Adaptation to Climate Change with a Focus on Rural Areas and India

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Ministry of Environment & Forests
Government of India

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It gives me immense pleasure to introduce this joint publication of the German development cooperation institution Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and Ministry of Environment and Forests (MoEF), Government of India. The publication on 'Adaptation to Climate Change with a Focus on Rural Areas and India' gives an insight into the challenges faced by rural communities due to climate variability and climate change and suggests options to adapt to the impacts of climate change in six crucial sectors: agriculture, forestry, biodiversity, water resources, coastal zone management, and disaster risk management.

Government of India has taken several steps to address climate change and reduce the vulnerability of rural populations to adverse impacts of climate change through implementation of National Missions and preparation of State Action Plans on Climate Change (SAPCC).

As a follow up of such actions, MoEF and GIZ started in 2009 the Indo-German bilateral cooperation project 'Climate Change Adaptation in Rural areas of India – CCA RAI', funded by the German Federal Ministry of Economic Cooperation and Development with four states as project partners, namely Madhya Pradesh, Rajasthan, Tamil Nadu and West Bengal. The project aims to increase the resilience of the rural communities and enables them to live better with a changing climate. Most of the objectives of this project are consistent with the objectives of NAPCC.

This publication has been jointly prepared by GIZ and MoEF under the CCA RAI project, with inputs from various national and international experts, in order to take stock of current knowledge and experiences about adaptation to climate change in rural areas. Bearing in mind the challenges faced by rural communities, examples from India and elsewhere illustrate some possible ways of dealing with the consequences of climate change. This review will help to define knowledge gaps and refine adaptation options.

I trust that this publication will provide a good basis for the government and policy planners to identify and prioritise adaptation options for India. It will also be a useful information source for academicians, civil society and experts.

I congratulate GIZ and MoEF for bringing out this useful publication at a time when adaptation to the impacts of climate change has become important for overall sustainable development. I look forward to further such publications under this joint initiative.

Dr Tishya Chatterjee

Secretary, Government of India, Ministry of Environment and Forests

About GIZ

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH was formed on 1 January 2011. It brings together the long-standing expertise of the Deutscher Entwicklungsdienst (DED) gGmbH (German Development Service), the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (German Technical Cooperation) and InWEnt – Capacity Building International, Germany. For further information, go to www.giz.de.

GIZ is owned by the German Government and works in the field of international cooperation for sustainable development. GIZ is also engaged in international education work around the globe and currently operates in more than 130 countries worldwide.

GIZ in India

Germany has been cooperating with India by providing expertise through the organisations now forming GIZ for more than 50 years. To address India's priority of sustainable and inclusive growth, GIZ's joint efforts with the partners in India currently focus on the following areas:

- Energy: Renewable Energy and Energy Efficiency
- Sustainable Urban and Industrial Development
- Natural Resource Management
- Private Sector Development
- Social Protection
- Financial Systems Development
- HIV/AIDS – Blood Safety

Upon completion of this compilation of knowledge and experiences on adaptation to climate change, I would like to thank the following for their guidance and support: Mr. J.M. Mauskar, Special Secretary (MoEF), Mr. R.R. Rashmi, Joint Secretary (MoEF), and Dr S. Satapathy, Director (MoEF), Dr D.N. Pandey, Member Secretary (State Pollution Control Board, Govt. of Rajasthan), Mr. T.S. Srinivasmurthy, Director of Environment (Govt. of Tamil Nadu), Mr. Debal Ray, Chief Environment Officer (Department of Environment and Forests, Govt. of West Bengal) and Mr. Lokendra Thakkar, Project Coordinator (Environmental Planning and Coordination Organisation, Govt. of Madhya Pradesh).

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On behalf of all the authors I acknowledge the support from Ms. Rosie Füglein for journalistic editing and proof reading and Ms. Susanne Fritz for the design and layout of this publication.

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INTRODUCTION

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The impacts of climate change are being felt all over the world. It is becoming warmer, rainfall is more erratic, the sea level is slowly rising and extreme weather events are becoming more frequent and intense. Prolonged periods of drought, floods and shifting climatic zones are endangering development successes. The poor and marginalised are often most affected by climate variability and change.

India is a large emerging economy with a great variety of geographical regions, biodiversity and natural resources. However, the country is one of the most vulnerable to climate change risks worldwide. More than half of India's population of over 1 billion people lives in rural areas and depends on climate-sensitive sectors like agriculture, fisheries and forestry for their livelihoods. Natural resources and the environment are already under pressure as a result of rapid urbanisation, industrialisation and economic development. Climate change is projected to exacerbate these pressures.

The Indian Ministry of Environment and Forests and GIZ India are working together to devise ways of dealing with the inevitable impacts of climatic change. The Climate Change Adaptation in Rural Areas of India (CCA RAI) project aims to strengthen the capacities of vulnerable rural communities in India to live with climate variability and change. The work includes supporting governments of four partner states, local communities and other relevant stakeholders in identifying, developing and carrying out adaptation measures in pilot regions. This publication has been produced in the context of the project to provide an overview of the main issues in current adaptation discussions and recognised adaptation options in a number of thematic areas.

The input has come from a range of experts who were willing to share their know-how in order to provide policy-makers, practitioners and other interested readers with an understanding around adaptation to climate change and show how it can be integrated into different thematic areas. The publication also aims to assist experts working in a given field to understand the adaptation concerns of other fields, thus advancing the development of cross-sectoral and overarching solutions.

Global climate change trends and its impacts

Key messages

- Climate change is already taking place. Rural areas will be particularly affected as it impacts on water resources, agriculture, overall biodiversity and ecosystems like forests and coastal zones, as well as human health.
- While the trend of temperature increase – though not its magnitude – is fairly clear, key climate variables like precipitation are hard to project. This means that decision-making for climate change adaptation is fraught with uncertainty.
- 700 million people in rural India depend on climate-sensitive sectors for their livelihood and are at maximum risk from climate change.

Climate projections

Global concentrations of greenhouse gases (GHGs) in the atmosphere have been rising since the industrial revolution as a result of human activities. During the 20th century, Earth's mean **global temperature** rose by almost 0.74 °C and is expected to increase by a further 1.1 °C to 6.4 °C by the end of the 21st century (IPCC 2007a).

Mean **global sea levels** are also expected to rise by 2100, although the exact extent is still a topic of heated debate, with estimates ranging from 18 cm to 140 cm (IPCC 2007a).

Other climate variables will also be affected by a global rise in temperature. An increase in **global precipitation** is projected, but this increase will very likely be spread unevenly across different regions: high latitude and equatorial regions are expected to receive more precipitation and mid-latitude regions a range of changes. Projected precipitation patterns are far from certain, with considerable variations likely even within the given ranges. Many subtropical areas are expected to become drier. In some areas such as the Sahel, however, even the direction of change is unclear.


Weather versus climate

Weather is the actual atmospheric conditions at a given time and location, whereas **climate** refers to weather averaged over a longer period of time, often 30 years.

In addition to changes in the mean values for temperature, sea level rise, and precipitation, climate change will also lead to greater variability in the weather, as well as more weather extremes. Events such as floods, droughts, heat waves and typhoons are expected to become more frequent and intense.

It must be emphasised that in most cases there is a degree of **uncertainty** associated with these climate projections. In part this uncertainty arises from the scale of analysis: global averages can be projected with much more certainty than projections for specific locations. The level of uncertainty also differs across different aspects of climate change, with more accurate projections available for temperature than for precipitation. Nevertheless, despite this uncertainty, it is highly unlikely that there will be no change at all. Therefore, while climate information is being improved, the available climate projections should already be used to identify and counteract possible impacts (GIZ 2011a).

Climate change impacts

The climatic changes described above will have serious implications for a number of sectors and resources, including agriculture, water availability and quality, and ecosystems like coastal zones. They will also have an influence on the frequency and magnitude of natural disasters. Very minor changes to temperature can have major impacts on systems on which human livelihoods depend, including changes to water availability and crop productivity, the loss of land due to sea level rise and the spread of disease. The lives and livelihoods of many different communities will be at risk. Rural areas are highly vulnerable to climate change, since people there depend heavily on natural resources such as local water supplies and agricultural land. In fact, about 70 % of the population in developing countries live in rural areas, where agriculture is their main source of livelihood (IPCC 2007b).

The **agricultural sector** is already threatened by existing stresses such as the limited availability of water resources, land degradation, biodiversity loss and air pollution; climate change will thus make already sensitive systems even more vulnerable. Whereas climate change could improve yields of some crops in mid- to high-latitudes, in areas such as the tropics even minimal warming will lead to crop yield losses. A temperature increase of between 2 and 4 °C may, for example, cause agricultural losses in the Philippines, yet rice yields in Indonesia and Malaysia are projected to increase (IPCC 2007b).

Agricultural yields and livelihoods will also be affected by climate-related impacts on the quantity and quality of **water resources**. As temperatures increase, the need for irrigation will rise in those areas projected to become drier. Especially the Middle East and South-East Asia will suffer increasing water stress, expressed as a high ratio of water withdrawal to renewable water resources (IPCC 2007b).

As glaciers and snow cover melt, areas that depend on melt water will be affected by the changing seasonality of water flows (spring floods and summer water shortages) and by severe water reductions in the long-term. Seasonal changes in rainfall and temperature are already having an impact on agro-climatic conditions, growing seasons, planting and harvesting calendars as well as on pest, weed and disease populations. In particularly affected areas, this will lead to crop failure and loss of livestock, which in turn increases livelihood insecurity and the likelihood of out-migration and possibly dependency on food aid (IPCC 2007b).

Population growth in the river deltas of Myanmar, Bangladesh, India and Pakistan has pushed agricultural land uses out to **coastal zones** at high risk from flooding and sea level rise. While inundation may have some positive impact on agricultural production, with perennial floods bringing silt and nutrients that increase soil fertility, prolonged floods have had a detrimental impact on crop yields. In Bangladesh, temperature extremes, drought and salinity intrusion are also causing declining crop yields (IPCC 2007c).

Droughts, wildfire, ocean acidification and other climate-related disturbances will increase the stress on **forests**, coral reefs and other ecosystems, with negative consequences for **biodiversity** and ecosystem goods and services. A rise in sea temperature will increase the occurrence of coral bleaching, with resulting declines in fish stocks that are an important source of income and subsistence protein in developing countries. Drought has already caused significant tree mortality in the Argentinean Andes and the eastern Mediterranean, while more severe storms are disrupting the ecosystem functioning of mangroves and salt marshes. Settlements in coastal and river flood plains are particularly vulnerable to floods, sea surges and sea level rise (IPCC 2007f).

Particularly vulnerable communities will be affected by an increasing frequency and intensity of **natural disasters**. Hot extremes, heat waves and heavy precipitation are predicted to become more frequent, and tropical cyclones will become more intense. Precipitation is very likely to increase in frequency in high latitudes and is likely to decrease in most subtropical land regions, continuing recent observed trends. These changes are predicted to lead to an increase in storms, floods and landslides, but also to an increased risk from forest fires due to prolonged dry spells (IPCC 2007c). Throughout 2010, changes in weather patterns have resulted in a series of devastating natural disasters, especially in South Asia, where heavy floods in Pakistan affected more than 20 million people (over 10 % of the total population) and killed more than 1,700 people.

The impact of climate change is also felt in cities since more people abandon rural areas that are strongly affected by climate change and migrate to cities. Extreme weather events such as floods and heat waves can also pose significant health threats such as diarrheal disease, dehydration or cardiac complications. In addition, mean temperature changes can alter the range and transmission potential of diseases such as malaria. Higher coastal water temperatures in South Asia may also lead to more widespread and toxic cholera outbreaks (IPCC 2007d). Issues related to cities and climate change and health and climate change are not covered in this publication. The focus is on natural resource-related sectors with a particular emphasis on rural areas and India.

Climate change impacts in India

For their survival and livelihoods, 700 million Indians living in rural areas directly depend on climate-sensitive sectors like agriculture, forests and fisheries and natural resources such as water, biodiversity, mangroves, coastal zones, and grasslands. Furthermore, the adaptive capacity of dryland farmers, forest dwellers, fisher folk and nomadic shepherds is very low. Climate change is likely to impact all natural ecosystems as well as socio-economic systems in India. In addition, poverty is a critical factor that limits the adaptive capacity of rural people in India (GoI 2008).

The Indian Government's National Communications (NATCOM) report of 2004 identifies the following as the impacts of climate change most likely to affect India between now and 2100:

- Decreased snow cover will affect snow-fed and glacial systems such as the Ganges and Brahmaputra. 70 % of the summer flow of the Ganges comes from melt water.
- Erratic monsoons will affect India's rainfed agriculture, peninsular rivers, water and power supply,
- Wheat production will drop by 4-5 million tonnes, even with a rise in temperature of only 1 °C.
- Rising sea levels will cause displacement along one of the most densely populated coastlines in the world, also threatening freshwater sources and mangrove ecosystems.
- Floods will increase in frequency and intensity. This will heighten the vulnerability of people in the country's coastal, arid and semi-arid zones.
- Over 50 % of India's forests are likely to experience shift in forest types, adversely impacting associated biodiversity, regional climate dynamics and livelihoods based on forest products.

Meaning of adaptation to climate change

Adaptation is needed to prepare communities, regions, countries and societies for the consequences of climate change.

Adaptation to climate change

Adjustments in human and natural systems in response to actual or expected climate stimuli or their impacts that moderate harm or exploit beneficial opportunities (IPCC 2007e)

Practically, adaptation to climate change means doing things differently because of climate change (UNDP 2004). Most often, it does not mean doing completely new things, but rather purposefully modifying development interventions. Adaptation itself is not a development objective, but necessary for safeguarding beneficial outcomes. Adaptation measures may be compared with a baseline of 'doing nothing', resulting in bearing losses and not making use of opportunities. Bearing losses occurs paricularly when those affected have no capacity to respond in any other way (for example in extremely poor communities) or where the costs of adaptation measures are considered to be high relative to the risk or expected damage.

Adaptive capacity

The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2001)

Adaptation can mean one or a number of the following:

Strategy	Example
Share losses	Support from extended family, insurance, or social programmes
Modify threat	Change in the management of dykes and dams to modify flood patterns
Prevent impacts	Redistribution of water to avoid scarcity
Change use	Change crops or soil management
Change location	Relocation of settlements or economic activities
Research	Improve seed research
Change behaviour and rules	Rainwater harvesting; conservation

(Source: OECD 2009)

To a certain extent, adaptation happens every day as we adjust to changes around us. This is called autonomous adaptation. However, to make use of adaptation opportunities in different sectors, capacities need to be developed at different levels and policies need to be adjusted. The chart modified from the World Resources Institute (WRI) shown on the following page describes categories of activities along a continuum of adaptation and development ranging from a 'development focus' to an 'impact focus'.

It includes:

1) activities that increase human development and address drivers of vulnerability, e.g. diversification of livelihoods;
2) activities that reduce climate risks in affected sectors, e.g. reforestation and other measures related to natural resource management;
3) activities that aim at building response capacities through training, strategic use of climate information and its integration into planning, eg. monitoring water quality or disaster risk management;
4) activities that confront climate change by addressing concrete impacts, e.g. managing coral reefs in response to bleaching.

Continuum of adaptation activities

1 Addressing drivers of vulnerability:	2 Managing indirect climate risks:	3 Building response capacity:	4 Adressing direct impacts:
Viet Nam: Improving access to markets in poor rural areas of Viet Nam *(Provincial People's Committees of Ha Tinh and Tra Vinh/GIZ)*	**India:** Stabilising sand dunes: stratification of vegetation to counteract worsening desertification *(Rajasthan Pollution Control Board/GIZ)*	**Philippines:** Integrating the consideration of climate risks and the identification of adaptation options into local development planning *(Philippine Department of Environment and Natural Resources/GIZ)*	**Viet Nam:** Reforestation and diversification of mangrove forests to protect coastal zones from increasing storm surges *(Provincial People's Committee of Bac Lieu/GIZ)*
Uganda: Providing women with crossbred goats and instruction in graze-free feeding *(Karamoja Agropastoral Development Programme)*	**Brazil:** Participatory reforestation in Rio de Janeiro's hillside favelas to combat flood-induced landslides *(City of Rio de Janeiro)*	**Mali:** Teaching farmers to collect climate data and integrate it into their planting decisions *(Gouvernment of Mali/ Swiss Agency for Development and Cooperation)*	**Indonesia:** Managing coral reefs in response to widespread coral bleaching *(World Wide Fund for Nature)*
Cuba: Vaccination programme to eradicate diseases in low-income areas *(Cuban Ministry of Health)*	**Tanzania:** Reviving traditional enclosures to encourage vegetation regeneration and reduce land degradation *(Tanzanian Ministry of Natural Resources and Tourism)*	**Bangladesh:** Using nationally standardized risk assessment procedures to develop a community adaptation plan of action *(Local Government of Bangladesh)*	**Nepal:** Reducing the risk of glacial lake outburst floods from Tsho Rolpa Lake *(Government of Nepal)*

development focus ← → impact focus

(Source: adapted from WRI)

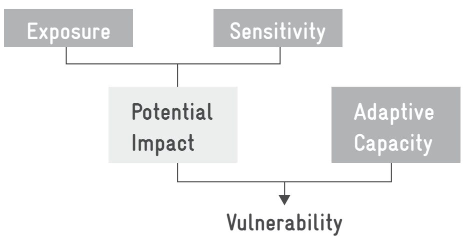
Vulnerability to climatic changes

How vulnerable a country or society is to the effects of climate change depends not only on the magnitude of climate stimuli or their effects but also on the sensitivity and capacity of the affected system to cope with or adapt to such stress. Sensitivity to climatic stress is generally high when societies depend on natural resources or ecosystems, e.g. agriculture and coastal zones. Adaptive capacity – the ability to adapt and cope with climatic stress – relies on various factors, such as wealth, technology, education, and access to resources.

Vulnerability

Vulnerability is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2007e).
Vulnerability is a function of the character, magnitude and rate of climate change and the degree to which a system is exposed, along with its sensitivity and adaptive capacity. It increases as the magnitude of climate change or sensitivity increases, and decreases as adaptive capacity increases (OECD 2009).

The vulnerability framework in the chart below describes vulnerability as a function of exposure to the impacts of climate change, sensitivity of the system and adaptive capacity. It takes into account that socio-economic systems can reduce or intensify the impacts of climate change.



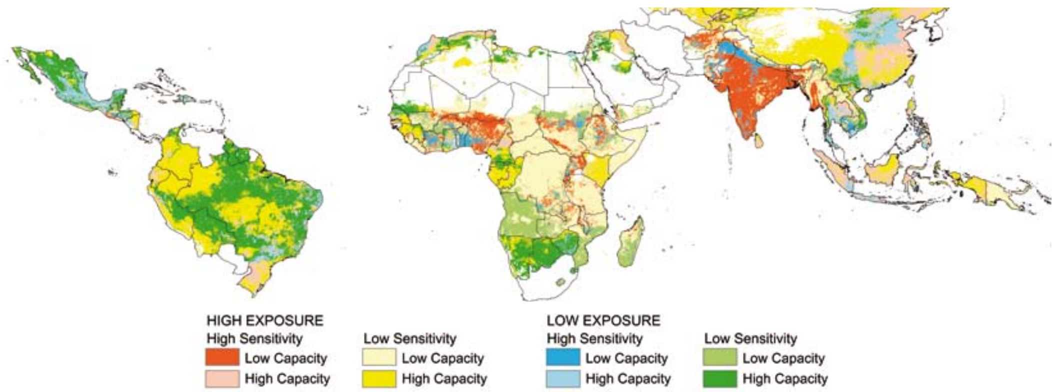
(Source: adapted from Allen Consulting Group)

Vulnerability of a given system or community depends on:

- the type and magnitude of climate change to which it is exposed (exposure);
- how sensitive or affected it is to this change (sensitivity);
- the extent to which the system is capable of adjusting or adapting to this change (adaptive capacity).

While vulnerability must be defined on a case-by-case basis, it can generally be said that poor communities are especially vulnerable to climate change, variability and climate extremes. This is due to their limited access to resources, secure housing, proper infrastructure, insurance, technology and information. On a broader scale, the Climate Change Agriculture and Food Security (CCAFS) research programme developed the following map that shows how exposure, sensitivity and (adaptive) capacity interact to determine the vulnerability of different regions to food insecurity. 'The red areas are food-insecure and intensively farmed regions that are highly exposed to a potential five per cent or greater reduction in the length of the growing season. Such a change over the next 40 years could significantly affect food yields and food access for 369 million people – many of them smallholder farmers – already living on the edge. Note, that this category includes almost all of India and significant parts of West Africa.' (CCAFS 2011)

Vulnerability to food insecurity: exposure, sensitivity and (adaptive) capacity

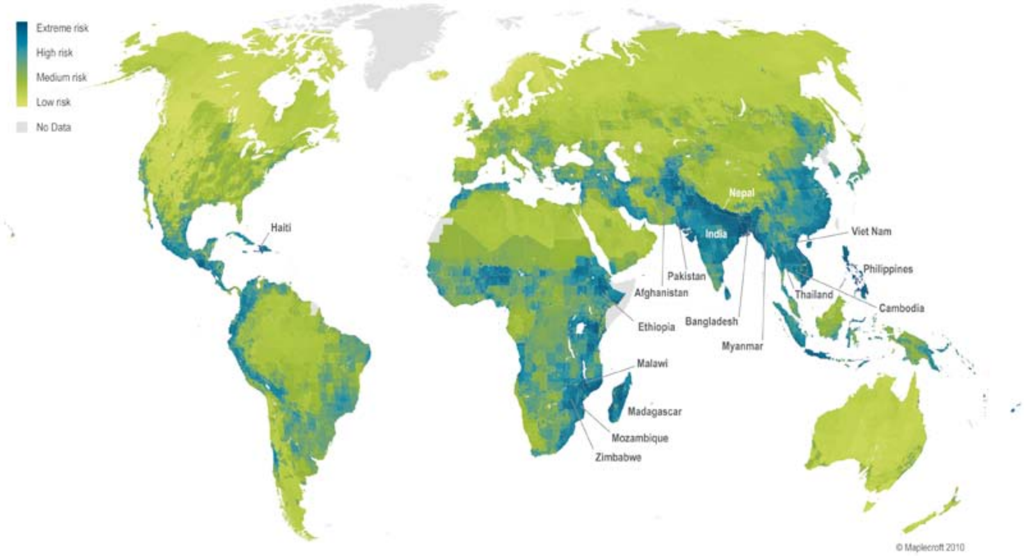


(Source: CCAFS 2011)

Maplecroft (2010) calculated and ranked the vulnerability of human populations of 170 countries over the next 30 years. In order to assess national vulnerabilities, 42 social, economic and environmental factors were analysed around three core aspects:

- exposure to climate-related natural disasters and sea-level rise;
- human sensitivity, which was assessed through an analysis of population patterns, development, natural resources, agricultural dependency and conflicts;
- the adaptive capacity of a country's government and infrastructure to combat climate change.

