemented with Chlorpyrifos, Monocrotophos and Quinalphos

The isolates were streaked into separate agar plates containing pesticide concentrations of 100 and 500ppm and incubated at $37^0$C. The visible growth of strains were observed on the $1^{st}$ and $2^{nd}$ day of incubation.

### Growth of isolates in liquid (nutrient broth) media supplemented with Chlorpyrifos, Monocrotophos and Quinalphos

1ml of 48hr old cultures were inoculated into 100ml nutrient broth with 500ppm concentration of chlorpyrifos, monocrotophos and quinalphos in triplicate and incubated under aseptic conditions. Proper controls without pesticides were also maintained. The growth of bacteria in broth was measured by the turbidity of the solution. The absorbance was read at 610nm in a UV-Visible spectrophotometer for 5 days.

**Chlorpyrifos Biodegradation studies by GC-MS analysis**

1ml of 48 h old cultures were inoculated into 250 ml nutrient broth added with 250 ppm concentration of Chlorpyrifos and incubated for 10 days. Proper controls were also maintained without bacterial inoculants. Extraction and GC-MS analysis of Chlorpyrifos residues were carried out by following EPA 525.2 method at C.E.P.C.Laboratory and Technical division, Kollam.

## RESULTS AND DISCUSSION

### Isolation and identification of pesticide degrading strains

Three different and dominant bacterial strains were isolated from the soil and marked as strains S1, S2 and S3. The strain S1 was gram positive rod shaped, S2 gram positive cocci and S3 was gram negative rod shaped on staining. On the basis of morphological and biochemical characteristics (Table.1) the bacterial isolates S1 and S2 were identified as members of *Bacillus* and *Micrococcus* sp. In the case of S3 the 16S rRNA sequence demonstrated significant similarity with *Ochrobactrum thiophenivorans* based on nucleotide homology and phylogenetic analysis.

**Table1**
**Biochemical characteristics of bacterial strains isolated from agricultural soil**

| Sl. No. | Morphological and biochemical characteristics | Strain 1 | Strain 2 | Strain 3 |
|---|---|---|---|---|
| 1 | Colony morphology | Abundant, opaque, white waxy growth | Circular, opaque with translucent centre, elevated colony, yellow, smooth | Shiny/Opaque confluent, mucoid |
| 2 | Cell shape | Rod | Cocci | Rod |
| 3 | Gram Reaction | + | + | - |
| 4 | Motility | + | + | - |
| 5 | Indole test | - | - | - |
| 6 | Methyl red | - | - | - |
| 7 | Voges-Proskauer | - | - | - |
| 8 | Catalase | + | + | + |
| 9. | Oxidase | - | + | + |
| 10 | Citrate utilization | - | + | + |
| 11 | Starch hydrolysis | + | - | + |
| 12 | Gelatin hydrolysis | - | + | - |
| 13 | Lactose | - | - | + |
| 14 | Urease | - | - | - |

**Growth of isolates in nutrient agar medium supplemented with Chlorpyrifos, Monocrotophos and Quinalphos**

In nutrient agar medium, treated with pesticides all the three isolates exhibited luxuriant growth in 100ppm. The *Micrococcus* sp and *Ochrobactrum thiophenivorans* showed visible growth in 500ppm of all the three pesticides on the 1st day of incubation itself. Whereas *Bacillus* sp doesn't exhibit visible growth in 500ppm pesticide treated nutrient agar plates of Chlorpyrifos and Quinalphos even on the 2nd day of incubation (Table.2).

**Table2**
**Growth of strains in a Agar plates with different concentrations of pesticides**

| Sl. No. | Strains | Chlorpyrifos | | Monocrotophos | | Quinalphos | |
|---|---|---|---|---|---|---|---|
| | | 100 (ppm) | 500 (ppm) | 100 (ppm) | 500 (ppm) | 100 (ppm) | 500 (ppm) |
| 1 | *Bacillus sp* | + | - | + | + | + | - |
| 2 | *Micrococcus sp* | + | + | + | + | + | + |
| 3 | *Ochrobactrum thiophenivorans* | + | + | + | + | + | + |

*(+)Visible growth observed, (-) No visible growth observed*

**Growth of isolates in liquid (nutrient broth) media supplemented with Chlorpyrifos, Monocrotophos and Quinalphos**

In nutrient broth, *Bacillus* sp was found to be more tolerant to monocrotophos than chlorpyrifos evident from the cell optical density values. The growth rate was found to be nominal in quinalphos treated broth media. Another trend observed was the increase in turbidity towards the 4th day of incubation in all the three pesticide treatments followed by a decrease on the 5th day of incubation (Fig.1).

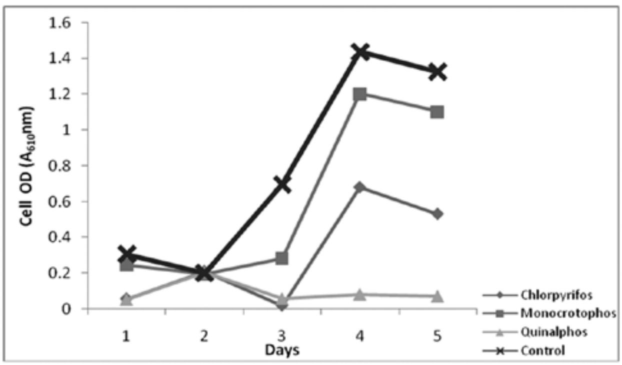


**Fig. 1**
**Growth of *Bacillus sp.* in 500ppm concentration of pesticides (cell OD $A_{610}$nm)**

In *Micrococcus* sp inoculated test broth, a significant reduction in cell OD was found on the 1st day of incubation in Monocrotophos and Chlorpyrifos pesticide treatments compared with control. But the growth rate was found to be enhanced during the second day of incubation. On the 4th and 5th day of incubation the growth rate was found to be increased in quinalphos treated nutrient broth(Fig.2).

Chlorpyrifos was found to be stimulatory to *Ochrobactrum thiophenivorans*. The cell OD was found to be gradually increased towards the 5th day of incubation. The growth rate was higher compared to control throughout the experimental period. *Ochrobactrum thiophenivorans* was found to be more tolerant to monocrotophos compared to *Bacillus* sp (Fig.3).

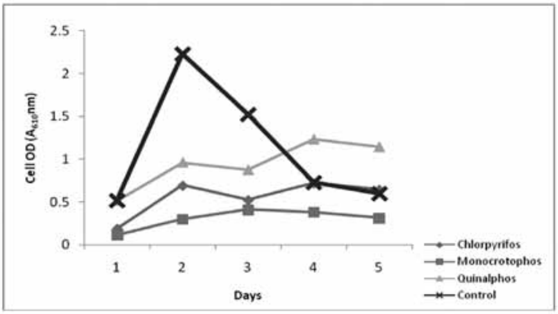


**Fig. 2**
**Growth of Micrococcus sp. in 500ppm concentration of pesticides (cell OD $A_{610}$nm)**

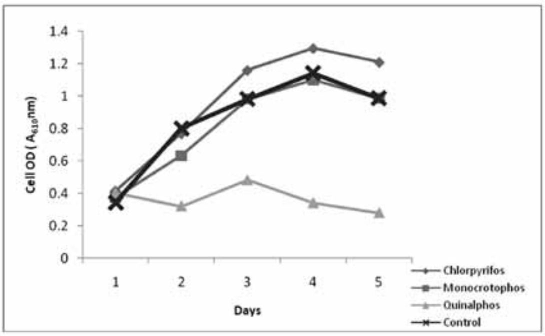


**Fig. 3**
**Growth of Ochrobactrum thiophenivorans in 500ppm concentration of pesticides (cell OD $A_{610}$nm)**

**Chlorpyrifos Biodegradation studies by GC-MS analysis**

GC-MS studies performed using bacterial cultures after an incubation period of 10 days revealed that all the three strains could degrade chlorpyrifos in liquid media (Fig.4). *Ochrobactrum thiophenivorans* exhibited the highest degrading capacity with the complete mineralization of 250ppm chlorpyrifos within 10 days.

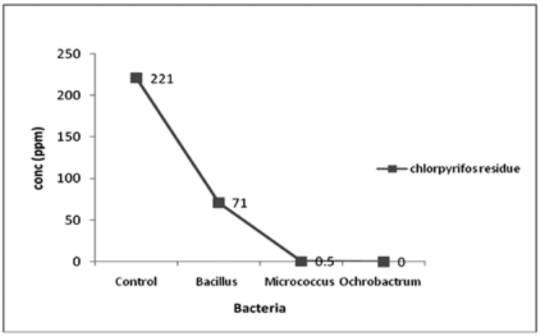


**Fig. 6**
**Chlorpyrifos residue (ppm) in liquid media inoculated with isolated bacterial strains after 10 days of incubation**

In the present study, we have isolated and identified three organophosphorus degrading bacterial strains including *Bacillus* sp., *Micrococcus* sp.,and *Ochrobactrum thiophenivorans*. *Bacillus* sp. is previously reported to be degrading monocrotophos (Rangaswami and venkateswaralu., 1992; Bhadbhade *et al*., 2002) and quinalphos (Gengadharan and Ramdas., 2009). Guha *et al*., 1997 reported the involvement of plasmids in the degradation of Chlorpyrifos by *Micrococcus* sp. isolated from soil. *Ochrobactrum* sp. including *Ochrobactrum tritici sp* and *Ochrobactrum grignonese* sp were previously reported to be isolated from soil samples (Lehuhn *et al*., 2000). Kampfer *et al* (2008) isolated *Ochrobactrum thiophenivorans* from potato rhizosphere and industrial environment. X.-H Qiu *et al* (2006) reported *Ochrobactrum* sp B2 is capable of mineralizing Methyl parathion. Complete mineralization of chlorpyrifos or utilization of monocrotophos and quinalphos by *Ochrobactrum thiophenivorans* has not been reported previously.

## CONCLUSION

Bioremediation is a cost effective method for degrading toxic compounds into innocuous products. From the present study it is evident that bacterial strains capable of mineralizing organophosphorus compounds do exists in agricultural soils itself and are efficient in degrading higher concentrations of pesticides. All the three isolated strains are useful in pure culture remediation process of organophosphorus pesticides especially *Ochrobactrum thiophenivorans*, which exhibited a complete mineralization of chlorpyrifos in liquid media. Future studies are to be conducted to study the isolates degrading efficacy in soil and the genetic basis of pesticide degradation.

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# Status of Traditional and Other Methods of Pest Management in Paddy Fields of Panamaram Panchayat in Wayanad District

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## INTRODUCTION

The production process of the dominant, conventional agricultural system is implicated in a host of well-researched and well-documented environmental problems ranging from loss of biodiversity to soil degradation and water pollution, and other problems (Altieri and Nicholls 2001; McLaughlin *et. al.* 1995; Pimentel *et. al.* 2005). Ecological problems created by chemical insect control methods and their relevance to human health are receiving serious attention everywhere (Nasrine, 2008). As modern agricultural practices reduce or eliminate the resources and opportunities for natural enemies of pests, their numbers decline, decreasing the biological suppression of pests. Today, many agricultural scientists agree that modern agriculture faces an environmental crisis.

Farmers and cultivation practices were existed even before green revolution. Chemical pest control measures were not in use during that period. It doesn't mean that pests were not there. But farmers have had the practice of following traditional methods of pest management without harming nature and ecosystems. Nowadays, the reports on the impacts of pesticides on the health and biodiversity are coming from different parts of the globe, in the form of new diseases, mutations, malformations, threats to ecology and biodiversity, etc. Even then farmers continue to use chemical pesticides indiscriminately, and thereby polluting the ecosystems and environment.

Recently the application of chemical fertilizers and pesticides has tremendously increased in Wayanad district, especially on food crops particularly paddy and vegeTables. Wayanad is a part of Western Ghats that harbor many diverse and endemic species which are highly adapted to their microhabitats. Farmers in Wayanad have started to use chemical fertilizers and pesticides since the advent of green revolution. Earlier studies revealed that application of chemical pesticides has severe impacts on the peaceful environment that supports species diversity. Apart from this, chemical pesticides can cause severe health problems. Even though studies on the traditional knowledge and the impact of chemical pesticides on various agricultural crops are available in plenty in various parts of the globe that of Wayanad district where the level of pesticide application is very high is meagre. The present study is an effort to analyze the status of traditional and other pest management practices in paddy fields of Panamaram Panchayat in Wayanad District.

The present study was conducted with the following objectives:

i) To identify the traditional and other methods of pest management practices in paddy fields of Panamaram Panchayat.

ii) To find out the status of pest management practices with respect to age groups.

iii) To list the pesticides being applied in paddy fields of Panamaram Panchayat.

**METHODOLOGY**

The area selected for the present study is Panamaram Grama Panchayath in Wayanad District. The total area of Panamaram Panchayath is 80.90 sq km. The Panchayath is located in the centre of the District and constitutes 23 wards, and paddy is being cultivated in all the wards. Most of the paddy fields are rain fed and drains into Panamaram Puzha, one of the major tributaries of the Kabani River that flows through this Panchayath. The livelihood of most of the people is entirely based directly or indirectly on agricultures.

The duration of the present study was four months [May to August, 2011]. Data collected through representative sampling from paddy cultivating areas of all the wards in Panamaram Panchayath. Primary data collected directly from 115 respondents. Status of pest management practices was investigated on the basis of age groups (group 1-age below 45 years; group 2-age 45-60 years; group 3-age above 60 years). The data were analysed with the help of Microsoft Office Excel software package.

**LITERATURE REVIEW**

Heckman (1979) observed that the widespread application of chemical pesticides to control rice pests (microbial pathogens, weeds, nematodes, snails, insects, and rodents) has significantly increased grain yields. However, as the pesticides are often nonspecific, they have the potential to profoundly modify the soil-floodwater communities of wetland rice fields. Rice fields, being agronomically managed wetland ecosystems with a high degree of environmental heterogeneity operating on a short temporal scale, harbour a rich and varied fauna.

According to Changways and Daijei (1988) the plants, virus, aquatic and other micro organisms, fungi, bacteria, insects, invertebrates such as crabs larger forms of life such as vertebrates (amphibians, fishes, reptiles, birds and mammals), etc are affected due to continuous application of pesticides in agricultural fields. Bramble in 1989 opined that no one knows for certain, the extent of the damage done to wildlife due to the use of pesticides.

Hansra and Singh (1998) stated that the traditional knowledge of farmers acquired through experience play an important role in rice cultivation. Based on the rich ecological knowledge of traditional farmers, they manage natural resources, pests & diseases and conserve the biodiversity.

Pinmental *et. al.* (1992) observed that aquatic living species die on the pesticides washed down from the agricultural field to river, lakes and other water reservoirs.

Henkel (1995) has of opinion that continuous use of chemical pesticides in monocropping system often leads to contamination of surface and subsurface soils.

Wayanad is a part of Western Ghats that harbour many diverse and endemic species which are highly adapted to their microhabitats (Mayerset et. al. 2000). Three hundred and forty species of vertebrates (36% of all vertebrate species) are endemic to the Western Ghats. (Daniels, 2001)

Study by MSSRF (2005) showed that paddy fields are nature's *in-situ* water harvesting devices which bountifully feeds the water bodies to ensure perennial water availability. Paddy fields harbour a wide range of floral and faunal diversity. Myriads of medicinal plants that naturally grow in paddy fields are popular in primary health care. Water hens, moor hen, cattle egret, kingfishers, etc are some of the important avian fauna that depend on paddy fields either for their habitat requirements or for life sustenance. Thus, paddy field can be construed as a treasure trove of biodiversity.

Compared to the predators, the faster recovery of insect pest populations after a pesticide induced reduction suggests that pesticides cause substantially higher mortality to predators than to pests (Bambaradeniya and Edirisinghe, 2008).

## RESULTS AND DISCUSSION

The present study focused on pest management methods which have been practiced at present in Panamaram Panchayat. Traditional, cultural, and chemical methods of pest management practices were observed in the study, in which the dominant one was the application of chemical pesticides. Of the 115 farmers interviewed, 87.8% reported pest infestation of at least one species during the crop season (July to December, 2010). The rest (12.2%) mentioned no pest damage or ignored low infestation levels. 66.9% respondents reported diseases, and the rest (33.1%) reported no diseases or ignored some instances. About 97% of the farmers reported that, they had to manage weeds during the crop season.

### Status of Pest Management Practices with Respect to Age Group

The pest management practices play a significant role in paddy cultivation as pests have the potential to affect the yields. In the present study, to analyse the status of pest management, the respondents were categorized in to three on the basis of age (age - below 45 years, between 45 & 60 years, and above 60 years).

Caterpillars (case worms, leaf folders, stem borers etc) of various insects (*Nephalocrosis medinalis, Nimphula dipentalis, Scirpophaga incertulas* and *Orciolia oryza* ); Sap feeders such as Brown plant hopper *(Nilaparvatha lugans),* Rice bugs (*Leptocoriza acuta*), and thrips (*Baliothrips biforminus, Haplothrips gamglebavari* etc.) were the common insect pests found in the rice fields of Panamaram Panchayat. Farmers employ cultural practices, traditional practices, and application of chemical pesticides as measures to control pests (insects, diseases and weeds). The mode of pest management practices vary among different age groups.

**Cultural Practices**

The cultural methods of insect pest management include clearing & plastering of field bunds, traditional ploughing (ploughing with yoke helps to control weeds) and summer ploughing. Clearing and plastering of field bunds have been practiced by all the farmers. In the first age group, 39.5 % farmers follow summer ploughing and 7.9 % farmers follow traditional ploughing (ploughing with yoke). In the second age group, 34.2 % farmers practice summer ploughing and 18.4% farmers follow traditional ploughing method (ploughing with yoke). In the third age group, 39.5 % farmers practice summer ploughing and 10.5 % farmers follow traditional ploughing (ploughing with yoke). The present study showed that the intension of growing traditional varieties was not to manage pests and diseases, but the fact that while growing traditional varieties, occurrence of pests and disease were rare. Traditional varieties have been cultivated by 13.2%, 15.8% and 7.9% farmers among the age group-I, II and III respectively. The status traditional and chemical methods of pest management practices is shown in Fig.1..

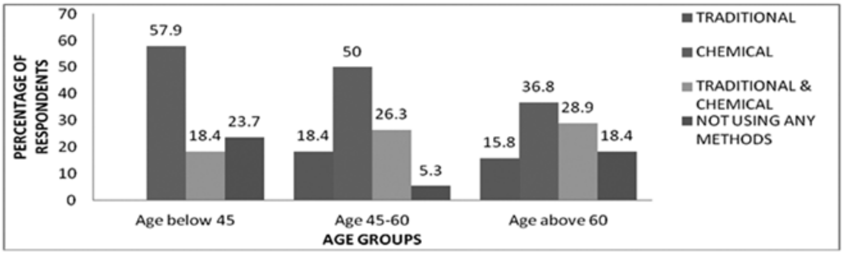


**Fig. 1**
**Status of traditional and chemical methods of pest management practices**

**Traditional Practices for Pest Management**

The traditional practices of pest (insect) management include the usage of two plant species, *Artemisia nilagirica* and *Ficus exasperata;* and the application of wood ashes early in the morning.

**Usage of *Artemisia nilagirica:*** SAwome farmers use the plant *Artemisia nilagirica* to control caterpillars. The branches of this plant along with leaves are cut and planted in the fields where caterpillar infestation has occurred. Farmers said that while doing so caterpillar infestation was found reduced. It is also used as a prophylactic measure. Caterpillar infestations during the early stages of growth (seedling stage) are controlled by this method.

**Usage of *Ficus exasperata*:** *F. exasperata* is also used to control caterpillars as mentioned in the above method. Besides, the branches of these plants along with leaves are used to wave/beat the caterpillar attacked areas, so that due to the rough surface of the leaves caterpillars fell into the water, and when the water is drained caterpillars either die or flow away from the fields.

In the first age group, no farmers have been using traditional methods of pest management. In the second age group, 18.4 % farmers and in the third age group, 15.8 % farmers follow traditional practices for insect pest management.

**Chemical Methods of Pest Management**

Chemical pest management practices - for controlling insects, diseases and weeds - include the application of insecticides, fungicides and herbicides. Among farmers in first age group, the chemical method of pest management using chemical insecticide was practiced by 57.9% farmers. In the second age group, 50 % farmers apply chemical insecticides and in the third age group, 36.8 % farmers apply chemical insecticides for the same.

Some farmers mostly use traditional practices, and along with chemical pesticides are also used in severe infections. Both traditional and chemical methods of pest management practices were utilized by 18.4 % , 26.3 % and 28.9 % farmers in the first, second and third age groups respectively.

Surprisingly, a considerable proportion of farmers - 23.7% - do not employ any specific methods of pest management practices apart from cultural methods. A small percentage (5.3 %) of farmers does not practice any of the pest management practices. A considerable proportion, 18.4 % farmers do not practice any of the insect pest management practices.

Chemical insecticide usage is higher (57.9%) among the farmers in age group-I, and least (36.8%) in the age group-III. In the age group-II, 50% farmers use chemical insecticides. It is to be noted that bio pesticides have not been used by even a single farmer among all the age groups. In all the age group, a certain percentage of farmers do not practice pest management methods.