The Climate Change Vulnerability Index (CCVI) 2011



(Source: Maplecroft 2010)

The Climate Change Vulnerability Index reflects the vulnerability of different countries to extreme climate-related events and changes in major climate parameters. It revealed that many countries are at 'extreme risk' from the impacts of climate change, including, in Asia: Bangladesh (1), India (2), Philippines (6), Viet Nam (13) and Pakistan (16). Other countries in the highest risk category are: Madagascar (3), Nepal (4), Mozambique (5), Haiti (7), Afghanistan (8), Zimbabwe (9), and Myanmar (10). Over the next 30 years it is expected that their vulnerability to climate change will increase due to predicted rises in air temperature, precipitation and humidity.

'Almost the whole of India has a high or extreme degree of sensitivity to climate change, due to acute population pressure and a consequential strain on natural resources. This is compounded by a high degree of poverty, poor general health and the agricultural dependency of much of the populace.' (Maplecroft 2010)

Linking adaptation to development

Key messages

- Climate change affects the livelihoods of people, resulting in a need for adaptation in key development sectors. There is thus a direct link between adaptation and development.
- For maximum effectiveness, adaptation should be integrated into development planning and decisions.
- Features of practical adaptation include: making use of climate information, applying a cost-benefit rationale, broadening climate risk management, improving coordination and communication among involved stakeholders, making use of good practices and innovations.

Developing countries are particularly vulnerable to climate change, due to their often higher exposure to weather and climatic extremes and climate variability. Furthermore, their economies are often highly dependent on climate-sensitive resources, whereas their adaptive capacity is relatively low. It is predominantly the poor who will be affected disproportionately. Climate change affects key development sectors such as agriculture, water and human health. Consequently, it also affects the objectives of development measures, projects, policies and development planning on various levels. Given that development choices today influence the adaptive capacity of people and their governments well into the future, there is ample opportunity, but also an urgent need, to integrate climate change considerations into development activities and decision-making.

To ensure that adaptation is effective in supporting overall development objectives, it may be useful to consider the following when planning practical action:

- Adaptation should build on the **best available information** about impacts, vulnerabilities and adaptation options. An unprecedented amount of knowledge is available about experienced and expected change, yet uncertainties remain. Improving data availability, translating it into user-friendly information and choosing interventions on the basis of what can be known are key tasks ahead. Targeted interventions are possible when fairly clear-cut information about impacts is available. Otherwise, the precautionary principle (e.g. avoiding building in flood-prone areas, diversifying income sources) should apply and no-regret options (e.g. combating soil erosion) should be the focus.

- Presenting economic figures on how much can be saved by avoiding impacts and comparing the costs of the different options can help to promote adaptation and choose the most efficient among possible options. Knowledge on the **economics of adaptation** is clearly still limited, but recent studies provide both robust figures and methods that can be applied for prioritisation (World Bank 2010).
- **Risk management** is a key feature of adaptation. Current approaches dealing with climate risks have to be strengthened. They can range from risk reduction to risk sharing – e.g. in disaster management or water resources management. Climate projections will have to be taken into account and new methods and procedures are required.
- Adaptation may require complex **governance processes**. New stakeholders have to be involved, as climate change will require action by people who have not explicitly considered climate change in their past decisions.
- **Communication** among the different thematic communities will have to improve and strategies in the various areas need to be efficiently coordinated and managed. Capacity development is key in such a complex and dynamic environment.
- Often adaptation does not entail completely new things. In all sectors there is ample **existing knowledge** about and experience with specific techniques and management strategies that are of great value for addressing climate change. Increasing the robustness of livelihoods or agricultural systems, for example, is an important contribution to adaptation in itself. In this context, specific techniques like efficient irrigation or watershed management already contribute greatly to the adaptive capacity of regions. Building on an understanding of key climate change risks, such techniques can be improved, targeted or transferred to regions where they have not been previously employed. Improved knowledge and technologies, such as new crop varieties, may be further spread to promote adaptation to climate change.

Adaptation at the international level

The international community has acknowledged that a joint effort is needed to solve the global problem of climate change. The Nobel Prize-winning **Intergovernmental Panel on Climate Change (IPCC)**, chaired by Dr R.K. Pachauri from The Energy and Resources Institute (TERI) in India, has over time provided a scientific foundation and informed the political debates and public perception. IPCC regularly assesses and synthesises the state-of-the-art in climate science. Based on its work, the need to stabilise global temperature at 2 °C above pre-industrial level is widely accepted internationally. In addition, adaptation-related research on climate impacts, vulnerability and adaptation, is assessed. IPCC's latest Fourth Assessment Report, published in 2007, states, for example, that 'climate change is projected to impinge on the sustainable development of most developing countries of Asia.'

The **United Nations Framework Convention on Climate Change (UNFCCC)** was agreed in 1992. It initially focused strongly on mitigating greenhouse gases to achieve 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system', which is the ultimate objective of the convention. In addition, adaptation to climate change is anchored in the UNFCCC and has been further developed since. This two-track approach of 'avoiding the unmanageable, managing the unavoidable' is essential in international climate policy. This publication also addresses the necessity of linking mitigation and adaptation efforts.

Major milestones in adaptation under the UNFCCC

- The Marrakesh Accords set up the Special Climate Change Fund (SCCF) and the Least Developed Countries Fund (LDCF) to support adaptation under the Global Environment Facility.
- The Nairobi Work Programme catalyses actions, provides a forum to improve the knowledge base and understanding on adaptation issues, and facilitates informed decisions on practical adaptation actions.
- The Buenos Aires Programme of Work outlines areas of climate change adaptation for the international community to work on. It supports developing countries by mobilising multilateral and bilateral support for climate change.

- The Adaptation Fund under the Kyoto Protocol offers developing countries resources from a 2 % levy on projects of the UNFCCC's Clean Development Mechanism through what is known as a Direct Access modality.
- The Copenhagen Accord and Cancun Agreement focus on Fast Track Funding and long-term targets to finance adaptation.
- The Cancun Adaptation Framework agreed in Mexico in 2010 provides a comprehensive umbrella for adaptation to climate change under the UNFCCC.

The UNFCCC has seen intensified negotiations since its summit in Bali in 2007. The climate summit in Copenhagen in December 2009 did not deliver on the expectations of many to bring about a comprehensive climate treaty. For adaptation to climate change, the Cancun Conference in 2010 was a small step forward since it brought about strong recognition of adaptation to climate change in its 'shared vision', lending equal weight to both adaptation and mitigation measures, especially in developing countries.

The **Cancun Adaptation Framework** outlines:
- areas of activities needed for adaptation;
- institutional arrangements at different levels;
- a special work programme that develops recommendations for approaches that address loss and damage associated with climate change;
- the engagement of relevant expertise and stakeholders;
- a clear commitment to support developing countries in implementing adaptation.

The Cancun Adaptation Framework establishes a process to provide support to least developed countries and other countries to develop and implement national adaptation plans as a means to address medium and long-term adaptation needs. An adaptation committee with technical support and overview functions was established. Countries are requested to report on their activities and support to other countries.

Governance and policies for adaptation

Key messages

- In the absence of extensive legislation on adaptation to date, the most widespread policy instruments currently are: adaptation strategies, climate change action plans and climate-relevant provisions in sector policies and development planning.
- Adaptation strategies often outline mid- to long-term and cross-sectoral adaptation priorities.
- Applying a climate lens to sector and development policies provides the opportunity to consider climate risks from the development planning phase onwards.
- Governance for adaptation requires flexibility of institutional structures and procedures and cross-sectoral coordination.

Governance and policies can bring about changes for adaptation, both at international and national level. In order to facilitate effective adaptation responses, the use of climate information, strategic orientation, cross-sectoral coordination and mainstreaming needs to be promoted. Regarding governance for adaptation, cross-sectoral committees, task forces and working groups have already been established in many countries.

In the absence of legislation on adaptation in most countries, adaptation strategies, sometimes called action plans, are currently the most common policy instrument for adaptation. They inform action and outline priorities beyond regular planning cycles and sectoral boundaries of decision-making processes. Adaptation strategies can take very different forms but are commonly based on a similar overall structure. They typically involve a stakeholder process of gathering the relevant information, commissioning, where necessary, additional studies, and agreeing on procedures, mandates and eventually priorities and a strategy. They also provide a framework for cross-sectoral consultation and coordination and can serve as a forum to get climate scientists on board and in touch with decision-makers who have not dealt with climate aspects so far. A review of the institutional and regulatory frameworks is often a further component of adaptation strategies. Typically, adaptation strategies describe an objective, mission or vision, and outline how to get there. Questions that adaptation strategies try to answer are: what are the key risks and vulnerabilities? What has to be tackled and when? Which adaptation options are there to choose from? What are benchmarks for success? Who will do what? And last, but not least: how and when should the action be followed-up?

Examples of national adaptation strategies

Tunisia is an early mover when it comes to adaptation strategies. It developed its National Adaptation Strategy as early as 2005. In a two-year consultation and analysis process, the Tunisian Ministry for the Environment supported by GIZ (then GTZ) on behalf of the German Federal Ministry of Economic Cooperation and Development (BMZ) developed the strategy, agreed on it and then communicated it to all relevant stakeholders. Tunisia's strategy focuses on agriculture, water resources and biodiversity. It outlines activities and institutionalises the topic of adaptation, including the creation of a national council for climate change. Tunisia's Adaptation Strategy is binding for all three sector strategies.

Indonesia developed a national climate strategy called the Indonesia Climate Change Sectoral Roadmap (ICCSR 2010-2030). As a long-term vision, the ICCSR sets national goals, sectoral targets, milestones and priorities for action with regard to mitigation of climate change and adaptation to it. It provides input to the national medium-term development plan. It is based on vulnerability and economic analyses for key sectors, developed with inputs from more than 100 local and international experts. Lead agency is the National Development Planning Agency (BAPPENAS). GIZ (then GTZ) provided support for the development of the strategy.

In the Philippines, a National Adaptation Strategy was launched in early 2010. The consultation process was supported by GIZ (then GTZ) on behalf of the German Federal Ministry for the Environment.

India's National Action Plan for Climate Change (NAPCC)

In June 2008, Prime Minister Manmohan Singh released the first National Action Plan on Climate Change (NAPCC) for India. Currently, all Indian states are preparing State Action Plans on Climate Change (SAPCC) to operationalise the NAPCC.

NAPCC outlines how India plans to address national climate change concerns over the coming years without compromising the country's development. The plan enlists the following eight core missions addressing both climate change adaptation and mitigation concerns across different sectors (GoI 2008a):

- **The National Solar Mission** promotes the development and use of solar energy for power generation and other uses. Its ultimate objective is to make solar energy competitive with fossil-based energy options.
- **The National Mission for Enhanced Energy Efficiency** aims at implementing a host of programmes that will improve energy efficiency in the energy-consuming industries and sectors. Incentives are among others: energy-savings certificates, reduced taxes for energy-efficient appliances and public private partnerships.
- **The National Mission on Sustainable Habitat** promotes energy efficiency as a core component of urban planning. It includes the extension of the existing Energy Conservation Building Code as well as more efficient waste management and recycling and more environment-friendly transportation.
- **The National Water Mission** sets the goal of a 20 % improvement in water use efficiency through pricing and other measures.
- **The National Mission for Sustaining the Himalayan Ecosystem** aims to conserve biodiversity, forest cover, and other ecological values in the Himalayan region. Background: the region's glaciers, which are projected to recede as a result of global warming, are a major source of India's water supply.
- **The National Mission for a 'Green India'** focuses on the afforestation of 6 million hectares of degraded forest lands and the extension of forest cover from currently 23 % to 33 % of India's territory.

- **The National Mission for Sustainable Agriculture** supports climate adaptation in agriculture through the development of climate-resilient crops, the expansion of weather insurance mechanisms and innovative agricultural practices.
- **The National Mission on Strategic Knowledge for Climate Change** seeks to establish a better understanding of climate science, impacts and challenges. This mission envisions a new Climate Science Research Fund, improved climate modelling, and increased international collaboration. It also encourages private sector initiatives to develop adaptation and mitigation technologies through venture capital funds.

India's State Action Plans for Climate Change (SAPCC)

All Indian states are developing State Action Plans on Climate Change in line with the NAPCC to define how they will integrate adaptation and mitigation of climate change into their political agenda, ongoing government schemes and practical actions. The Ministry of Environment and Forests provided a common framework for the development of SAPCC in 2010 and invited development agencies – GIZ, United Nations Development Programme (UNDP), UK Department for International Development (DFID) and World Bank – to provide technical assistance to selected states in the development of these plans. The SAPCC identify and prioritise adaptation and mitigation options. Ideally, the plans are developed through a broad participatory planning process. This involves all major stakeholders, including government officials from various government departments, policy-makers, academics, non-governmental organisations, scientists, the private sector, civil society and local communities.

In addition to specific adaptation strategies, many sectoral policies and development planning procedures are relevant for adaptation. Important policy areas include:

- rural development (e.g. guaranteed employment for the rural poor for part of the year, investment in rural infrastructure);
- spatial planning (e.g. land use planning, zoning regulations);
- environmental regulations (e.g. strategic environmental assessments);

- water policies and planning (e.g. Integrated Water Resources Management approaches, water tariffs);
- agricultural pricing (e.g. tariffs, minimum price guarantee, and subsidies for agricultural commodities);
- risk management (contingency plans, insurance, seed banks).

Some policies can be directly identified as contributing to adaptation (e.g. water pricing reforms promoting efficient water use in water-scarce areas). Yet, in most cases the climate relevance of policies and development planning is not entirely clear a priori. Approaches that systematically integrate adaptation considerations into policies, strategies and plans have thus gained importance. Governance and policies for adaptation are given consideration throughout this publication, with an indication of the sectoral policies that can be relevant for adaptation in the thematic area of the respective chapter.

Integrating adaptation into development planning

The Organisation for Economic Co-operation and Development (OECD) has developed a Policy Guidance on integrating climate change adaptation into development planning. It suggests identifying appropriate levels of interventions (national to project level) and selecting appropriate entry points (along the policy or project cycle). Depending on the level of analysis intended, it outlines how to apply a 'climate lens' to a policy, strategy, regulation, plan, or programme to improve its general direction and priorities. This is done by investigating the extent to which measures might be affected by climate change or could make use of arising opportunities.

Additionally, four general steps for how to develop adaptation measures in different settings have been agreed upon in this Policy Guidance (OECD 2009). They are:

- assess vulnerability;
- identify possible adaptation measures;

- select adaptation measures;
- develop a monitoring and evaluation framework for selected adaptation measures.

After prioritising options, the adaptation measures chosen should be integrated into policies, processes, plans, programmes and other activities to avoid parallel actions for adaptation to climate change.

GIZ has developed a training course based on this Policy Guidance, which teaches the principles of applying a climate lens and the four-step approach for adaptation at different levels (GIZ 2011b). In addition, the course covers the interpretation of climate data and building the institutional capacity needed to deal with adaptation as a continual process. A training of trainers course entitled Integrating Climate Change Adaptation into Development Planning was conducted in India in July 2011.

Training of trainers to integrate climate change adaptation into development planning. (photo: Britta Heine)

GIZ has developed and piloted a practical approach called Climate Proofing for Development. This approach aims at incorporating issues of climate change into policy and development planning at different levels. The tool offers a flexible, participatory approach that is easy to use and even works without a computer.

In Viet Nam, for example, a Climate Proofing for Development exercise was carried out in five municipalities of the Mekong Delta where climate change impacts are already making themselves felt. It involved a systematic analysis of climate risks that could jeopardise the sustainability of measures previously identified in local development planning. Responses to climate change were identified and prioritised in poverty-relevant value chains such as rice cultivation and livestock husbandry.

Thanks to efforts to improve market participation of the poor, the proportion of poor households in the project municipalities dropped from its 2006 level of 40 % to 29 % in 2009. Climate Proofing for Development is helping to safeguard this success in poverty reduction. The provincial government even plans to make climate proofing a standard element of local development planning. This will boost adaptive capacity in the region, while timely consideration of climate change aspects will help to prevent malinvestment (GTZ 2010).

Climate Proofing for Development in India

The sustainability of public programmes and investments may be at risk due to climate change. Therefore, GIZ has developed the tool Climate Proofing for Development. In India, public investment schemes and rural development programmes are being climate proofed in Madhya Pradesh, Rajasthan, Tamil Nadu, and West Bengal.

By using the Climate Proofing tool policy makers analyse whether the objectives of government projects might be threatened by climate change and how the planned measures can be adapted accordingly if deemed necessary. Climate proofing also assesses how selected public schemes are already contributing to adaptation. This is followed by an elaboration of options for how the schemes could further prepare communities for climatic changes and build capacities to deal with climate change.

Moving ahead on adaptation in India

Adaptation to climate change is still a relatively new field of work. Apart from the high priority of reducing emissions of greenhouse gases through mitigation, the importance of dealing with inevitable impacts of climate variability and change through adaptation has gained worldwide recognition in recent years. Efforts are being made from international to local levels to integrate adaptation to climate change into ongoing policy, planning and decision-making processes. Conceptual understanding of adaptation is advancing at a fast pace and practical examples of climate change adaptation are rapidly developing in many countries, particularly in those most at risk from the effects of climatic changes.

India is a major player in international climate discussions. At national and state level in India, adaptation to climate change is being integrated into policies through the National Action Plan on Climate Change, which in turn will be operationalised through State Action Plans on Climate Change. Vulnerability assessments and climate proofing government schemes are being piloted at state level with the assistance of the Indo-German cooperation project on Climate Change Adaptation in Rural Areas of India (CCA RAI). At district and community levels, many initiatives are being tested and assessed in order to determine their potential to contribute to adaptation. The actors are the Indian government, nongovernmental organisations, scientific institutions and communities themselves.

Since technical adaptation interventions are also being designed and implemented through joint Indo-German development projects, it was considered appropriate and important to take stock of current knowledge and developments in the field of adaptation to climate change by producing this publication. It focuses on natural resource related sectors in rural areas, using examples of adaptation interventions from a number of different countries, but with priority reference to India.

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ADAPTATION IN AGRICULTURE

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ADAPTATION IN AGRICULTURE

Abstract

Agriculture plays a two-fold role in climate change: on the one hand, it is severely affected by climate change; on the other hand it is a significant contributor to greenhouse gas emissions. Most of the global challenges are closely connected to agriculture and also to climate change. Rising food prices, for example, are caused by an ever growing world population and by speculations on the world market but also to a large degree by natural and climate related disasters.

Adaptation in the agriculture sector means addressing the negative impacts of climate change and making use of the opportunities that often come with a changing climate. The overall aim of adaptation in agriculture is to reduce farmers' vulnerability and improve their adaptive capacity. A prerequisite for this is understanding climate change, especially at the level of the individual farmer, but also in a broader context. However, this has to be accompanied by supportive policies, a range of agricultural extension services, intensive agricultural research and innovative risk management tools.

In addition to all these topics, it is concrete adaptation options at farm level, as well as community-based adaptation approaches that will attract the reader's attention on the following pages. Two other issues that must not be overlooked are agricultural water management – another huge global challenge closely connected to agriculture and climate change – and the relationship between adaptation and mitigation.

 

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ADAPTATION IN AGRICULTURE

1.1 How does climate change impact agriculture?

Key messages

- Agricultural production is vulnerable to climate risks, as is food security.
- Impacts will vary in intensity at local, regional and global levels.
- There is still uncertainty concerning the extent of impacts, but agricultural production in the developing world is projected to be worst affected.

Climate change will have a major impact on biophysical and socio-economic conditions, as the table below illustrates. Agriculture will be one of the sectors that will be hardest hit by adverse climate conditions, since agricultural production is extremely vulnerable to underlying climate risks such as drought, intense and erratic rainfall, and temperature shifts, which are a result of the intensification of the water cycle *(see chapter 4.1)*. Yet, the intensity of the impacts will differ from community to community, region to region and continent to continent.

Impacts of climate change on agriculture worldwide

Biophysical impacts	Socio-economic impacts
• Physiological effects on cultivated crops, pasture, forests, fish, rangeland and livestock (quantity and quality) • Changes in the quantity and quality of land, soil and water resources • Increased weed and pest challenges, alien invasive species • Sea level rise, changes to ocean salinity • Sea temperature rise causing fish to inhabit different ranges	• Changes in yields and production • Reduced gross domestic product (GDP) from agriculture in the long term • greater fluctuations in world market prices • Changes in geographical distribution of trade • Increased number of people at risk of hunger and food insecurity • Migration and civil unrest

(Source: OECD 2009)

Local food security may be particularly at risk in arid and semi-arid ecosystems, in fragile mountain and coastal areas and on small islands. In general, it can be said that the effects of climate change on agriculture will be felt most in the developing world and in least developed countries (Müller et al. 2009; FAO 2010; World Bank 2010). The most serious effects on agricultural production are projected for South Asia, southern Africa, the West African Sahel and Brazil (Lobell et al. 2008; Schneider 2009).

How climate change impacts agriculture in India

Agriculture is one of the largest contributors to India's GDP, approximately 20 %. It is the main source of livelihood for almost 60 % of the country's total population. The impacts of climate change on agriculture will therefore be severely felt in India. It has been projected that under the scenario of a 2.5 °C to 4.9 °C temperature rise in India, rice yields will drop by 32 %-40 % and wheat yields by 41 %-52 %. This would cause GDP to fall by 1.8 %-3.4 % (GoI 2011; Guiteras 2007; OECD 2002).

Despite the gloomy predictions about the negative impacts for India's agricultural sector, climate change is generally also expected to bring opportunities, e.g. production gains through the CO_2 fertilization effect[1] or the expansion of cultivated land to higher altitudes and northern latitudes. However, it must be noted that to date all climate change projections have been accompanied by uncertainty – not primarily concerning trends but extent (IFPRI 2009; UNFCCC 2009).

[1] Plants make food by taking in carbon dioxide and converting it into organic compounds and releasing oxygen through the process of photosynthesis. In this way they contribute to carbon sequestration. Higher concentrations of CO_2 in the atmosphere increases plant productivity. This is called the CO_2 fertilization effect.