**Disease Management**

Bacterial leaf blight, Brown leaf spot, Blast, Sheath blight and Foot rot were the common diseases reported in Panamaram Panchayat. The predominant method of disease management observed in the Panchayat was the application of chemical pesticides (53.9%). Application of chemical pesticides have been practiced by 55.3 % farmers in the age group- I. In the second age group, 68.4 % farmers use chemical pesticides. Only 36.8 % farmers apply chemical pesticides for controlling diseases in the third age group. The rest of the farmers do not follow disease management practices at all. Usage of chemical pesticides (fungicides) is higher (68.4%) in the second age group and least (36.8%) in the third age group. Among the farmers in the first age group 55.3% applied chemical fungicides. It is important to note that at least a single farmer do not use bio pesticides for controlling diseases among all the age groups.

**Weed Management**

Weeding is an important practice in rice fields. The present study shows, 93.9% farmers employ hand weeding, while 3.5 % farmers apply herbicides for controlling weeds. A very few farmers (2.6 %) do not practice weeding at all. Among the farmers in the age group-I, 92.1% were practicing hand weeding, and 5.3% were applying herbicides for controlling weeds. In the second age group, 92.1% farmers follow hand weeding and 2.6% farmers apply herbicides; and in the third age group, 97.4% farmers follow hand weeding and 2.6% farmers apply herbicides for controlling weeds. Rest of the farmers does not practice weeding.

**Chemical pesticides used in Panamaram Panchayat**

From the study, it is evident that, the most commonly used chemical insecticide in Panamaram Panchayat is Ekaleks (Quinalphos), followed by Rogor (Dimethoate) and Fenval (Dltamthrin). Other chemical insecticides used include Acetaff (Azaphate), Malathion (Mercaptathion), Karate (Lambda-cyhalothrin), Hostathion (Triazaphos), and Tatamida (Imidachloprid). Except Karate, Fenval and Tatamida all other insecticides are Organophosphates. Bavistin (Carabdazim) and Hinosan (Edifenphos) were the commonly used pesticides (Fungicides) to manage diseases. Phytolan (Copper oxychloride), Indofil (Mancozeb), Saaf (Carbendazim & Mancozeb), and Tilt (propiconazole) were the other fungicides used to manage diseases. Fernaxan and Geamaczone were the herbicides applied to control weeds and these were used by few farmers only.

**CONCLUSION**

Farmers have been using cultural, traditional and chemical methods for pest and disease management. The predominant method of pest management is the application of chemical pesticides and most commonly used chemical pesticides were Organophosphates. The mode of various pest management methods and practices vary among different age groups. The younger farmers do not merely depend on traditional practices and they mostly depend on chemical pesticides than other farmers. A few percentages of farmers in the second and third age groups depend on traditional methods and more farmers in the second age group use traditional practices among all the age groups.

Most of the farmers follow hand weeding and only a very few farmers applied herbicides. At least a single farmer does not used bio pesticides. All the organophosphate pesticides which were applied in the fields are included in either of the following: class 1b- highly hazardous, class II- moderately hazardous, and class III-slightly hazardous by WHO (World Health Organization, 2009). USEPA (United States Environmental Protection Agency) listed these pesticides as possible human carcinogens or endocrine disrupting chemicals. The present study showed that, these pesticides are still used indiscriminately.

The study revealed that, many farmers who have been cultivating rice traditionally have been changed to use chemical inputs. The study showed that only a small percentage of farmers has been using traditional seeds and traditional following ploughing method. Sujithkumar in 1999 opined that major fact that brought about this change was the introduction of high yielding varieties and profit based farming.

Farmers said that diseases became prevalent only after the introduction of new varieties of rice (high yielding varieties) and only chemical pesticides have been used as a measure to control disease. Vijayalakshmi *et. al*. in 2007 had opined like this. Farmers were in the opinion that no diseases were observed when they have cultivated traditional varieties.

An important observation in the current study is that even today, there are a few farmers who have been cultivating rice without using any chemicals in their fields, and obtaining favourable yields. Indike, in 2002 stated that the traditional methods were closer to nature and its balance.

The study recommends:

i) Actions have to be taken and effectively implemented to conserve, maintain and document the traditional wisdom and traditional practices of our farmers since they do not harm the environment.

ii) Adequate measures have to be taken immediately to gradually reduce and ultimately ban the usage of chemical pesticides in agriculture as most of the pesticides which being used are either of the following: Highly hazardous, moderately hazardous, Potential Human Carcinogen, Endocrine Disrupting Chemicals, etc.

iii) Steps have to be taken to make the farmers aware of the impacts of chemical pesticides on environment, biodiversity, food security and health.

iv) Promote environmental friendly and sustainable farming methods.

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# Effect of Adding Secondary and Micronutrients in improving the Soil Productivity Parameters in the Sandy Soils of Onattukara Region

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## INTRODUCTION

Onattukara is the traditional sesame cultivating area of Kerala occupying the taluks of Karunagappally, Karthikappally and Mavelikkara in Kollam and Alleppy districts adjacent to the fragile Kuttanad ecosystem. In Onattukara the soil is deficient in major and micronutrients. Factors such as low water and nutrient holding capacities, prevalence of macropores in soil, high percolation rate add up to the problem of low productivity of oil seed crops such as sesame in this area. The present paper focuses on the influence of the addition of sulphur and boron in improving the soil quality parameters and also enhancing the productivity of sesame in Onattukara sandy soil of Kerala.

## MATERIALS AND METHODS

The study was conducted in the Instructional farm of Onattukara Regional Agricultural Research Station, Kayamkulam. The area is located at 90 30' N latitude and 76°20' East longitude at an altitude of 3.05m above mean sea level. The soil belongs to typical Oxy aquic quartzi Psamment sub group. The levels of sulphur tried were 0, 7.5, 15.0 and 30 kg S $ha^{-1}$ and the levels of boron tried were 0, 2.5, 5.0 and 7.5 kg B $ha^{-1}$ which were applied as gypsum and borax respectively. There were 16 treatment combinations with two replications.

## RESULTS AND DISCUSSION

### Effect of treatments on the soil quality parameters

Soil nutrient status in a locality reveals its production potential for maintaining crop sustainability (Table 1). Parameters such as organic carbon (0.30%), available phosphorus (6.5 kg $ha^{-1}$), available potassium (62 kg $ha^{-1}$), exchangeable calcium (0.48 cmol $kg^{-1}$), exchangeable magnesium (0.03 cmol kg-1), available sulphur (10.2 kg $ha^{-1}$), available boron (0.18 ppm), pH (5.1), EC (0.3 d $Sm^{-1}$) were estimated prior to crop raising and we can see that the soil is low in available nutrients. Application of sulphur and boron resulted in general increase in the nutrient status of Onattukara sandy soil (Table 2).

**Table 1**
**Available nutrient status of Onattukara soil after the application of secondary and micronutrients**

| Treat-ments | Organic carbon (%) | | Available P (kg ha$^{-1}$) | | Available K (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | First crop | Second Crop | First crop | Second Crop | First crop | Second Crop |
| $S_0 B_0$ | 0.245 | 0.207 | 7.50 | 6.50 | 62.74 | 65.40 |
| $S_0 B_1$ | 0.252 | 0.212 | 10.40 | 9.45 | 101.92 | 108.60 |
| $S_0 B_2$ | 0.260 | 0.220 | 12.20 | 10.26 | 122.08 | 133.75 |
| $S_0 B_3$ | 0.280 | 0.229 | 17.10 | 15.10 | 128.80 | 149.05 |
| $S_1 B_0$ | 0.295 | 0.250 | 18.10 | 16.66 | 123.50 | 116.65 |
| $S_1 B_1$ | 0.298 | 0.265 | 22.00 | 20.00 | 140.00 | 134.33 |
| $S_1 B_2$ | 0.409 | 0.285 | 22.60 | 21.60 | 142.54 | 149.00 |
| $S_1 B_3$ | 0.418 | 0.295 | 21.40 | 20.40 | 155.00 | 157.55 |
| $S_2 B_0$ | 0.402 | 0.210 | 21.70 | 20.70 | 132.16 | 125.50 |
| $S_2 B_1$ | 0.413 | 0.328 | 20.50 | 18.80 | 141.68 | 132.70 |
| $S_2 B_2$ | 0.425 | 0.335 | 21.90 | 19.90 | 143.06 | 140.50 |
| $S_2 B_3$ | 0.436 | 0.349 | 21.80 | 19.80 | 166.50 | 171.45 |
| $S_3 B_0$ | 0.458 | 0.362 | 23.80 | 21.80 | 137.60 | 138.45 |
| $S_3 B_1$ | 0.470 | 0.379 | 24.70 | 22.90 | 196.32 | 160.45 |
| $S_3 B_2$ | 0.479 | 0.385 | 25.40 | 23.80 | 196.00 | 162.50 |
| $S_3 B_3$ | 0.495 | 0.399 | 25.50 | 23.90 | 204.48 | 172.00 |
| F-S.B | 2.67* | 2.77* | 5.16** | 8.86** | 4.75** | 5.45** |
| CD - S.B | 0.1130 | 0.3841 | 4.88 | 3.046 | 65.65 | 32.418 |

The organic carbon content of the soil was significantly influenced by the application of different levels of sulphur and boron. $T_{16}$ ($S_3 B_3$) recorded the highest value of 0.479 per cent. The trend was similar in the second crop also. The highest value of 0.399 per cent was recorded by $T_{16}$ ($S_3B_3$). Hence we can say that sulphur and boron might have favored the enrichment of soil organic matter. As evidenced by the significant effect on the biometric characters of the crop, the organic matter status in the soil might have been improved by the nutrient application and enhanced crop growth. A significant and positive correlation between boron and organic matter was reported by Kher and Isher (2006).

**Table 2**
**Available nutrient status of Onattukara soil after the application of secondary and micronutrients**

| Treatments | Available sulphur (kg ha$^{-1}$) | | Available Boron(ppm) | |
|---|---|---|---|---|
| | First crop | Second Crop | First crop | Second Crop |
| $S_0$ $B_0$ | 20.00 | 16.55 | 0.259 | 0.320 |
| $S_0$ $B_1$ | 25.60 | 17.55 | 0.350 | 0.716 |
| $S_0$ $B_2$ | 24.98 | 24.45 | 0.393 | 1.230 |
| $S_0$ $B_3$ | 26.50 | 25.95 | 0.486 | 1.720 |
| $S_1$ $B_0$ | 36.20 | 30.60 | 0.263 | 0.405 |
| $S_1$ $B_1$ | 32.00 | 26.90 | 0.717 | 1.100 |
| $S_1$ $B_2$ | 35.00 | 38.85 | 1.100 | 1.470 |
| $S_1$ $B_3$ | 34.00 | 31.95 | 1.640 | 1.690 |
| $S_2$ $B_0$ | 38.00 | 45.50 | 0.392 | 0.465 |
| $S_2$ $B_1$ | 39.25 | 40.40 | 1.080 | 0.830 |
| $S_2$ $B_2$ | 33.67 | 44.00 | 1.360 | 1.530 |
| $S_2$ $B_3$ | 40.52 | 41.95 | 1.790 | 2.160 |
| $S_3$ $B_0$ | 42.83 | 50.75 | 0.356 | 0.473 |
| $S_3$ $B_1$ | 46.22 | 47.0 | 1.068 | 0.889 |
| $S_3$ $B_2$ | 40.00 | 45.60 | 1.675 | 1.160 |
| $S_3$ $B_3$ | 44.00 | 53.40 | 2.210 | 2.270 |
| F-S.B | 9.67** | 6.60** | 11.70** | 6.56** |
| CD - S.B | 10.20 | 11.637 | 0.698 | 0.7950 |

Available phosphorus content of soil was favorably influence by the application of these secondary and micronutrients. In a soil with inherent phosphorus content as low as 6.5 kg ha$^{-1}$ rated as very low among soil fertility parameters, application of these nutrients resulted in increase in phosphorus content to as much as 25.50 kg ha$^{-1}$ and 23.90 kg ha$^{-1}$in the first and second year respectively. Soluble sulphate from gypsum might have promoted the displacement of phosphate in soil and thus increased its availability.

With regard to the availability of potassium, a critically low nutrient in this type of soil we can see an increase as 204.48 kg ha$^{-1}$ and 172 kg ha$^{-1}$ for both the years respectively. This may be due to the displacement of potassium by calcium present in gypsum. The positive influence of sulphur and boron in making potassium available to plants is further evident from the lowest values shown by those treatments which received neither of these nutrients. In both crops the values were respectively 62.74 kg ha$^{-1}$ and 65.40 kg ha$^{-1}$. Chaurasiya *et al*. (2009) reported that the available nutrients were significantly influenced by the application of sulphur at increasing rate from 0 to 40 kg S $ha^{-1}$. Sulphur in gypsum might have favorably influenced the availability of this nutrient in soil and increasing levels enhanced its availability. The readily soluble sulphate radical from gypsum might have promoted the increase in the available sulphur status of the soil. The solubility of gypsum is 1.6 g $litre^{-1}$. With increase in the levels of sulphur, an increasing trend in soil status was also observed. More over a synergistic relationship between sulphur and boron was also observed. $T_{14}$ ($S_3B_1$) recorded the highest value of 46.22 kg $ha^{-1}$ followed by $T_{16}$ ($S_3B_3$) in the case of the first crop whereas the same treatment recorded the value of 53.40 kg $ha^{-1}$in the second crop.

Boron content of the soil was estimated by hot water extraction method. Increasing level of applied boron showed an increasing trend with regard to the availability and the highest value of 2.21 ppm was recorded by $T_{16}$. The same trend was repeated in the second crop also with a highest value of 2.27 ppm. Renukadevi *et al*. (2004) reported that B@ 2 kg $ha^{-1}$ increased the available boron status of soil.

**Effect of Secondary and Micronutrients on the Yield and Yield Attributes of Sesame**

Application of secondary and micronutrients in the form of sulphur and boron resulted in a definite increase in crop yield during both the seasons (Table 3).

**Table 3**
**Effect of secondary and micronutrients on the yield of sesame**

| **Treatments** | **Seed yield (kg $ha^{-1}$)** | | |
|---|---|---|---|
| | **I crop** | **II Crop** | **Pooled data** |
| $S_0$ $B_0$ | 585.94 | 537.50 | 561.72 |
| $S_0$ $B_1$ | 1104.17 | 1113.17 | 1108.67 |
| $S_0$ $B_2$ | 1057.29 | 1055.73 | 1056.51 |
| $S_0$ $B_3$ | 940.11 | 1020.56 | 980.33 |
| $S_1$ $B_0$ | 734.38 | 732.81 | 733.59 |
| $S_1$ $B_1$ | 1010.38 | 1041.40 | 1025.89 |
| $S_1$ $B_2$ | 968.75 | 938.54 | 953.65 |
| $S_1$ $B_3$ | 1091.15 | 1084.38 | 1087.76 |
| $S_2$ $B_0$ | 953.12 | 1063.54 | 1008.33 |
| $S_2$ $B_1$ | 979.17 | 1055.72 | 1017.44 |
| $S_2$ $B_2$ | 1127.61 | 1128.65 | 1128.13 |
| $S_2$ $B_3$ | 1028.65 | 1034.89 | 1031.77 |
| $S_3$ $B_0$ | 953.12 | 948.95 | 951.04 |
| $S_3$ $B_1$ | 1377.61 | 1172.94 | 1275.27 |
| $S_3$ $B_2$ | 895.83 | 894.27 | 895.05 |
| $S_3$ $B_3$ | 1460.94 | 1407.30 | 1434.12 |
| F-SXB | 13.77** | 28.31** | 25.66 ** |
| CD(SXB) | 156.255 | 91.938 | 30.52 |

The highest value of 1460.94 kg $ha^{-1}$ was recorded by $T_{16}$ ($S_3B_3$) followed by $T_{14}$ ($S_3B_1$) which were on par with each other. The lowest value of 585.94 kg $ha^{-1}$ was recorded by $T_1$ ($S_0B_0$). In the case of the second crop also the same trend was observed. The highest value of 1407.30 kg $ha^{-1}$ was recorded by $T_{16}$ ($S_3B_3$) and was significantly superior to other treatment combinations. This was followed by $T_{14}$ ($S_3B_1$). The lowest value of 537.50 kg $ha^{-1}$ was recorded by $T_1$ ($S_0B_0$).

## CONCLUSION

Sustaining soil productivity is the major challenge before the policy makers and planners and the stake holders in the years ahead in feeding the forthcoming generations. Onattukara sandy soil, identified as problem soil in the soil map of Kerala needs a definite nourishment with essential nutrients especially that of the secondary and micronutrients so as to sustain the crop productivity. Application of sulphur and boron has been found to improve soil attributes as well as the yield of sesame in this soil.

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# Selection of Plant Species Suitable for Green Belt and Polluted Areas

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## INTRODUCTION

Plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbondioxide, oxygen and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce pollution level in the environment .The ambient environment of an urban area may be contaminated with several pollutants such as sulphur dioxide, nitrogen oxides, carbon monoxide, heavy metals etc. These plants growing in the urban area would be exposed not only to one but to many pollutants and their different conditions. It has been reported that plants constantly exposed to environmental pollutants absorb, accumulate and integrate these pollutants into their systems. Air pollution can directly affect plants via leaves or indirectly via soil acidification. These effects are most often apparent in the leaves which are usually the most abundant and most obvious primary receptor of large number of air pollutants. The ability of each plant species to absorb and adsorb pollutants by their foliar surface varies greatly and depends on several biochemical, physiological and morphological characteristics. By measuring changes in leaves of plants it is possible to estimate the overall effect of large number of pollutants. The response of plants to air pollution can be determined by evaluating the Air Pollution Tolerance Index (APTI).

Plants are assessed for their tolerance index to establish the air pollution level. This index is known as Air Pollution Tolerance Index. There are many factors controlling tolerance in plants. The index can be determined by analyzing the values of four different biochemical parameters such as leaf extract pH, total chlorophyll, ascorbic acid content and relative water content. Chlorophyll content of plants signifies its photosynthetic activity as well as growth and development of biomass and it varies from species to species. Chloroplasts are the primary site of attack by air pollutants such as Suspended Particulate Matter, Sulphur dioxide ($SO_2$) and Nitrogen Oxides

($NO_X$). Air pollutants make their entrance into tissues through the stomata and cause partial destruction of chloroplasts and thus decreases pigment content in the cells of polluted leaves. Degradation of chlorophyll contenthas been widely used as indicators of pollution. In some plant species it can be seen that certain pollutants have the ability to increase the chlorophyll content of plants. pH is another biochemical parameter to determine APTI. pH generally showed the relation between type of air pollution. Leaf pH is reduced by acidic pollutants such as Sulphur dioxide, Nitrogen Oxides etc as these pollutants diffuse and form acid radicals in the leaf matrix by reacting with cellular water. Ascorbic acid is natural antioxidants in plants and it plays a significant role in the light reaction of photosynthesis. Ascorbic acid plays vital role in cell wall synthesis, defense and cell division. Ascorbic acid content can be used to determine tolerance of plants to air pollution. Pollution load is found to increase the ascorbic acid content of plant species. The relative water content in a plant body helps in maintaining its physiological balance under stress conditions of air pollution Air pollution load lowers the rate of transpiration in plants and hence relative water content of plant increases. The increase in water content occurred due to the reduced transpiration as a result of air pollution (Agbaire and Esiefarienrhe, 2009).Thus the extent of air pollution can be estimated by studying the air pollution tolerance index of plant species

The objectives of the study were:

- To determine air pollution tolerance index among the selected plant species
- To determine plant species suiTable for green belt areas and that for polluted areas

## METHODOLOGY

### Study Area

The area for the determination of Air Pollution Tolerance Index was Thiruvananthapuram City.

### Sampling

Leaf samples were collected from plants situated in three different areas of Thiruvananthapuram city i.e. near air quality monitoring stations. Plant species selected for study are *Nerium indicum, Mangifera indica, Psidium guajava* and these were collected from Overbridge, Pettah, Murinjapalam respectively. A serene area which was apparently least polluted was chosen as the control site

### Determination of Air Pollution Tolerance Index

Leaf samples were analyzed for different parameters such as pH, Chlorophyll, Relative water content and Ascorbic acid content to determine Air Pollution Tolerance Index. APTI was determined using the following formulae:

APTI = (A (T+P) +R)/10

A= ascorbic acid content, T = total chlorophyll,

R= relative water content, P= pH

**Determination of Air Quality Index**

Air Quality Index (AQI) can represent the overall air quality status in a better way since the cumulative effect of all the pollutants and the related standard can be taken into account. Concentrations of pollutants such as Sulphur dioxide, Nitrogen oxides and Respirable Suspended Particulate Matter at the three different experimental sites (air quality monitoring stations) and the ambient air quality standards were obtained from the Pollution Control Board. AQI can be determined using the formulae:

AQI - $(\sum Ri / i) \times 100$

$R_i$= Concentration of Pollutant / Standard value of Pollutant

**RESULTS AND DISCUSSION**

Four biochemical parameters such as pH, total chlorophyll, ascorbic acid content and relative water content were analysed for three plant species. Biochemical parameters for *Mangifera indica, Psidium guajava and Nerium indicum* are shown in Table 1. APTI of each plant species was found out both for experimental site and control site. Percentage increase in APTI value thus obtained is tabulated in the Table 2. The pollutant concentrations and Air Quality index at various experimental sites are shown in Table 3.

**Table 1**
**Biochemical parameters for different species**

| Parameters | *Mangifera indica* | | *Psidium guajava* | | *Nerium indicum* | |
|---|---|---|---|---|---|---|
| | Control site | Experi-mental site | Control site | Experimen-tal site | Control site | Experimen-tal site |
| Total chlorophyll (mg/g) | 1.29 | 1.42 | 1.543 | 2.161 | 1.610 | 1.366 |
| Ascorbic acid content (mg/g) | 1.11 | 1.5 | 0.505 | 0.5832 | 0.3909 | 0.3508 |
| Relative water content (%) | 82.66 | 88.97 | 60.718 | 72.647 | 63.677 | 74.20 |
| pH | 4.54 | 5.05 | 5.12 | 5.51 | 5.57 | 5.47 |
| APTI | 8.91 | 9.87 | 6.41 | 7.71 | 6.65 | 7.66 |

**Table 2**
**Percentage increase in Air Pollution Tolerance Index of plant species**

| Plant species | Control site | Experimental site | Percentage increase in APTI |
|---|---|---|---|
| *Mangifera indica* | 8.91 | 9.87 | 10.709 |
| *Nerium indicum* | 6.648 | 7.659 | 15.207 |
| *Psidium guajava* | 6.4082 | 7.7120 | 20.345 |

**Table 3**
**Pollutant concentrations and Air Quality Index at experimental sites**

| Experimental site | Sulphur dioxide | Nitrogen oxides | Respirable Suspended Particulate Matter | Air Quality Index |
|---|---|---|---|---|
| Pettah (residential area) | 6.65 | 24.64 | 49.15 | 52.27 |
| Murinjapalam (sensitive area) | 6.5 | 25.73 | 51.05 | 67.78 |
| Overbridge (sensitive area) | 6.9 | 27.39 | 56.68 | 73.4 |

## CONCLUSION

Biomonitoring of plants was found to be an important tool to evaluate the impact of air pollution. Air Pollution Tolerance Index of plant species selected exhibhited significant variation from species to species. The percentage increase in APTI for *Mangifera indica, Nerium indicum* and *Psidium guajava* are 10.709, 15.207, and 20.345 respectively. *Mangifera indica* showed least percentage increase in APTI and Psidium guajava showed maximum percentage increase in APTI. Air quality index values at the experimental sites were also determined. Air quality index values at Pettah, Murinjapalam and Overbridge were obtained as 52.27, 67.78 and 73.4 respectively. In the determination of air quality index value, it can be seen that moderate air pollution prevails at all the three experimental sites. Percentage increase in APTI value of plant species from control site to experimental site indicate the level of pollution existing at these sites. Thus, plants can be used as indicators of polluiton

Eventhough moderate air pollution exists at the three experimental site, the percentage increase in APTI value was different for the three plant species Thus it can be concluded that of the selected plant species, *Mangifera indica* with least percentage increase in APTI was found to be more tolerant to air pollution whereas Psidium guajava with maximum percentage increase in APTI was found to be sensitive towards air pollution. Tolerant species can be used for abatement of air pollution and sensitive species serves as biological indicators of air pollution. APTI values provided valuable information for landscapers and green belt designers to select sensitive as well as tolerant varieties of plant species for using them to identify pollution loads on the environment and also to use tolerant varieties for curbing the menace of air pollution. Thus sensitive plant species are suitable for green belt areas and tolerant species are suitable for polluted areas

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# Studies on the Effect of Eco Friendly Organic Resources on Crop Yield and Soil Health

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## INTRODUCTION

A new concept in the agricultural systems is gradually taking place, to include environmental and sustainability concepts without compramising on the gross production. Several treatment approaches have incorporated organic manures as a key operation in advanced management systems. Deterioration in soil quality, especially soil organic matter and its associated nutrient supply to soil, has been cited as one of the major factors for yield decline in various crops in most of the South-Asian countries. More over massive use of fertilizers and pesticides supported by heavy subsidies as a part of "Green Revolution Strategy" has led to the present problems. The problems and toxicities can be tackled by adopting alternate technologies and management of soil without any harm to the ecology.

Modern agriculture depends heavily on chemical fertilizers and pesticides and the indiscriminate use of these chemicals has made the soil sick and problematic. The distortion in soil fertility and deteoriation in soil health are due to improper and indiscriminate use of chemical fertilizers alone without manures.The growing application and cost of chemical farm inputs, new seeds, costly agronomic practices, flood irrigation, monoculture, stagnant rather declining yield, all have seriously threatened to the economic as well as ecological viability of conventional farming. This is a serious cause of concern for the soil health, human health and the entire agro-eco-system. With the advent of green revolution a serious threat to the environment has been witnessed. Fuelled by ever increasing population to produce more food and fiber, to meet the demands from the limited rather shrinking land area, man's activity has resulted in degradation beyond restoration. Soil organic matter is an essential component with key multifunctional roles in soil quality and related to many physical and biological properties of soil.

The bio-farming or organic farming is a natural way of cultivation which works in perfect harmony with nature. It is harmless to the micro organisms present in the soil and absolutely supportive to the natural soil health and agro-ecosystem. Further, it works for better soil texture and soil development with sufficient availability of humus content. The application of chemical fertilizers and pesticides produce very harmful and sometime even fatal effects on the health of farmers . Hence organic farming methods are widely employed in under developed and developed countries largely because of economics and lack of chemicals. However they are widely accepted in developed countries as a reaction to intensive or factory farming. In Kerala there is an increasing awareness among the public about the drawbacks of various chemicals used in agriculture and hence more farmers are switching over to organic farming. They are also attracted by the poison free healthy organic products. In order to safeguard the interest of our farmers, protect the health of consumers and to conserve the purity of the environment, it is highly essential to switch over to organic farming in major crops of Kerala.

With these background the present study was envisaged to assess the effect of various organic resources on soil health and evaluate the yield of a vegeTable crop (Tomato) which is both grown in tropical and subtropical regions.

## MATERIALS AND METHODS

A pot culture study using Tomato (Vty. Vellayani Vijay) as test crop was carried out in the Department of Soil Science & Agricultural Chemistry, at the College of Agriculture, Vellayani during 2011-2012. The study was conducted during the third crop season March-May as a part of the experiential learning research. Ten days old seedlings were transplanted to the main pots @ two seedlings per hill. The soil was mixed with the potting mixture and used as the potting medium @ 8 kg per pot. The total number of treatments tried were 5, and the number of replication were four which was laid out in a CRD pattern. The treatments details are furnished below. These organic sources were applied to the crop as per the recommended dose in the POP(2011). The initial and post harvest soil samples were collected and analysed based on the procedure described by Jackson(1973). The compost is prepared in the compost yard attached to the Department of Soil Science using the available wastes. Similarly coir pith compost is also prepared. The details of treatment is given in Table 1.

**Table 1**
**Treatment details**

| Treatment | Details |
|---|---|
| $T_1$ | 100 % of N as Vermicompost + P & K |
| $T_2$ | 100 % N as Coirpith compost + P & K |
| $T_3$ | 100 % Dashagavya+ P & K |
| $T_4$ | 100 % Panchagavya+ P & K |
| $T_5$ | Cowdung slurry ( Control) |

### Methods of preparing Panchagavya and Dashagavya

**Panchagavya**: Cowdung (7 kg) and cow ghee (1 kg) were mixed in a clean plastic container thoroughly both in morning and in evening hours and kept aside for 3 days. After 3 days cow 's urine (10 L) and water (10 l) were added. The mixture was kept for 15 days with regular mixing both in morning and in evening hours.After 15 days, cow milk (3 l), cow curd(2 l) , tender coconut water( 3 l) , jaggery (3 kg) and ripened banana(12 nos.) were added to the mixture. It was covered in shade with plastic mosquito net. The solution was ready for spraying after 20 days.

**Dashagavya:** Extracts of five plants *Oscimum sanctum, Lawsonia inermis,Indigofera tinctoria, Leucas asoera,Pongamia pinnata* which have antifungal properties were mixed with Panchagavya preparation taken in a container of 1:5 . This solution was stirred thoroughly for five minutes everyday for a week

**Dehydrogenase activity**

Dehydrogenase activity was estimated as per the procedure described by Casida et al.1964. About 6 g of air dried soil was weighed into 250 ml erlen meyer flask.One ml of Triphenyl tetra zolium chloride was added and incubated for 24 hours at $27^0$C. After incubation the soil was quantitatively transferred to a glass funnel and was given washings consecutively till the volume reached 100 ml.The colour intensity was read in a spectrophotometer. A series of standards were used for preparing the calibration curve.The results were expressed in terms of TPF hydrolysed $g^{-1}$ of soil 24 hours , in micrograms.

## RESULTS AND DISCUSSION

The results on the yield and the nutrient status of the organic sources are presented in Table 2. From the dat presented, it is evident that significant difference in yield was noticed due to different treatments. The treatment $T_3$ with the application of Dashagavya recorded the highest value for yield followed by Panchagavya and vermicompost treated pots. An increase of 75 % in the yield over the control plot was noticed. It is evident from the study that plants treated with Dashagavya is efficient in producing more number of fruits This might have been due to the spurt in the microbial population that increases the solubility and availability of various other nutrients. Similar effects on the green gram was observed by Somasundaram (2003). Besides the treatments $T_3$ ( Dashagavya) and $T_4$ ( Panchagavya) were found to be on par with each other revealing the hormonal effect of both of these microbe rich solutions.Similar result was also reported by Reddy (2004) who reported the hormonal effect of Dashagavya & Panchagavya. The lowest values were recorded with the application of cowdung alone ( $T_5$ )

**Table 2**
**Results on the yield and the chemical characters**

| Treatments | Yield ( kg/plant) | pH | EC |
|---|---|---|---|
| $T_1$ | 2.025 | 7.2 | 0.13325 |
| $T_2$ | 1.625 | 7.7 | 0.13325 |
| $T_3$ | 2.675 | 5.35 | 0.1355 |
| $T_4$ | 2.475 | 5.40 | 0.1725 |
| $T_5$ | 1.52 | 6.85 | 0.1565 |
| **C.D.** | **0.32** | **0.53** | **0.01** |

From the Table 2, it is inferred that an acidic pH was noticed with the Panchayagavya and Dashagavya which is again an indirect effect of increased microbes. Coir pith Compost and vermicomposts pH values were near neutral ,ranging between 7.2 and 7.7 ; the lowest values corresponded to Dashagavya (5.35) and Panchgavya (5.40) addition treatments and the highest to coir pith compost and vermicompost. The increased microflora might have released some organic acids on fermentation which might have decreased the pH.

With regard to electrical conductivity, the treatments $T_1$, $T_2$ and $T_3$ were found to be on par with each other. Treatment $T_4$ recorded the highest value with Panchagavya. The highest value with the Panchagavya might have been due to the release of certain organic fractions resulting in higher mobility of ions.

The nutrient content of various organic resources are given in in Table 3.

**Table 3**
**Nutrient content of various organic resources**

| Treatments | N | P | K |
|---|---|---|---|
| $T_1$ | 3.2 | 1.125 | 1.3825 |
| $T_2$ | 2.3 | 1.3 | 1.9 |
| $T_3$ | 2.4 | 1.9 | 1.85 |
| $T_4$ | 2.87 | 0.75 | 2.125 |
| $T_5$ | 1.65 | 0.675 | 1.075 |
| **C.D.** | .295668 | 0.24 | 0.26 |

The total N content of the composts and liquid manures such as panchagavya and Dashagavya on wet basis, ranged from 1.65% to 2.87 % . This increase is due mainly to the carbon loss during composting This result is in agreement with the data of Inbar *et al*. (1993), on vermicompostng which show an increase in the N-content from 1.7% to 3.5%. The nitrogen content of the compost is significantly superior than the other treatments in the present study with a value of 3.2 % . When the data are expressed on the basis of dry matter it is obvious that N becomes concentrated during composting, which from the agricultural stand point is a very valuable aspect of composting.

With respect to phosphorus content, treatment $T_3$ (Dashagavya) recorded the highest value for P content which was significantly higher than the other treatments. Whereas in the case of potassium content Dashagavya recorded recorded the highest value in the treatment $T_1$( 2.12 %). This might have been due to the active microflora capable of solubilizing the organic sources.

The effect of treatments on soil nutrient status is given in Table 4.

The available nitrogen after the harvest of the crop was significantly influenced by different treatments. The treatment $T_4$ (Panchagavya) was found to be significantly higher than the other treatments except $T_1$ ( 276.775) with the application of vermicompost. Treatment $T_5$ with the application of cow dung alone registered a lowest value of 202.925 kg ha-1. The significant increase in the nitrogen content might be due to the presence of microbes in the panchagavya solution and the presence of growth promoting hormones and minerals in the vermicompost.

**Table 4**
**Effect of treatments on soil nutrient status**

| Treatments | Available N (Kg ha-1) | Available P (Kg ha-1) | Available K (Kg ha-1) | Organic Carbon (%) |
|---|---|---|---|---|
| T1 | 276.775 | 24.81 | 173.225 | 2.3 |
| T2 | 255.25 | 20.8675 | 165.925 | 1.65 |
| T3 | 210.3775 | 21.625 | 176.425 | 2.125 |
| T4 | 286.65 | 22.5275 | 182.775 | 1.975 |
| T5 | 202.925 | 19.94 | 135.1 | 1.925 |
| **C.D.** | **11.24** | **3.31** | **52.8** | **0.37** |

With respect to soil available phosphorus,$T_1$ (vermicompost) recorded the highest value followed by $T_4$ and $T_3$ which were found to be on par. However a lowest value was observed with the application of cow dung alone. The carbonic acid and organic acids produced during the decomposition of organic matter solubilized insoluble phosphate in the soil unavailable P forms, resulting in the release of phosphate into the solution (Chien, 1979). Thus, preparation of vermicompost is based on the concept of solubilization of insoluble phosphorus into plant available form (water and citrate solubleforms) during the process of composting (Sailajakumari and Ushakumari, 2002). Most of these released phosphates are taken up by microflora and the rest might have been re-fixed due to the abundance of calcium in the system (Singh, 1982). With respect to soil available potassium, all the treatments were found to be on par with treatment $T_5$, the lowest value was recorded with the application of cow dung alone.

In the case of soil organic carbon content as inferred from Table 4. highest value was recorded with the application of vermicompost which was on par with the treatments involving the application of Dashagavya and Panchagavya.The variations imposed by the treatments are believed to influence the microbial activity and C mineralization considerably causing difference in organic carbon status of the experimental soil Such increase in organic carbon content due to manuring was reported by Mathan et al. 1978.The lowest value was recorded with the application of coirpith ( 1.65%)

The effect of treatments on soil dehydrogenase activity is given in Table 5.

**Table 5**
**Effect of treatments on soil dehydrogenase activity**

| Treatments | Dehydrogenase activity($\mu$g of TPF hydrolysed $g^{-1}$ of soil 24 $hrs^{-1}$) |
|---|---|
| $T_1$ | 150.79 |
| $T_2$ | 123.25 |
| $T_3$ | 213.21 |
| $T_4$ | 164.49 |
| $T_5$ | 120.77 |
| **C.D.** | **60.96** |

Microbiological processes in soil have been measured using several parameters, such as microbial biomass, respiration, and enzymatic activities (Goyal et.al.2003).

Enzyme activity is essential in both mineralisation and transformation of organic C and plant nutrients. Dehydrogenase is an enzyme which is an integral part of intact cells of all microorganisms and which reflects the total oxidative activities of soil microflora and often used as indicators of biological activity in soils because of its occurrence only within the living cells unlike other enzymes which can occur in extra cellular state also. From the Table 5, it is inferred that the treatments involving the application of Dashagavya and Panchagavya recorded highest values for the enzyme dehydrogenase 213.21 and 164.49$\mu$g of TPF hydrolysed $g^{-1}$ of soil 24 $hrs^{-1}$.A faster multiplication of the microflora in response to an abundant source of energy rich compounds,carbon and nutrients derived from the added organics and chemical fertilizers could be attributed to this observation (Ross,1971). This observation was in conformity with the findings of Dick *et al.* (1988) who obtained significantly higher values for dehydrogenase activity in manured plots compared to fertilized plots in a long term experiment.

## CONCLUSION

Organic and inorganic fertilizers are used primarily to increase nutrient availability to plants; however, they can affect the population, composition, and function of soil microorganisms (Marschner et al., 2003). However, farmers are often forced to make decisions about their fertilizer strategy that reflects economic rather than agronomic pressure. From the present study it is concluded that eco friendly manurial schedules can be adopted to increase the yield, soil microbial population and thus soil health which includes the liquid manures such as Dashagavya and Panchagavya and other organic manures such as vermicomopst.

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# Assessment of Soil Quality of Rural and Urban Areas with Different Land Use Patterns in Thiruvananthapuram District, Kerala

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## INTRODUCTION

Soil is the upper weathered and humus containing layer of the earth's crust which sustains plant life and contains numerous living organisms and their dead remains. Soil is an important sink for pollutants through precipitation, sorption and immobilization reactions. Many toxins added to the soils by different anthropogenic activities can build up to concentrations that become serious threats to plant and animal health (Alloway, 1996). The quality of soil can be badly affected by the presence of metal pollutants. Another important reason for soil pollution is due to the application of defective methods in the cultivation process which includes repeated and excessive use of pesticides and fertilizers at random. Only few studies has been undertaken to assess the heavy metal status in the soils of Thiruvananthapuram District (Sathyanarayana, 1997). The objective of the present study is to assess and compare the contamination level in selected rural and urban areas with different land use patterns in Thiruvananthapuram District.

## MATERIALS AND METHODS

Thiruvananthapuram District in Kerala state, South India covers an area of 2192 square kilometres. The study stations in various rural and urban areas of Thiruvananthapuram District were selected after a reconnaissance survey, and were located using Survey of India Toposheets. For the present study, sixteen sampling stations including coastal areas, market areas, sewage disposal areas, industrial areas, road-side areas, gasoline station areas, agricultural areas and undisturbed area (control) were selected in rural and urban parts) of Thiruvananthapuram District. This includes eight stations in rural areas (S1-Vizhinjam, S2-Vilappilssala, S3-Kochuveli, S4–Mangalapuram, S5-Palode, S6-Balaramapuram, S7-Pallichal and S8-Anappara) and eight in urban areas (S9-Shangumugham, S10-Valiathura, S11-Peroorkkada, S12-Thampanoor, S13- Sreekaryam, S14-Chalai, S15- Karamana and S16-Ambalathara.

Soil samples (0-15 cm depth) from the sampling stations were collected during the pre-monsoon, monsoon and post-monsoon seasons of the study period (April 2009 to January 2010). Composite samples were taken by mixing the samples collected from five different sites of each station. Soil sampling and analysis of soil physico-chemical characteristics were carried out according to the standard procedures of Michael (1984) and Gupta (1999). The concentration of the heavy metals viz. lead, chromium, manganese, copper and zinc in the acid digested soil samples were determined (Saxena, 1994) using an Atomic Absorption Spectrophotometer (Model ,GBC 932 AA). The data given in the Tables and figures are expressed as the mean ± S.D.

## RESULTS AND DISCUSSION

The results of the soil textural analysis of rural and urban stations are given in Fig. 1. The coastal areas, S1 and S9 are with sandy soils. The market area soils (station – S6 and S14) are in silty clay textural class with the highest amount of clay content which in turn is reflected in its organic matter content (Burke *et al.*, 1988). In Stations - S7 and S15 (gasoline station areas), the soils are of silty clay loam nature which in turn showed high concentration of heavy metals. This is in agreement with the previous studies conducted by Gohil *et al.*, (2009) which showed that heavy metal availability will be more in silty clay loamy soils.

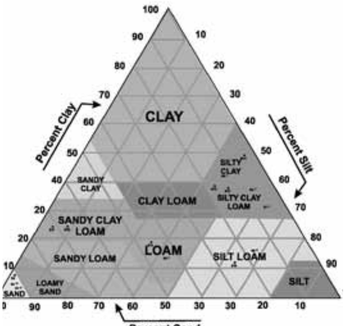


**Fig. 1**

**Textural analysis of rural and urban soils:**

The results of the physico-chemical characteristics of soils in the selected rural and urban stations during the three different seasons are given in Tables 1-3. Soil temperature was high in urban areas compared to rural areas as the heat effect arising from pollution will be more pronounced there (Mark *et al.*, 1997). The rural area soils showed higher electrical conductivity values than the urban area soils. This is due to the fact that conductivity depends on moisture content of the soil. As the moisture content of the rural area soils were higher than that of the urban area soils, rural area soils will have higher conductivity values than the urban area soils (Kersten, 1952). In all the three seasons, the control stations (S8 and S16) showed no significant changes with respect to soil electrical conductivity values. The urban area soils showed higher bulk density values than the rural area soils except in the Stations, S3 and S11 as in these urban area soils, water holding capacity is also higher when compared with the respective rural area soils (Bockheim, 1974). The urban area soils showed higher pore space values than that of the rural area soils (Chun *et al.*, 1973). The rural area soils showed higher water holding capacity values than the urban area soils as water retention and movement are restricted in urban area soils(Bockheim, 1974). But in industrial area stations, S3 and S11, water holding capacity was higher in the urban station, S11 compared to the rural station, S3. This may be due to the fact that soils having lower organic matter content have a very low water holding capacity (Alexander, 1977). The urban area soils showed higher pH values than the rural area soils. This is in agreement with the studies conducted by Biasioli *et al.* (2006) that showed that pH will be higher in urban city soils than in rural area soils.