1.2 What does adaptation in agriculture mean?

Key messages

- Adaptation to climate change in agriculture aims at reducing farmers' vulnerability by improving their adaptive capacity.
- Analysing adaptive capacities and vulnerabilities helps to identify appropriate adaptation options
- There are many different options for adaptation and levels of intervention within agriculture. They range from technical options at farm level and knowledge transfer of innovative technologies to policy adjustments and crop insurance schemes.

Adaptation to climate change in agriculture aims to minimise peoples' vulnerability by improving their ability to cope with the impacts of climate change, which is also known as 'adaptive capacity' *(see introduction, page 19)*. Adaptive capacity is often limited, particularly in poor rural areas where people live on subsistence agriculture and generally have little formal education. Here, people have to be provided with climate change-related information and given access to social, economic, institutional, and technical resources. However, it is extremely important that new adaptation strategies and measures be integrated into existing capacities, assets and resources. An analysis of the existing adaptive capacity and assets of a given target group is therefore a crucial starting point, as can be seen in the following example.

Historically, small-scale farmers in drought-prone areas of the Sahel have always autonomously adapted in the short and long term to changes in climate. They have used drought-adapted crops such as sorghum and adjusted their production practices, spreading risk, for example, by staggered sowing, weeding fields promising the highest yield first, or using hand-dug wells to irrigate their fields in the event of low rainfall. However, these farmers are often not aware of the overall scale of climate change and of the fact that their adaptation practices may not be able to cope with current climate change impacts, thereby threatening their ability to sustain their family's livelihood. At first, social networks might provide some kind of safety net, but a sustained dry spell would most probably exhaust the farmers' adaptive capacity. With the help of an extension service[2] designed to generate understanding, local farmers' adaptation strategies could be more promising and successful – not only in the case of the Sahel.

Agricultural extension services *(see also section 1.4.4)* can help farmers to become aware of the overall scope of adaptation to climate change and to receive information on the availability of technical water and nutrient management alternatives (e.g. flood plain cultivation with flood irrigation and groundwater recharge or drip irrigation). They can even help them to access credit and insurance. With this awareness of climate change at all levels, farmers could, for example, be connected to a publicly planned and financed broad-scale irrigation infrastructure. This could connect the small-scale farmers' irrigation schemes to the water supply needed during droughts and make them less dependent on their own individual water sources (New Agriculturist 2007).

This example shows that adaptation in agriculture must include creating awareness and understanding of climate change and its risks at all levels, in order to enable farmers and rural communities to effectively identify and utilise their available adaptive capacity. A survey conducted in the small village of Spitti in the Indian state of Himachal Pradesh demonstrated that most farmers had been made aware of the changing climatic conditions by the problems they faced in their day-to-day life. The impacts felt included prolonged dry periods and less snowfall, resulting in low apple production. Although farmers were already adapting to these changes using their own capacities, more training was required to make them aware of new technologies and thus help them adapt efficiently. Some farmers have switched from traditional apple farming to short duration crops like peas, turnip and lentils for better returns. Low rainfall also prompted farmers to invest in water harvesting structures (DARE/ICAR n.d.).

[2] Extension services are systems that provide information, know-how and technologies for farmers, their organisations and other market actors. They facilitate interaction with other relevant partners, e.g. in research, education or agro-business. Extension services also offer assistance to develop technical, organisational and management skills and practices (FAO 2010b).

1.3 Governance and policies for adaptation in agriculture

Public policy can either be supportive to adaptation or it can, at times, create barriers or disincentives to adaptation. Hence, policies constitute an essential prerequisite and framework for enhancing the adaptive capacity of agricultural producers (Howden et al. 2007; Schimmelpfennig et al. 2007).

So far, numerous options for policy-based adaptation to climate change have been identified for the agricultural sector. Policies include efficient water allocation, promoting seed research and changes to subsidies and taxes (Smith & Lenhart 1996). An overview of specific policies and their impacts on agriculture is given in the following table.

Policy options for adaptation in agriculture

Policy option	Potential impacts and target points
Promote agricultural research	• Developing crop and livestock technologies (e.g. better heat and drought-resistant crops) • Enhancing seed banks • Encouraging the transfer or adoption of locally important innovations (e.g. water harvesting systems) • Making use of complementarities between public and private agricultural research
Promote crop and livestock diversification and agrobiodiversity	• Avoiding monocultures • Reducing the risk of crop failure (e.g. by advising farmers to grow drought-resistant food crops such as cassava, millet, or sorghum)
Promote adoption of technologies	• Modernising farm operations • Using adapted seeds
Increase efficiency of water infrastructure and water use	• Providing opportunities to reduce direct dependence on natural factors such as precipitation and runoff and reduce vulnerability to climatic variations and natural disasters • Improving irrigation systems

Disperse information on conservation management practices	• Protecting fields from water and wind erosion • Using management practices that reduce dependence on irrigation in order to decrease water consumption without reducing crop yields • Changing tillage practices (e.g. zero tillage on formerly overused/ depleted land)
Provide agricultural extension services	• Improving knowledge on agricultural crop and livestock management and on drought and flood management
Promote investments in agriculture	• Increasing agricultural productivity • Improving management practices
Promote investment in better information & forecasts	• Improving communication technologies in order to improve access to and handling of information • Refining modelling techniques that bring high-quality short-term forecasts to many parts of the world • Supporting the diffusion of information to help interpret forecasts in terms of their agronomic and economic implications
Provide food reserves and reduce post harvest losses	• Creating temporary relief • Increasing short-term food security

Although some options need to be implemented in the **short term** to respond to the immediate impacts of climate change, adaptation must be viewed as a **long-term** challenge that imperatively has to be considered in planning (IPCC 2007). Long-term policies include, for example, investment in rural infrastructure or granting property rights. Further examples of short and long-term adaptation options and supporting policies to promote adaptation measures can be found in *annex A* of this chapter.

Finally, it is important to keep in mind that sectoral policies must be aligned with other closely related climate-sensitive sector policies like water, forest and other natural resources or public health. This means: a **multi-sectoral policy approach** for adaptation is desirable.

India's National Mission for Sustainable Agriculture

The National Mission for Sustainable Agriculture is one of the eight missions in India's National Action Plan on Climate Change (NAPCC). It stresses how crucial agriculture is to India's economy and the livelihood of its people, since the agriculture sector supports more than half the country's population of over 1 billion people. The mission focuses on four areas that are relevant for the endeavours of India's agricultural sector to adapt to climate change:

- dryland agriculture
- risk management
- access to information
- use of biotechnology

Priority actions for **dryland agriculture** with particular relevance to adaptation will be:

- developing drought and pest-resistant crop varieties;
- improving methods to conserve soil and water;
- conducting stakeholder consultations, training workshops and demonstration exercises to help farming communities share and disseminate agro-climatic information;
- providing financial support to enable farmers to invest in and adopt relevant technologies to overcome climate-related stresses.

Some of the priority actions in the field of **agricultural risk management** are:

- strengthening current agricultural and weather insurance mechanisms;
- development and validation of weather derivative models (by insurance providers, ensuring access to archived and current weather data);
- creating web-enabled, regional language based services to facilitate weather-based insurance;
- developing geographical information systems (GIS) and remote sensing based methodologies for detailed soil resource mapping and land use planning at the level of a watershed or river basin;
- mapping vulnerable eco-regions and pest and disease hotspots;
- developing and implementing region-specific contingency plans based on vulnerability and risk scenarios.

(Source: GoI 2008)

1.4 Adaptation options in agriculture

Key messages

- The overall aim of adaptation measures is to safeguard agricultural production despite climate change by modifying production systems.
- Income risks should be managed better. Options include introducing risk management tools like crop insurance, providing financial services and creating opportunities for income diversification.
- Supporting access to markets and market information, combined with infrastructure development, can help to exploit market opportunities.

There are several options for adaptation to climate change that can safeguard agricultural production. One is to enhance existing production systems by **using different practices** (e.g. changing sowing patterns) and **new technologies** (e.g. irrigation systems, adapted varieties). Another option is to **use a different production system** that is better suited to the changed climatic and environmental conditions. That presupposes **using new or existing varieties** that are adapted to extreme environmental conditions. They also provide the genetic material agricultural research needs to develop technical innovations. A further option is to **promote agrobiodiversity**, i.e. the genetic resources for food and agriculture, support natural ecosystems capacity to mitigate the impact of extreme events (e.g. inclusion of woodlots, protection of water resources, or wetlands).

Before changing to different production systems, it is important to **explore market demands** and ensure there are opportunities for marketing the produce. Researching and **utilising existing local varieties** that are adapted to extreme environmental conditions is another important measure. These varieties also constitute a fundamental part of the genetic material **agricultural research** needs to develop new adapted varieties *(see section 1.4.3)*.

As mentioned earlier, an important task in climate change adaptation is **capacity building**. This applies to the numerous aspects of adaptation options and strategies on all levels – be it the farmer who receives advice on water-saving cropping systems or political decision-makers who receive support from scientific analyses and development consultation.

1.4.1 Selection criteria for adaptation options in agriculture

It is essential to have selection criteria that help decision-makers to identify which adaptation strategies or measures to implement and when to implement them. This is particularly the case if we take into consideration the fact that the process of choosing the right adaptation options is happening in the uncertain environment of climate projections and continuous change. There is often no definite answer to questions like:

- How is the local climate likely to change and how fast?
- How sensitively will certain agricultural systems actually respond to this change?
- Will potential adaptation options perform well and will they pay off financially in the long run?

For subsistence farmers in rural areas, who generally have low adaptive capacity, many of the choices will require putting in enormous effort. Hence 'choosing wrong can be costly, even deadly' (Leary et al. 2007).

According to Leary, criteria for the selection of adaptation measures might be:

- economic and social benefits;
- consistency with development objectives;
- environmental impacts and spill-over effects;
- cultural acceptance and social feasibility.

Prioritising adaptation measures implies defining and applying criteria that help to decide when to implement an appropriate adaptation option. Consequently, anticipatory, i.e. planned, adaptation would be particularly favourable in cases where future impacts are potentially catastrophic or irreversible. Conversely, it might make sense to defer adaptation in cases where it would be very costly. In any case, the 'adaptation measure that yields the greatest benefit' should always be chosen (Rosegrant et al. 2008). With regards to agriculture, benefits are generally related to the farmer's income, e.g. increased agricultural yields.

In any event, **no-regret options** that are beneficial even without climate change should be prioritised (Kumar 2008). One of these no-regret options might be the introduction of adapted crop varieties and species (e.g. water-efficient crops). Finally, the decision on which practice to choose should be well matched with the farmers' given capacities, e.g. the financial resources available. Integrating no-regret options that provide a good balance between costs and benefits into an anticipatory strategy is certainly the most promising way forward. They help to cope with climate change and, at the same time, contribute to sustainable development (Rosegrant et al. 2008).

1.4.2 Technical options at farm level

It is important that adaptation measures are site-specific and fit the given conditions. The table on the next page shows a list of technical and management-based adaptation options at farm level. As reflected in the annex, practices related to **cropping systems** are subdivided into inputs, soil, crops and water. Management-based adaptation practices related to **livestock systems** are subdivided into inputs, water and animal management.

It is difficult to distinguish between good agricultural practices and 'pure' climate change adaptation options. Good agricultural practices often derive from efforts and experience that farmers acquire over time in adapting to different climatic conditions – be it short or long-term changes in weather and climate. The justification for calling any measure an adaptation option rather than just good 'old' agricultural practice lies in the process of **identifying a certain measure by taking climate change into account**. First of all, the climate risks have to be analysed, then possible solutions are collected and selected on the basis of certain criteria. Finally, the identified solutions are integrated into **planned adaptation policies**. The list of technical practices presented in the following table can be described as good agricultural practices that can be used separately or in combination to adapt to local climatic changes.

Adaptation options at farm level

Climatic/ landscape zone	Arid and semi-arid	Humid	Coastal areas	Mountain areas
Cropping systems				
Examples for inputs: new and adapted varieties	• Drought-tolerant crops (such as millet instead of corn) and varieties	• Early maturing varieties	• Salt-tolerant varieties	• Crop diversification, e.g. off-season crops, short-season crops, fruit cultivation
Crop management	• Enhancing crop rotation practices • Changing cropping patterns	• Improving seed storage	• Integrating trees and bushes to reduce water runoff and erosion and to provide flood protection	• Maintaining agrobiodiversity to conserve frost-tolerant species and varieties • Applying soil and water conservation measures, e.g. contour cropping and terracing
Livestock systems				
Examples for inputs	• Using supplementary feeds and concentrates	• Using adapted livestock breeds	• Constructing livestock shelters	• Using supplementary feeds
Animal management	• Continuously matching stock rates with pasture production • Changing grassland cutting frequency • Restricting extensive livestock farming	• Enhancing animal welfare, e.g. vaccinating animals to protect them and reduce the spread of disease	• Moving herds from waterlogged fields	• Continuously matching stock rate with pasture production • Increasing feed reserves • Designating special areas for livestock grazing • Protecting steep slopes by avoiding overgrazing so that the vegetation cover remains stable

A more detailed compilation of adaptation options at farm level can be found in *annex B and C* at the end of this chapter. These lists are intended to support practitioners in finding adaptation options that fit the climatic conditions of a given region. Hence methods are classified according to arid, humid, coastal, or mountainous conditions. Methods usually fit more than one agro-climatic zone; the categorisation is not meant to be rigid.

Animal management

Semi-arid and arid areas are particularly vulnerable ecosystems. Nomadic and semi-nomadic livestock keeping based on extensive grazing systems can make the best of what these ecosystems provide. Overgrazing, however, can lead to desertification. It is thus vital to ensure that **stocking rates** do not exceed the carrying capacity of the grasslands. This also refers to **allowing the pastures sufficient time to recover** between grazing periods, which may require frequent herd movement over long distances. The **composition of the herds** grazing on these pastures is another important factor: goats are the most nimble species of grazing livestock and can live on land inaccessible to other animals. However, as a result of their bite depth and the fact that they eat a very wide range of food, they also pose a threat to many plants. The soil surface can be damaged not only by overgrazing but also by cattle trampling. The soil is exposed and becomes susceptible to wind erosion (World Bank 2003). The following example from Rajasthan shows how livestock farmers can adapt to climatic changes.

Pastoralists adapting to climate change in India's Rajasthan province

- **Background:** Rangelands in semi-arid regions of Rajasthan are highly degraded and at risk of further degradation as a result of expected climate change impacts. This applies in particular to poorer households which are highly dependent on fodder availability to feed their livestock.
- **Approach:** Communities were encouraged to implement physical and administrative measures to protect and develop pasture lands. This included protecting areas from grazing by planting vegetative fences, digging trenches and building stone walls, along with stone check dams, gully plugs and water harvesting structures, to conserve soil and water *(see also section 1.4.7)*. Administrative measures put emphasis on the communities' capacities to develop and maintain pastures and to create and manage buffer stocks of fodder.

- **Outcome:** Multiple benefits resulted from the combination of these measures. The productivity of the land was increased – fodder production in Kunday village tripled within two years, for example. Drought resilience is likely to improve as the regeneration of vegetation continued even in periods of below-average and highly variable rainfall. Agricultural land in the surrounding area benefitted from groundwater recharge and increased soil water retention.

Adapted varieties

During the past decade, research institutions have put a great deal of effort into research on adapting staple crops to abiotic stresses (e.g. drought, heat, flooding and salinity). Nevertheless, agricultural biodiversity is still declining, posing a threat to genetic adaptability and future food security. With climate change, growing water insecurity and renewed concerns about food security in the wake of recent price spikes, the potential welfare gains from effectively adapted varieties are enormous. Gains from adapted varieties could make the difference between survival and starvation for poor people in developing regions prone to climate change.

Hence, public, scientific, private and legal institutions need to step up their efforts to enable farmers to **benefit from crops adapted to climate change** and access planting material and knowledge. This also applies to traditional, locally adapted varieties which address regional and local agro-ecological peculiarities and offer site-specific solutions, in contrast to modern, standardised varieties that do not take account of changed growing conditions.

Impacts of climate change on sorghum in India

A study carried out on sorghum, one of India's most important crops, helped to give insights into the possible impacts of climate change. The study focused on winter and monsoon crops of sorghum in three different climate zones of India: central (CZ), south-central (SCZ) and south-west (SWZ). According to the findings, an increased temperature will most likely lead to an overall decrease in crop production. By 2020, monsoon sorghum production was predicted to decrease by 14 % in CZ and SWZ and by 2 % in SCZ, whereas winter sorghum production was estimated to decrease by up to 7 % by 2020. However, the authors pointed out that very low cost adaptation strategies, like changing variety and sowing date, could reduce the impacts and vulnerability of winter sorghum and help maintain the productivity of sorghum under changing climatic conditions.

(Source: Srivastava et al. 2010)

Agrobiodiversity conservation should form a basic component of adaptation strategies and biodiversity-friendly farming practices *(see also chapter 3)*. The ex situ conservation of seeds, involving storage in refrigerated banks or botanical gardens, is essential, but does not go far enough. Broader and better integrated conservation schemes are needed, which rely primarily on in situ concepts, i.e. concepts that bring genetic resources back to the fields and into farmers' communities. There, the continuous exposure and interaction of the organisms with their environment allows for a dynamic adaptation process. Hence, agrobiodiversity conservation is not only about deep-freezing a drought-tolerant strain of millet for many decades in a gene bank. Even more important is continuing to grow and breed the seeds in the fields, where they are exposed to a wide range of agricultural and ecological conditions.

The social dimension of these adaptive processes is no less important. In particular, poor sectors of the population must be enabled by governments or development organisations to adapt to changing environmental conditions. Traditional knowledge and social organisations must be strengthened and further developed. Women play an important part in this process. In farming communities around the world they always have been and still are the keepers and preservers of genetic resources.

Adapted varieties preventing starvation – an example from Karnataka, India

Sankappa is a small farmer owning three hectares of dryland in the village of Vittalpura in Bellary district, Northern Karnataka, India. This village is situated on the semi-arid Deccan Plateau and receives annual rainfall of 500 mm over a three-month period, which allows just one generation of millet to be grown between July and October. The amount of rainfall in this part of the country has dropped continuously over the last years. It was below 300 mm in 2003.

Like his forefathers and other farmers of the village, Sankappa grows foxtail millet (Setaria italica). The millet varieties grown and conserved by the farmers of Vittalpura over the years have excellent drought resistance. 'All other crops failed due to extreme drought, and my family and livestock were saved from starvation only by the foxtail millet harvest,' said Sankappa.

(Source: Bala 2004)

1.4.3 Agricultural research

Key messages

- Agricultural research for development is fundamental to climate change adaptation.
- An interdisciplinary research approach with strong cooperation among national and international researchers is essential to find options for adaptation to climate change.

Agricultural research for development (e.g. producing new drought-tolerant varieties or breeds) is essential for conserving natural resources and in this context also for food and nutrition security. It also contributes to achieving adaptation and mitigation targets. Agricultural research for development is not basic research. It is practical and development-oriented, aiming to support farmers, extension services, agricultural traders, politicians and governments in creating innovations for and growth in the agricultural sector.

The 15 centres of the Consultative Group on International Agricultural Research (CGIAR) play a key role in **international agricultural research**. The results of the centres' research are public goods and are therefore generally accessible and non-patentable. The CGIAR centres also contribute to the preservation of agrobiodiversity and some centres conserve seedlings, seeds and tubers in their gene banks. Eleven of the 15 CGIAR centres maintain a total of over 650,000 samples of crop, forage and agroforestry genetic resources. These represent approximately 10 % of the 6 million accessions stored in over 1,300 gene banks around the world.

Agricultural research for development relies on transfer of local experts' know-how. That is why the CGIAR centres, with their general international and regional focus, cooperate closely with local farmers and national institutions as well as with non-governmental organisations. They are also involved in a slowly growing number of projects with the private sector. One example of successful cooperation between the CGIAR centres and local farmers and institutions worked on improvement of drought-resistant maize (Zea mays L.) in southern Africa. Drought reduces global maize yields by as much as 15 % each year, causing losses of more than 20 million tonnes of grain. More than 50 new drought-tolerant maize varieties developed by the International Maize and Wheat Improvement Center and its partners are grown on 1 million hectares in Africa, resulting in average yield gains of 20 % over the varieties they replaced.

At national level in most developing countries it is **universities** and **national research institutions** that can provide valuable input for research projects on climate change adaptation and mitigation. However, financial resources are most critical for National Agricultural Research Systems (NARS). The NARS are defined, in a given country, as encompassing all institutions, public or private, that devote their activities full time or partially to agricultural research with a commitment to a national research agenda. In India, the Indian Agricultural Research Institute (IARI), New Delhi, is one of the premier institutions carrying out extensive research and coming up with innovations in the field of agriculture and climate change adaptation. Other important organisations include the institutes working under the Indian Council of Agricultural Research (ICAR), such as the Central Research Institute for Dryland Agriculture, Hyderabad, or various state universities with agricultural departments.

India's National Initiative on Climate Resilient Agriculture

In December 2010, a new scheme called the National Initiative on Climate Resilient Agriculture with a budget of 3,500 million Indian rupees was approved by the Indian cabinet to deal with the issue of climate change impacts on agriculture. The objective of this scheme is capacity building of scientists and other stakeholders in climate-resilient agricultural research in combination with the application of research results through awareness training and exchange visits.

The institutes that will be implementing this scheme during the remaining part of India's XI Annual Plan are the following:

- Central Research Institute for Dryland Agriculture (Hyderabad)
- Indian Agricultural Research Institute (New Delhi)
- Indian Institute of Horticultural Research (Bangalore)
- Central Institute of Agricultural Engineering (Bhopal)
- National Dairy Research Institute (Karnal)
- Central Marine Fisheries Research Institute (Kochi)
- Indian Council for Agricultural Research, Research Complex for North East Hill Region (Shilong)
- 100 *Krishi Vigyan Kendras* (KVK – Farm Science Centres) at district level all over the country

(Source: GoI 2011)

Finally, in summary, it can be said that a lot of research on adaptation in agriculture has been carried out so far but putting it into practice remains the great challenge. One way of transferring innovations to the local farm level is described in the following section.

1.4.4 Agricultural extension: education and innovation transfer

Key messages

- Extension and education must be strengthened in order to enhance farmers' capability to respond to climate change issues.
- Extension services are an essential element for transferring climate change-related innovations to rural areas.

Agricultural extension (also known as agricultural advisory or extension services) plays a crucial role in promoting agricultural productivity, increasing food security, improving rural livelihoods, and promoting agriculture as an engine for pro-poor economic growth *(see also section 1.2)*.

Farmers in developing countries or emerging economies that largely depend on agriculture mainly use traditional methods that were handed down by their ancestors. Generally, these methods were well adapted to the more or less stable conditions of the past. Nevertheless, with the increasing changes in climate conditions, farmers have to **adapt their cultivation and harvest management methods**. To achieve this, they may make use of innovations (new cultivation methods) or knowledge about traditional practices that have been virtually forgotten (e.g. about well adapted crop varieties). Agricultural extension services and improved agricultural education are essential here. They enable farmers to gain systematic knowledge that will help them to respond to short and long-term environmental changes and to challenges posed by the global food and agricultural system.

There is another important reason why it is crucial that agricultural extension services in developing countries be strengthened: a **transfer from theory into practice** must take place to enable research results and innovations to find their way into the field. Adopting technological innovations is one of the most frequently advocated strategies for agricultural adaptation to climate change (Smit & Skinner 2002).

Agricultural extension services play an essential role in overall agricultural development. Not only do they make the diffusion of innovations possible, they also facilitate an **exchange of experience** among farmers and serve as a direct link between farmers and the government (Speranza et al. 2009). One example are the *Krishi Vigyan Kendras* (KVK – Farm Science Centres) in India. They can be found across the entire country and are under the overall administration of the Indian Council for Agricultural Research (ICAR). These centres play an important role in disseminating the latest agriculture technologies among Indian farmers. They work in alliance with district level departments and agencies in different states.

1.4.5 Agricultural insurance

Key messages

- The increasing frequency of extreme weather events is causing financial losses on a scale that traditional risk management strategies and social safety nets can no longer cope with.
- Agricultural insurances supplement, but do not replace, comprehensive risk management strategies.
- Insurance products that are suited for agriculture in the context of rural development must be created.

With the increase in extreme weather events such as droughts, floods and exceptionally strong winds that often affect entire regions, traditional risk management strategies and social safety nets are often no longer able to counteract the resulting negative impacts. Within a comprehensive risk management strategy that includes diversification of agricultural activities and income, agricultural insurance can help people to cope with the financial losses incurred as a result of weather extremes. Insurances support farmers in their adaptation process and prevent them from falling into absolute poverty. Apart from **stabilising household incomes** by reducing the economic risk, insurance can also **enhance farmers' willingness to adapt**, to make use of innovations and invest in new technologies. Additional **credit insurance** schemes may increase the creditworthiness of farmers applying for loans and thus **support investment in agricultural production**.

A project in Malawi that was initiated by the World Bank in 2005 shows how insurance can make a difference: Malawian peanut farmers lacked access to credit and therefore could not buy high-quality seeds. Agricultural credit institutions were reluctant to grant credit due to the high default risk – especially because of crop failure due to weather events (Sadler 2011). A weather-based crop insurance scheme was designed to provide compensation in the event of insufficient rainfall during a crop growing cycle, leading to insufficient yields or no yield at all.

The insurance policies were bundled with loans to farmers that allowed them to purchase high-quality seeds. Depending on location, insurance premiums amounted to 6-10 % of the sum insured, made up of the cost of seed and the interest payable – an amount easily repayable from the increased productivity of the improved seeds. In the event of a severe drought, the borrower would pay a fraction of the loan; the rest would be paid by the insurer directly to the bank. A marketing organisation served as a central distributor for the insurance and the seeds.

The advantage of this arrangement – lending coupled with crop insurance – is that it allowed farmers in the pilot areas to access finance that would not have been available to them otherwise. Only because the crop insurance policies mitigated the weather risk associated with lending did offering loans to insured farmers become attractive to local banks. The reason: due to the insurance, the farmer is less likely to default, which has a stabilising effect on the bank's portfolio and risk profile. Without this assurance, banks rarely give loans to low-income farmers, since they pose a high risk. As the farmers used these loans to purchase higher yielding, certified groundnut seed, they were able to realise high returns on their investment. The World Bank, in conjunction with the non-profit organisation Opportunity International, acted as a catalyst in developing this weather insurance product in Malawi. They provided technical assistance and training.

In India it is the National Agricultural Insurance Scheme (NAIS) of the Ministry of Agriculture that provides comprehensive risk insurance to farmers to cover yield losses due to non-preventable risks such as natural fires and lightning, storms, cyclones, typhoons, tornados, floods, droughts or pests and diseases (GoI 2010).

A weather-based crop insurance scheme (WBCIS) is another option initiated by the Indian Ministry of Agriculture. This weather-based insurance product was designed to cover losses in the event of adverse weather conditions like rainfall and temperature, to name the most important ones. It was piloted in the state of Karnataka during the Kahrif (autumn) season of 2007. Currently, it is being implemented across India by various insurance agencies (GoI n.d.).

Innovative risk management instruments: index-based insurance

For any insurance product to be appropriate in a developing country context, it has to meet two basic criteria. On the one hand, it must be low cost in order to be affordable for small-scale farmers. On the other hand, it has to provide its clients with a sufficient degree of security in order to protect them against potential losses. In contrast to traditional agricultural insurance scheme, which is dependent on costly on-site loss assessment, a new and innovative product known as index-based insurance offers alternative opportunities for managing covariant risks[3] in agricultural business.

Index-based insurances are characterised by standardised contracts and payments for damages. That means that instead of insuring individual farmers against individual losses, the insurance company uses an index of thresholds for certain weather elements in a region, e.g. a fixed minimum amount of precipitation within a certain period and region. If the rainfall does not reach the fixed minimum insured, this triggers the indemnity payment to everyone who has taken out this insurance. While traditional agricultural insurance schemes require quite a high amount of administrative effort and assessing claims involves high transaction costs, parametric insurance schemes entail far lower transaction costs once they have been developed and put in place.

This approach is widely perceived as a highly promising concept, which was taken up in numerous pilot projects to test suitable methodologies. However, although index-based insurance has promising prospects as a risk management instrument with affordable premiums for small-scale farms, it is still in its infancy. So far, there are only a few efficient index-based insurance schemes.

In the face of climate change, further development of insurance schemes that are specially tailored to agriculture is needed to effectively complement other risk management strategies for farmers, such as crop and income diversification. Apart from offering low transaction costs, which can be supported by the use of innovative distribution channels (such as mobile banking or input suppliers), the insurance products also need to be easy to understand, as insurance literacy in the target groups is usually low. Raising farmers' awareness of the advantages of insurance as a risk management tool and creating trust towards insurance companies are further challenges.

[3] Covariant risks are systemic risks from external factors like floods, droughts etc., which affect large numbers of farmers in a given area.

In conclusion, agricultural insurance supplements, but does not replace, farmers' risk management strategies. It is crucial that *ex ante* strategies to reduce the negative impacts of climate change be developed and implemented.

1.4.6 Community-based adaptation to climate change

Key messages

- Community-based initiatives assess the vulnerability of communities and take measures to strengthen their resilience.
- Farmers' field schools are training groups of farmers on different adaptation measures in a very practical way.

Communities who live in marginal areas and whose livelihoods are highly dependent on natural resources are among the most vulnerable to climate change. They have long been exposed to many kinds of environmental changes and have developed coping strategies, but the extent of future hazards often exceeds their adaptive capacity. The fact that many of them are marginalised worsens their situation.

Many community-based initiatives first address the issue of vulnerability assessment to understand communities' risks and vulnerabilities towards climate change before suggesting measures for adaptation (CARE International 2009). In rural areas, however, where community income is mainly derived from farming, the focus of activities often lies on adapting existing farming practices to a changing climate. **Farmers' field schools** (FFS) constitute a practical group-based approach to train farmers. They involve groups of farmers learning hands-on agricultural adaptation measures. They meet regularly and are guided by a trainer to discuss relevant agricultural topics and different adaptation measures. What is even more important: they also work together to apply their newly acquired knowledge in the field. Ownership is key in these farmers' field schools. It is the group members who prepare a plan describing the content of the learning sessions and who decide which measures to implement in the field. In addition to implementing adaptation strategies at local community level, mainstreaming such strategies within national development measures requires coordination across all levels of management and policy-making (Orindi & Eriksen 2005). The concept of farmers' field schools was introduced in India in 1994. By 2005, 8700 of these schools were active across the country. Currently, they are active in many states, including Andhra Pradesh and Uttar Pradesh (ILRI 2006).

A project on Sustainable Agrobiodiversity Management in the Mountain Areas of Southern China shows how farmers field schools work in practice. They largely rely on the farmers' self-motivation and help them to find solutions to common problems through field testing and exchange of experience. The project, jointly implemented by German development cooperation organisations and the Chinese Ministry of Agriculture started in 2006. It encourages farmers to protect traditional local crops and plants, such as sticky rice, local fruits and vegetables, and to use them either for their own consumption or to bring them to the market. Encouraged by positive experiences in the project, farmers have also come up with their own ideas on how to further protect agricultural diversity in their villages.

Community-based adaptation – an example from eastern India

- **Background:** Kodikitunda is a very small village in the Indian state of Orissa. The population consists mainly of farmers of tribal origin who have small land holdings and depend on rain-fed agriculture as one of their main sources of livelihood. Lately, due to heavy rainfall and longer dry spells, communities have faced shortages of water for irrigation and problems like dropping crop yields and soil erosion. Furthermore, the lack of financial resources often limits farmers' access to better farming technologies.
- **Approach:** A non-governmental organisation (NGO) called Agragamee has been active in helping farmers in Kodikitunda to cope with changing climatic conditions since 1994. The measures taken by the NGO with the involvement and help from the villagers include: construction of check dams, field ponds and wells, contour bunding and gully plugging. Tree plantations were also created at strategic locations. Local institutions like water user societies and women's self-help groups were established and received support.

- **Outcome:** The farmers have benefited most from increased tree cover, as it has reduced soil erosion to a great extent and also helped in groundwater restoration. Not only are the farmers continuing to plant trees in order to maintain the tree cover, they are also imposing fines on anyone violating regulations designed to protect the trees. Apart from improving the agricultural land, the efforts have helped farmers to diversify their income, e.g. through selling timber and non-timber products.

(Source: Pande & Akermann 2009)

1.4.7 Agricultural water management

Key messages

- Climate change influences the spatial and temporal availability of water, which in turn impacts food and fodder production.
- Options in agricultural water management range from increasing the supply to managing the demand side.

Food production and agriculture are the largest consumers of water. About 70 % of global water taken from rivers and groundwater go into irrigation (IWMI 2007). All agricultural production depends on water. With the imminent threat of climate change, this resource is under huge pressure. Intensification of the water cycle will impact on the spatial and temporal variability of precipitation and on rainfall intensities, causing droughts or floods. Consequently, droughts in certain regions will last longer and become more intense, and fluctuations in river discharge and groundwater recharge will be more pronounced. The increased variability of rainfall, runoff and groundwater recharge implies reduced predictability for water management activities in agriculture and thus increases production risks in farming. Small-scale farmers, for whom risk avoidance is of vital importance, will be particularly hard hit by this uncertainty.

Options for action in agricultural water management *(see also chapter 4.4.4)* that are conceived to help farmers to cope with the impacts of climate change will have to focus on issues such as:

- **Increased flexibility of operations.** Technical infrastructure, cropping patterns and water management measures must be geared to allow for flexible operations. This enables quick and easy adjustments in water availability by adding water (irrigation) or draining as part of an adaptive water management system.
- **Adaption of production systems.** In coastal areas, for example, salt water intrusion due to the rise of the sea level will cause salinisation and necessitate adapted production systems with plants that have a higher salt tolerance.
- **Implementation of new cultivation methods.** Ridges, terraces or planting holes are a few examples of new cultivation methods that help to catch or drain surface water. In combination with improved land management practices (e.g. agroforestry), this contributes to a reduction in soil erosion and improved livelihoods.
- **Availability of historical and prognostic data.** The importance of data management related to water resources and their future dynamics must be given increased attention (e.g. using new technologies, such as remote sensing).[4]
- **Consumer awareness and conservation.** Clear water use rights and pricing will lead to more sustain able and considerate consumption and help to conserve the diminishing sources of freshwater.
- **More attention to demand management.** Options to increase water supply by greater water extraction from rivers, springs and groundwater or by storing seasonal excess water in large reservoirs will decrease in the long run. Instead, attempts to promote demand management by inducing farmers to use water more efficiently and to prevent non-beneficial losses will have to be given priority.
- **Finding practical solutions for existing needs.** Nevertheless, in rural areas, where the vast majority of the population are subsistence farmers, the focus will still be on the water supply side. Building small water storage facilities or rebuilding traditional ones will help small farmers to make their living, as illustrated in the following example.

[4] The term 'remote sensing' generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface and in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation). Different kinds of platform (e.g. aircraft, satellites, kites etc.) and sensor (e.g. single lens reflex camera, infrared sensor etc.) can be used.

Andean subsistence farmers in Bolivia are traditionally engaged in rainfed agriculture in semi-arid mountain regions and are hence very vulnerable to the effects of climate change. Water shortage in the dry season has always affected crop growth, but with climate change even the rainy season has become less reliable. More and more dry periods are occurring during the rainy season, alternating with torrential precipitation events. Farmers therefore attempt to use supplemental irrigation.

Farmers examining their new atajados (large ponds), Potosí Department, Bolivia. (photo: Edmundo Navia)

The Agricultural Development Program (PROAGRO), implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), runs water harvesting projects in nine Bolivian communities. The programme improves traditional water harvesting systems built by farmers and supports the construction of new, small reservoirs that collect water from small permanent streams or springs. In cases where there is no permanent water source at all, large ponds, or *atajados*, are constructed. These are fed by surface runoff from surrounding slopes, which is the only way of making water accessible. The farmers contribute to the projects by providing their manpower and some local building material. The overall financing comes from PROAGRO and the municipalities. PROAGRO works closely with NGOs to assist farmers in sustainably managing the water harvesting systems, increase water use efficiency and conserve vegetation and thereby stabilise surrounding slopes. Furthermore, local experts are trained to design and implement water harvesting projects independently in their communities.

New, small reservoir, collecting water from permanent springs. (photo: Johanna Götter)

Since 2008, PROAGRO has implemented more than 775 water harvesting systems including 372 *atajados*, serving nearly 1300 families. Water harvesting, and with it irrigation, safeguards the yields of traditional crops like potatoes and therefore the food security of the farmers' families. Some of them are even able to sell their surplus at local markets. Another outcome: the harvested water allows the farmers to diversify their crops. They are, for example, beginning to grow vegetables and forage, which leads to a more balanced diet for their families and animals.

1.5 Linking adaptation and mitigation

Key messages

- The agricultural sector directly contributes 14 % of total greenhouse gas (GHG) emissions.
- There are four broad mechanisms for GHG mitigation that have very different potential – both for mitigation itself and for synergy with adaptation.
- It is difficult to create incentive structures to foster the implementation of mitigation options in agriculture.

Agriculture plays a dual role in climate change. On the one hand, it is a sector that will be severely affected by a changing climate; on the other hand, it is a significant contributor to global GHG emissions. The agricultural sector directly contributes 14 % of total GHG emissions. The main sources are nitrous oxide, particularly from use of fertilizers, methane from paddy rice production, and methane and ammonia from livestock keeping and manure management (Stern 2006). In addition, 18 % of global GHG emissions in the form of carbon dioxide (CO_2) are caused by land use change, tropical deforestation and forest degradation – which mainly occur to make way for agricultural uses and timber extraction.

There are basically four broad mechanisms for GHG mitigation in agriculture and agroforestry (Smith et al. 2007a, b):

- reducing **methane and nitrous oxide emissions** from agricultural production;
- producing different forms of **biomass** for energy use as a substitute for fossil energy sources;
- supporting **forests** through reforestation, afforestation and agroforestry;

- storing **carbon** by increasing soil carbon content.

Depending on local production conditions and incentive structures, e.g. prices for emission certificates and energy prices, these different options have very different mitigation potential. They also have very different potential for synergy with adaptation.

Generally, reducing agricultural nitrous oxide emissions and – with the exception of paddy rice systems – also methane emissions is likely to have low potential for synergy with adaptation. On the contrary, increasing agricultural yields, e.g. by optimising fertilizer input, can increase water use efficiency of crops and, hence, save water which is often a main necessity for adaptation in agriculture. This can be relevant in cases where higher temperatures associated with climate change are reducing water availability or increasing evopotranspiration rates. But, since fertilizer use also leads to nitrous oxide emissions from soils, the application of fertilizer, including timing, need to be managed well.

Producing different forms of bioenergy or wood on cropland could have a similar effect. If less cropland is available for food production, productivity on the remaining land has to be increased, which may again lead to higher nitrous oxide emissions. However, both bioenergy production and forestry, particularly agroforestry, have a great deal of potential for synergy with agricultural adaptation. Introducing new options for income generation and livelihood support, widening currently typical crop rotations, and taking a more flexible view of seasonality with regard to planting and harvesting dates, are possible elements of future farming systems. They could adapt to climate change and could probably lead to more volatile production conditions. A suitable mix of annual and perennial food crops, together with agroforestry and low-input bioenergy crops could also play a substantial role in adaptation strategies in many countries.

Increasing soil carbon content provides an opportunity for triple-win situations. The vast areas of degraded soils worldwide mean that improving their fertility and soil carbon content could store huge amounts of carbon and thus contribute to climate change mitigation. At the same time, this would increase agricultural yields and hence improve rural livelihoods. Moreover, it would make many farming systems more resilient to changing temperatures and rainfall patterns.

The problem with all these agricultural mitigation options is the difficulty of providing suitable and effective incentive structures to foster their implementation. First of all, agricultural emissions, unlike fossil fuel emissions, are very complex to measure and monitor. Hence, it is difficult to ensure that emissions are actually reduced, e.g. in the case of methane and nitrous oxide, or that carbon is permanently stored in agricultural soils. These problems are even worse in poor countries that lack the necessary administrative infrastructure, property rights and financial means. Based on incomplete measurements, designing appropriate policy instruments, such as agricultural emission taxes or including the agricultural sector in emissions trading schemes, is even more complicated. In order to realise at least some of the synergy potentials between adaptation and mitigation in the agriculture sector, one option could be to use available adaptation funding to support some of the above-mentioned measures.

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Annex A: Short and long-term adaptation options and supporting policies

Adaptation option	Supporting policies
Short-term	
Crop insurance to protect against risk	Improve access, risk management, revise pricing incentives
Crop/livestock diversification to increase productivity and protect against diseases	Availability of extension services, financial support
Adjust timing of farm operations to reduce risks of crop damage	Extension services, pricing policies
Change cropping intensity	Improved extension services, pricing policy adjustments
Livestock management to adjust to new climate conditions	Provision of extension services
Changes in tillage practices	Extension services to support activities, pricing incentives
Food reserves and storage as temporary relief	Improving access and affordability, revising pricing
Changing crop mix	Improving access and affordability, revising pricing, etc.
Modernisation of farm operations	Promote adoption of technologies
Permanent migration to diversify income opportunities	Education and training
Defining land-use and tenure rights for investments	Legal reform and enforcement
Both short and long-term	
Development of crop and livestock technology adapted to climate change stress: drought and heat tolerance	Agricultural research (crop and livestock trait development), agricultural extension services
Develop market efficiency	Invest in rural infrastructure, remove market barriers, property rights
Irrigation and expansion of water storage facilities	Public and private sector investment
Efficient water use	Water pricing reforms, clearly defined property rights
Promoting international trade	Pricing and exchange rate policies
Improving forecasting mechanisms	Information needs to be distributed across all sectors
Institutional strengthening and creating decision-making structures	Reform existing institutions connected with agriculture

(Source: adapted from Kurukulasuriya & Rosenthal 2003)

Annex B: Adaptation options at farm-level for **cropping systems** by climatic/landscape zone

Climatic/ landscape zone	Arid and semi-arid	Humid
Cropping systems		
Inputs: choice of new, adapted and suitable varieties, i.e. switch to:	• Drought-tolerant crops (such as millet instead of corn) and varieties • Salt-tolerant varieties • Early maturing varieties • Indigenous crops (adapted to local conditions)	• Early maturing varieties • Crops with greater rooting depth • Indigenous crops that are better adapted to local conditions
Inputs: fertilizer use	• Altering fertilizer rates to maintain grain or fruit quality consistent with the prevailing climate • Compost and mulch application to increase soil organic matter and the soil's water retention capacity • Use of mineral fertilizer to guarantee optimal plant nutrition and development	• Altering fertilizer rates to maintain consistent grain or fruit quality • Compost and mulch application • Use of mineral fertilizer
Inputs: plant protection and seeds	• Use of improved seed material • Use of biological pest and disease control, e.g. natural predators or use of agro-chemicals for plant protection	• Maintaining or improving quarantine capacities and monitoring programmes, e.g. integrated plant protection methods, • Use of biological pest and disease control, e.g. natural predators or use of agro-chemicals for plant protection

Coastal areas	Mountain areas
• Crops with greater rooting depth • Salt-tolerant varieties • Indigenous crops (adapted to local conditions)	• Crop diversification, e.g. off-season and short season crops, fruit cultivation, crops tolerant to cooler seasons and more intensive rainfall
• Altering fertilizer rates to maintain grain or fruit quality consistent with the prevailing climate • Compost and mulch application • Use of mineral fertilizer	• Compost and manure application (to increase soil organic matter, soil water retention capacity and thereby reduce runoff)
• Use of improved seeds	• Use of varieties and species resistant to pests and diseases • Disease management, e.g. by using a mixture of varieties • Intercropping

Climatic/ landscape zone	Arid and semi-arid	Humid
Cropping systems		
Soil management	• Wind erosion control, e.g. by controlled bush clearing and planting new hedgerows • Changes in tillage practices: to conserve soil moisture (e.g. crop residue retention and reduced soil evaporation) and ensure better infiltration of water and increase the water reserves in the soil • Increase organic matter content of soils for enhanced water and nutrient storage capacity, soil structure and soil fertility • Rehabilitation of degraded forests and watersheds, e.g. reclamation of desert and development of sandy land, restoring land using green manure	• Fluvial erosion control, e.g. sustaining vegetation cover, contour ploughing, contoured hedgerows and buffer strips • Changes in tillage practices, i.e. conservation agriculture for better water infiltration
Crop management	• Introduce adapted irrigated types of land use • Enhance crop rotation practices • Crop diversification, e.g. mixed cropping systems • Change cropping intensity • Adjustments to planting and harvesting dates • Vary transplanting depth for rice plants • Alter row/plant spacing to increase root extension to soil water	• Improved seed storage, • Enhanced crop rotation practices • Crop diversification (mixed cropping systems) • Adjustments in planting and harvesting dates • Integration of trees and bushes to reduce water runoff and erosion
Water management	• Improve water management by having a greater diversity of options for water sources (small streams, shallow wells, boreholes, rainwater storage) • Use of surface irrigation methods (furrows and small basins) • Rehabilitation and improvement of traditional irrigation systems • Upgrading rainfed agriculture through integrated rainwater harvesting systems • More efficient water use, using deficit irrigation, e.g. rice intensification or dry seed rice (mitigates the impact of delayed monsoons)	• In-situ soil moisture conservation – technologies that increase rainwater infiltration • Land drainage, wetlands management