In all the three seasons, the rural area soils showed higher moisture content values than the urban area soils except in the Stations, S3 and S11. This may be due to the fact that the water holding capacity of rural areas is higher when compared with their respective urban area soils. But in the case of Stations, S3 and S11 both in industrial areas, the urban station studied is having more water holding capacity than the rural area soils where the soil is sandy (Howard *et al.*, 1993). The rural area soils showed higher total nitrogen content values than the urban area soils except in the Stations, S3 and S11 (industrial areas). This may be due to the fact that moisture content shows positive correlation with total nitrogen content (Birch, 1958) which is comparatively higher in rural soils as compared to urban soils. The industrial area soils of the Stations, S3 and S11 showed that the total nitrogen content was higher in the urban area soil, S11as compared with rural area soil, S3 as the rural area has got sandy soil which has lower water holding capacity and moisture content which in turn will affect the total nitrogen content (Burke *et al.*, 1988). The rural area soils showed higher phosphorus and potassium content values than the urban area soils except in the Stations, S3 and S11 (industrial areas). This may be due to the positive correlation between organic matter and phosphorus content (Van *et al.*, 1992). In the industrial areas studied, i.e. Stations, S3 and S11, the phosphorus and potassium content recorded higher values in the urban study stations. The reason for this may be due to the higher organic matter content of the urban area than that of the rural area (Walker and Adams, 1958). The urban area soils showed higher chloride content values than the rural area soils. This may be due to the fact that in urban area soils, the metal toxicity will be higher when compared with the rural soils which in turn have an effect on salinity rise in soils (Daryl *et al.*, 2003). But in the case of Stations, S4 and S12 both roadside areas, the rural area (S4) soils showed higher chloride content than the respective urban area (S12) soils. This may be due to the fact that the urban soils of Station, S12 has been raised from the existing pavement level with suiTable material to stabilize the top layer as there is always run-off problem there. This in turn will reduce the salinity level in soils (Vorobieff, 2005). The present study also found the nutrient status of agricultural area soils (stations – S5 and S13) were higher than that of the control area soils. This may be due to the application of inorganic fertilizers in the soil for agriculture (Richard, 1992).

**Table 1**
**Physical characteristics of rural and urban soils**

| Sl. No. | pH | | | Conductivity (mho/cm) | | | Temperature (°C) | | | Pore space (%) | | | Water holding capacity (%) | | | Bulk density (g/cc) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM |
| S1 | 7 | 7.7 | 7.1 | 0.07 | 0.049 | 0.032 | 32.6 | 30 | 31.5 | 57.8 | 57.8 | 57.8 | 0.04 | 0.05 | 0.03 | 1.56 | 1.58 | 1.57 |
| S2 | 5 | 5.7 | 5 | 1.52 | 0.88 | 0.463 | 30 | 29.7 | 31 | 30.2 | 30.2 | 30 | 1.33 | 1.34 | 1.32 | 0.71 | 0.72 | 0.71 |
| S3 | 5.7 | 6.4 | 6.3 | 0.26 | 0.15 | 0.094 | 32.5 | 30 | 31.5 | 38.3 | 38.2 | 38.1 | 0.15 | 0.17 | 0.15 | 1.14 | 1.14 | 1.2 |
| S4 | 6.1 | 7.1 | 6.5 | 0.26 | 0.082 | 0.057 | 31.6 | 30 | 31.4 | 40.1 | 40.1 | 40.1 | 0.15 | 0.15 | 0.14 | 1.23 | 1.24 | 1.23 |
| S5 | 5.3 | 6 | 5.5 | 1.09 | 0.245 | 0.326 | 29.9 | 29 | 31 | 30.3 | 30.3 | 30.2 | 0.79 | 0.75 | 0.74 | 0.5 | 0.9 | 0.9 |
| S6 | 4.7 | 5 | 4.9 | 3.14 | 1.35 | 1.343 | 31.1 | 30 | 31.4 | 25.4 | 25.4 | 25.3 | 1.84 | 1.87 | 1.86 | 0.2 | 0.3 | 0.3 |
| S7 | 6.2 | 7.3 | 6.7 | 0.14 | 0.072 | 0.048 | 33 | 30 | 31.4 | 45.3 | 45.3 | 44.9 | 0.13 | 0.13 | 0.11 | 1.26 | 1.25 | 1.25 |
| S8 | 5.4 | 6.2 | 5.9 | 0.44 | 0.225 | 0.211 | 29.5 | 29.8 | 31 | 32.5 | 32 | 32 | 0.27 | 0.27 | 0.25 | 1.09 | 1.1 | 1.11 |
| S9 | 8.7 | 8.3 | 7.3 | 0.06 | 0.042 | 0.028 | 32.6 | 30 | 31.5 | 58.9 | 58.9 | 58.8 | 0.02 | 0.03 | 0.03 | 1.58 | 1.6 | 1.6 |
| S10 | 5.7 | 5.7 | 5.3 | 1.33 | 0.528 | 0.451 | 32 | 30 | 31.3 | 30.2 | 30.2 | 30.1 | 1.23 | 1.25 | 1.23 | 0.8 | 0.8 | 0.78 |
| S11 | 5.7 | 6.3 | 6.2 | 0.27 | 0.174 | 0.099 | 32.2 | 30 | 31.1 | 35.5 | 35.5 | 35.2 | 0.18 | 0.2 | 0.2 | 1.11 | 1.12 | 1.15 |
| S12 | 6.1 | 7.3 | 6.7 | 0.25 | 0.073 | 0.049 | 31.3 | 30 | 31.4 | 42.0 | 42.1 | 41.9 | 0.13 | 0.14 | 0.12 | 1.24 | 1.25 | 1.23 |
| S13 | 5.3 | 6.2 | 5.7 | 0.52 | 0.225 | 0.214 | 32 | 29.9 | 31.2 | 31.3 | 31.3 | 31.3 | 0.54 | 0.54 | 0.51 | 0.93 | 1 | 0.97 |
| S14 | 4.8 | 5.3 | 4.9 | 1.6 | 1.305 | 0.865 | 31 | 30 | 31.3 | 29.3 | 30 | 30 | 1.84 | 1.84 | 1.83 | 0.3 | 0.5 | 0.46 |
| S15 | 6.9 | 7.5 | 7 | 0.07 | 0.064 | 0.04 | 33 | 30 | 31.4 | 48.3 | 48.3 | 48.2 | 0.11 | 0.12 | 0.11 | 1.28 | 1.28 | 1.28 |
| S16 | 5.7 | 6.2 | 6 | 0.33 | 0.197 | 0.118 | 31.1 | 29.8 | 31 | 35.1 | 35.1 | 34.8 | 0.25 | 0.26 | 0.23 | 1.11 | 1.1 | 1.11 |

*PrM- Pre-Monsoon Season, M- Monsoon Season, PoM - Post-Monsoon Season*

**Table 2**
**Chemical characteristics of rural and urban soils**

| Sl. No. | Moisture content (%) | | | Chloride (mg/g) | | | Organic matter(g %) | | | Total Nitrogen (g %) | | | Phosphorus (g %) | | | Potassium (g %) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM |
| S1 | 1.74 | 1.81 | 1.76 | 0.34 | 0.338 | 0.339 | 0.52 | 0.59 | 0.57 | 24.5 | 42 | 12.6 | 4.42 | 3.75 | 3.62 | 66.5 | 64.7 | 25.6 |
| S2 | 12.54 | 12.6 | 11.8 | 0.05 | 0.046 | 0.045 | 3.03 | 3.84 | 3.84 | 63.1 | 105 | 182.7 | 52.5 | 89.8 | 75.3 | 189.7 | 147.4 | 106.1 |
| S3 | 5.46 | 5.55 | 5.54 | 0.053 | 0.052 | 0.052 | 1.569 | 1.772 | 1.765 | 44.8 | 70 | 132.3 | 6.21 | 30.56 | 14.41 | 125.5 | 145.5 | 99.33 |
| S4 | 4.78 | 4.9 | 4.9 | 0.045 | 0.045 | 0.044 | 1.397 | 1.626 | 1.562 | 43.5 | 63 | 119.7 | 5.31 | 27.68 | 13.15 | 106.3 | 143.5 | 90.3 |
| S5 | 9.42 | 9.62 | 9.62 | 0.046 | 0.046 | 0.046 | 2.569 | 3.696 | 3.6 | 59.6 | 91 | 157.5 | 43.57 | 64.11 | 69.21 | 163.4 | 184.6 | 100.7 |
| S6 | 15.17 | 15.25 | 15.11 | 0.046 | 0.047 | 0.046 | 5.655 | 5.769 | 4.448 | 70 | 168 | 252 | 159.8 | 106.4 | 76.36 | 189.7 | 187.3 | 155 |
| S7 | 2.38 | 2.4 | 2.36 | 0.046 | 0.044 | 0.046 | 1.155 | 1.579 | 1.155 | 30.1 | 56 | 107.1 | 4.45 | 7.86 | 5.68 | 83.48 | 128.5 | 60.2 |
| S8 | 8.55 | 8.61 | 8.59 | 0.046 | 0.046 | 0.045 | 1.69 | 2.081 | 2.512 | 49.2 | 77 | 144.9 | 25.76 | 44.64 | 41.65 | 133.0 | 168.9 | 102.8 |
| S9 | 0.19 | 0.22 | 0.22 | 0.41 | 0.406 | 0.407 | 0.345 | 0.367 | 0.335 | 20.3 | 42 | 40.8 | 3.53 | 0.71 | 0.78 | 34.38 | 17.08 | 25.59 |
| S10 | 11.85 | 11.9 | 11.5 | 0.047 | 0.047 | 0.046 | 2.672 | 2.838 | 3.836 | 61 | 98 | 182.7 | 52.46 | 66.07 | 50.2 | 174.6 | 398.4 | 301 |
| S11 | 6.79 | 6.82 | 6.76 | 0.046 | 0.046 | 0.045 | 1.569 | 1.94 | 1.867 | 47 | 70 | 138.6 | 10.67 | 33.21 | 16.41 | 127.2 | 64.51 | 102.3 |
| S12 | 2.7 | 2.9 | 2.9 | 0.044 | 0.044 | 0.043 | 1.328 | 1.688 | 1.455 | 35.4 | 56 | 107.1 | 5.31 | 14.64 | 7.78 | 85.27 | 43.53 | 84.28 |
| S13 | 8.67 | 8.69 | 8.6 | 0.046 | 0.046 | 0.046 | 2.207 | 2.491 | 2.255 | 49.6 | 77 | 157.5 | 40.09 | 63.04 | 67.95 | 144.2 | 178.4 | 155 |
| S14 | 13.3 | 14 | 13.6 | 0.046 | 0.047 | 0.046 | 3.5 | 3.881 | 3.87 | 64.4 | 154 | 195.3 | 159.8 | 92.14 | 75.52 | 189.7 | 434.8 | 415.5 |
| S15 | 2.35 | 2.36 | 2.29 | 0.046 | 0.045 | 0.046 | 0.69 | 0.909 | 0.905 | 29.6 | 49 | 103.83 | 4.45 | 4.11 | 2.73 | 66.52 | 26.56 | 52.68 |
| S16 | 8.06 | 8.1 | 8 | 0.046 | 0.046 | 0.046 | 1.69 | 2.081 | 2.41 | 47.6 | 70 | 144.9 | 12.46 | 41.96 | 27.24 | 130.8 | 85.38 | 106.9 |

**Table 3**
**Heavy metal content of rural and urban soils**

| Sl. No. | Pb (mg/kg) | | | Zn (mg/kg) | | | Mn (mg/kg) | | | Cu (mg/kg) | | | Cr (mg/kg) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM | PrM | M | PoM |
| S1 | BDL | BDL | BDL | 43.2 | 73.1 | 40.3 | 140 | 100.2 | 130.3 | 19.2 | 18.7 | 20.5 | 0.2 | BDL | BDL |
| S2 | 0.6 | 0.3 | 0.44 | 70.2 | 352.1 | 245.4 | 105.2 | 310.5 | 310.6 | 90.4 | 70.6 | 88.5 | 0.3 | 0.2 | 0.26 |
| S3 | 0.6 | 0.7 | 0.56 | 220.4 | 100.2 | 310.1 | 78.6 | 69.7 | 78.3 | 79.6 | 71.9 | 77.9 | 0.4 | 0.2 | 0.33 |
| S4 | 0.9 | 0.6 | 0.76 | 510 | 220.9 | 535.4 | 401 | 225.6 | 512.6 | 78.2 | 74.7 | 75.0 | 0.4 | 0.4 | 0.4 |
| S5 | BDL | BDL | BDL | 70.4 | 52.3 | 92.3 | 88.6 | 78.4 | 89.3 | 79.6 | 76.2 | 77.5 | 0.2 | BDL | 0.57 |
| S6 | 0.6 | 0.6 | 0.4 | 90.1 | 70 | 186.5 | 111.4 | 142.5 | 127.9 | 80.3 | 98.4 | 99.8 | 0.2 | 0.3 | 0.28 |
| S7 | 0.9 | 0.9 | 0.86 | 340.2 | 470.1 | 752 | 540.2 | 398.6 | 567 | 95.2 | 90.5 | 93.6 | 0.7 | 0.6 | 0.8 |
| S8 | BDL | BDL | BDL | 75.4 | 40.4 | 72 | 70.3 | 63.2 | 70.2 | 90.2 | 88.1 | 89.2 | BDL | BDL | 0.32 |
| S9 | BDL | BDL | BDL | 52.3 | 86 | 42 | 157.4 ± 0.157.4 ± 157.4 | 109.5 | 510 | 20.2 | 18.9 | 20.0 | 0.2 | BDL | BDL |
| S10 | 0.8 | 0.3 | 0.4 | 69 | 314 | 252 | 146.4 | 152.3 | 152.1 | 92.6 | 89.8 | 90.6 | 0.4 | 0.3 | 0.28 |
| S11 | 0.6 | 0.7 | 0.61 | 320 | 112.3 | 312.3 | 65.4 | 310.5 | 361.9 | 86.8 | 85.4 | 85.6 | 0.4 | 0.2 | 0.38 |
| S12 | 0.6 | 0.6 | 0.7 | 360 | 216.9 | 502.9 | 512 | 213.9 | 509.4 | 82.2 | 81.2 | 82.0 | 0.3 | 0.3 | 0.38 |
| S13 | BDL | BDL | BDL | 220 | 67.5 | 89.5 | 88.6 | 86.5 | 86.5 | 87.2 | 83.7 | 86.5 | 0.3 | BDL | 0.6 |
| S14 | 0.4 | 0.5 | 0.38 | 98.1 | 72.7 | 182.9 | 115 | 152.3 | 138 | 95.6 | 93.3 | 94.3 | 0.3 | 0.3 | 0.26 |
| S15 | 1 | 0.8 | 0.9 | 360.3 | 508 | 760.4 | 569.8 | 396.5 | 538 | 98.3 | 84.1 | 87.4 | 0.8 | 0.6 | 0.82 |
| S16 | BDL | BDL | BDL | 74.4 | 52.3 | 77.1 | 78.6 | 68.6 | 65.8 | 88.2 | 83.3 | 85.3 | 0.20 | BDL | 0.31 |

*BDL-Below Detected Level*

In all the rural and urban stations studied, the concentration of lead is below the standard permissible levels of 100mg/kg (Awashthi, 2000) during the study period. The urban area soils showed higher lead content values than the corresponding rural area soils. This may be due the fact that as the major sources of lead generated in soils are from anthropogenic sources such as auto-emissions, and the industrial sources will be more in urban areas compared to rural areas. The concentration of zinc in soils of majority of rural and urban st2ations studied was below the permissible level of 300 mg/kg (Ewers, 1991) except in sampling stations S3 and S11 (industrial areas), S4 and S12 (road-side areas) and S7 and S15 (gasoline station areas) which were the areas prone to high levels of pollution. The urban area soils showed higher zinc content values compared to the corresponding rural area soils. This may be due to the fact that the zinc concentrations in soils show a strong positive correlation with population density and vehicular density, which was more in urban areas compared to rural areas (Edward and Karen, 2000). In the rural and urban soils of the study area, the concentration of manganese is below the permissible level of 2000 mg/kg (Ewers, 1991). The urban area soils showed higher manganese content than the corresponding rural area soils. The manganese concentration in soils show a strong positive correlation with traffic density which will be more pronounced in urban areas compared to rural areas. In the soils of all sampling stations, the concentration of copper is below the standard permissible level of 100mg/kg (Ewers, 1991). The urban area soils showed higher copper content values than the corresponding rural area soils. This may be due to the fact that air-borne copper is deposited in the soil from suspended solids and combustion sources of which 97% will be deposited on to the soil and this will be more in the urban areas than the rural areas (Deborah, 2005). In rural and urban soils of Thiruvananthapuram District studied, the concentration of chromium was detected below the standard permissible level of 100 mg/kg (Ewers, 1991). The urban area soils showed higher chromium content values than the corresponding rural area soils. This may be due to the fact that chromium accumulation tends to be more in contaminated areas (Krzysztof *et al.*, 2004). Therefore results of the present study show that the urban areas are more contaminated with heavy metals than the rural areas due to high population density and anthropogenic activities.

## CONCLUSION

In the study area, the nutrient content of urban area soils with agricultural activities, industrial activities etc. was found significantly less compared to that of the rural area soils with the same land use patterns. Also the urban area soils were more prone to heavy metal contamination than the rural area soils especially in the gasoline station and road-sides of Thiruvananthapuram district. Therefore the soil quality with respect to physical and chemical characteristics of urban areas in Thiruvananthapuram District was found to be more degraded compared to that of the rural areas. In the present study, it has been clearly shown that there is heavy metal contamination in the rural and urban areas of Thiruvananthapuram district. This will reduce the soil microbial population. The crops cultivated in these contaminated areas in turn may cause health problems to the consumers. So proper remedial measures to check soil contamination should be adopted.

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# Evaluating Composite Ecosystem Value of Agricultural Landscapes in Kochi Metropolitan Region

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## INTRODUCTION

Nature is dynamic; therefore resilience and adaptability is the key for communities and settlements to be sustainable. This suggests that development should be such that it causes minimum alteration to natural systems and their dynamics. To achieve this physical components of natural systems, which are the 'natural landscapes', should be protected from degradation so that they can perform their ecosystem functions, especially because ecosystem processes and function provide beneficial services to humans (direct, indirect, and non-use services). Therefore, for spatial planners natural landscapes are the structural framework for planning adapTable and resilient settlements. Kochi urban agglomeration has evolved and continues to evolve within the relatively young, highly dynamic physiographic region of Vembanad estuary making it an ideal setting to study the interaction and interrelationship of natural landscapes and urbanizing landscapes. Apart from the natural wetlands the region is composed of agricultural landscapes. Paddy fields are the predominant ones towards the western portion of the region and towards the east on high lands have dry cultivation. Today agricultural lands are at the verge of being converted into urban land uses as they are soft targets especially in a scenario were agriculture, horticulture etc are losing popularity as means for livelihood largely due to its unsustainable nature economically and technologically. The result being, loss of rich fertile cultivable lands which is a loss not only in terms of the states food security but also in terms of loss of habitat for a huge biodiversity. Hence understanding the actual ecosystem benefits of these agricultural lands are critical to protect the habitat, and the cultural practices closely associated with agriculture in the state.

The present study aimed at evaluation of the ecosystem value of agricultural landscapes in Kochi Metropolitan Region. The major objectives are:

- To evolve a generic evaluation technique to rate landscapes for their ecosystem value

- To identify the relevance of agricultural landscapes in terms of ecosystem value

The research develops a scientific technique for evaluation of ecosystem value of landscapes based on landscape ecology and ecosystem functions, thereby making the evaluation technique applicable for evaluation of all types of landscapes. The availability of adequate reliable data is the major constraints for such an exhaustive study on the ecosystem services of agricultural landscapes in Kochi

## METHODOLOGY

### Evaluation Technique to Rate Landscapes for their Ecosystem Value

A methodology has been derived to identify the ecosystem value of various landscapes and spatially represent the critical agricultural landscapes that are under threat from urbanization.

The first step was to identify the different landscape typologies present in Kochi metropolitan region. The landscape typologies were identified by correlating the land cover as observed from latest satellite imagery (google earth image) and the land use classification of the Kochi metropolitan region as defined in the comprehensive development plan of Kochi (CDP, 2009). The satellite imagery was enhanced by varying the color bands so as to differentiate the natural land cover from the built cover. The landscape typologies identified are water bodies (comprising of estuary and inland water ways), natural wetlands, paddy fields, dry cultivated land, sparsely built up area, densely built up area. Of these landscape typologies only the un-built landscape typologies are considered for ecosystem evaluation as here the unbuilt landscapes are evaluated against the built landscape for its development impact, therefore the built landscapes is viewed as a matrix reflecting human interventions.