Coastal areas	Mountain areas
• Fluvial erosion control, sea water erosion, e.g. planting new hedgerows and restore mangroves • Rehabilitation of degraded forests and water-sheds, e.g. re-establishing wetlands	• Fluvial erosion control (contour planting, barriers, terraces, cover crops, water harvesting and micro-irrigation techniques) • Multi-use plants (highland legumes, vetches) • Increase organic matter content of soils (enhanced water and nutrient storage capacity) • Changes in tillage practices to conserve soil moisture and prevent runoff • Rehabilitation of degraded forests
• Improved seed storage • Integration of trees and bushes, terracing, soil cover and forests for protection against flooding	• Frost protection for crops, e.g. using enclosures, trees • Maintain agrobiodiversity to conserve frost-tolerant species and varieties • Plant on contour lines or parallel to slope to avoid erosion • Apply soil and water conservation measures (e.g. contour cropping, terracing)
• Wetland management and flood recession • Building dykes and check dams to reduce flood exposure • Maintaining mangrove forests for protection against flooding	• Adapt crop planning to changed water availability patterns • Switch to less water intensive agriculture (drip irrigation, rainwater harvesting, watershed restoration) • Watershed management and land use planning to avoid cultivation on steep slopes and flooded valleys (thereby fluvial erosion/gully)

Climatic/ landscape zone	Arid and semi-arid	Humid
Cropping systems		
Other additional options	• Migration and altering the location of cropping activities • Using climate forecasting to reduce production risk and setting up and developing meteorological predictions even in remote regions • Greater use of what are known as 'non-timber forest products'	• Migration and altering the location of cropping activities • Using climate forecasting to reduce production risk

Annex C: Adaptation options at farm-level for **livestock systems** by climatic/landscape zone

Climatic/ landscape zone	Arid and semi-arid	Humid
Livestock systems		
Inputs	• Ensure adequate water supplies • Use supplementary fodder • Use adapted livestock breeds • Construct livestock shelters, heat protection, cooling • Increase reliance on indigenous fodder plants that are better adapted to droughts and pests	• Use adapted livestock breeds • Construct livestock shelters
Animal management	• Use different animal species/breeds • Continuously match stock rates with pasture production • Altered rotation of pastures, modification of times of grazing • control extensive livestock farming and consider intensification of livestock production using fodder crops, silage and indoor rearing (reduced emissions mean a positive trade off with regard to mitigation)	• Change grassland cutting frequency • Enhance animal welfare, e.g. vaccinate animals to protect them and reduce spread of diseases • Moving herds from water-logged fields • Windbreak and woodland planting to provide shelter from extreme weather
Water management	• Run-off storage for supplemental irrigation of fodder crops, using storage structures such as farm ponds, earth dams, water pans and underground tanks	• Prevent pollution of aquifers by infiltration of agro-chemicals • Protect ponds and water pans

Coastal areas	Mountain areas
• Migration and altering the location of cropping activities • Soft and hard shelter construction: integrate wood, stone or coconut leaf walls	• Integration of livestock • Promote off-farm income generation • Introduce post-harvest technologies • Abandonment of areas unsuitable for crop cultivation – designation of conservation areas • Afforestation and protection of steep slopes

Coastal areas	Mountain areas
• Provide livestock shelters (e.g. trees, shaded areas)	• Increase vegetation cover of pasture using drought-tolerant varieties • Increase pasture reserves for harsh winters • Restore degraded pasture • Revival of traditional pasture management • Construct livestock shelters • Use supplementary feeds
• Moving herds from water-logged fields • Windbreak and woodland planting to provide shelter from extreme weather	• Modify grazing times • Continuously match stock rate with pasture production • Increase feed reserves • Prevent grazing on steep slopes • Protect conservation areas (high biodiversity) from grazing animals
• Protect ponds and water pans	• Expansion/rehabilitation of pasture water supply • Development of irrigated pasture • Provision of secure water supply for livestock • Protect streams

(Sources annex B and C: Teri 2003; Baethgen et al. 2003; Smith & Lenhart 1996; Rosegrant et al. 2008; Howden et al. 2007; Ziervogel et al. 2008; Mandip 2007; Blessin 2009; Kumar 2008; Schneider 2009; Greenpeace 2008; UNFCCC 2006; UNFCC 2009; USAID 2009)

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Abstract

Climate change is projected to have a major influence on where specific forest types will grow and what they will look like. But forests also have an influence on climate change: if they suffer degradation, forests are a source of greenhouse gases; if they are conserved, they act as sinks for carbon.

To address the impact of climate change on forests, flexible approaches are needed to promote adaptation. These approaches comprise both changes in the design and implementation of policies and programmes as well as new modes of governance that ensure stakeholder participation, secure land tenure and forest user rights. Financial incentives may also be needed to promote mitigation and adaptation.

Ecosystem-based adaptation can support restoration and avoid degradation of forests. It is cost-effective and easily accessible to the rural poor in many forest regions. Local forest-related knowledge and practices also represent an important source of adaptive capacity. Adaptive co-management between local resource user groups and local authorities is therefore a key strategy in many forests. However, even if adaptation measures are fully implemented, unmitigated climate change would, over the course of the current century, exceed the adaptive capacity of many forests. Thus, linking adaptation to mitigation and promoting synergies is particularly crucial in the case of forests, since it provides more benefits than planning and implementing adaptation and mitigation measures separately.

Climate change exerts its effects by acting synergistically with other forces like habitat fragmentation or unsustainable exploitation. However, this aspect was intentionally left out of this chapter, primarily due to lack of conclusive scientific knowledge.

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2.1 How does climate change impact forests?

Key messages

- In all biomes[1], climate change is projected to lead to shifts in distribution of forest types and species as well as in their composition.
- Forests influence climate change: as sources of greenhouse gases when they are destroyed and as sinks for carbon when they grow or expand.
- The productivity of tropical forests is projected to increase where sufficient water is available; however, in drier tropical areas, forests are projected to decline.

Climate is probably the most important determinant of global vegetation patterns and has a significant impact on forest ecology (including biodiversity), forest distribution and productivity (Kirschbaum et al. 1996).

In regard to a changing climate, Bernier & Schoene (2009) even went as far as to say: 'Forest adaptation to future environmental or social conditions resulting from climate change may significantly alter how and why forestry is practised in many parts of the globe.' They also noted: 'With the climate, and as a result the environment, undergoing perceptible changes within the life span of trees, achieving sustainable forest management will increasingly resemble aiming at a moving target.' When dealing with that moving target, it is important to keep in mind that a change in mean annual temperature as small as 1 °C over a sustained period is sufficient to bring about changes in species composition as well as distribution of many tree species (IPCC 1996). Under unavoidable and stable emission scenarios, forest productivity in currently temperature-limited or humid climates will stay constant or even increase as a result of CO_2 fertilisation. Under scenarios that assume that emissions remain stable or grow, forest productivity is expected to increase in northern biomes and decrease in the currently more productive southern forests due to the impact of pests and fire. The latter will produce high carbon emissions that will exacerbate climate change.

[1] Major climatically or geographically defined ecological units, primarily defined by their similar climatic conditions, flora, fauna and soils.


Studies in India using different models show that all forest types (temperate to tropical) are projected to experience an increase in net primary production (NPP) between the 2030s and 2070s (Chaturvedi et al. 2010; Ravindranath et al. 2006).

Under most scenarios, temperate forests are likely to be less affected than other forest types. Productivity is likely to increase in temperate forests closest to the poles and to decrease in temperate forests bordering the subtropics. Increasingly prevalent storms could cause major disturbances. Growth scenarios indicate that productivity in some subtropical woodland could increase due to the fertiliser effect of higher atmospheric CO_2 levels but, in other cases, rising temperatures, higher evaporation and lower rainfall could result in lower productivity.

Droughts will increase the prevalence of fire and predispose large areas of forest to pests and pathogens. In the subtropics the trend of increased fire is projected to wane in the latter part of the current century as lower rainfall reduces the availability of grass fuel. The subtropical domain contains many biodiversity hotspots that are at particular risk, even under stable or moderate climate scenarios. The productivity of tropical forests is projected to increase where sufficient water is available; in drier tropical areas, however, forests are projected to decline.

Tropical forests, particularly rain forests, have the highest biodiversity of all land ecosystems; even moderate climate change (as projected in unavoidable and stable scenarios) would put some of this biodiversity at considerable risk.

Anthropogenic impacts, such as deforestation and land-use changes, are likely to be of significant importance when discussing future trends in timber trade. The Intergovernmental Panel on Climate Change (IPCC) indicates that the majority of costs incurred by climate-related changes in forests and the forest sector are the result of lost ecosystem services. IPCC has therefore been a consistent advocate for increasing the resilience of forest ecosystems by reducing external pressures, as caused by fragmentation, large-scale disturbances, pollution, and invasive species.

Supply and demand for forest products – global trends

Kleine et al. (2007) evaluated the IPCC Report of 2007 regarding major climate change-related trends for forest products. The results were:

- The proportion of timber harvested from plantations will increase.
- Industrial demand for wood will increase only slightly.
- Global fuel wood consumption has peaked and will level out or decline. However, there is also the scenario of higher energy prices with the dramatic increase in fuel wood consumption that will entail.
- Charcoal consumption will increase.
- Due to rotation times[2], industrial timber production will shift in emphasis from temperate to tropical forests and from the Northern to the Southern Hemisphere.

How climate change impacts forests in India

According to projections based on a global dynamic vegetation model, the impacts of climate change on forests in India (Gopalakrishnan et al. 2011) are the following:

- About 45 % of the forested area is likely to undergo change by 2035. The changes comprise an expansion of tropical evergreen forests in the eastern India plateau and the Western Ghats, slight expansion of forests into the western part of central India, and almost no change in vegetation type in the north-east.
- Vulnerability assessments show that the vulnerable forest areas are spread across India, with a higher concentration in upper Himalayan stretches, parts of central India, the northern Western Ghats and Eastern Ghats. North-eastern forests, the southern Western Ghats and the forested regions of eastern India are estimated to be the least vulnerable.
- Temperate forests (over 50 % of India's forest area) are the most vulnerable. They are followed by tropical semi-evergreen forests and dry and moist deciduous forests.

[2] Time period from planting seedlings to harvesting a tree.

2.2 What does adaptation in forests mean?

It is widely accepted that the possible impacts of climate change on forests and the forest sector are considerable, many have already been observed. As forest conditions change, there is an inherent need to change management and policy measures to minimise negative impacts and exploit the benefits to be derived from climate change. Traditional sustainable forest management (SFM), as defined by the United Nations Forum on Forests in seven thematic elements (see box below), provides a very good basis, but will, in many cases, not be flexible and innovative enough to respond to the upcoming challenges.

The UN Forum on Forests and the seven thematic elements of sustainable forest management

Since the 1992 World Summit on Sustainable Development in Rio de Janeiro, countries have been discussing a common global framework to promote sustainable forest management. In 2007, member states of the United Nations Forum on Forests finally agreed on a Non-Legally Binding Instrument on All Types of Forest (NLBI) – or 'Forest Instrument' for short. The primary purpose of the Forest Instrument is to promote political commitment and action at all levels to enhance sustainable forest management and the contribution of the forests to poverty eradication.

The seven thematic elements of sustainable forest management were developed by the United Nations Forum on Forests in 2004 and were reaffirmed in 2007. They were also introduced as a major reference into the Forest Instrument, which can be used as an overall policy framework for all forest relevant initiatives and processes in a country.

The seven thematic elements of sustainable forest management are:

1. extent of forest resources;
2. forest biological diversity;
3. forest health and vitality;
4. productive functions of forest resources;
5. protective functions of forest resources;
6. socio-economic functions of forests;
7. legal, policy and institutional framework.

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ADAPTATION IN FORESTS

Climate change is not the primary cause of degradation of forests. Fragmentation and unplanned exploitation are main driving forces for the transformation of forests. Climate change aggravates the effects of these forces further.

Adaptation in the forest sector is crucial since local communities rely heavily on forests for their livelihood and since the impacts of climate change on forests, such as loss of biodiversity, are irreversible (Ravindranath & Sathaye 2002).

There are a number of different approaches for adapting forests to climate change: no intervention, reactive adaptation with often short-term action, and planned, proactive adaptation.
Currently, most forest management belongs to the first – no intervention – or at best the second category, as many local forestry practices are based on the implicit assumption that local climate conditions will not change.
Reactive adaptation management may include salvage cutting, post-disturbance changes in industrial processes to convert salvaged timber, updated harvest scheduling, recalculated allowable cuts or development of socio-economic support programmes for affected local communities. Short-term actions, such as disaster action plans, are needed after extreme events and disturbances (e.g. storms, fires) to provide people with the basic essentials they need to survive.
Planned, proactive adaptation involves redefining forestry goals and practices in advance to accommodate climate change-related risks and uncertainties. It is mostly **medium and long-term** and involves deliberate, anticipatory interventions at different levels and across sectors.
In addition to these approaches, it is the **ecosystem approach** and adaptive management that play important roles in adapting forests to climate change.The ecosystem approach works on the assumption that climate change is likely to impact multiple elements in an ecosystem. Furthermore, in many tropical countries, agriculture and livestock production systems depend to a large part on forest biodiversity and biomass. Therefore, forest adaptation has to follow an ecosystem-based approach, which means it has to consider all the elements of an ecosystem: forests, plantations, grazing land, livestock, agricultural land, and water resources.

The ecosystem approach

An ecosystem approach should involve the following aspects:

- knowledge of the elements or components of the ecosystem and interlinkages or interdependencies among them;
- knowledge of the projected impacts of climate change and the vulnerability of the forest ecosystems and forest-dependent communities;
- emphasis on conservation, restoration, and sustainable use of forest resources through a participatory approach;
- identification of the factors contributing to forest degradation and loss as well as identification of measures to address these drivers that may impact the ecosystem services provided by forests, including biodiversity and carbon storage and sequestration;
- participation of all the stakeholders in developing and implementing adaptation and management practices – with special consideration of local communities;
- integration of local or traditional practices of adaptation to climate variability into adaptation plans;
- monitoring the changes in vegetation status and the impacts of the new adaptation or management practices implemented.

Adaptive management can be viewed as a systematic process for continually improving sustainable forest management policies and practices by monitoring and then learning from the outcomes of operational programmes. Forest management aims at moderating or offsetting the potential damage caused by climate change and taking advantage of opportunities created by it. Adaptive forest management is one tool that could enable managers to do that by modifying the structure and the consequent functioning of the forest ecosystem (Innes et al. 2009, see next box). **Adaptive co-management** goes even further. It is based on cooperation between forest authorities and local communities *(see also section 2.4)*.

Adaptive forest management – challenges and governance issues

Many challenges for adaptive management in general and adaptive management of forests, in particular, touch upon governance issues. These can be summarised as follows:

- distinguish impact of climate change from the impact of other pressures such as changes in land use;
- deal with risks that might come up in the future;
- take decisions despite little time or possibility of testing different options and assessing results from experiments: the climate may have already changed and experiments may no longer be valid;
- apply win-win, no-regret or low-regret measures instead of putting action on hold pending the availability of all desired information;
- improve the availability and quality of climate-related data;
- make sound economic cases for investing in adaptation;
- adapt institutions: make organisational culture, established structures and forest management policies more flexible and better prepared to quickly react to challenges not yet known before crises arise;
- move the responsibility for coordinating adaptation to powerful central bodies; apply an integrated cross-sectoral approach, e.g. in national development strategies; combine measures within and outside the forest sector;
- deal with the diverse, sometimes contradictory and competing, values and interests of the various stakeholders

2.3 Governance and policies for adaptation in forests

Key messages

- Flexible approaches to policy design are needed. They have to be sensitive to the context in question and must not rely on a single, one-size-fits-all mechanism.
- New modes of governance are required that enable meaningful stakeholder participation and provide secure land tenure and forest user rights, as well as sufficient financial incentives.

Forests are socio-ecological systems. Managing the societal impacts of altered forests and of the actions of society on altered forests is just as important as managing the biological systems. Policies will have to ensure flexibility for forest managers to respond adequately to the local conditions of the forest site, to accommodate indigenous knowledge and to consider the needs of local people regarding the provision of forest goods and services.

Sustainable forest management that incorporates the additional objective of adaptation will be at the centre of forest policy. National Forest Policies, such as the **national forest programmes**, which are seen as a process of societal dialogue around forests, should serve as the core instrument of forest governance. Forests in most countries are controlled and managed by governments (forestry departments) and most countries have legislation, policies and programmes to promote community participation and management of forests, with or without adequate tenurial rights.

Secure land tenure and forest user rights are an indispensable precondition for investment in sustainable forest management by the private sector, communities and smallholders. However, this is a necessary condition but not a sufficient one. It is the contribution to people's livelihoods that should dictate decisions about how to use the land. Any policy or change in conditions that makes **alternative land uses** more profitable than forestry creates incentives for deforestation and undermines the ability of the forest sector to adapt to climate change.

Inter-sectoral coordination is crucial. Policies in other sectors may directly or indirectly, intentionally or unintentionally, influence decisions affecting forests, sometimes more so than forest-sector policy itself. This is critical in the context of adaptation, since policies in other sectors may reduce the adaptive capacity of the forestry sector and impede its ability to cope with climate change. Two sectors are particularly important in this regard: agriculture and energy.
Essentially, any measure that renders agriculture more profitable can increase incentives to clear forests for farmland, and it is probable that in some countries agriculture will receive support for adaptation to climate change, which again might increase pressure on forests. Communication and coordination between the forest and agriculture sector is therefore essential. Possible trade-offs and likely economic, social and environmental impacts need to be fully considered when drafting

policies. The same is true for energy policies, especially regarding biofuels, which also have an impact on the agricultural sector, and for hydropower if it requires land to be flooded.

In any case, forest adaptation policies and strategies need to be assessed in the light of their **impact on other sectors and vice versa**. This poses new challenges to policy integration and cross-sectoral coordination. We have to change the time scales of our thinking and planning from short term to medium and long term. Adaptation strategies may require additional investment and may therefore change the balance between the costs and benefits of forest management itself.

The high level of **uncertainty** poses additional challenges: the hierarchical top-down forest policy that still prevails in many countries is highly inappropriate to respond to them. All this demands a readiness to **modify institutions** and **include new stakeholders** into forest-related planning and policies. Designing appropriate multi-stakeholder processes could be a starting point, including, for example, setting up policy networks and **network governance** (Glück et al. 2009).

Finally, an essential element of any adaptation strategy will be to ensure adequate **monitoring**. New indicators and sampling methods will be required to monitor the impacts of climate change. **Policies and regulatory instruments** will also have to be adjusted to accommodate monitoring needs.

Last, but not least, we have to **strengthen the institutional capacity** of departments and bodies concerned with forest management, research and protection. This includes strengthening their ability to enforce the legislation needed to decrease forests' vulnerability to climate change.

Policy options for adaptation in forests

Policy option	Potential impacts and target points
Integrate forest issues into overall adaptation strategies	• Allocating human and financial resources • Reinforcing political importance and overall coordination
Enhance inter-sectoral coordination	• Dealing with sectors that directly or indirectly, intentionally or unintentionally, influence decisions affecting forests, especially the agriculture and energy sector
Implement national forest programme and the UN Forest Instrument of 2007	• Facilitating societal dialogue around forests and enhancing stakeholder participation • Developing a comprehensive policy framework for all forest-related initiatives and processes in a country • Improving coordination
Enhance law enforcement and transparency	• Implementing policies • Combating illegal logging • Increasing the sector's credibility
Secure land tenure and develop fair and equitable cost and benefit sharing schemes	• Engaging the private sector or communities and attracting investment
Empower traditional and indigenous communities	• Applying traditional knowledge and benefiting from hands-on experience and observation • Supporting adaptation of the generally most vulnerable parts of society
Apply ecosystem vulnerability assessments and ecosystem-based adaptation approaches	• Setting priorities for action • Interacting with other sectors • Saving costs, since ecosystem approaches are often less cost-intensive and more likely to create win-win situations
Promote economic valuation of forest ecosystem services	• Linking adaptation with mitigation measures
Apply monitoring and evaluation of adaptation measures	• Recognising trends and applying proactive adaptation
Support capacity development of institutions	• Inviting new stakeholders to participate • Enhancing flexibility within institutions • Promoting network governance that gives room for innovative approaches

Mission for a Green India

The National Mission for a Green India is one of the eight missions under India's National Action Plan on Climate Change (NAPCC). The Mission for a Green India recognises that climate change phenomena will seriously affect and alter the distribution, type and quality of the country's natural biological resources and the associated livelihoods of the people. It acknowledges the influences that the forestry sector has on environmental amelioration though climate mitigation, food security, water security, biodiversity conservation and livelihood security for forest-dependent communities. But local communities are not only the beneficiaries of the Mission. According to the Mission for a Green India, the communities as well as decentralised governments are meant to play a key role when it comes to governance and project implementation.

The Mission for a Green India puts 'greening' in the context of climate change adaptation and mitigation. It is meant to enhance:

- ecosystem services such as carbon sequestration and storage (in forests and other ecosystems);
- hydrological services;
- biodiversity and adaptation of vulnerable species/ecosystems to the changing climate;
- other provisioning services such as fuel, fodder, small timber and non-timber forest products.

The concrete objectives of the Mission are to:

- increase forest/tree cover on five million hectares of forest/non-forest lands and improve quality of forest cover on another five million hectares (a total of ten million hectares);
- improve ecosystem services, including biodiversity, hydrological services and carbon sequestration as a result of treatment of 10 million hectares;
- increase the forest-based livelihood income of about three million households living in and around the forests;
- increase annual CO_2 sequestration by 50 to 60 million tonnes in the year 2020.

(Source: GoI 2008)

2.4 Adaptation options in forests

Key messages

- There is no universally applicable approach to adapting forests to climate change. Forest managers should, therefore, be flexible enough to deploy the adaptation measures they deem most appropriate for their local situation.
- Local forest-related knowledge and practices, developed over generations under changing environmental conditions by indigenous and local communities, represent an important source of adaptive capacity.
- Options for adaptation vary among geographical regions and forest types. Adaptations in commercial forestry operations are very different from those made by communities that depend on forests for subsistence.

The following reflection developed by Innes at al. (2009) illustrates the challenges related to proactive adaptation: 'If the forest canopy is lost, then a manager is faced with important decisions. Current forestry practice for natural forests suggests that attempts should be made to replace the forest with the same species composition as the original forest. However, this fails to take into account that the **existing forest was probably established under different climatic conditions from those at the site today**, and that there is a strong possibility that whatever caused the canopy loss will occur again under future climates. There is a widespread assumption that the forest currently at a site is adapted to the current conditions, but this ignores the extent to which the climate has changed over the past 200–300 years, and the lag effects that occur in forests. As a result, replacement of a forest by one of the same composition may no longer be a suitable strategy.'

Efforts to encourage proactive adaptation not only have to take into account changing climatic conditions. They also have to address another reality: stakeholders in the forest sector often have **diverse values and interests** that can impede efforts to reach consensus on adaptation goals. Adaptation strategies must, therefore, pay explicit attention to normative issues such as trade-offs among competing values and interests or distribution of costs among stakeholders. They also have to take into consideration uncertainty and leave space for changing preferences, e.g. timber species used for furniture, and unintended consequences on the markets over time. Greater recognition of local institutions and individual actors involved in planning and decision-making processes may enable successful implementation of adaptation measures in forests.

A key strategy applicable to many forests, regardless which scenario is used, is **adaptive co-management** between forest authorities and local communities. Policies and regulations must be sufficiently flexible to allow for adaptive co-management to take place. Furthermore, there needs to be a recognition that mistakes will be made.

In regard to the various services of forest ecosystems, adaptation options themselves may be differentiated as follows (Seppälä et al. 2009):

- maintaining and providing ecosystem services;
- maintaining and providing provisioning services;
- maintaining and providing regulatory services;
- maintaining and providing cultural services.

2.4.1 Maintaining and providing ecosystem services

Maintaining ecosystem services comprises maintaining the extent of forests, facilitating natural adaptation of biological diversity and maintaining forest health.

Major activities to **maintain the extent of forests** involve first of all reducing deforestation and enhancing forest cover through afforestation and reforestation, that is establishing forests in areas where there was no forest before or re-establishing it where deforestation has taken place. In Ghana, Burkina Faso and Mali, for example, governments are supporting programmes to adapt forest ecosystems to predicted climates, e.g. through afforestation and reforestation, but also through research into resistance and adaption to drought and bushfire (Idinoba et al. 2009).

Plantations play an important role in maintaining the extent of forests, enhancing forest cover and reducing pressure on existing forests. The choice of species within new plantations should take into account projected trends in climate change. It is also important to keep in mind that demand for fuel wood and timber will increase in the future. Possible measures to maintain the extent of forests may include:

- reducing deforestation and applying sustainable forest management practices in natural forests;
- using plantation species better adapted to future climate conditions than traditional ones;
- introducing anticipatory planting according to projected climate change at a given latitude and altitude;
- making use of plantations to supply an increasing demand for wood, but being aware of changes to groundwater levels caused by new plantations;
- converting plantations to more natural forest types so as to enhance ecosystem services;
- integrating biofuel production into an overall concept in order to avoid conversion of forests;
- enhancing local welfare by promoting community-based forest management and restoration, developing agroforestry, making microfinance available, and promoting a greater role for women;
- offering training in management, manufacturing and marketing of non-timber forest products (NTFP);
- supporting efforts to improve welfare through sound governance, strengthening institutions, greater participation and education, greater accountability, reinforced monitoring and community access to benefits.

Facilitating **natural adaptation** of biological diversity is crucial as it enhances the resilience of ecosystems. In this regard, many actions associated with sustainable forest management are 'no-regret' options to reduce greenhouse gases that would pay for themselves even without a climate change policy. However, as part of a proactive adaptation approach, it is useful to consider the following additional measures:

- employing landscape-level approaches[3] to conserving biodiversity, enabling species to migrate to areas with more suitable climates;

[3] Forest landscape-level approaches aim to improve both ecological integrity and human well-being. According to the Global Partnership on Forest Landscape Restoration, this may involve the following principles: (i) restoring a balanced and agreed package of forest and broader landscape functions, (ii) active engagement, collaboration and negotiation among stakeholders, (iii) working on a larger landscape level, for example a watershed, and (iv) learning and adapting within and across sites, countries, regions, and globally.

- assisting migration of provenances and species;
- reducing fragmentation and maintaining connected areas of forest, especially links between protected areas;
- protecting primary and natural secondary forests;
- expanding reserve systems to ensure protection of genetically diverse populations and species-rich ecosystems;
- enhancing diminished ecosystem services or replacing lost ecosystem services;
- changing the species composition of forest stands and planting forests with genetically improved seedlings adapted to a new climate.

There is considerable evidence that climate change affects **forest health and vitality** and will continue to do so. Forest management may be able to reduce the impacts of events such as forest fires, pathogens or insect epidemics. But it will not be able to soften the impact of other events, such as extreme storms or droughts. In this context, following the philosophy of proactive adaptation means using the events themselves as an opportunity for adaptation by removing the inertia within a forest that buffers it against change. This includes:

- increasing the genetic diversity of trees used in plantations;
- reducing the impact of climate change and major changes to a forest which may render it more susceptible to future events;
- applying management techniques such as thinning, prescribed burning and selective cutting to mitigate the threat of mega-fires;
- developing strategies for dealing with forest insects, pathogens, and invasive species and applying phytosanitary standards.

2.4.2 Maintaining and providing provisioning services

Maintaining and providing provisioning services consists of maintaining the productivity of forest ecosystems and the tangible socio-economic benefits from forests under climate change.

Proactive adaptation management by **communities** may include diversification of forest-based and non forest-based income sources and better local governance of forest resources. But capacity building for monitoring and coping with possible calamities on an unprecedented scale is also important. Promoting co-management and community forestry is useful in increasing local adaptive capacity by strengthening the role of traditional knowledge in forest management and by putting decisions in the hands of the people – because they are the first to feel the effects of climate change. An example from Ghana illustrates how this can work.

In Ghana's modified *Taungya* system, land is cleared and initially planted with both food crops and tree seedlings. When fully grown, the trees are harvested by the administration for timber. The Government of Ghana has modified this classic approach so as to provide more flexibility and take into account financial benefits for farmers and other stakeholders involved. It has transferred the ownership of the trees from the government to the farmers and local communities. This modified approach involves more than planting food crops and economic trees on the land: continuous care is required and the necessary inputs must be applied throughout the tree's life. It has been confirmed that this modified *Taungya* system can provide important local-level contributions to increasing forest cover and enhancing adaptation (ETFRN 2009).

India's Joint Forest Management

In the early 1990s, the Government of India initiated community based natural resource management and developed guidelines for a programme called Joint Forest Management (JFM). Over the last two decades, twenty eight states have adopted this programme by involving the communities living in forest fringe areas in conservation, protection and management of forests and by sharing the benefits towards sustainable livelihoods for the local communities. It has been estimated that by February 2007, 21.4 million hectares of forestlands were being managed under the JFM programme, by approximately 99,868 JFM Committees in 28 states in India. It is thought that the JFM initiative had a great impact in some forest dependent communities in terms of enhancement of their socio-economic status. One assumption is that an increased forest cover and economic benefits of JFM are also helping forest fringe communities to adapt to changing climatic conditions, depending on the way JFM is being implemented in different states. GIZ commissioned Winrock International India – a non-profit organisation dealing with sustainable resources management – to analyse the effect JFM has on forest ecosystem resilience and whether it has increased adaptive capacities of vulnerable communities (Goswami n.d.).

2

Most adaptations to local climate conditions serve more than one purpose. **Local forest-related knowledge and practices** and associated social institutions, developed over generations under changing environmental conditions by indigenous and local communities, represent an important source of adaptive capacity for local forest-dependent communities in the face of climate-change impacts on forest ecosystems.

Making use of local knowledge for adaptation in India's forests

In north-eastern India, the soil and vegetation management practices developed over generations by local communities have been shown to enhance soil fertility and minimise erosion losses in shifting cultivation areas (Ramakrishnan 2007).

In the Himalayas, where communities are faced with erratic rainfall during spring and summer, farmers have developed agroforestry practices to ensure food security and additional income, particularly growing cardamom, bamboo groves and fruit trees (Verma 1998).

Within the **industrial forest sector**, proactive adaptation should take account of the fact that tropical plantations are more likely to remain viable under future climate than temperate or boreal plantations. The shorter rotation times of the faster growing species will reduce the risk of maladaptation and damage by extreme weather events. A trend is therefore projected by which industrial timber production emphasis will move from temperate to tropical forests and from the Northern to the Southern Hemisphere.

The following proactive measures are proposed to complement sustainable forest management and maintain provisioning services:

- undertaking landscape planning to minimise fire and insect damage (e.g. by introducing multi-species plantings and reducing logging waste);
- shifting to species or areas that are more productive under new climatic conditions;
- altering stand management within and between regions according to timber growth (i.e. shortened or extended rotation periods) and harvesting patterns (i.e. reducing damage to remaining trees, and salvaging dead timber);

- adjusting to altered wood size and quality;
- adjusting fire-management systems;
- implementing soil conservation practices;
- evaluating local preferences carefully and assisting communities in choosing and applying options for tree and forest management;
- taking account of traditional knowledge and cultural and spiritual values.

2.4.3 Maintaining and providing regulatory services

Maintaining and providing regulatory services means maintaining soil and water resources and enhancing forestry's contribution to global carbon cycles under conditions of climate change.

Experienced foresters and local communities understand the protective functions forests can have. These are important to safeguard infrastructure and human life and are widely used in mountain areas. Forests also play an important role in watershed management; they can **enhance the quality and quantity of soils and water**. However, forests use more water than grasslands. Consequently, new plantations may cause changes to groundwater levels and reduce stream flows.

It makes sense to **combine mitigation and adaptation measures**, since forests can only contribute to mitigation if they keep their adaptive capacity to climate change. Furthermore, mitigation might be used as a potential way of financing adaptation measures. When looking at the combination of mitigation and adaptation agroforestry is especially interesting as it offers the possibility of channelling benefits to local people. It sequesters carbon, reduces risks, enhances diversification and helps stabilise livelihoods *(see also section 2.5)*.

2.4.4 Maintaining and providing cultural services

Maintaining and providing cultural services encompasses cultural values and local knowledge, as well as aesthetic, spiritual, educational and recreational services provided by forests.

It has already been underlined that traditional and local **forest-related knowledge** is an asset for developing local adaptation approaches. Consequently, it is important to counteract the erosion of forest-related knowledge in forest-dependent societies. Multidisciplinary and participatory research should be enhanced. The efforts of indigenous and local communities should be supported, e.g. by documenting and preserving their knowledge and practices in coping with climate variability and associated changes in forest structure and function. Changes in **legislation** may become necessary to take account of the fact that traditional practices, such as hunting, may be impacted by changing species composition or migration behaviour.

Recent publications dealing with forests and adaptation to climate change do not specifically propose **gender-sensitive adaptation** measures. However, it can be assumed that the commonly known gender-sensitive impacts of forest degradation will be aggravated by climate change. Assessments of vulnerabilities, priorities and preferences should be looked at in a gender-sensitive manner. Of course, this also applies to the adaptation measures themselves.

The **aesthetic, spiritual, educational and recreational services** provided by forests quite often fall in the category of provisioning services. However, they are of equal importance for societies all over the world. Forests in urban areas, for example, have positive effects on people's health. They can alleviate the effects of extreme temperatures and they are a source of tranquillity within an environment of constant stress.

2.4.5 Research and monitoring

Key messages

- More research is required to reduce current uncertainties about climate change impacts on forests and people and to improve knowledge about management and policy measures for adaptation.
- Nevertheless, despite the limitations of current knowledge, climate change is progressing too quickly for us to be able to postpone adaptation action and wait for the outcome of further studies.

Adaptation studies in the forest sector have not yet been initiated. There are very few long-term monitoring plots in the tropical forest regions that are able to generate data on impacts and responses of vegetation to the changing climate. Although data is limited and climate projections and dynamic global vegetation models are fraught with uncertainty, it can be conclusively said that forests are highly vulnerable to climate change.

Politicians and policy-makers need to recognise that flexibility and **room to experiment** with and test management options are needed to deal with uncertainties. New indicators and sampling methods will be required to monitor the impacts of climate change. Reliable projections of regional and local impacts of climate change require investment in research and monitoring infrastructure and increased support for early warning systems and preparedness measures.

Assessing impact requires baselines, which in turn require **valid data** on climate, as well as on the quantity and quality of forests. Many countries are currently making enormous efforts to develop reference levels for greenhouse gas emissions within the REDD+ framework. Here, data are collected, and modelling takes place for a hypothetical 'business as usual' scenario. Approaches to Measuring, Reporting and Verification (MRV) of emission reduction activities are under development. Proactive adaptation management in forests can benefit from from these efforts by modifying such systems and also applying them to monitoring and evaluating adaptation measures in the forest sector.

REDD and REDD+

REDD stands for Reducing Emissions from Deforestation and Forest Degradation. It aims to significantly reduce emissions in developing countries at comparatively low cost for the international community. The basic idea is to compensate national governments and local stakeholders in tropical forest countries for quantified and verified emission reductions. In addition to forest conservation activities, REDD+ also includes the 'enhancement of forest carbon stocks', for instance by improving forest management, rehabilitating forests and reforestation.

(Source: GTZ 2009)

2.5 Linking adaptation and mitigation

Key messages

- Linking adaptation to mitigation in the forest sector is necessary and provides more benefits than planning and implementing them separately.
- Additional cost for adaptation may be covered by mitigation revenues.

Even if adaptation measures are fully implemented, unmitigated climate change would, during the course of the current century, exceed the adaptive capacity of many forests.

Increasing ecosystem resilience is a crucial first step towards adaptation and mitigation because forests can only sequester carbon and successfully store it if they are vital and healthy. Both these characteristics are directly affected by climate change. They can only be maintained if the forests are able to adapt to climate change. This adaptive capacity can be enhanced by increasing ecosystem resilience, which is a direct function of biodiversity and management techniques.

Mitigation and adaptation are generally considered separately in addressing climate change. However, they are intricately linked: many mitigation-driven actions could have either positive consequences for adaptation (e.g. preventing soil erosion) or negative ones (e.g. greater likelihood of pests and fires as a result of an increase in monocultures). Similarly, adaptation actions could have positive or negative implications for mitigation. Thus, there is a need to avoid trade-offs between adaptation and mitigation and promote synergy. A study has highlighted potential options for promoting synergy, particularly in the land use sector (Ravindranath et al. 2006). Potential examples of actions that promote both mitigation and adaptation include:

- **Agroforestry:** it can contribute to carbon sequestration in trees and soil and at the same time reduce the vulnerability of communities to climate change by diversifying livelihoods, e.g. through tree-based non-timber forest products

- **Coastal mangrove plantations:** they can sequester carbon in trees and soil while providing protection to coastal areas from sea water intrusion
- **Sustainable agricultural practices** involving organic manuring, mulching, soil and water conservation practices, and multiple cropping: they can not only enhance soil organic carbon sequestration, but also reduce the vulnerability of crops to moisture stress and drought, thus impacting positively on yields.

Several projections of the IPCC indicate significant risks that the forest's carbon-regulating services will be entirely lost. This is because land ecosystems will turn into a net source of carbon if there is a rise in global temperature to 2.5 °C or more above preindustrial levels. Moreover, since forests also release large quantities of carbon if deforested or impacted by other degrading stressors, they could exacerbate climate change further.


Mangrove forests in West Bengal. (photo: Ilona Porsché)

Reducing deforestation and degradation of natural forests, for example, offers mitigation and adaptation benefits. Any forest management plan that strives to maintain forest health and vitality, reduce risk, prevent forest degradation and maximise productivity helps to avoid deforestation and therefore contributes to both deforestation and therefore to both mitigation and adaptation. One of the major problems involved in linking adaptation and mitigation is that adaptation is often a response to local circumstances and is therefore a local concern that benefits local populations, while mitigation is a response to a global concern and is usually dealt with at the country scale (Bernier et al. 2009). It is therefore necessary to integrate climate change-mitigation and adaptation in forest-related societal processes. This will raise awareness of the complexity of the issue and make it possible to better link up the local and national level.

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ADAPTATION AND BIODIVERSITY

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ADAPTATION AND BIODIVERSITY

Abstract

The fundamental role biodiversity and functional ecosystem services play for adapting to climate change has long been undervalued in discussions on climate change adaptation. However, there is no denying the fact that climate change is increasingly putting pressure on ecosystems and aggravates the effects of other stresses expediting the loss of biological diversity. The degradation of ecosystems and loss of biodiversity deprive especially the rural poor of their natural resources base and exacerbate poverty.

Adaptation decisions across sectors and geographical areas therefore need to maximise positive and minimise negative impacts on biodiversity. In this context ecosystem-based adaptation, which integrates the use of biodiversity and ecosystem services into an overall adaptation strategy, can be cost-effective and yield various social, economic and environmental co-benefits for local communities. This has been made explicit through the international study on The Economics of Ecosystems and Biodiversity (TEEB).

At the same time the maintenance of intact ecosystems is one of the areas with the greatest potential for achieving the objectives of both climate change adaptation and mitigation. Due to the major role they play in the carbon cycle, terrestrial and marine ecosystems are of special importance here.


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ADAPTATION AND BIODIVERSITY

3.1 How does climate change impact biodiversity?

Key messages

- Climate change and associated disturbances are increasingly putting pressure on ecosystems and can exacerbate the effects of other existing stresses.
- Impacts of climate change on biodiversity from the ecosystem to genetic level can already be observed today and reveal significant ecological, social and economic consequences.
- Conserving natural terrestrial, freshwater and marine ecosystems and restoring degraded ecosystems is essential for global carbon and water cycles and in adapting to climate change.

Biodiversity and climate change are interconnected – not only through climate change effects on biodiversity and ecosystems, but also through changes in biodiversity that affect climate change (SCBD 2009). Natural terrestrial, wetlands and marine ecosystems play a key role in global carbon and water cycles and in adapting to climate change. The degradation of ecosystems in turn reduces carbon storage and sequestration capacity, leading to increases in emissions of greenhouse gases and accelerated climate change. At the same time changes in temperature and atmospheric CO_2 levels have adverse and often irreversible impacts on ecosystems and species which can already be observed today (Campbell et al. 2009). Last but not least, human activities for climate change mitigation or adaptation can have positive or negative effects on biodiversity and ecosystem services.

Biodiversity

Biodiversity is the variety of life on earth. The Convention on Biological Diversity (CBD) defines biological diversity as the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part. This includes diversity within species (genetic diversity), between species and of ecosystems.

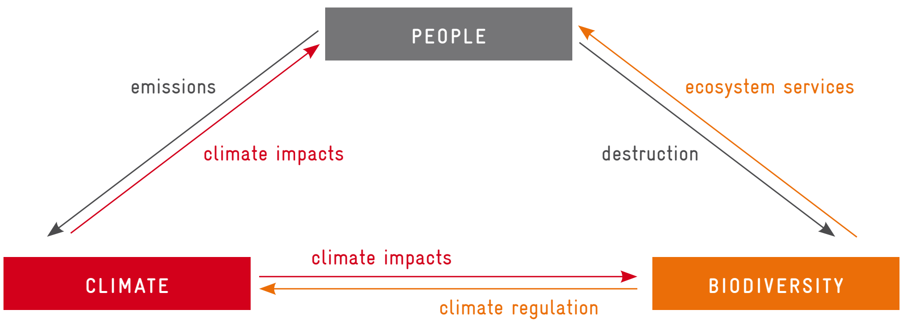
Ecosystem

The CBD defines an ecosystem as a 'dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit'. If one part is damaged it can have an impact on the whole system. Humans are an integral part of ecosystems. Ecosystems can be terrestrial or marine, inland or coastal, rural or urban, undisturbed or modified by human activity. They can also vary in scale from global to local.

Ecosystem services

Biodiversity is the foundation of ecosystem services. The different aspects and levels of biodiversity (genes, species, ecosystems) directly and indirectly contribute to ecosystem goods and services. Examples include food, freshwater, timber, climate regulation, protection from natural hazards, erosion control, pharmaceutical ingredients and recreation.

(Sources: CBD 1992; TEEB 2008)



(Source: Kus et al. 2010, adapted from the Royal Society 2007)

The Intergovernmental Panel on Climate Change (IPCC) concluded in its Fourth Assessment Report (IPCC 2007b) that climate change will have significant impacts on many aspects of biological diversity. The rise in temperature projected for the next 100 years is comparable to the increase in temperature over the past 10,000 years. This magnitude and rate of climate change poses particularly severe challenges for natural ecosystems. Species and ecosystems will have to adapt at a much faster rate than over the past geologic times. Increasing CO_2 concentrations, global warming, rising sea levels, and associated disturbances (e.g. floods, droughts, storms, fires, increased rates of pests and diseases, ocean acidification) are putting pressure on ecosystems and exacerbate the effects of other existing stresses, including habitat fragmentation and conversion, over-exploitation, pollution and invasive alien species.

The Fourth IPCC Assessment Report projects that approximately 10 % of species assessed so far will be at an increasingly high risk of extinction for every 1 °C rise in global mean temperature, within the range of future scenarios modelled in impact assessments. The review of recent scientific literature on the links between biodiversity and climate change prepared by the World Conservation Monitoring Centre of the United Nations Environment Programme (UNEP-WCMC) supports the key findings of the IPCC with a greater range of evidence from direct observation, experimental studies and modelling studies (Campbell et al. 2009).

Climate change related responses by species and ecosystems can already be observed today. Among them are shifting geographic ranges and migration of species; changes in life cycles, flowering, reproduction and ecological interactions; CO_2 fertilisation favouring fast growing species. Projecting the rate of extinction is difficult due to lags in species' responses, incomplete knowledge of natural adaptive capacity, and the complex cascade of inter-species interactions. Biological systems, from individuals to ecosystems, will often respond to climate change in rapid transformations after a long period of little change. Such rapid transformations usually occur when 'tipping points' or 'critical thresholds' are crossed. Increasing frequency and intensity of extreme climate events have the potential to more readily breach tipping points and thresholds leading to escalating extinctions and widespread reorganisation of ecosystems.