### Ecosystem Service Evaluation

The Millennium ecosystem assessment identifies estuaries to be having the highest ecosystem benefit followed by swamps and floodplains (MEA, 2003). In Kochi's context the estuary and the associated natural wetland is therefore assigned the highest ecosystem service value followed by the paddy fields with moderate ecosystem service value followed by dry cultivated land with low ecosystem value. It has to be noted that the built landscape also has certain ecosystem service value associated with them.

### Evaluation of Intrinsic Physical Quality of Landscape Patches

This is evaluated as a cumulative factor called landscape component value by overlaying the landscape patch size value by calculating the area and landscape patch shape value by calculating the ratio between patch area and perimeter. The patch size is relevant for the enhanced ecosystem performance and shape is relevant as it determines the undisturbed core area that is available as habitat for the species within. The overlay analysis of ecosystem service value and landscape component value of the landscape patches gives the composite ecosystem value of each landscape patches.

Further the landscapes under threat are identified by superimposing the mapping of composite ecosystem value over the land use mapping. This is essentially the extrinsic factor that influences the landscape patches. Industrial land use is assigned high impact, densely built up area is assigned moderate impact and sparsely built up area is assigned low impact. This inventory of composite ecosystem value and critical landscapes under threat of urbanization helps prioritize landscapes for protection, restoration or revival.

**Illustration1**

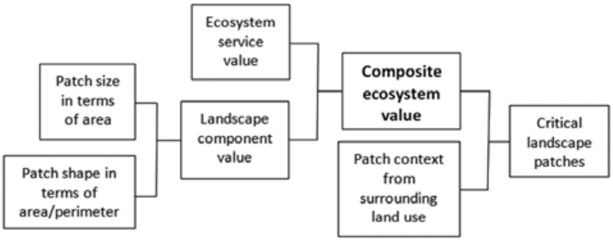



**Illustration2**

| Factors | Evaluated in terms of; | Value range | | |
|---|---|---|---|---|
| | | High | Medium | Low |
| Ecosystem service | Ecosystem benefits | 3 | 2 | 1 |
| Patch size | Sq.m | - | - | - |
| Patch shape | Area/ perimeter | - | - | - |
| Landscape component | Overlay analysis value | 3 | 2 | 1 |
| **Composite ecosystem** | Overlay analysis value | 3 | 2 | 1 |
| Patch context impact | Surrounding land use | 3 | 2 | 1 |
| Critical landscape patches | Threat from surrounding land use | 3 | 2 | 1 |

**Fig.1**
**Methodology of overlay analysis**

## RESULTS AND DISCUSSION

Primarily the landscape types have been broadly classified as water bodies, natural wetlands, and agricultural lands. The evaluation technique has being derived and after the overall analysis and evaluation of all the natural landscapes, detailed study on the agricultural landscapes is done.

Now that the primary objective is achieved, the next objective of spatial identification of agricultural landscapes under threat is taken up. While studying agricultural landscapes in Kochi it can be identified that there are broadly two types of agricultural lands, namely paddy fields and dry cultivated lands.

The spatial analysis maps generated from the overlay analysis is given in figs.2-8.

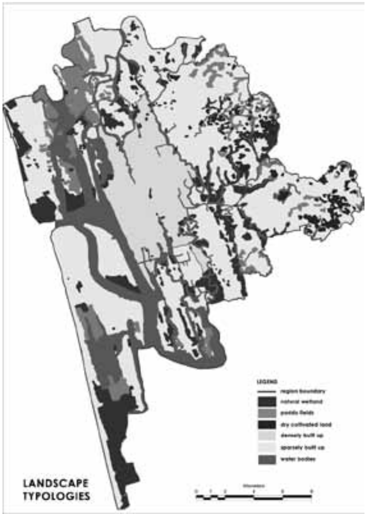



**Fig. 2**
**Landscape Typologies**

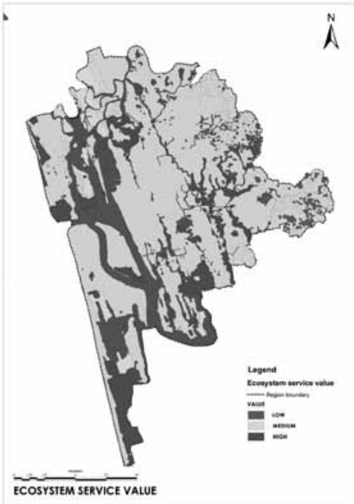



**Fig. 3**
**Ecosystem Service Values**

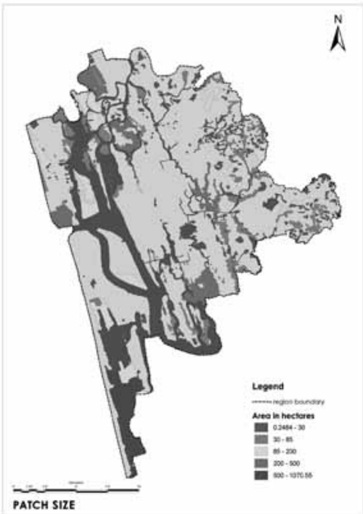



**Fig.4**
**Patch Site**

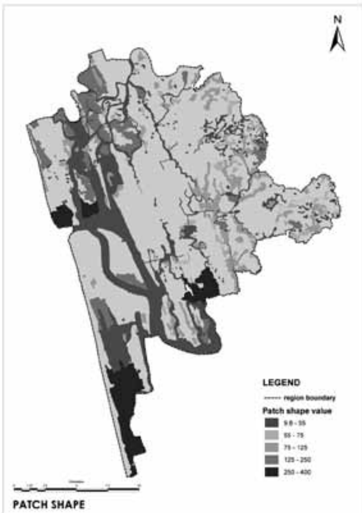
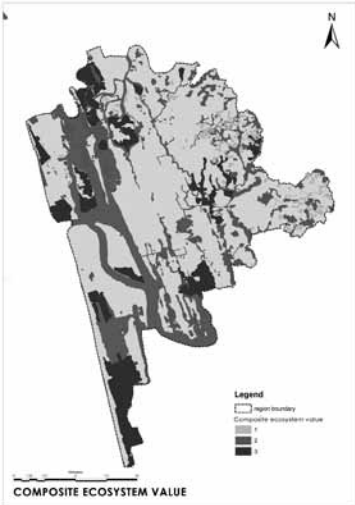



**Fig. 5**
**Patch Shape**



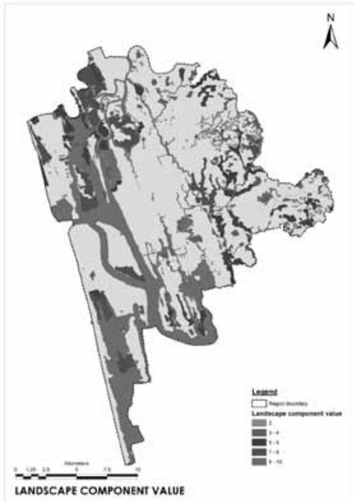




**Fig. 6**
**Composite Ecosystem Value**

**Fig. 7**
**Landscape Component Value**

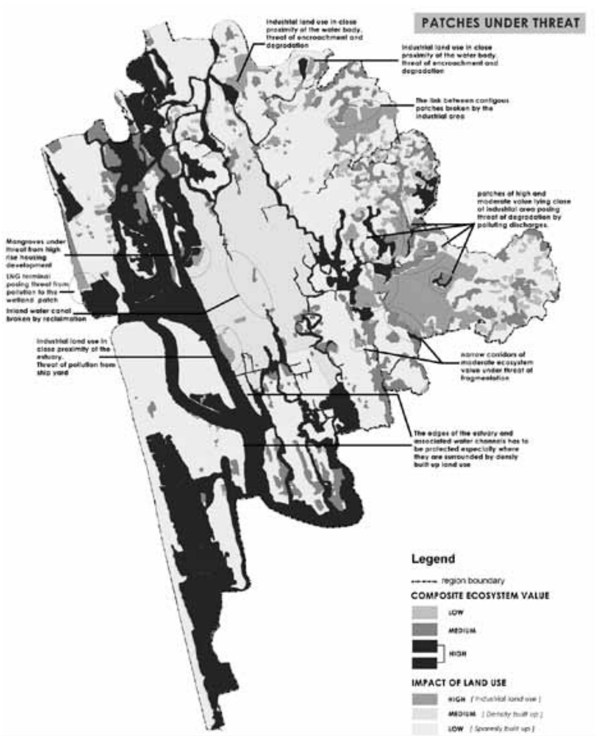



**Fig.8**
**Patches under Threat**

The details with respect to agricultural landscape patches identified through spatial analysis is given in Table 1.

**Table 1**
**Agricultural landscape patches identified through spatial analysis**

| **Patch typology** | **Number of patches** | **Smallest patch** (Area in ha) | **Largest patch** (Area in ha) | **Total area** (Area in ha) |
|---|---|---|---|---|
| Paddy fields | 79 | 0.9 | 286.01 | 2574.44 |
| Dry cultivated land | 94 | 0.24 | 76.9 | 770.53 |

The analysis clearly indicates that dry cultivated patches are smaller in size and are more in number indicating they are most fragmented. The reason for fragmentation is developmental activities around these landscapes. The patches with high ecosystem value are found to be those with large area and minimum convolutions. Those with moderate value are found to be linear in nature and therefore behave like linking corridors. These corridors can be used positively to link fragmented patches which were naturally linked. The ones with lower values are found to be smaller, more fragmented and highly convoluted. These are also capable of integrating themselves into more functionally useful system of landscapes.

Further, almost 80% of land under paddy field patches comes under high composite ecosystem value. This is because of the high value that paddy fields have with respect to various ecosystem functions like waste assimilation, bird habitat, nutrient recycling, flood control etc which the dry cultivated land does not have. Therefore dry cultivated lands have a relatively lower composite ecosystem value compared to paddy fields. Apart from that the reason for most of the paddy field patches to come under high composite ecosystem value is because of its higher landscape component value which is because of its size and shape values. Most of the paddy fields in Kochi region are large in size when compared to the smaller fragments of dry cultivated land.

## CONCLUSION

It can be concluded that in Kochi paddy fields are high valued landscapes based on its ecosystem functions and physical landscape features when compared to the dry cultivated land. But the similar evaluation method if applied to a region where paddy fields are highly degenerated, fragmented and smaller in size and if there are dry cultivations that are large non fragmented then the findings might be different. Therefore this technique lays emphasis on the importance of the landscape features of any landscape patch for it to perform its ecosystem function. Also the analysis concludes that size and shape of landscape patches affects its ability to perform its physical ecosystem functions like linking similar patches for migration of species, nutrient flow, edge functions like protection of core habitat etc.

The patches at high risk from urbanization that is, those surrounded by industrial land use and those surrounded by high density built up areas are identified as vulnerable and special actions to protect these landscape patches from degradation has to be taken.

The estuary and inland water ways system with its high ecosystem value, large size, hierarchical connectivity, and contagion stands as the high priority area for protection and conservation. Natural wetlands are found to occupy a wide range of patch size and patch shape values. This indicates that these landscape patches perform multiple functions that attribute to these varying values. The patches of large size and very high shape value have highest percentage of core habitat. Such patches acts as hubs for a variety of flora and fauna. Also large patches has the greatest ability to perform many ecosystem functions and thereby provide ecosystem services such as flood control, waste assimilation and recycling, etc. Hence those landscapes should be protected and conserved. The predominant patch type among the three patches is natural wetlands. Considering the high ecosystem value associated with wetland it is critical to protect and conserve these wetlands especially those of high component value.

It is also found that most of the natural landscapes lost are within and in close proximity of high density built up areas (mainly city core). Also the mangroves (Mangalavanam) are already almost destroyed by the surrounding developmental activities. The pattern reflects the impact of development on natural landscape patches. If these natural systems are not conserved it would lead to further degradation of the natural defense mechanism of natural systems from drastic environmental changes.

Broadly the landscape patches that are of high composite ecosystem value can be identified for conservation, those of moderate value identified for revival and those of low value identified for restoration.

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# The Socio-economic Impact of Geographical Indications – Kerala Scenario

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## INTRODUCTION

Geographical Indications (GI) protection is very important for India on account of its rich cultural heritage and diverse geography which are responsible for the availability of vast number of native products that are unique to specific regions. In India, under the GI Rules, the applicant has the obligation to explain how the GIs serves to designate the goods as originating from the territory, region or locality as the case may be, in respect of the quality, reputation or other characteristics which are due exclusively or essentially to the geographical environment with its inherent natural and human factors and the production, processing or preparation which are unique to that region (GoI, 1999a). It also insists on the description of the human creativity involved if any. The protection of GIs also extends the protection of Traditional Knowledge associated with the GIs. As per the Trade Related aspects of Intellectual Property Rights Agreement (TRIPS), unless a geographical indication is protected in the country of origin, other countries have no obligation to protect the same (GoI, 1999b). The GoI enacted the Geographical Indications of Goods (Registration and Protection) Act, 1999 and also notified the Geographical Indications of Goods (Registration and Protection) Rules, 2002 with a view to providing for the registration and better protection of geographical indications relating to goods. Both the Act and the rules were brought into force on 15th September, 2003.

The TRIPS Agreement defines Geographical Indication as any indication that identifies a product as originating from a particular location, where a given quality, reputation or other characteristics of the product are essentially attribuTable to its geographical origin (TRIPS, 1994). The definition of GI in the Geographical Indications of Goods (Registration & Protection) Act, 1999 is based on the TRIPS definition with the added criterion that in the case of manufactured goods at least one of the activities of either production or processing or preparation of the goods concerned should take place in the specified geographical area (GoI, 1999c). Thus, GIs act as a signaling device conveying information about the origin, quality or reputation of products which, on one hand enable indigenous producers to get market recognition and build goodwill around their products and, on the other hand protect consumers from counterfeit goods.

**The Registration of Geographical Indications in India**

Under the GI Act, GOI has established a Geographical Indications Registry at Chennai for registration of GIs, with all India jurisdictions. Under the Act, the Controller-General of Patents, Designs and Trade Marks is the 'Registrar of GIs' and is responsible for supervision of the Geographical Indications Registry.

Any association of persons or producers or organization or statutory authority can apply for registration to the Registrar of Geographical Indications. After the receipt of application, it is published in the Geographical Indication Journal and within three months any person can file opposition against the registration (Das, 2006). The registrar will forward the copy of the opposition to the applicant for which the applicant need to reply within two months. After this procedure, the Registrar will issue the certificate of registration, which is valid for ten years and can be renewed further. The most important feature of the act is the registered users are also authorized to use the name.

In India, Till March 2012, 172 goods have been registered under GI Act (GIR, 2012), the distribution of which is as given in Table 1.

**Table 1**
**Goods registered under GI Act till March 2012**

| Class of Goods | Total Number |
|---|---|
| Handicrafts | 110 |
| Agricultural Goods | 44 |
| Manufactured products | 14 |
| Food Stuff | 4 |
| **Total GIs Registered** | **172** |

Some of the well known GI goods specific to India are 'Darjeeling Tea'(Agricultural), 'Pochampalli Ikat', 'Aranmula Kannadi' (Handicraft). This break up shows that the majority of the registered products is in the area of handicrafts and are included under the handloom textiles like 'Pochampalli Ikat' and Kuthampully Sarees.

As of now, Kerala has twenty unique registered GIs, out of which, the 10 products comes under handicrafts and the other 10 under Agricultural goods. It is interesting to see that out of the total of 44 agricultural goods from the entire country, only five rice varieties have received registration and all of these products are from Kerala.

This paper focuses on the existing GI protection system for the rice varieties from Kerala, which are already registered as Geographical Indications and the impact of protection among the farming community of Palakkad district.

## METHODOLOGY

To understand the basic concept and to plan the study, secondary data was used. For the primary data collection questionnaires were used.

The first Indian geographical indication 'Darjeeling tea' got registered in October 2004, it is now time to assess the impact of registration. A survey of two registered GI rice varieties from Kerala – *Palakkadan Matta* and *Navara* was conducted. Personal interviews and observation method were used. Questionnaires were framed and from the agricultural offices, the list of five different geographical areas from Palakkad, where paddy is the principal crop and is extensively cultivated were selected. The selection of the villages was on the basis of certain factors like concentration of the traditional farmer's population, the villages where farming is the major income source for the families, and the farming community is actively involved through their *Padasekhara Samithis* in the programmes conducted by the agricultural departments. The study in regard to the rice varieties has brought out the fact that the socio economic condition of the producers is weak and some measures have to be introduced to explore the possibility of using the geographical indication mechanism as a means to improve the situation. After finalization of the sample selection, the information was procured through field work. The interviews with the farmers were conducted in Malayalam and their responses were recorded in English. Both questionnaire and photographic documentation facilitated as the data for study. The data was systematically analyzed and the result of the survey has been used to estimate the impact of GI registration on the producer's standard of living, economic conditions and social status.

## RESULTS AND DISCUSSION

The survey of farmers shows that the income level of the farmers has not improved significantly after the GI registration. Positive Social impact is visible in the standard of living, and the possibility for farmers to educate their children in good schools and colleges. The survey results shows that the next generation is not interested in agriculture as it is not economically beneficial and it is affecting their social status. The farmers want their children pursue alternate professions than farming to overcome this situation.

The government is procuring the paddy through Supplyco's paddy procurement scheme which has contributed to the improvement in the economic condition to some extent, as they are able to sell the product in bulk even though they may not receive a premium price. The farmers are expecting a premium price for their GI products.

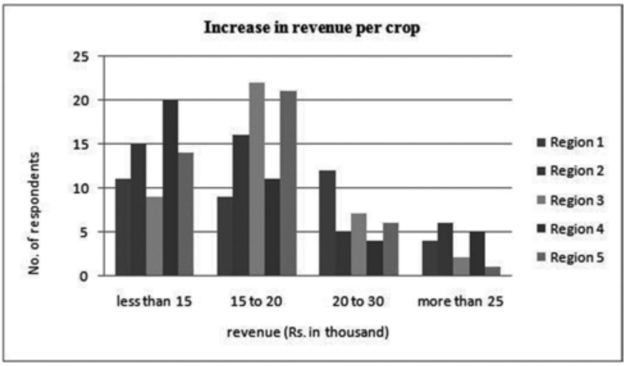


**Fig. 1**
**Survey data- Increase in Revenue per crop**

The revenue per crop is increased in a minimal level. The farmers are not able to fetch a premium price for their product. This revenue itself is not so sTable and highly depends upon the climatic conditions, availability of monsoon etc. GI product's quality, reputation or other characteristics are due exclusively or essentially to the geographical environment specifically in the case of agricultural products. Only 14% of the farmers surveyed are able to earn more than Rs. 25,000/-, which itself is very less compared to the current economic conditions.

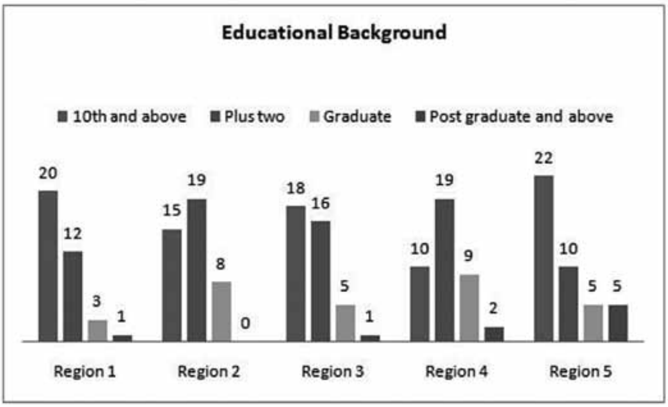


**Fig. 2**
**Survey data- Educational background of Farmers**

The level of education among the farmers has improved. In the earlier days the farmers from the rural area were not interested even in the school education, but now demonstrate the willingness to go for higher studies. Farmers are now sending their children to good schools and even among the younger generation, people are going to the post graduate level of education.

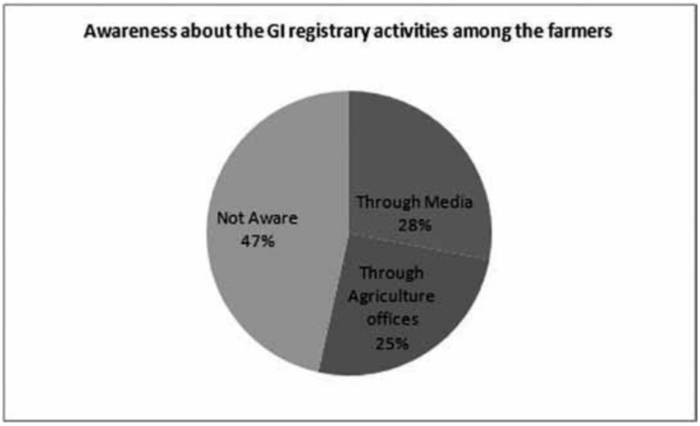


**Fig. 3**
**Survey data- Awareness about the GI registrary activities among the farmers**

The level of awareness about the geographical indications and its benefits is low among farmers and they are not aware about the registration procedures. At farmer's level they are not even aware that their product holds a RGI tag and it has the advantage of getting a premium price. But they are willing to attend the awareness programs and campaigns if organized. Farmers are expecting more efforts from the government level to achieve the maximum benefits to the farming community.

**Expected outcome from GI Registration**

In case of the agricultural products, the farmers expect an increase in price for the producers and special strategies for branding and promotion and their marketing in both domestic and export markets. They are facing shortage of in-house funds for taking up post registration measures. Survey done among the farmers revealed that currently the action related to GI appears concentrated only on registration. There should be a mechanism for enforcing and monitoring the GI products. Extensive awareness creation about the nature of the rights and the ways to protect the rights are required . Use of appropriate marketing techniques must be employed in order to attract the attention of potential consumers. Methods like certification marks could be used in addition to GI, if it helps to make consumers aware of the value of the GI products. In many aspects the rural communities in India depends upon the government and government agencies for funding and regulation, so the role of government as a stakeholder becomes very important. This survey has drawn the conclusion that in case of agricultural products, the post GI measures has to be improved with the help of Government / NGOs intervention.

## CONCLUSION

The identification of potential GI products could be done on the basis of the area of origin, indigenous specifications and uniqueness. India is known to possess a large number of products that could qualify for the protection under GIs, as the protection of GIs could be the first initiative to protect the Traditional Knowledge. It is important that the involvement of Government and NGOs and stakeholders has to be brought together for the successful implementation of the process. Initial development becomes effective in the community level thus contributes to the rural development. Any effort to improve this sector will contribute to development of the rural economy of developing countries like India.

**ACKNOWLEDGEMENTS**

The Authors gratefully acknowledge the guidance from Sri. Mata Amritanandamayi Devi, Chancellor, Amrita University. Authors are thankful to the Geographical Indications Registrary, Chennai, for the data available in the public domain. The authors wish to thank the farmers and the Padasekhara Samithis from Palakkad, for their active participation and cooperation in the survey.

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# Study on the Status of Usage of Non Cultivated Leafy Vegetables with Emphasis on Traditional Knowledge

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**INTRODUCTION**

Leafy vegetables form a major source of Vitamin and micro-nutrients especially for the vegetarians. In remote rural settlements where vegetable cultivation is not practiced and market supplies are not organized, local inhabitants depend on indigenous vegetables, both cultivated in kitchen garden and wild, for enriching the diversity of food. Traditional knowledge in this regard has been carried over from generation to generation (Shalini Misra *et. al.,* 2008).

The present paper is based on a preliminary attempt to study the non cultivated leafy vegetables in Thirunelli Panchayat and their traditional knowledge. The study gives information on the status of usage of non cultivated leafy vegetables and medicinal properties by six different socio-cultural groups including five tribal communities such as Adiyar, Kattunaikar, Kurumar, Kurichyar & Paniyar and a heterogenous non-tribal group from Thirunelli Panchayat in Wayanad District.

The principle objective of the study is to analyze the status of usage of non cultivated leafy vegetables among different age groups as well as different socio-cultural groups. Other specific objectives are:

- To analyze the traditional knowledge and knowledge about medicinal properties of non cultivated leafy vegetables among different age groups as well as six different socio-cultural groups of Thirunelli Panchayat.
- To document the traditional knowledge (medicinal properties) related to non cultivated leafy vegetables.

**METHODOLOGY**

**Study area**

The selected study area was Thirunelli Panchayat of the Wayanad district, because of the greater concentration of tribal communities in the Panchayat and its bio-resource richness. Thirunelli Panchayat is a tribal rich area. Using non cultivated leafy vegetables is a regular practice of tribal communities. Tribal communities depend mainly on non cultivated leafy vegetables for nourishment.

**Sampling procedure**

The data required for the study was obtained through representative sampling. Respondents were selected on the basis of three age groups (age below 30, between 30 & 50 and above 50) from six different socio-cultural groups (Adiyar, Paniyar, Kurichyar, Kurumar, Kattunaikkar and non-tribes). The data were analysed with the help of Microsoft Office Excel software package.

## REVIEW OF LITERATURE

The predominance of wild collected species confirms the work of Westphal *et. al.* (1985) which noted that uncultivated plants provide the principal source of leafy vegetables in tropical and sub-tropical regions. Cunningham *et. al.* (1992) showed the use of wild plant foods in regions with low agricultural potential or during periods of drought contributes to food security and provides dietary supplements to the staple diet. Nutrient composition and nutritional importance of green leaves and wild food resources in an agricultural district, Koutiala, in southern Mali have been done by Nordeide *et. al.* (1996). In a small traditional community of Mapuche Indians in temperate parts of Argentina (with climate similar to that of Poland), 24 wild edible plants species are known (Estomba *et. al.*, 2006). Gendered knowledge and changing trends in utilization of wild edible greens in Western Ghats, India done by Narayanan and Kumar (2007). Studies on non-cultivated plant foods in West Africa carried out by Robert *et. al.* (2009).

## RESULTS AND DISCUSSION

The study discusses the status of usage of non cultivated leafy vegetables and its medicinal properties. Wild leaves are among the most widely consumed wild foods of the Panchayat. Most of the non cultivated leafy vegetables are locally referred to and classified as weeds, sprouting and flourishing after rains. While some leaves are high in fats, others are high in proteins and most are good source of vitamins and minerals. Out of 90 species obtained from the present study 34 species are present in paddy fields, 41 are along with upland crops, three are present in river side, seven are present in road side and five are present in forest. The present study revealed that the majority of non cultivated leafy vegetables are present along either with wet land crops or with up land crops.

**Usage of Non Cultivated Leafy Vegetables**

The study discusses the usage of non cultivated leafy vegetables among three different age groups; age group 1 (age below 30), age group 2 (between 30 & 50) and age group 3 (above 50) as well as six different socio-cultural groups (Adiyar, Paniyar, Kurichyar, Kattunaikkar, Kurumar and Non-tribal communities). Age group 3 use more leafy vegetables than age group 1 & 2; and among different socio-cultural group, Adiyar use more leafy vegetables than other tribal communities.

The Fig.1 shows the percentage of non cultivated leafy vegetables being used by different age groups. Age group 1(below 30 years) using 47.8%, age group 2 (between 30 & 50) using 62.2%, and age group 3 (above 50) using 87.8% leaves among 90 leaves.

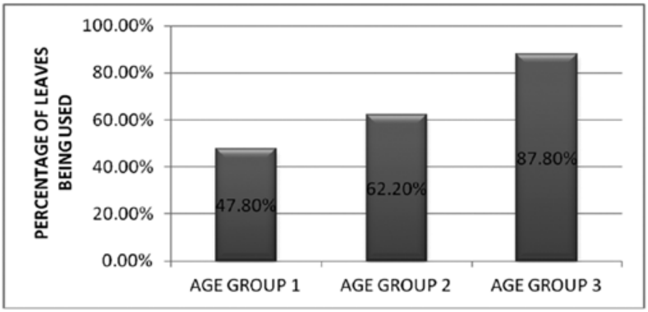


**Fig. 1**
**Percentage of non cultivated leafy vegetables being used by different age groups**

The present study revealed a total of 57 different species were used by Adiyar in Thirunelli Panchayat, 33 were used by Paniyar, 27 were used by Kurichyar, 10 were used by Kattunaikkar, 6 were used by Kurumar and 63 were used by non-tribal communities among 90 species of leaves.

### Traditional Knowledge and Knowledge about Medicinal Properties

The study discusses the traditional knowledge and medicinal properties of non cultivated leafy vegetables among different age groups; age group 1 (age below 30), age group 2 (between 30 & 50) and age group 3 (above 50); as well as different socio-cultural groups (Adiyar, Paniyar, Kurichyar, Kattunaikkar, Kurumar and Non-tribal communities). Respondents under age group 3 are more aware about the medicinal properties of non cultivated leafy vegetables.

Fig. 2 shows the awareness of medicinal properties of non cultivated leafy vegetables provided by different age groups.

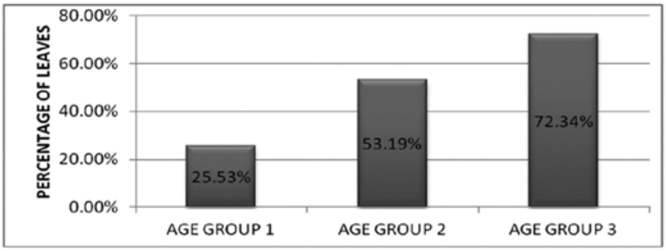


**Fig. 2**
**Awareness of medicinal properties of non cultivated leafy vegetables by different age groups**

The results shows, the respondents under age group 1 (below 30 years) having the knowledge about the medicinal properties of 12 non cultivated leafy vegetables (25.53%), the respondents under age group 2 (between 30 & 50 years) having the knowledge about the medicinal properties of 25 (53.19%) non cultivated leafy vegetables, and the respondents under age group 3 (above 50 years) having the knowledge about the medicinal properties of 34 (72.34%) non cultivated leafy vegetables among 47 leaves. Among 90 leaves subjected for the study, people know about the medicinal properties of 47 leaves. Age below 30 years has a little knowledge about the medicinal properties of non cultivated leafy vegetables.

The present study shows, 45.16% of respondents from Adiyar, 33.33% of respondents from Paniyar, 25% of respondents from Kurichyar, 50% of respondents from Kattunaikkar, 16.67% respondents from Kurumar and 56.52% of respondents from Non-tribes were aware of medicinal properties of non cultivated leafy vegetables.

Among the 90 leaves used by the respondents in the study as food, 47 are used as medicine. Respondents used 47 non cultivated leafy vegetables as medicine as well as food.

### Documentation of the Traditional Knowledge (Medicinal Properties)

The current study revealed that several leaves have been used by the communities to cure many diseases like circulatory disorders, ear, nose, throat & eye disorders, gastro-intestinal disorders, respiratory disorders, skeletal disorders, urinary disorders, skin disorders, reproductive disorders and nervous disorders (Table 1).

**Table 1**
**Traditional knowledge on medicinal properties of non cultivated leafy vegetables**

| Sl. No. | Botanical Name | Family | Common Name | Medicinal Properties |
|---|---|---|---|---|
| 1 | *Aerva lanata* (L.) | Amaranthaceae | *Cheroola* | Urinary bladder stone |
| 2 | *Alternanthera braziliana* (L.) | Amaranthaceae | *Mysore cheera* | To prevent Cancer |
| 3 | *Alternanthera sessilis* L. | Amaranthaceae | *Ponnamkanni* | Cataract, Abdominal pain, Hair Growth, Vision, Maintain body temperature |
| 4 | *Amaranthus spinosus* L. | Amaranthaceae | *Mullan cheera* | Oedema, Blood purification, Chest pain |
| 5 | *Amaranthus viridis* L. | Amaranthaceae | *Kuppa cheera* | Vision |
| 6 | *Azadirachta indica* A.juss | Meliaceae | *Aryaveppu* | Diabetes |
| 7 | *Bacopa monnieri* (L.) | Scrophulariaceae | *Brahmi* | Memory, Brain development, Fits |
| 8 | *Bidens biternata* (Lour.) | Asteraceae | *Alotti Chappu* | Ear pain, Abdominal pain |
| 9 | *Boerhavia diffusa* L. | Nyctaginaceae | *Thazhuthama* | Diabetes, Vision |
| 10 | *Capsicum frutescens* L. | Solanaceae | *Kanthari chappu* | Cholesterol, Wound, Skin allergies, Cancer |

| Sl. No. | Botanical Name | Family | Common Name | Medicinal Properties |
|---|---|---|---|---|
| 11 | *Centella asiatica* L. | Apiaceae | *Muthil, Koda-kanela* | Blood pressure, Tonsillitis, Throat pain, Head ache, Gingivitis, Hepatitis, Worm infestation, Eliminate poison from the body, Gastritis, Gastric ulcer, Urinary problems, Hair Growth , Skin allergies, Memory, Brain development |
| 12 | *Chamaesyce hirta* (L.) | Euphorbiaceae | *Vayal alatta* | Head ache, Hair Growth |
| 13 | *Cissus discolour* Blume, Cat | Vitaceae | *Baruma* | Cold and cough, Fever, Back pain, Arthritis, Itching in the toes |
| 14 | *Cissus repens* Lam. | Vitaceae | *Vellabaruma* | Arthritis |
| 15 | *Cynodon dactylon* (L.) | Poaceae | *Karuka* | Cold and cough, Wound |
| 16 | *Diplocyclos palmatus* L. | Cucurbitaceae | *Eiviral* | Blood pressure, Diabetes, Uterus cleaning |
| 17 | *Eclipta prostrata* (L.) | Asteraceae | *Kanjanni* | Hair Growth, Liver growth and process |
| 18 | *Emilia sonchifolia* Fosberg, Ceylon J | Asteraceae | *Muyal cheviyan* | Cold sore, Throat pain, Tonsilitis, Vision |
| 19 | *Eryngium foetidum* L. | Apiaceae | *African Malliyila* | Gastritis |
| 20 | *Hygrophila ringens* (L.) | Acanthaceae | *Bochappu* | Mensus problems, Diarrhoea |
| 21 | *Hygrophila schulli* (Buch, Ham.) | Acanthaceae | *Vayal chulli* | Oedema, Rheumatic arthritis |
| 22 | *Indigofera linnaei* Ali Bot. | Fabaceae | *Njand kanni chappu* | Hair Growth |
| 23 | *Justicia gendarussa* Burn.f | Acanthaceae | *Vatham kolli* | Rheumatic arthritis |
| 24 | *Leucas aspera* (Willd) | Labiatae | *Thumba* | Oedema, Cholesterol, Gingivitis, Throat pain, Head ache, Cold sore, Cold and cough, Fever, Allergic problems, Breathing difficulty, Arthritis, Wound, Vision, Chicken pox, Worm infestation, Abdominal pain, Gastric ulcer |
| 25 | *Marselia quadrifolia* L. | Marseliaceae | *Unuval* | Cold sore, Back pain |
| 26 | *Mimosa pudica* (L.) | Mimosaceae | *Thotta vadi* | Diabetes, Breathing difficulty, Hair Growth |

| Sl. No. | Botanical Name | Family | Common Name | Medicinal Properties |
|---|---|---|---|---|
| 27 | *Momordica charantia* Var. | Cucurbitaceae | *Kattu paval* | Diabetes |
| 28 | *Monochoria vaginalis* Presl. | Pontederiaceae | *Kola Vazha* | Fits |
| 29 | *Mucuna bracteata* D C | Fabaceae | *Kattu payar* | Diabetes |
| 30 | *Oxalis corniculata* L. | Oxalidaceae | *Puliyarila* | Stomach problems, Diarrhoea |
| 31 | *Pandanus fascicularis* Lamk. | Pandanaceae | *Kaitha* | Worm infestation |
| 32 | *Persicaria chinensis* L. | Polygonaceae | *Chooral chappu* | Back pain, Arthritis |
| 33 | *Phyllanthus amarus* (Schum. & Thornn.) | Euphorbiaceae | *Keezhar nelli* | Hepatitis |
| 34 | *Plectranthus amboinicus* Lour. | Lamiaceae | *Panikoorkkal* | Cold and cough |
| 35 | *Portulaca oleracea* L | Portulaceae | *Kozhuppa* | Hair Growth |
| 36 | *Premna serratifolia* Linn | Verbenaceae | *Munja* | Gastric ulcer, Haemorrhoid |
| 37 | *Punica granatum* L. | Punicaceae | *Urumambazham* | Cold and cough |
| 38 | *Remusatia vivipara* Roxb. | Araceae | *Marachemb* | Stomach cleaning |
| 39 | *Scoparia dulcis* L. | Schrophulariaceae | *Kallurukki, Chakkara thumba* | Oedema, Osteo- arthritis, Urinary problems, Vaginal discharge |
| 40 | *Senna occidentalis* L. | Caesalpiniaceae | *Ponnari, Ponnanthakara* | Back pain, Breast abscess for cattle |
| 41 | *Senna tora* L | Fabaceae | *Thakara* | Blood formation, Oedema, Dizziness, Cholecystitis, Abdominal pain, Constipation |
| 42 | *Solanum americanum* Linn | Solanaceae | *Ambadi chappu, Kakka chappu* | Abdominal pain, Diabetes, Cold sore, Skin allergies, Vision |
| 43 | *Solanum violaceum* Ortega | Solanaceae | *Puthari Chunda* | Gingivitis |
| 44 | *Sonerila rheedei* Wight & Arm | Melastomataceae | *Nilappuli* | Fever |
| 45 | *Sphaeranthus indicus* L. | Asteraceae | *Adakkamani chappu* | Tick infestation on cattle |
| 46 | *Urena lobata* L. | Malvaceae | *Oorakam* | Cold and cough, Fever, Back pain, Arthritis |
| 47 | Un Identified | | *Kattumathan* | Back pain |

Respondents opined that certain leaves have favourable using period. *Hygrophila ringens* (L.), *Persicaria chinensis* L., *Solanum americanum* Linn are used in post natal period and *Hygrophila schulli* (Buch, Ham.) is used in pregnant period.

## CONCLUSION

The present study revealed that the age group 1(below 30 years) has been using 47.8%, age group 2 (between 30 & 50) 62.2%, and age group 3 (above 50) 87.8% leaves. Age group 3 has been using more leaves than age group 1 and 2.

The awareness of medicinal properties is high in people belonging to the age group 3 (above 50). The respondents under age group 1 (below 30 years) had the knowledge about the medicinal properties of 12 non cultivated leafy vegetables (25.53%), the respondents under age group 2 (between 30 & 50 years) had the knowledge about the medicinal properties of 25 (53.19%) non cultivated leafy vegetables, and the respondents under age group 3 (above 50 years) had the knowledge about the medicinal properties of 34 (72.34%) non cultivated leafy vegetables among 47 leaves.

Eight leaves were used for circulatory disorders, ten leaves for ear, nose, throat & eye disorders, 20 leaves for gastro-intestinal disorders, nine leaves for respiratory disorders, 11 leaves for skeletal disorders, three leaves for urinary disorders, 13 leaves for skin disorders, four leaves for reproductive disorders and nine leaves for nervous disorders. Some leaves like *Centella asiatica,* which is used for circulatory disorders, gastro-intestinal disorders, ear, nose, throat & eye disorders, urinary disorders, skin disorders and nervous disorders are used for more than one disorder.

Shimoda (2003) revealed high plant diversity in a paddy field compared with vegetation in an abandoned field. A study by Gisella S Cruz-Garcia et. al. (2011) on wild food plants revealed that rice fields constitute the most important growth location where 70% of the plants are found, followed by secondary woody areas and home gardens. From the present study, out of 90 species 34 species are present in paddy fields, 41 are along with upland crops, three are present in river side, seven are present in road side and five are present in forest. The present study revealed that the majority of non cultivated leafy vegetables are present along either with wet land crops or with up land crops. Most of the respondents feared to collect leaves from paddy fields because of pesticide application. In depth studies on these aspects are needed to establish the findings.

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# Effect of *ex vitro* Conditions on Survival of Micropropagated Gladiolus (*Gladiolus grandiflorus* L. cv) Vinks Glory during Acclimatization.

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## INTRODUCTION

Gladiolus is an important cut flower crop belongs to the Family Iridaceae. It is valued for its attractive spikes. The genus comprises 180 sp with more than 10000 cultivars (Roy *et al*. 2006). The technique for micropropagation has been standardized in gladiolus. But problems have been encountered in *ex vitro* establishment of plantlets. Plantlets that have grown *in vitro* have been continuously exposed to a unique microenvironment that has been selected to provide minimal stress and optimum conditions for plant multiplication. These conditions contribute a culture induced phenotype that cannot survive the environmental conditions when directly placed in greenhouse or field. The physiological and anatomical characteristics of micropropagated plantlets necessitate that they should be gradually acclimatized to the green house environment. Normal development of micropropagated plantlets during acclimatization and hardening stage is mandatory to ensure a high per cent of survival after transplanting to *ex vitro* conditions. Hardening and *ex vitro* establishment of plantlets are the most difficult stages in the micropropagation of gladiolus (Razdan,2003). Micropropagation on a large scale can be claimed to be successful only when plantlets after transfer from culture to soil show high survival rates. Standardizing the techniques for *ex vitro* establishment of tissue culture plantlets of gladiolus will streamline the supply of elite planting material in sufficient number for large-scale cultivation.

## MATERIALS AND METHODS

*In vitro* rooted plantlets of Gladiolus cv. Vinks Glory comprised the experimental material. These plantlets were produced based on the following protocol. Cormels were collected from field grown gladiolus plants. Cormels were dehusked and immersed in 1000 times diluted labolene solution for 30 minutes, washed thoroughly in running tap water for five minutes and then in distilled water. These cormels were surface sterilized with 0.08 per cent mercuric chloride for ten minutes with intermittent shaking inside a laminar air flow chamber. The solution was drained and cormels were washed four to five times with sterile distilled water. Cormels were inoculated in MS medium (Murashige and Skoog, 1962) with BA 2.00 mg/l and NAA 0.50 mg/l and multiple shoot initiation was obtained .After 2-3 subcultures, individual shoots measuring 2.50-3.50 cm length excised from the shoot proliferating cultures were subjected to *in vitro* rooting in IBA 2 mg/ l.