Changes in the Indian Summer Monsoon are considered to be such a tipping point, expecting to double the drought frequency, while these effects will be aggravated by the effects of Himalayan glaciers melting and reduced river flow (Lenton et al. 2009). Although there is still uncertainty in this area, the literature reviewed indicates that climate change is already impacting biodiversity from the ecosystem to genetic level with significant ecological, social and economic consequences.

One important ecosystem that is at high risk due to climate change is coral reefs, affecting the productivity of global fisheries and over 500 million people worldwide who depend on coral reefs for their livelihoods (TEEB 2009). Not only coral reefs, but many other biodiversity-rich areas are located in developing countries. Ecosystem degradation and biodiversity loss deprive low-income population groups of their natural resources base, increase poverty and further reduce their capacity to adapt to climate change.

India and its biodiversity

India ranks among the top ten species-rich nations with high endemism. So far, 91,200 species of animals and 45,500 species of plants have been documented in India's ten bio-geographic regions. It is therefore considered one of the world's 'mega diverse' countries in terms of biodiversity. The country possesses an exemplary diversity of indigenous and traditional knowledge, and a variety of ecological habitats like forests, grassland, wetlands, coastal/marine and desert ecosystems. India is recognised as one of the eight centres of origin and diversity of crop plants (Vavilovian Centers), with more than 300 wild ancestors and close relatives of cultivated plants, which are still evolving under natural conditions (MoEF 2009).

The IPCC in its summary report released in February 2007, has estimated a huge loss of biodiversity for biodiversity-rich mega diverse countries such as India due to climate change (IPCC 2007).

Biodiversity erosion in the Sundarbans

The Sundarbans, an eco-region that covers the southern tip of India's West Bengal and Bangladesh's South, is both unique, and uniquely fragile. It is one of the most extensive mangrove forests in the world, with very high species diversity (18 major mangroves, 22 minor mangroves and 36 mangrove associates). These mangrove forests are one of the most significant strongholds of the Royal Bengal Tiger, an endangered species and the national animal of India. In addition, the mangroves presents a natural buffer against coastal erosion and seawater ingress into one of the most densely populated regions of the world where about 4.5 million Indians and about 7.5 million Bangladeshis live.

The Sundarbans are characterised by developmental constraints in terms of rapidly growing population on the one hand and a lack of appropriate transportation, modern energy services, adequate healthcare delivery, and education on the other hand. Global climate change is making matters worse for the region and its inhabitants, both human and wildlife. Sea levels are rising faster than the global average and high intensity events such as severe cyclones and tidal surges are becoming more intense. Loss of land is now a reality. As land-based lievelihood activities get impacted due to rising sea levels, coastal erosion, loss of mangrove cover, and saltwater incursion, more and more people are exploiting the living resources of the ecosystem in a manner that will be difficult to sustain over the long term. The situation has the potential to erode ecosystem integrity due to overexploitation of natural resources. For these reasons climate vulnerability assessments are being carried out in the region and adaptation measures are undertaken by various Indian and international organisations.

Panchanan Gayen, 60 years old, lives in a village called Beguakhali on Sagar Island. He is one out of millions in the Sundarbans who depends on the land and the sea for his and his families' livelihood. Agriculture is his primary occupation. But he also tried his hand as fish whole seller, wood whole seller, and as medicine supplier in the past. Panchanan Gayen says: 'I am witness to immense changes which took place during the last three decades. Our village had huge stretches of sandy beaches and dense mangrove jungles along the coast. These jungles were stocked with a variety of mangrove species and wildlife. We lost these unique vegetative features and wildlife after 1980. In the past Beguakhali was quite a big village. It is located at the south western side of Sagar Island. The river is fast eroding our village and it has already lost 26 hectares of land in the last three decades. The river has already washed away 35 houses in the recent past. My house was almost one kilometre away from the river, but now it is on the river side. Affected families have been relocated and resettled on the northern part of this island.'

(Source: WWF 2010)

3.2 What does adaptation mean in relation to biodiversity?

Key messages

- In many cases, 'classical' development activities undertaken to improve livelihoods through the sustainable management and conservation of biodiversity, automatically lead to adaptation benefits.
- There are three main ways to describe how biodiversity is linked to adaptation, that is the role of biodiversity in overall societal adaptation strategies (ecosystem-based adaptation), the impact of adaptation strategies on biodiversity, and adaptation in the area of biodiversity conservation and management itself.

The linkages between biodiversity and adaptation are more and more considered in adaptation strategies which in the past often tended to focus on technological and structural measures in different sectors. This is because intact, well functioning ecosystems, with natural levels of biodiversity, are usually more able to continue to provide ecosystem services and resist and recover more readily from extreme weather events than degraded, impoverished ecosystems (SCBD 2009). The role of biodiversity in adaptation is therefore receiving increasing attention, especially in vulnerable areas where human adaptive capacity is low and local communities depend upon their natural resource base.

In many cases, **classical development activities** undertaken to improve livelihoods through the sustainable management and conservation of biodiversity and natural resources lead to adaptation benefits. They help to buffer households, communities and ecosystems from various stresses that result from different aspects of global change – from climate change to problems related to population increase, insecure and changing land ownership, environmental degradation, market globalisation and market failures. Possible examples for classical development activities with a positive effect on adaptation are:

- community-based natural resources management (e.g. development-oriented nature conservation);
- integrated watershed management;

- maintenance of diverse and healthy ecosystems (e.g. agroforestry, mixed cropping);
- sustainable forest management;
- livelihood diversification considering indigenous species (e.g. agrobiodiversity, home gardens).

The Convention on Biological Diversity (CBD) Expert Group on Biodiversity and Climate Change has discussed new approaches that specifically aim at reducing climate change impacts on biodiversity and ecosystems, or that take advantage of biodiversity and ecosystem services in adaptation strategies. The group´s findings were published in the report 'Connecting Biodiversity and Climate Change Mitigation and Adaptation' (SCBD 2009). Basically, it distinguishes the following three ways in which biodiversity is linked to adaptation:

Ecosystem-based adaptation as part of an overall adaptation strategy
Ecosystem-based adaptation is the use of biodiversity and ecosystem services as part of an overall adaptation strategy across major adaptation sectors. It includes the sustainable management, conservation and restoration of ecosystems to provide services that help people adapt to the adverse effects of climate change. Typical actions are:

- coastal defence through the maintenance and/or restoration of mangroves and other coastal wetlands ('natural infrastructure') to reduce coastal flooding and coastal erosion;
- conservation and restoration of forests to stabilise land slopes and regulate water flows;
- conservation of agrobiodiversity to provide specific gene pools for crop and livestock adaptation to climate change.

Adaptation strategies and their impact on biodiversity
Biodiversity can be impacted positively or negatively by adaptation strategies and its measures, depending on the way in which such strategies are implemented. The following two examples illustrate the necessity to increase the positive and decrease the negative effects of adaptation to biodiversity:

- Adaptation strategies increasing the diversity of agro-ecosystems can be beneficial for biodiversity and ecosystem services.
- Hard infrastructure constructed to prevent flooding can result in maladaptation in the long term if it removes natural flood regulation properties or disturbs sediment or nutrition flows.

Adaptation strategies for biodiversity conservation and management

Biodiversity conservation and management requires adaptation strategies for its own sake – also to maintain the role of biodiversity in contributing to societal adaptation as part of an overall adaptation strategy. The conservation sector is only recently beginning to develop adaptation measures. Strategies in this sector that are likely to increase the resilience of biodiversity to climate change could be:

- improving protected area design;
- maintaining habitat connectivity in the wider landscape;
- adapting management and business plans;
- reducing various anthropogenic pressures.

These three areas scrutinising the relationship between biodiversity and climate change adaption are all interlinked. Ultimately, within the context of an overall adaptation policy a broader perspective is required that focuses on how ecosystems can be managed and conserved in order to deliver ecosystem services in a changing climate (Campbell et al. 2009).

3.3 Governance and policies for adaptation in relation to biodiversity

Key messages

- Decision-makers need to be sensitised that there is a need to identify ecosystems of strategic importance and their key functions.
- Mainstreaming biodiversity and ecosystem services into adaptation policies, plans and programmes is key.
- The value of biodiversity and ecosystem services should be considered in cost and benefit analyses and in decision-making processes prioritising and selecting adaptation options.

3

ADAPTATION AND BIODIVERSITY

Policies need to consider that adaptation to climate change usually involves a range of biodiversity-relevant actions at the following levels: ecosystem or landscape, different land use systems, inter- and intra-species diversity.

When deciding on measures to address a projected climate change impact there are usually a range of available options, which involve different sectoral interests, time horizons and trade-offs. To ensure that adaptation decisions across sectors and geographical areas **maximise positive impacts and minimise negative impacts on biodiversity**, the Convention on Biological Diversity (CBD) recommends the following principles[1]:

- The potential of ecosystem-based adaptation options as a complement to technological or structural solutions should be fully considered.
- The value of biodiversity and ecosystem services should be considered in cost and benefit analyses and decision-making processes prioritising and selecting adaptation options. Since valuable ecosystem services are often invisible in national and local accounts and budgets, policy makers and markets can fail to adequately consider the value of these goods and services.
- Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) should be applied in a way that ensures full consideration of all available alternatives.
- Adaptation decisions should allow for monitoring and adaptive management approaches, particularly because of the high degree of uncertainty in projections about future impacts on which adaptation decisions are based.

Further research is required on **costs and benefit analyses** across adaptation options. The Economics of Ecosystems and Biodiversity (TEEB) study is a major international initiative to draw attention to the global economic benefits of biodiversity. It makes a compelling cost-benefit case for public investment in ecological infrastructure (TEEB 2009). It focuses mainly on restoring and conserving forests, mangroves, river basins and wetlands as a cost-effective response for adaptation generating social, economic and cultural co-benefits.

[1] Examples of common adaptation action in different sectors and geographical areas, the impacts on biodiversity and suggested ways to maximise or minimise these effects are summarised in Annex III of the Report of the 2nd Ad Hoc Technical Expert Group on Biodiversity and Climate Change (SCBD 2009).

Rethinking growth: the valuation of ecosystems and biodiversity in India

'You cannot manage what you do not measure', is the conviction of the Green Indian States Trust (GIST). GIST is an Indian NGO which was created in 2004 to promote sustainable development in India and bring forth climate change concerns with respect to biodiversity conservation and the application of economic valuation tools.

Among other things GIST publishes state-level 'green accounts' to encourage India's policymakers and corporations to overcome their almost exclusive dependence on the limited economic compass of Gross Domestic Product (GDP) growth to manage India's progress. GIST has replaced 'GDP growth' with a holistic alternative called 'Environmentally adjusted GDP'. This alternative accounts for all vital aspects of national wealth and well-being, such as changes in the quality of health, the extent of education, or the quality and quantity of natural resources.

GIST is supported by the Deutsche Bank India Foundation, the Centurion Bank of Punjab and GIZ.

(Source: GIST n.d.)

Risks to biodiversity from climate change can be assessed using available **ecosystem vulnerability assessment** methods. In order to sensitise decision-makers there is a need to identify ecosystems of strategic importance and their key functions like the contribution to rural livelihoods, food security or climate regulation. No one single methodology exists for conducting such assessments. But examples from the national scale or one specific protected area demonstrate how vulnerability assessment can be used to enhance the knowledge base for biodiversity-climate interactions and the identification of possible adaptation options. Further development and validation of tools is still necessary. In Peru and Tunisia GIZ is piloting ecosystem vulnerability

An ecosystem vulnerability assessment is being carried out for this cork oak forest in Tunisia, taking into account climate and non-climate stressors. (photo: Ghazi Gader) assessment approaches which analyse changes in key ecosystem processes taking into consideration climate change and other stressors. The results are intensively discussed with key stakeholders in order to develop and prioritise appropriate adaptation strategies. The design of such vulnerability assessments depends on the specific needs and circumstances, and may include the use of traditional knowledge, participatory approaches, and scientific climate modelling.

The need for **integrated adaptation strategies** across sectors to avoid maladaptation is becoming increasingly recognised (AIACC 2007). For example, there is a high level of interdependence between agriculture and water resources, where sustainable watershed management can act synergistically to improve agricultural practice, whereas unsustainable watershed management can have a negative impact on agricultural practice and vice versa (Lasco et al. 2008). Integration and cross-sectoral cooperation will require significant institutional capacity. Institutional networks to support the inclusion of biodiversity and the effective participation of local communities in adaptation strategies are likely to be a key determinant of the integration of biodiversity into adaptation (Campbell et al. 2009). Traditional knowledge, indigenous peoples' rights, local social and cultural institutions play a crucial role in the design and choice of adaptation strategies (PAR 2010).

Innovation based on both traditional knowledge and latest scientific findings is of high importance. The in-depth knowledge of indigenous communities must be seen as a precious source for new adaptation measures required to face climate change impacts. The need to adapt to climate change has, for example, often led to a revival of traditional practices in agriculture and of land-management techniques. This applies especially to stress-prone environments.

Policy options for adaptation in relation to biodiversity

Policy option	Potential impacts and target points
Adaptation strategies addressing: **-> ecosystem/landscape** **-> production system** **-> inter- and intra-species diversity**	Contributing to: • the resilience of the whole system through the links between natural and cultivated landscapes • the improvement of the supportive role of different land use systems (agriculture, forestry, fisheries, nature conservation including tourism) for the protection and restoration of ecosystems • the maintenance of species and genetic diversity
Ecosystem Vulnerability Assessments	• Assessing climate change induced risks to biodiversity and ecosystem services as a basis to develop adaptation strategies • Complementing existing vulnerability assessments for different sectors
Valuation of ecosystem services and biodiversity	• Putting environmental considerations on the agenda of decision-makers by monetising services that ecosystems provide 'free of charge', e.g. climate regulation, water regulation, flood management, nutrient cycling, erosion control, soil formation (Van der Wateren et al. 2004)
Ecosystem-based adaptation and investments in ecological infrastructure	• Integrating the use of biodiversity and ecosystem services into an overall adaptation strategy, which can be cost-effective and generate social, economic and cultural co-benefits and contribute to the conservation of biodiversity
Mainstreaming biodiversity and ecosystems services into policies (among others through Strategic Environmental Assessments)	• Ensuring that (adaptation) decisions across sectors and geographical areas maximise positive impacts and minimise negative impacts on the different aspects and levels of biodiversity, i.e. genes, species, ecosystems
Climate proofing of biodiversity management and conservation strategies	• Providing adaptation strategies for biodiversity conservation and management for its own sake • Applying climate proofing to National Biodiversity Strategies and Action Plans (NBSAPs) or Protected Area Management Plans
Empowerment of traditional and indigenous communities	• Generating innovations to cope with climate changes through the combination of traditional knowledge and new knowledge • Making use of communal efforts and functioning local institutions to manage natural resources and biodiversity at the ecosystem or landscape level in an appropriate way
Policy impact analyses and cyclical approaches	• Enabling new research, experimentation, monitoring and adjusted management through iterative, cyclical approaches in which biodiversity outcomes are appraised

3

3.4 Adaptation options

Key messages

- Activities at the ecosystem and landscape level aim to mitigate and buffer the effects of climate change through ecosystem protection and restoration, landscape rehabilitation and the sustainable use of natural resources.
- The identification and valuation of ecosystem services can inform spatial planning processes. Climate change and biodiversity concerns need to be integrated in land-use and development planning processes, e.g. through Strategic Environmental Assessment.
- The resilience of biodiversity to climate change can be enhanced by reducing non-climatic stresses in combination with conservation and strengthening of protected area networks, restoration and sustainable management strategies.
- The need to replenish inter- and intra-species diversity in ecosystems has encouraged community management of genetic resources, especially in agricultural systems.

3.4.1 Adaptation strategies at ecosystem and landscape level

Activities at the ecosystem and landscape level aim to mitigate and buffer the effects of climate change through ecosystem protection and restoration, landscape rehabilitation and the sustainable use of natural resources. Successful restoration of ecosystems will need to focus on **restoring ecosystem functionality** rather than re-creating the original species composition. Examples are:

- restoration of wetlands, peatlands, watersheds and coral reefs;
- reforestation of tropical hillsides, riparian forests and mangroves;
- rangeland rehabilitation and improved pasture management;
- revegetation in drylands.

Such ecosystem-based adaption can yield various social, economic and environmental co-benefits for local communities as shown in the following table.

Examples for co-benefits through ecosystem-based adaptation

		Co-benefits			
Adaptation measure, e.g.	**Adaptation**	**Social & cultural**	**Economic**	**Biodiversity**	**Mitigation**
Mangrove conservation	Protection against storm surges, sea-level rise and coastal inundation	Provision of employment options (fisheries and prawn cultivation), contribution to food security	Income generation for local communities through marketing of mangrove products (fish, dyes, medicines)	Conservation of species that live or breed in mangroves	Conservation of carbon stocks, both above and below-ground
Forest conservation	Maintenance of nutrient and water flow, prevention of land slides	Recreation, protection of indigenous and local communities and their cultural heritage	Income generation through sustainable use of forest products, ecotourism etc.	Habitat conservation of forest plants and animal species	Conservation of carbon stocks, reduction of emissions from deforestation or degradation

Restoration of agricultural productivity and biodiversity in India's North

A growing challenge in India's state Uttar Pradesh is the declining productivity of food grains, especially wheat and rice, due to water-related land degradation such as sodification. Poorly managed irrigation has left millions of hectares of land unproductive. At the cost of approximately $248.8 million the Uttar Pradesh Sodic Lands Reclamation Project I and II in 1993 and 1998 reclaimed a total of 253,715 hectares of formerly sodic lands through more sustainable agricultural practices. Within the reclaimed lands, soil quality and productivity have increased: Cropping intensity has tripled; rice yields increased from 0.9 to 3.5 tonnes per hectare, and wheat from 0.4 to 3.0 tonnes per hectare. The market value of land increased fourfold. More than 552,000 households, i.e. more than 1 million people, benefited directly from project activities. The project further showed that the investment in sustainable land management also improved environmental quality as evidenced by an over five-fold increase in floral and faunal diversity as well as microbial biomass in sampled areas. These positive changes are important preconditions to buffer the effects of climate change.

(Source: World Bank 2008)

Ecosystem vulnerability assessments can support the identification and prioritisation of adaptation measures across sectors at landscape level. They help identifying changes in key ecosystem processes and services under different scenarios of future climate. The **identification and valuation of ecosystem services** can also inform spatial planning processes. In general, climate change and biodiversity concerns should be integrated in all land-use planning processes (OECD-DAC ENVIRONET 2008). This can be facilitated through **Strategic Environmental Assessment** (SEA).

In Viet Nam, for example, a SEA was conducted in 2007 and 2008 to integrate environmental issues into the land use planning process for the Nhon Trach district near Ho Chi Minh City. An assessment of the possible consequences of climate change for Nhon Trach district was made as part of the SEA. The assessment of climate change impacts included analyses of possible temperature increase, precipitation changes, sea level rise, and saltwater intrusion. Proposed recommendations and measures for adapting to climate change included, amongst others (OECD-DAC ENVIRONET 2008):

- Mangrove forests should be continued to be preserved in the district in order to mitigate increasing hazards from high tides.
- Dyke systems that prevent the invasion of seawater in the district should be further maintained and developed.
- Agricultural land that was converted to other use should have tree coverage of at least 15 percent to control soil erosion.
- Cropping systems should be adapted/optimised in order to reduce the vulnerability of the agricultural system to climate change impacts, for example via diversification or by using new or traditional crops that are more suitable for the changing conditions.

Payment for Ecosystem Services (PES) – an example from Himachal Pradesh, India

Palampur town is situated in the foothills of Dhauladhar range in Kangra district of Himachal Pradesh in India. The Palampur Municipal Council (PMC) is responsible for drinking water supply in the town comprising of 852 households, 168 commercial establishments and 78 public enterprises. Bohal spring, situated upstream in Bohal village has been one of the major four sources of drinking water for the PMC and of superior quality as compared to others. Over the last few decades discharge from Bohal spring has declined substantially, from about 7-8 litres per second to 3-4 litres per second. This has been a major concern for the PMC.

The GIZ project 'Capacity building of Panchayati Raj Institutions in Himachal Pradesh' conducted a geo-hydrological survey of the area to delineate the infiltration zone for the Bohal spring system in the water management plan. The pilot project brought together key stakeholders in the upstream and downstream – the local communities of two villages in the Bohal spring catchment, the Forest Department, the Irrigation and Public Health Department and not to forget the PMC. Together they prepared a catchment protection, forest management and water management plan for the Bohal spring system.

The process led to the signing of a 20 years lasting agreement between the PMC and the Village Forest Development Society (VFDS) of Bohal outlining the Payment for Ecosystem Services (PES) arrangement. The PMC would pay to the VFDS Rs. 10,000 per annum with a provision of 10% increment every five year for source protection. The VFDS agreed to completely stop open grazing of livestock in the catchment area, control lopping and fodder harvesting, and implement a forest management plan in the catchment area. The VFDS and PMC agreed to jointly monitor the provisions of the agreement twice every year. There is also a provision to review the PES agreement every five years.

(Source: GIZ)

3.4.2 Strengthening the resilience of different land use systems

In **protected area management and nature conservation** reducing existing stresses on species and ecosystems (habitat loss and fragmentation, pollution, over-harvesting etc.) offers a low-risk, high-payback starting point in building resilience of natural systems.

Furthermore, enhancing sustainability of the protected area system and improving connectivity of protected areas and natural landscapes remain important in biodiversity conservation. These measures increase the probability of maintaining viable populations of species and provide opportunities for species to adapt, e.g. by migration. In Brazil, for instance, territorial conservation strategies are considered a key element in the protection of forests, biodiversity in general and climate. Brazilian-German development cooperation has supported the allocation of land and resource use rights, the proclamation of 53 new protected areas covering more than 200,000 km², and the planning and establishment of more than 700,000 km² of land serving as ecological corridors to support species migration with the moving climate zones.

In the face of climate change there is a need to focus conservation efforts on key sites which are likely to provide refugia, i.e. locations where species have maintained populations during previous phases of climate change. Another need is to prioritise areas of high endemism, as many of these have been relatively climatically stable for millions of years and have species with a high degree of specialisation. However, better regional and local monitoring is required to inform decisions on biodiversity conservation (SCBD 2009; Commonwealth of Australia 2009).

When it comes to **agricultural systems** commonly employed strategies to enhance their resilience and productivity include according to the Platform for Agrobiodiversity Research (PAR 2010):

- diversification of agricultural landscapes (agroforestry);
- diversification of production systems (cultivation of a higher diversity of crops and crop-livestock-trees integration);
- low-input agriculture, soil conservation, and improved water use efficiency (mulching, cover crops, rainwater harvesting, re-vegetation, fallow, intercropping, crop rotation);
- adjustments in crop and herd management *(see also chapter 1.4)*.