The experiment was laid out in CRD with six replications. Five different potting media were prepared using different proportions of sand, soilrite, soil, coir pith and leaf mould. The treatments were $A_1$ (sand), $A_2$ (Soilrite), $A_3$ (Sand and soil 1:1), $A_4$ (Sand, Soil and coirpith 1:1:1) and $A_5$ (Sand, Soil and Leaf mould1:1:1). The potting media were sterilized by autoclaving them at 15 p.s.i for 45 minutes. 4 mg/l and 8 mg/l solutions of a triazole compound, Triadimefon were prepared and applied to the potting media. The treatments were denoted as $B_0$ – control, $B_1$ - 4 mg/l and $B_2$ - 8 mg/l. The *in vitro* grown plantlets were planted in sterile potting media inoculated with a mixture of 5 g root bits of guinea grass infected with AMF. The treatments were denoted as $C_1$-*Glomus fasciculatum* and $C_2$-*Glomus monosporum.* Height of the potting media inside the container was maintained at 4 cm and 6 cm levels which were denoted as $D_1$ and $D_2$ respectively.

The culture vessels with *in vitro* rooted plantlets were opened and plantlets were taken out using sterilized forceps. The agar adhering to the roots were completely removed by thorough washing. For this first the plantlets were kept under running tap water and then washed in distilled water. During all these processes, care was taken for not damaging the roots. The plantlets were subjected to a fungicide treatment in 0.1 per cent Indofil (Dithane M- 45) by dipping in it for a period of 10 minutes. These plantlets were planted in disposable cups filled with sterilized potting media and subjected to different treatments .The plants were kept inside a humidity chamber covered with polythene sheets of 350 gauge thickness for a period of 30 days.

After 15 days of planting out, the plantlets were irrigated twice a week with 0.1 MS solution. Humidity inside the chamber was adjusted by lifting the polythene sheet and plantlets were gradually exposed to sunlight. Observations were taken at 15 days interval.

## RESULTS AND DISCUSSION

Survival per cent of plantlets with respect to different potting media were studied at fortnightly intervals. Among the different potting media tried, soilrite was found to be the best potting media regarding plant survival (Table 1). Soilrite recorded 86.11 per cent survival after the first fortnight and 80.55 per cent survival after the second fortnight of planting. This might be due to the optimum conditions of aeration, water holding capacity and nutrients present in soilrite. Similar results were observed in micropropagated carnation by Jagannatha *et al*. (2001). Media with two or more components showed relatively low survival. Sand: soil: leaf mould (1: 1: 1) recorded a survival of 41.66 per cent and sand: soil: coirpith (1: 1:1) recorded 44.44 per cent after one month of planting. This is in agreement with Bilderback *et al*. (1982) who obtained higher plant growth in a media composed of single component as compared to that of blended media.

**Table 1**
**Survival rate of micropropagated gladiolus plantlets as influenced by potting media, triazole, mycorrhizae and height of the potting media in the container**

| Treatment | Survival rate (%) | |
|---|---|---|
| | 15 DAP | 30 DAP |
| **1. Potting media** | | |
| Sand ($A_1$) | 77.77 | 59.72 |
| Soilrite ($A_2$) | 86.11 | 80.55 |
| Sand : Soil ($A_3$) | 72.22 | 52.77 |
| Sand : Soil : Coirpith ($A_4$) | 58.33 | 44.44 |
| Sand : Soil : Leaf mould ($A_5$) | 59.72 | 41.66 |
| **2. Triazole** | | |
| Control ($B_0$) | 63.33 | 47.50 |
| 4 mg/l ($B_1$) | 73.33 | 54.16 |
| 8 mg/l ($B_2$) | 70.83 | 55.83 |
| **3. Mycorrhizae** | | |
| *Glomus fasciculatum* ($C_1$) | 66.11 | 58.33 |
| *Glomus monosporum* ($C_2$) | 64.44 | 52.77 |
| **4. Height of potting media** | | |
| 4 cm ($D_1$) | 73.33 | 68.33 |
| 6 cm ($D_2$) | 61.66 | 51.11 |

Triadimefon, a triazole compound which is a plant growth retardant, was tried in the *ex vitro* establishment study. Plantlets treated with triazole at a concentration of 4 mg/l showed a higher survival rate of 73.83 per cent 15 days after planting, whereas one month after planting, those treated with 8 mg/l concentration showed 55.83 per cent survival followed by 4 mg/l with 54.16 per cent survival. Control plants recorded 47.50 per cent survival after one month of planting. It is evident that triazole treatment recorded higher survival per cent than untreated plants. Davis *et al*. (1986) obtained better survival of ornamental plants treated with triazole while transplanting to greenhouse. Samasya (2000) also obtained similar results during the *ex vitro* establishment stage of micropropagated orchids.

The plantlets were inoculated with two arbuscular mycorrhizal fungi during the *ex vitro* establishment stage. The two mycorrhizal fungi tried in the present study exerted differential effect on survival of plantlets. *Glomus fasciculatum* inoculated plantlets recorded 58.33 per cent survival and those inoculated with *Glomus monosporum* recorded 52.77 per cent survival of the plantlets one month after planting. Various workers reported improved survival of micropropagated crops during the *ex vitro* establishment stage due to the inoculation of arbuscular mycorrhizal fungi in several crops (Puthur *et al*., 1988; Ramesh, 1990; Sreelatha, 1992; Vidal *et al*., 1992; Wang *et al*., 1993; Sato *et al*., 1999; Estrada-Luna, 2000; Binet *et al*., 2007)

Height of the potting media in the container did not show significant effect on treatments. According to Tilt *et al*. (1987) the key to plant growth responses may not lie in the size of container or type of media, but in the matching of medium and container geometry with plant growth habit. Media and container are physical components of growing systems. However, plants respond to the microenvironment created by the potting media, irrigation methods, containers and nutrients. The effects of all these reflect in plant growth.

Survival rates obtained in this study was moderate however; the growth rate did not come up to the expected levels as that of field grown plants. The shift in partition of assimilates from leaves to the *ex vitro* developed corm might be the reason for the initial slow growth of the plantlets. Production of cormels *in vitro* and planting out of these cormels may help to overcome this situation. Future works should be oriented in this direction.

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# Geospatial Technology for Drought Monitoring in Panchayats with Special Reference to Kasaragod District

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## INTRODUCTION

Drought is a slow-onset natural disaster, an insidious and creeping phenomenon which occurs in virtually all climate regimes. Drought is also related to the timing and effectiveness of the rains, thus, each drought year is unique in its climate characteristics and impacts. Therefore it is impossible to make a definition of drought that can be universally accepted (Wilhite 1993). During recent years climate change impacts have been combined with drought effects and caused serious problems in different part of the world (Dastorani and Afkhami, 2011). The cause for drought in Kerala is due to weather anomalies and developmental pressures resulting from the changes in land use, traditional practices, and life style of the Kerala state. The drought events exist for shorter periods, a few months or so; but cause severe losses to the crops in the agriculture sector and hit the power and drinking water systems badly. In this study an attempt has been made to apply Remote Sensing and Geographic Information System techniques for drought detection in Kasaragod district of the Kerala state.

Normalized Difference Vegetation Index (NDVI) and Deviation of NDVI from mean value are the indices used for the present study. NDVI is a satellite sensed index indicating the health of vegetation. In this study the 16 Day 250m MOD13Q1 Modis data over the years 2000 to 2012 for Kasaragod district were collected. The Moderate-resolution Imaging Spectro-radiometer (MODIS) is a scientific instrument on board the Terra and Aqua satellites. The instruments capture data in 36 spectral bands ranging in wavelength from 0.4 $\mu$m to 14.4 $\mu$m and at varying spatial resolutions. Band 1 and 2 are used for calculating the NDVI. After comparing the NDVI of a place from the mean NDVI value, drought prone panchayats of Kasaragod district was found. The paper aims in predicting the chance of drought by monitoring the NDVI deviation of an area from its mean NDVI value.

## METHODOLOGY

### Study Area

Kasaragod District, the northernmost district in Kerala state, is geographically located in between 12° 2' and 12° 45' north latitude and 74° 51' and 75° 25' east longitude, constituting an area of 1992 $Km^2$. The average annual rainfall is about 3500 mm.

The MOD13Q1 250m resolution MODIS data from the year 2000 to 2012 were downloaded and re-projected using NASA's MRT tool. Mean NDVI for the same period in the year is calculated from 13 year historical data. The current NDVI image is compared with its historical mean value and chance of drought of a particular area is evaluated. The drought thus obtained is compared with the corresponding mean NDVI value for the period and drought situation is evaluated. This information is segregated and distributed to the panchayat level where precautionary actions are taken to combat drought.

Mean NDVI= $(NDVI_1 + NDVI_2 + NDVI_3 + NDVI_4 ..... + NDVI_n)/n$

where $NDVI_i$ is the NDVI of the 16-day period over year 'i'.

NDVI Deviation = NDVI value – Mean NDVI over the same period over 'n' years.

Softwares used for this investigation are ERDAS Imagine 2011, ArcGIS 10 and Modis Reprojection Tool.

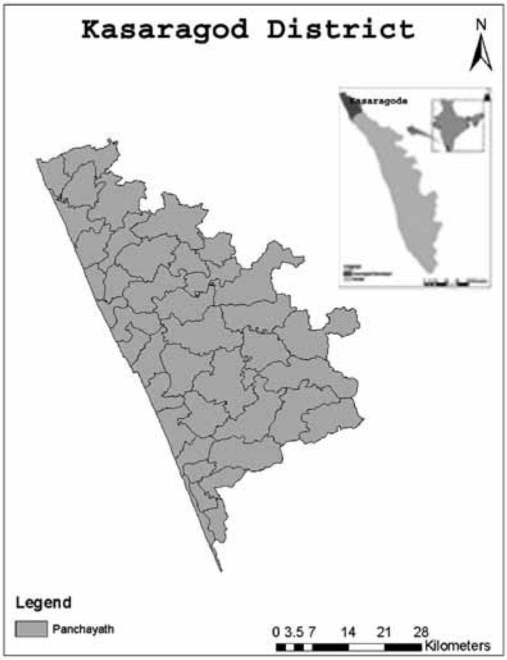
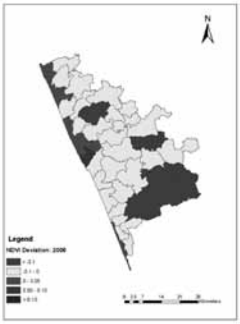



**Fig.1**
**Study area showing Panchayats of Kasaragode District**

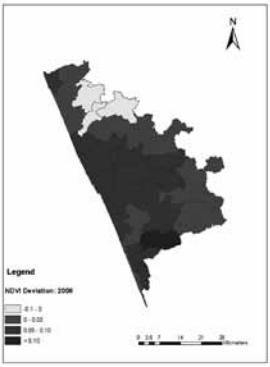
## RESULTS AND DISCUSSION

Panchayat level NDVI Deviation on a 16 Day time frame is analyzed for years 2000-2012. Figure 2 shows the Panchayat wise NDVI Deviation for the years 2006 to 2012 during May.

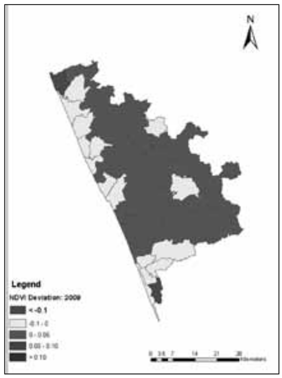


**Panchayat level NDVI Deviation: May 2006**

**Panchayat level NDVI Deviation: ay 2007**

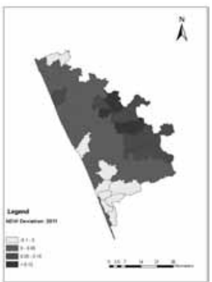


**Panchayat level NDVI Deviation: May 2008**

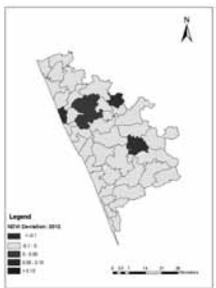


**Panchayat level NDVI Deviation: May 2009**

**Panchayat level NDVI Deviation: May 2010**



**Panchayat level NDVI Deviation: May 2011**



**Panchayat level NDVI Deviation: May 2012**

**Fig 2**
**NDVI Deviation during May for the years 2006 to 2012.**

In the month of May, year 2006, Panchayats Balal, East Eleri, West Eleri, Kayyurcheemeni, Kinanoor-Karindalam, Badiyadka, Kullikole showed drought prone situation. During May, 2009 vegetation in panchayats Thrikkaripur and Manjeswaram showed lower health status. Comparing with year 2011, most vegetation in Kasaragod is dry in May, 2012. Panchyats such as Mogral Puthur, Bellur and Kallar showed poorer health status for vegetation during the month of May in year 2012. Figure 3 gives Standard Precipitation Index (SPI) for the Kasaragod rain gauge station up to 2009.This study focused on monitoring changing drought prone situation in various panchayats of Kasaragod Districts using geospatial technology.

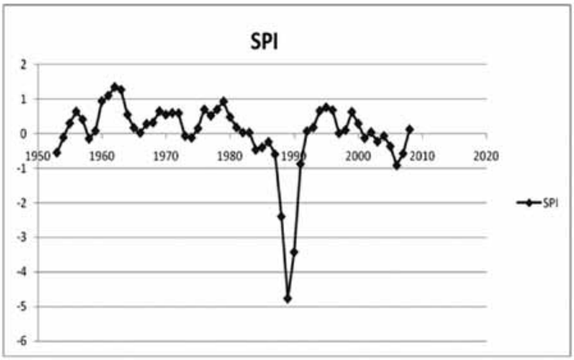



**Fig. 3**
**SPI variation of Kasaragod Station**

## CONCLUSION

Geospatial Technology plays a pivotal role for monitoring drought and has been successfully utilized in this investigation. The deviation of NDVI with time from the mean NDVI over the period 2000 to 2012 was found using Terra satellite product MODIS (MOD13Q1- Vegetation Indices 16 Day L3 Global 250m). High deviation of NDVI from the mean value can be prone to drought in some panchayats of Kasaragod district. The results of this investigation can be further refined and validated using SPI values of different rain gauge stations across the Kasaragod District.

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# Impact of Elevation of Atmospheric $CO_2$ on Biomass Production, Yield, Terrestrial Carbon and Nitrogen Dynamics and Residue Quality and Decomposition in Rice and Wheat and Modification of Mineralization Subroutine of CERES-N

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## INTRODUCTION

One of the major challenges of modern ecological research is to understand how the biosphere is responding to human-induced global environmental changes. One of such global change is the increase in atmospheric $CO_2$ since pre-industrial times, currently amounting to 370ppm which has huge impacts on the terrestrial ecosystem (Kimball, 1983). Atmospheric concentrations of carbon dioxide (CO2) have been steadily rising from pre industrial values of approximately 280 $molmol^{-1}$ to a current global mean of approximately 380 $molmol^{-1}$ (IPCC, 2007). Concentrations are projected to increase to approximately 540–958 $molmol^{-1}$ by the year 2100 (IPCC, 2001). Numerous effects of elevated atmospheric CO2 concentrations on plants have been documented (Kant Pratap et al., 2007), including changes in plant elemental composition (Taub *et* al.,2008). Increasing $CO_2$ levels typically lead to significant increases in photosynthetic rates, and can lead to changes in the growth of whole plants and plant community structure. Recently, there has been much interest in determining the capacity of sequestering carbon from the atmosphere. If terrestrial vegetation responds to increasing $CO_2$ levels with increased net primary production leading to storage of carbon, then terrestrial vegetation might play a significant role in preventing the effects of global warming, though to a limited extent. Another possibility is that $CO_2$ enrichment might alter the quality of organic matter, thereby indirectly affect the rate at which carbon and nitrogen are cycled within the soil plant system. The production and quality of belowground roots and plant are likely to be affected by the increase in atmospheric CO2 level with subsequent changes in their decomposition rates in soil. The effects of elevated $CO_2$ on aboveground physiological processes have been well studied. However, to date, soil ecosystems and the quality of residues particularly rice and wheat residues have received much less attention.

## MATERIALS AND METHODS

The experiments have been conducted in the research farm and in closed phytotron chambers at National Phytotron Facility of Indian Agricultural Research Institute (IARI), New Delhi. For the study, four types of experiments were conducted viz., Pot culture experiment under open top chambers with rice and wheat, field experiment under Free air CO2 enrichment technology of South Asian network with rice and wheat, wheat and rice residue decomposition study inside the national phytotron facility and the calibration of the model CERES for prediction of residue decomposition under elevated CO2 in atmosphere

### Pot Culture Experiment Under Open Top Chambers with Rice and Wheat

To study the impacts of elevation of $CO_2$ on crop growth and yield and terrestrial carbon pools, a pot culture experiment was conducted in open top chambers (OTC) in the farm of Indian Agricultural Research Institute, New Delhi in 2004-06 with surface soils collected from a Typic Haplustept. Rice and wheat were grown as test crops at ambient (approx. 370 m mol mol-1) and elevated (600±50 m mol mol-1) levels of atmospheric $CO_2$. Destructive sampling was done at four physiological stages of crop growth namely tillering (Rice) /crown root initiation (wheat), anthesis, grain filling and maturity. Biomass yield, carbon content and its uptake by different plant parts (*viz.* root, stem, leaf and grain) were observed. Various carbon fractions in rhizosphere soil, namely, microbial biomass carbon (MBC), dissolved organic carbon (DOC), carbohydrate carbon (CHC), labile carbon (LBC) as well as total carbon (TOC) were determined for both the crops at each of the crop growth stages.

**Open top chamber**

### Field Experiment Under Free Air CO2 Enrichment Technology

Rice and wheat crops were also grown in sequence in field under Free Air Carbon dioxide Enrichment technology of the South Asian Network, New Delhi and ambient field $CO_2$ conditions. The octagonal FACE ring is made up of PVC pipes of 200mm diameter and wall thickness of 4.5mm. Each arm of the octagon was fitted with a centrifugal air blower at one end for blowing air into the pipe and was closed at the other end. Four rows of holes (4mm diameter) were drilled on each arm for the outlet of CO2-enriched air. The CO2 was injected at the input of each air blower for pre-mixing with air within the pipe before its injection in the fields. All the eight arms of the octagon had independent supply of CO2 controlled by 8

**Free Air CO2 enrichment experiment**

on/off valves. A common computer controlled proportional integral differential (PID) valve controlled the quantity of $CO_2$ released into the arms. The fumigation of $CO_2$ gas into the field from the plenum was made at the crop canopy height. The residues of elevated atmospheric $CO_2$ (600±50molmol$^{-1}$) grown rice (RE) and wheat (WE) were collected from free air carbon dioxide enrichment (FACE) experiment and the residues of ambient atmospheric $CO_2$ (372mol mol$^{-1}$) grown rice (RA) and wheat (WA) crops were also collected from the land adjacent to the FACE experiment. Soil samples were collected from different depths at critical stages of crop growth of both the crops and analysed for different pools of carbon and nitrogen.

**Decomposition Study**

Decomposition study on residues of wheat and rice obtained from both FACE and ambient field was carried out in National Phytotron Facility, Indian agricultural Research Institute, New Delhi. Phytotron chambers maintained at ambient (370molmol$^{-1}$) and elevated (650molmol$^{-1}$) $CO_2$ concentrations were used for investigating the kinetics of residue decomposition wherein other natural conditions were simulated. In decomposition study litterbag technique as used by others (Schortemeyer et al., 2000) was followed. The individual litterbag was inserted into the centre of the pot containing 420 g soil. Destructive sampling of the pots was done at 15, 30, 45, 60, 75, 90, 105, 120, 135, 150 days of decomposition. Analysis was carried out to determine the dry weight and C/N ratios of residue sample remaining in lietter bags at various stages, microbial biomass carbon, total organic carbon and nitrate and ammoniacal forms of nitrogen in the soil at various stages of decomposition.

**Phytotron chamber and litter bag**

**Mineralization and Immobilization Routine of CERES-N**

The data from decomposition study with litterbag technique in National Phytotron Facility was used to evaluate the original CERES-N and to determine the best fitting rate constants of decomposition for the carbohydrate, cellulose and lignin pools in the model so as to fit to the observed results. The rate constants were obtained by trial and error method.

**RESULTS AND DISCUSSION**

**Biomass and Carbon Yield and Partitioning**

Average biomass yield of all the plant parts increased due to exposure to elevated $CO_2$ in open top chambers in both rice and wheat. The extent of increase in terms of percentage over ambient $CO_2$ conditions is expressed in the figure 1a. Relative preference of dry matter portioning to root was evident in wheat under elevated $CO_2$ while in case of rice preferential allocation of biomass to leaf and grain was recorded. Moreover, substantial root loss between anthesis /flowering and maturity was observed which indicated probable turnover of older roots during this time. Such loss was more under elevated $CO_2$ than ambient condition in both the crops. Fresh root weight and root volume measurements corroborated such trends. Carbon content in different plant parts (except grain in both the crops and root in rice) either remained unaffected or increased marginally due to increase in atmospheric $CO_2$, which suggests absence of dilution effect in spite of increase in biomass yield. This resulted in further significant increase in C uptake data under elevated $CO_2$ and it increased due to elevation of $CO_2$ by 35.56 per cent in rice and 42.91 per cent in wheat crop. Overall data suggested a clear indication of not only increase in biomass and C assimilation but also their preferred partitioning to underground portion as well as leaf (Fig. 1a). As a relatively large amount of assimilated C also remains in stem on maturity at elevated $CO_2$ (compared to ambient), its incorporation might be key to harness possibility of enhanced C sequestration in the long run.

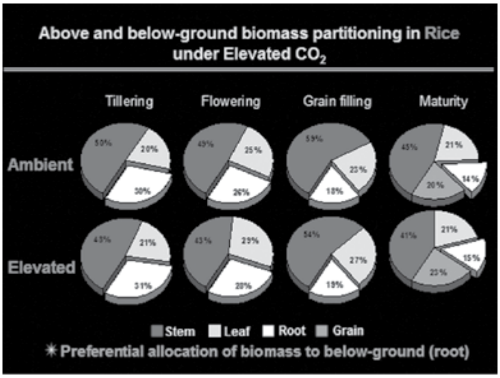


**Fig. 1a**
**Above below – ground biomass partitioning in Rice under elevated $CO_2$**

Fig. 1b Percent increase in biomass yield of different plant parts under elevated $CO_2$ over those under ambient $CO_2$ 1b Above and belowground biomass partitioning in rice under elevated $CO_2$

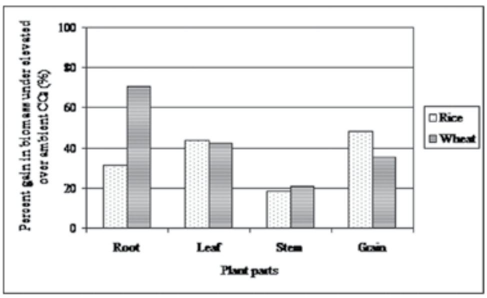


**Fig. 1b**
**Biomass yield different plant parts under elevated $CO_2$**

**Terrestrial Active Carbon Pools.**

The results of pot culture experiment under open top chambers and field experiment under FACE indicated that microbial biomass carbon (MBC) content in soil was positively affected by elevation of atmospheric $CO_2$ concentration. The respective gains were 40.7 and 16.59 per cent in rice and wheat rhizosphere soils, respectively during pot culture experiment. The corresponding increases for the two crops were 18.91 and 17.30 in field experiment.

All active carbon fractions in soil increased as a result of the increased atmospheric $CO_2$ concentration.

The specific gains in these carbon pools on exposure of the crops to increased $CO_2$ concentration were in the order of: Pot culture experiment Rice: MBC (40.70) > DOC (17.43) > CHC (9.079) > LBC (6.8) and Wheat: DOC (17.41) > MBC (16.59) > CHC (7.89) > LBC (7.55), Field experiment Rice: MBC (18.91) > DOC (15.35) > CHC (8.04) > LBC (7.43) and Wheat: DOC (17.91) > MBC (17.30) > CHC (8.88) > LBC (8.38).

The recalcitrant total soil carbon (TSC) content did not differ significantly in OTCs (pot culture study) in response to the elevation of atmospheric $CO_2$ concentration. Interestingly, in the field experiment a significant increase in total carbon contents in surface (0-10 cm) soil was observed under FACE. The soil in field under FACE has continuously been exposed to higher $CO_2$ for the past seven years. This long-term exposure to $CO_2$ with crop-stand might have increased the calcitrant carbon pool in soil. All carbon pools in soil collected from field declined in their quantity down the soil profile. The relative gains in the active carbon pools on exposure to elevated $CO_2$ also declined with increase in soil depth. This clearly indicated that the relative advantage of elevation of $CO_2$ is restricted to the upper layers of soil, symptomatic of the importance of rhizosphere effect in terms of root exudations and turn over. Though marginal, significant increase in total soil carbon in upper layers of FACE indicates a definite possibility of carbon sequestration in the longrun.

**Decomposition of Rice and Wheat Residues**

The effect of levels of $CO_2$ showed a decrease in degradability of the elevated $CO_2$ grown rice and wheat residues (RE, WE) compared to those grown under ambient atmospheric $CO_2$ concentration (RA, WA) (Fig. 2).Overall during decomposition, the carbon contents in RE was significantly higher than in RA, while C contents in WA and WE were at par. The C/N ratio of elevated $CO_2$ grown rice (72.28) and wheat (90.42) residues were greater than that in ambient $CO_2$ grown rice (67.12) and wheat (86.27) residues. The average C:N ratio of RA and RE during decomposition were 29.1 and 32.1, while that in WA and WE were 35.1 and 36.1, respectively. (Table 1) Total organic carbon (TOC) in RA treated soil was higher than in RE treated soil, but TOC in WE and WA amended soil did not differ significantly The microbial biomass C (MBC) in soil amended with ambient $CO_2$ grown rice and wheat residues (RA, WA) were higher than that in elevated $CO_2$ grown rice and wheat residues (RE, WE) (Table 4). The MBC in RA and RE amended soils were 317.1 and 293.4mgkg−1, while that in WA and WE were 275 and 257.3 mgkg−1, respectively. The total N mineralization as measured in terms of $NH_4^+$-N + $NO_3$−N was significantly higher in soil amended with ambient atmospheric $CO_2$ grown residues than with elevated $CO_2$ grown residues. Nitrogen mineralization was 13.4% higher in soil treated with RA than RE, while it was only 9% higher in soil treated with WA than WE. Overall, the N mineralization was 1.5 times higher in soil treated with rice residue than in wheat residue (Table1). enhanced microbial biomass proportionately increased N mineralization and therefore the Nmin:MBC was higher in soil amended with ambient $CO_2$ grown residues than with elevated $CO_2$ grown residues. The enhanced Nmin:MBC also proved that the microbes were more efficient inNmineralization in soil added with ambient grown residues. The experimental soil initially contained 27.0mgkg$^{-1}$of nitrate−-N. Though the initial values were same, a higher amount of $NO_3$−N was released into soil during the decomposition of ambient residues. This superiority of ambient residues with respect to the increase in N release can be ascribed to the higher nitrogen decomposition of ambient residues compared to elevated residues. In future, the rapid increase in $CO_2$ could produce residues like rice and wheat whose decomposition with relation to N mineralization would be slow. This has greater implications on N cycling in soil. As the rate of decomposition is slow, therefore the dependency of crops over fertilizer will be more but environmental protection point of view it would preserve N in soil by promoting less N loss.

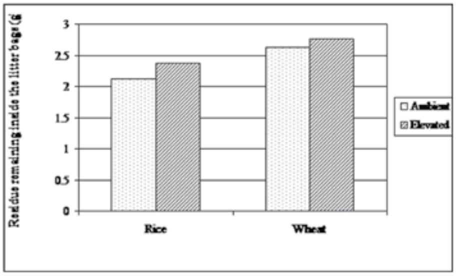


**Fig. 2a**
**Average amount of residue remaining during decomposition**

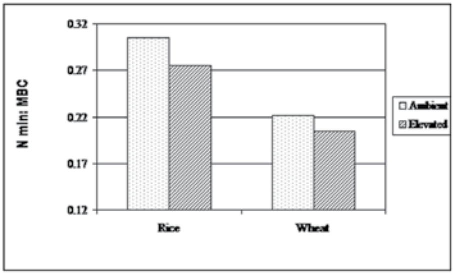


**Fig. 2b**
**Ratio of total nitrogen mineralization with MBC during decomposition**

**Table 1**
**Changes in C/N ratio and total N mineralization during decomposition**

| Days | C:N | | | | Total N (ammoniakal + nitrate) | | | |
|---|---|---|---|---|---|---|---|---|
| | Rice | | Wheat | | Rice | | Wheat | |
| | Ambient | Elevated | Ambient | Elevated | Ambient | Elevated | Ambient | Elevated |
| 0 | 67.12 | 72.28 | 86.27 | 90.42 | 47.8 | 47.8 | 47.8 | 47.8 |
| 30 | 35.74 | 39.82 | 43.82 | 43.63 | 29.5 | 27.6 | 22.0 | 20.5 |
| 60 | 29.58 | 32.87 | 35.06 | 35.62 | 36.2 | 31.7 | 22.9 | 20.5 |
| 90 | 26.26 | 28.87 | 32.32 | 33.50 | 46.3 | 39.9 | 28.0 | 29.2 |
| 120 | 24.75 | 26.65 | 29.28 | 30.32 | 57 | 49.4 | 35.5 | 32.0 |
| 150 | 23.35 | 25.12 | 27.37 | 28.43 | 66.1 | 57.9 | 42.9 | 38.2 |

### Calibration of Mineralization and Immobilization Routine of CERES-N

CERES-N simulates soil N transformations, including mineralization, immobilization, nitrification, and denitrification (Godwin and Jones, 1991). The mineralization and immobilization subroutine simulates the decay of two types of organic matter: fresh organic matter (FOM) and humus (HUM). At the beginning of the simulation, FOM was divided into three pools: 20% to carbohydrate (CARB), 70% to cellulose (CELL) and 10% to lignin (LIGN). The three pools decompose simultaneously each one having a maximum rate constant of decomposition. These rate constants were modified daily by three multiplicative factors based on C/N ratio of the residue, soil moisture and soil temperature in the corresponding soil layer. Thus mineralization rates of the three fresh residue pools simulated in the CERES model are: G1(j) = TF * $MF_x$* $CNRF_x$*RDECR(j) where, G1(j) is the proportion of the pool j (j=1 for carbohydrate, j=2 for cellulose and j=3 for lignin) that decays in one day; RDECR (j) is the decay rate constant of the pool j; TF is the temperature factor; MF is the moisture factor; and CNRF is the C/N factor.

The original version of the model overestimated the C and N mineralization processes. The modified decay parameters derived through a number of trials for carbohydrate, cellulose and lignin were 0.38, 0.01899 and 0.0035 $day^{-1}$ in case of rice residues grown under ambient $CO_2$. The respective values were 0.32, 0.01691 and 0.00266 $day^{-1}$ for rice residues under elevated $CO_2$ , 0.31, 0.01561 and 0.0013 $day^{-1}$ for wheat residues under ambient $CO_2$ and 0.29, 0.01508 and 0.0011 $day^{-1}$ for wheat residues under elevated $CO_2$. The process of decomposition and N mineralization from ambient and elevated grown rice residues fitted well to the modified CERES model. In case of wheat, decomposition from ambient and elevated $CO_2$ grown residues fitted well to the modified CERES model, while N mineralization was underestimated especially in case of elevated grown residues. A single value rate constant for decomposition of a particular class of compound (e.g., carbohydrate, cellulose and lignin) is not enough to predict its decomposition under different ecosystem. The modified sub routine of CERES was found to predict the decomposition and mineralization of RA, RE, WA and WE residues (Fig3).

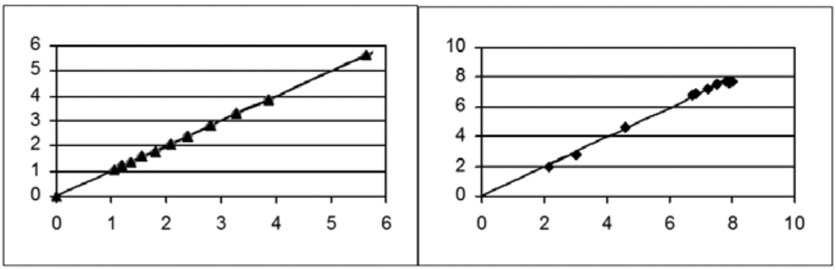


**Fig. 3**
**Observed (x-axis) vs predicted ( y-axis) curves of amount remaining and ammoniacal form of nitrogen associated with the decomposition of ambient grown rice residues (RE) under elevated atmospheric CO2 condition**

## CONCLUSION

The overall data from open top and FACE experiments suggested a clear indication of not only increase in biomass and C assimilation but also their preferred partitioning to underground portion as well as leaf. Terrestrial ecosystem structure and function is highly dependent on the relationship between plants and soil systems. As a relatively large amount of assimilated C also remains in stem on maturity at elevated $CO_2$ (compared to ambient), its incorporation might be key to harness possibility of enhanced C sequestration in the long run. All active carbon pools in soil increased under elevated $CO_2$ and though marginal, significant increase in total soil carbon in upper layers of FACE indicates a definite possibility of carbon sequestration in future. Thus terrestrial vegetation play a significant role in preventing the effects of global warming.

$CO_2$ enrichment altered the quality of organic matter; thereby indirectly affect the rate at which carbon and nitrogen are cycled within the soil plant system. Elevated atmospheric $CO_2$ grown rice and wheat residue quality will be decreased due to lowering of N content thereby widening of C:N. These attributes in elevated $CO_2$ grown residues will result in lower decomposition in soil than ambient $CO_2$ grown residue. Such decreased rate of decomposition might increase the residence time of the elevated $CO_2$-grown residue decomposition systems, thus supplementing sequestration of C in soil. In such situation lower N mineralization might increase the dependency of crops towards fertilizer N. However, the environmental benefit of lower Nmineralization is ascribed to the reduction of N loss through various mechanisms.

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# Impact of Weather Factors on the Population Dynamics of Sucking Pests in Coccinia (*Coccinia grandis* (L.) Voigt.) Ecosystem

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## INTRODUCTION

Coccinia (*Coccinia grandis* (L.) Voigt.) also known as ivy gourd, scarlet gourd, little gourd or Kowai fruit is a perennial herb, widely cultivated in South East Asian countries as a vegeTable. The tender fruits are rich sources of proteins and vitamins and the nutritional value was assessed to be as high as that of goat's milk and meat. The roots, stems and leaves of the plant are also used as ingredients of medicines for treatment of skin diseases, bronchitis and diabetes (Veeraragavathatham *et al*., 1998). The dominant sucking pests in coccinia ecosystem were scale insect *Saissetia hemispherica* (Targ.), aphid *Aphis spiraecola* Patch, leaf footed bug *Leptoglossus australis* F. and pentatomid bug *Aspongopus obscurus* F. For effective management of the pests, it is mandatory to assess the influence of weather parameters on the occurrence and distribution of pests. Often the stage of insect development can be tied to the growth stage of the crop which inturn is driven by weather conditions.

## MATERIALS AND METHODS

Local variety of coccinia obtained from Instructional farm, College of Agriculture,Vellayani was raised and maintained during the period from March 2005 to September 2006. It was raised in an area of 1000 $m^2$ with a spacing of 5 × 4 m. The crop husbandry practices were done as envisaged in the Package of Practices Recommendations of the Kerala Agricultural University (KAU, 2002) except the spacing adopted for planting. Pandals made of wooden poles and coir was erected and vines of individual plants were grown separately. Inter twining of vines was prevented by separating out the vines at weekly intervals. Ten plants were selected at random and the population of the *S. hemisphaerica* and *A. spiraecola* was recorded from 10 cm length of the mature vine and the growing point respectively. The total number of nymphs and adults feeding on a plant were recorded for *L. australis* and *A. obscurus*. The weather parameters *viz*., maximum and minimum temperature, relative humidity, rainfall and number of rainy days were recorded from the Department of

Meteorology, College of Agriculture, Vellayani. The average of the monthly data was worked out and used for the study. The monthly weather parameters were correlated with the population of pests during the month of observation and the succeeding month. Data was subjected to ANOVA. (Panse and Suhatme, 1985).

## RESULTS AND DISCUSSIONS

Correlation coefficients between weather parameters and incidence of pests during the month and succeeding month of observation are presented in Table 1.

During the month of observation, the population of *S. hemisphaerica* had significant positive correlation with maximum temperature (r value = 0.7992) and significant negative correlation with evening relative humidity (r value = 0.5943) and rainfall (r value = 0.5961). The minimum temperature, morning relative humidity and the number of rainy days did not influence the population of *S. hemisphaerica* significantly. The maximum temperature was positively correlated with the population of *S. hemisphaerica* of the succeeding month and had significant negative correlation with evening relative humidity (r value =⁻ 0.7394) and rainfall (r value =⁻0.7636). Though the relationships were not significant, minimum temperature and morning relative humidity was positively correlated and number of rainy days was negatively correlated with the populatio n of *S. hemisphaerica* of the succeeding month. The population observed in rainy and summer seasons clearly showed variation. An increase in the population was recorded during summer (Fig. 1). The finding was supported by the highly significant positive correlation of the population of *S. hemisphaerica* with maximum temperature and significant negative correlation with rain fall. The clear cut population fluctuation observed might be due to shorter life cycle and comparatively higher survival rate during summer and wash off of crawlers in rain.

**Table 1**
**Correlation coefficient between weather parameters and the population of sucking pests of coccinia during the month and succeeding month**

| Parameters | *S. hemisphaerica* | | *A. spiraecola* | | *L. australis* | | *A. obscurus* | |
|---|---|---|---|---|---|---|---|---|
| | A | B | A | B | B | A | A | B |
| Max. temp. | 0.7992** | 0.7657** | 0.8081** | 0.8204** | 0.7110** | 0.6645* | 0.4761 | 0.6596* |
| Min. temp. | -0.0175 | 0.0728 | 0.0753 | 0.0633 | 0.3797 | 0.0549 | 0.3751 | -0.0024 |
| RH Morn. | -0.0463 | 0.1930 | -0.0676 | 0.1841 | 0.0522 | -0.1615 | -0.0979 | 0.0247 |
| RH Even. | -0.5943* | -0.7394** | -0.5998* | -0.8575** | -0.2681 | -0.4507 | -0.1249 | -0.6826* |
| RF | -0.5961* | -0.7636** | -0.6178* | -0.8498** | -0.4261 | -0.5699 | -0.3941 | -0.6648* |
| No. of rainy days | -0.5082 | -0.5503 | -0.5512 | -0.7132** | -0.5714 | -0.5126 | -0.4674 | -0.4575 |

A - During the month, B - Succeeding month

** - Significant at 0.01, * - Significant at 0.05

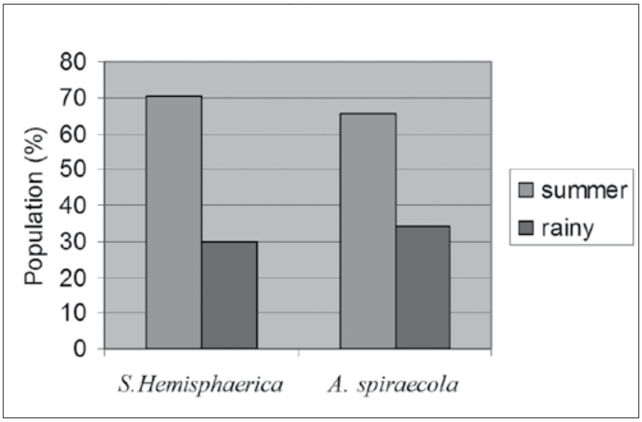


**Fig. 1**

**Seasonal variation in the population of major sucking pests in coccinia**

The population of *A. spiraecola* showed significant positive correlation with maximum temperature (r value = 0.8081) and significant negative correlation with evening relative humidity (r value =⁻ 0.5998) and rainfall (r value =⁻ 0.6178) of the corresponding month of observation. The minimum temperature was positively correlated and the morning relative humidity and the number of rainy days were negatively correlated with the population of *A. spiraecola* during the month, but the relationships were not significant. The maximum temperature (r value = 0.8204) had significant positive correlation whereas evening relative humidity (r value = 0.8575), rainfall (r value =0.7132) and the number of rainy days had significant negative correlation with the population of *A. spiraecola* in the succeeding month. The population was also positively correlated with minimum temperature and relative humidity though the relationships were not significant. A positive correlation of the population build up of *A. spiraecola* with maximum temperature and negative effect with rainfall was also observed. The results were in agreement with the observations of Prasad and Logisenan (1997).

The maximum temperature had significant positive correlation with the population of *L. australis* during the month of observation. The minimum temperature and morning relative humidity had positive correlation while evening relative humidity, rainfall and number of rainy days had negative correlation with the population of *L. australis*, though the relationships were not significant. The maximum temperature had significant positive correlation with the population of *L. australis* of the succeeding month also. The population of the pest was positively correlated with minimum temperature and negatively correlated with morning and evening relative humidity, rainfall and number of rainy days , though the relationships were not significant.

There were no significant correlations between the population of *A. obscurus* and the weather parameters. A positive correlation was recorded with the maximum and minimum temperature and negative correlation with other parameters when the population of the pest was correlated with the weather parameters of the current month of observation. The population of *A. obscurus* of succeeding month of observation showed significant positive correlation with the maximum temperature (r value =0.6596) and significant negative correlation with evening relative humidity(r value =⁻ 0.6826) and rainfall (r value =⁻ 0.6648). Though the relationships were not significant, the population of the pest had positive correlation with morning relative humidity and negative correlation with minimum temperature and number of rainy days.

An increase of temperatures, changes of rainfall in amount and distribution and as a consequence the general changes in availability of water will furthermore influence the productivity of the crop and also will highly influence the incidence of pests.

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