Maintaining agricultural biodiversity – an example from the Himalayas

In many areas of India people grow different crop combinations in order to minimise the risk due to harvest failure and at the same time maintain agricultural biodiversity.

Farmers in the cold deserts of the Indian Himalayas have developed a number of traditional cropping practices to adapt to the harsh climatic conditions. The cold desert areas of Indian Himalayas are characterised by fast-blowing winds that erode the immature sandy soils and extreme variations in daily and seasonal temperatures. There is erratic precipitation during spring and summer, which marks a short growing season (25 months). Farmers in such areas practice crop rotation, alternating paddy cultivation with wheat cultivation in the areas with irrigation, while wheat or barley is rotated with maize or mash in areas without irrigation. However, in cold reaches where paddy cannot be grown and two regular crops are not practicable, cultivation of wheat, barley, or masur (lentil) is followed by a fallow period during the winter. Crop rotation helps in maintaining soil productivity. Leguminous crops fix nitrogen. Intercropping maize, wheat, barley and millets conserves soil due to their different root systems, which extract nutrients from different layers of the soil. It also helps in crop diversification and control of any soil- or crop residue-borne diseases and insect pests.

(Source: Silori 2008)

3.4.3. Fostering inter- and intra-species diversity

Intra- and inter-species diversity need to be protected, used and redistributed to strengthen the resilience of different ecosystems *(see also chapter 1.4)*. In cases where there are existing barriers to migration of wild species, such as landscape fragmentation, assisted relocation or migration may be the only approaches to ensure the persistence of the species. This can be supported by additional engineering measures, if the appropriate habitat in the new area must first be created or modified to allow species to survive. Successful restoration of ecosystems (e.g. restoration of degraded forests) will require the use of a mixture of genetic provenances collected over a broad range of sites and climates. This way risks can be spread and the probability of restoration success can be increased.

For agricultural systems important adaptation measures that also enhance inter- and intra-species diversity include, for example (PAR 2010):

- protection, reintroduction and distribution of traditional crops through community seed banks and on-farm conservation;
- improvement of stress tolerance through farmers' selection and participatory plant breeding;
- use of stress-tolerant and fast-maturing crop species and varieties;
- use of stress-tolerant species and breeds of cattle.

As a last resort, species may need to be preserved outside an ecosystem context, for example in seed banks or zoos. Such ex situ conservation of threatened species is much more expensive for animals than for plants. That's why zoos and off-site breeding facilities can only accommodate a small fraction of species. For agricultural crops and wild relatives considerable experience exists in maintaining gene banks, and in linking ex situ and in situ conservation in farmers´ fields. Renowned institutions in this field are the International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) headquartered in Andhra Pradesh and the Tamil Nadu based M.S. Swaminathan Research Foundation that does research on sustainable agriculture and rural development.

Community-based management of genetic resources in India

The need to replenish diversity in agricultural systems has encouraged communities to build up community seed banks that facilitate the revival and distribution of traditional and stress-tolerant crops and varieties. In Uttar Pradesh, for example, the establishment of seed banks to facilitate the diversification of local food systems serves as a flood coping mechanism. In Bihar and Bengal community seed banks with a focus on rice have been established to strengthen the community seed supply of flood-resistant varieties. In Orissa it is saline-resistant varieties that get the most attention by local communities in the hope that their efforts will result in increased productivity in a submergence-prone area.

(Sources: Wajih 2008; Navdanya 2009; PAR 2010).

3.5 Linking adaptation and mitigation

Key messages

- Natural resources management is one of the areas with the greatest potential for achieving the objectives of both climate change adaptation and mitigation.
- However, adaptation or mitigation measures can also have negative effects on biodiversity.
- The creation of markets for 'forest carbon' offers opportunities for the development of other environmental markets and payments for ecosystem services.

Natural resource management is one of the areas with the greatest potential for achieving the objectives of both adaptation and mitigation, due to the major role that terrestrial and marine ecosystems play in the carbon cycle and above all as sinks, or stores, of carbon (Campbell et al. 2009).

Deforestation and forest degradation – through agricultural expansion, infrastructure development or destructive logging – account for nearly 20 % of global greenhouse gas emissions. Reducing Emissions from Deforestation and Forest Degradation (REDD) is identified as a strategy with the potential to support both mitigation and adaptation *(see also chapter 2.4.5)*.

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. At the same time REDD has the potential to provide significant biodiversity and adaptation benefits (Scheliha et al. 2009), and it can be seen as an opportunity to spearhead the development of other environmental markets and new international Payments for Ecosystem Services (PES), e.g. for freshwater enhancement, soil conservation or biodiversity conservation (TEEB 2009). Improving the management of protected areas to better retain forest cover may be an important component of an overall REDD strategy (Scharlemann et al. 2010). Good agricultural practices and agroforestry can equally reduce carbon loss and enhance soil organic matter. Thus, in most cases there is considerable potential to create synergies between climate change activities and biodiversity conservation, between adaptation and mitigation.

The Climate, Community & Biodiversity Alliance (CCBA) is a partnership of international NGOs and research institutes seeking to promote integrated solutions to land management. With this goal in mind, the CCBA has developed voluntary standards to help design and identify land management activities that simultaneously minimise climate change, support sustainable development and conserve biodiversity. For instance, in Chattisgrah, India, a carbon project for reforestation of privately-owned degraded lands using the native tree species *Gmelina arborea* and *Albizia lebbek* was validated to be in compliance with the CCBA standards (CBBA).

Yet, there may also be negative effects on biodiversity if measures are focusing narrowly on climate goals. Currently, many renewable energy projects are being planned without consideration of biodiversity impacts. Water resources can be directly impacted by reforestation where appropriate species are not used (Bhandari et al. 2007). Adaptation options in the water sector can involve draining wetlands, turning them into a net source of emissions (Mata & Budhooram 2007). Any adaptation option that involves the loss and degradation of natural ecosystems can result in greenhouse gas emissions, and may result in maladaptation in the long term. This area appears to require further research.

3.6 References and further reading

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ADAPTATION AND WATER RESOURCES

Abstract

Water resources and the way they are managed influence almost all aspects of social and economic life. Climate projections provide abundant evidence that changes in temperature and precipitation will strongly affect the availability and quality of water resources worldwide.

Higher temperatures, a rising sea level and an increase in the frequency of extreme weather events, such as floods, droughts and heat waves, will have the greatest impact on countries where water stress is already very high. Often these countries have only limited resources available to cope with and adapt to climate changes.

Population growth, urbanisation and changing consumption patterns will have a great impact on the future conditions of agricultural production. With more than 70 % of water being used for the agricultural sector, the linkages between agricultural production and water resources management clearly show the need for viable adaptation options to address this interconnection. The changing availability and quality of water resources due to climate change will not only have a great impact on food production, but also on sectors like energy, industry, sanitation, and health. Since the scope of these effects is unknown and unpredictable, responsive and flexible adaptation measures are needed.

As the classical top-down, supply-driven approach to water management has not delivered the desired results in the past; other concepts have been developed – for example, the concept of Integrated Water Resources Management which will be explored comprehensively in this chapter. The importance of capacity building for institutions and individuals, water managers and water users will also be addressed and a number of technical adaptation options will be presented.


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ADAPTATION AND WATER RESOURCES

4.1 How does climate change impact water resources?

Key messages

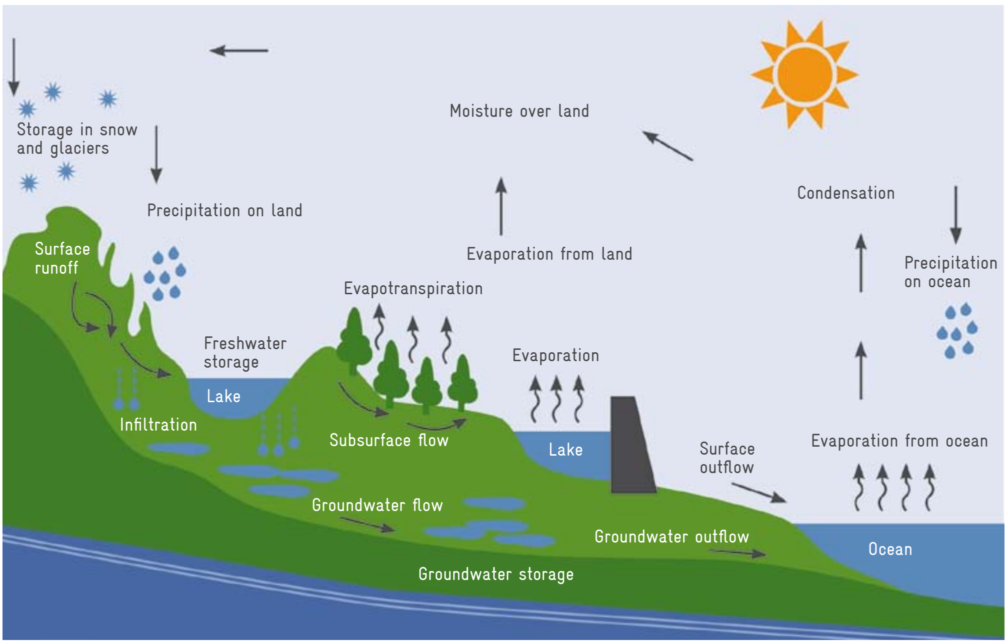
- Climate change will intensify the water cycle and will therefore have diverse impacts on human activities and the functioning of ecosystems.
- In India, the impacts of climate change on water resources will include higher variability and intensity of precipitation events, resulting in droughts and floods, increased glacier melts and sea level rise.

Over the last 100 years, the global climate has warmed by an average of 0.5 °C due to higher concentrations of greenhouse gases in the atmosphere. This trend will continue. This means that there will be more energy available on the Earth's surface, leading to an intensification of the water cycle (IPCC 2007a). These changes will have a substantial destabilising effect on the water cycle, resulting in greater variability in precipitation and stream flows, and increasing the intensity of extreme hydrological events (IUCN 2003).

The consequences will be diverse: many climate models project that up to 20 % of the world's population living in river basins will be affected by flood hazards by the 2080s (IPCC 2007b). The increasing rainfall variability will also lead to changes in river discharge, including longer periods of low flows, which will affect not only human activities but also ecosystem functioning. In some basins, slightly different rainfall patterns can result in vast changes in river discharge. The same is true for groundwater recharge, which is highly dependent on precipitation.

The water cycle

The water cycle refers to the continuous exchange of water between the atmosphere, land, surface and subsurface waters, and organisms. Water is stored in various compartments (e.g. oceans, lakes and groundwater) and moves from one to another through physical processes, such as evaporation, precipitation, infiltration, runoff, and subsurface flow, changing its aggregate state accordingly. Since solar energy plays a key role in evaporation and subsequent precipitation, rising temperatures will lead to an acceleration of the water cycle and to higher variability of precipitation events.



(Source: adapted from GoI 2009)

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ADAPTATION AND WATER RESOURCES

According to India's Initial National Communication (NATCOM) to the United Nations Framework Convention on Climate Change (UNFCCC), there will be an increase in mean temperatures of approximately 2 °C to 5 °C across the country by 2050. Higher air temperatures have already led to higher snowmelt rates and reduced snowfall. This can be observed in the Himalayas, where increased runoff can lead to mass movements such as mudflows. The impacts of melting Himalayan glaciers will also be felt in the downstream countries, i.e. India and Bangladesh. However, in the long run, the annual runoff in the Brahmaputra is projected to decline by 14 % and in the Indus by 27 % between now and 2050 (IPCC 2007c), which will also have tremendous consequences for water availability for all uses (e.g. households, agriculture).

The intensity of floods and severity of droughts in various parts of India is projected to increase. Hence, some river basins might face water scarcity (GoI 2004). The combination of population growth and climate change is predicted to reduce the availability of fresh water in India from the current 1900 to 1000 cubic meters per capita/year by 2025 (IPCC 2007b). Furthermore, rising sea levels may lead to increased saline intrusion into coastal and island aquifers, while increased frequency and severity of floods may affect groundwater quality in alluvial aquifers (GoI 2004).

As much as 60 % of the crop area in India is rain fed, with rainfall being largely confined to the southwest monsoon season from June to September (GoI 2004). While climate models are relatively consistent in predicting temperature increase, projecting the scope of precipitation changes remains very difficult. However, an overall increase in rainfall intensity, combined with a reduction in the number of rainy days, will have great effects for the majority of the land needed for agricultural production. North Andhra Pradesh and the west coast are already witnessing an increase in monsoon rainfall (+10 % to +12 % above the 100-year normal) and Madhya Pradesh, North East India and parts of Gujarat and Kerala are experiencing a decrease in monsoon rainfall: - 6 % to - 8 % below the 100-year normal (GoI 2004).

How climate change impacts water resources in India

Climate signals			
Heavy precipitation events	**Higher variability of precipitation, including increased droughts**	**Increase in air temperatures**	**Increase in water temperatures**
• Flooding • Adverse effects on quality of surface water and ground-water due to sewer overflows • Contamination of water supply	• Change in run-off • More widespread water stress • Increasing frequency and magnitude of drought-like situations • Increased water pollution due to lower dissolution of sediments, nutrients, pesticides and salt	• Melting glaciers and snowfields in the Himalayas affect-ing downstream river systems • More evapotranspira-tion • Increase in water temperatures	• Changes in lake and coastal ecosys-tems (e.g. more algae growth, coral bleaching) • Rising sea levels caused by thermal expansion and melting of glaciers, resulting in • Saline intrusion of coastal and island aquifers • Reduced quality of groundwater along the coastal plains

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4.2 What does adaptation in water resources management mean?

Key messages

- In order to ensure water security, water resources management has to incorporate climate change considerations.
- Water management measures should consider future risks and uncertainties in order to adapt to climate change.
- Well-proven and established measures need to be adjusted to the changing conditions. At the same time, new approaches need to be developed.

The impacts of climate change on water resources, such as the increase in extreme weather events like droughts and floods as well as higher rainfall variability, will exacerbate the vulnerability of people's livelihoods. Incorporating adaptation measures into the management of water resources is vital, particularly in those regions, such as semi-arid to arid areas, which suffer from harsh climatic conditions. Due to the limitation of climate models, projecting the scope of precipitation changes remains a very difficult task. This calls for special attention to prepare for higher rainfall variability.

Whereas, during past decades, water managers have already reacted to the changes in climate by adopting a range of practices, uncertain long-term challenges such as climate change and socio-economic trends have not been taken into account (Aerts & Droogers 2009; IPCC 2007c). Uncertainty makes it difficult to translate trends, such as higher rainfall variability, into quantitative terms that could serve as a basis to develop concrete water management strategies and measures. However, existing climate data and models have been instrumental in pointing out some general changes in the water cycle that are triggered by climate change. The implication for decision-making is that investments in water infrastructure will have to be made on the basis of unknown and uncertain future risks. It also means that management approaches that deal with existing risk and uncertainty have to be taken into consideration, along with climate scenario analyses and vulnerability assessments (IUCN 2003; Aerts & Droogers 2009).

As stressed in the introduction to this publication, mapping vulnerability and assessing its underlying factors are a crucial step in identifying the policies and measures needed to reduce vulnerability, increase adaptive capacity and highlight options for and constraints on adaptation. While assessments of such underlying factors help to establish approaches, the urgent need for action means that the process of identifying policies and measures should be undertaken simultaneously (Tideman & Khatana 2004). Key priorities for initial action in the water sector include:

- addressing current and expected water scarcity problems;
- dealing with floods and other extreme events;
- expanding the knowledge base on water resources;
- dealing with exposure to climate change and impacts;
- strengthening the national capacity for Integrated Water Resources Management and planning *(see section 4.4.1)*.

Adaptation in water resources management means adjusting well-proven and established measures to the changing conditions. New and innovative approaches to water resources management and its development are vital to reduce the vulnerability and livelihood insecurity among the poorest and facilitate adaptation to the uncertain effects of a changing climate. Climate Proofing constitutes such a new approach. It involves the systematic observation of the current and future risks and opportunities of climate change, leading to the identification of measures to address these issues *(see introduction, page 34, and section 4.4.3)*.

4.3 Governance and policies for adaptation in water resources management

To bring about effective adaptation to climate change in water resources management, greater attention must be paid to shaping and strengthening policies, mechanisms and structures of water governance on the local, national and regional level. This requires particular attention to the following elements:

- availability and communication of information;
- participation of all stakeholders involved, including local capacities for collective action and organisational capabilities of water users;
- sectoral integration and inter-sectoral coordination.

With regard to governance, sectoral integration and inter-sectoral coordination are of particular importance. National committees, task forces and working groups on climate change may provide a platform for coordination between sectors to identify cross-sectoral issues such as planning principles or provision of climate data. Many countries have already set up institutions of this kind. Administrative reforms and efforts can support the necessary coordination across different sectors and administrative levels. For instance, meteorological services and climatologists will need to work more closely with water planners, irrigation managers and agricultural extension services. Regional coordination in controlling river flows to avoid floods and water shortages is an example of coordination across different levels.

In general, adaptation in water management also requires adjustments in policy fields outside the water sector, such as:

- migration and settlement;
- transboundary cooperation in the event of disasters;
- regional and land use planning;
- agriculture, especially irrigation development.

To overcome conflicting objectives, such as the sustainable management of scarce water resources and increasing national food production, water professionals, planners and practitioners should aim at ensuring equity in the allocation of water. Both within agriculture and between agriculture and other sectors, water should be allocated on the basis of inventories of water availability, demand, consumption, return flows and losses.

India's National Water Mission

In order to mainstream climate change issues in the water sector, the Indian Government prepared its National Water Mission under the National Action Plan on Climate Change (NAPCC) in 2009. The mission highlights as its main objectives: conservation of water, minimising wastage and ensuring its more equitable distribution both across and within states through Integrated Water Resources Management. These objectives will be achieved by:

- establishing a comprehensive water database in the public domain to assess climate change impacts on water resources;
- promoting civic and state action for water conservation, augmentation and preservation;
- focusing attention to areas where water is over-used;
- increasing water use efficiency by 20 %;
- promoting Integrated Water Resources Management at basin level.

(Source: GoI 2009)

Policy options for adaptation in water resources management

Policy option	Potential impacts and target points
Policy analysis and change, mainstreaming adaptation	• Placing the adaptation issue at the heart of decision-making • Securing sufficient financial resources to implement adaptation • Creating the flexibility required for coordination between different sectors and administrative levels • Providing adequate institutional structures for adaptation
Adjustments in water management regulations	• Establishing appropriate spatial planning and building codes with regard to floods (e.g. avoiding high-risk and hazardous areas, specifications for the elevation of the lowest floor level, use of flood-resistant material) • Promoting water-saving devices (e.g. drip irrigation, multiple use systems, compulsory rainwater harvesting tanks for new buildings) • Improving efficiency of water distribution and use • Reusing waste water
Development of national, sectoral and regional adaptation strategies	• Providing a framework for coordinating adaptation activities • Assigning adaptation priorities (mid to long term) • Mobilising support within the country and from the international community
International cooperation	• Making use of international expertise on climate and climate impact data • Formulating adaptation strategies and setting adaptation priorities • Building up analytical monitoring capacities • Learning about tools for assessing policies and carrying out cost-benefit analyses
Capacity building	• Raising awareness of the effects of climate change on water resources, e.g. by introducing climate change into the curriculum for all school levels • Integrating knowledge of expected climate change impacts on the water cycle into water management
Incentives for adaptation	• Involving the private sector in planning and implementing adaptation measures (e.g. improving efficiency of water use) • Gaining the support of civil society and other actors for the development and implementation of adaptation strategies in the water sector

(Sources: IUCN 2003; Ngigi 2009)

4.4 Adaptation options in water resources management

Key messages

- Flexible water management approaches can help to deal with climate variability.
- Promoting integrated watershed management supports sustainable livelihoods, and adaptation to climate change.
- Technical water management measures must increase the efficiency and effectiveness of water use.
- Capacity building is needed to enhance understanding of viable adaptation options in water resources management.

Impacts of climate change can be diverse *(see section 4.1)*. Hence, setting priorities for adaptation involves assessing exposure to climate signals, determining sensitivity to a changing climate, and assessing the adaptation capacities at different levels (from national to community level).

Integrative and flexible approaches to water resources management, such as **Integrated Water Resources Management** and **Adaptive Water Management**, need to be taken into account in order to address the challenges posed by climate change.

4.4.1 Integrated Water Resources Management

'Classical' water resources management includes management of water resources in watersheds or river basins, looking at water quantity, quality and also at environmental issues. However, the positioning of water resources management within a wider context has led from the classical to the broader approach of Integrated Water Resources Management (IWRM).

Integrated Water Resources Management

'Integrated Water Resources Management is a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.'

(Source: GWP 2000)

IWRM is based on the acknowledgment that **different uses of water are interdependent**. Hence, for IWRM, the interdependence of different water uses and users, as well as their impacts on the state of water resources, are a central concern. To take this interdependency into account and to achieve economic, social and ecological sustainability it is essential to address the challenges of population growth and increased demand for food and water. In order to make that happen, policies, institutions and processes in different sectors and at different levels have to be coordinated effectively (InfoResources 2003). These requirements are expressed above in the most frequently cited definition in the international water debate.

While the concept of IWRM does not explicitly address climate change or climate variability, its holistic approach means that it can be seen as an appropriate tool for coping with this variability (Van Beek 2009). In general, adaptation in IWRM refers to measures that help to adjust to situations of increased uncertainty, risk and variability brought about by climate change. More specifically, following the IWRM principles means taking into account effects of climate variability and change that are already making themselves felt and others that are projected.

IWRM is a challenging and complex approach, but its flexibility offers various points of entry. This integrated approach to water resources management considers the catchment as a whole (Cap-Net 2009):

- Better water management makes it easier to respond to changes in water availability.
- Basin planning allows for risk identification and mitigation.
- Involvement and participation of stakeholders such as authorities, institutions, the public and private sector as well as civil society helps in mobilisation for action and in risk assessment.

- Good management systems allow the right incentives to be passed on to water users.

4.4.2 Adaptive Water Management

Due to the uncertain effects of climate change, identifying effective interventions is particularly challenging. Climate projections are often inconsistent and lack accuracy – especially at the regional and local level. This has guided climate adaptation research towards new – adaptive – approaches in water management that enable water managers to cope with future uncertainties. The concept of Adaptive Water Management aims at more institutional flexibility and provides stakeholders with a central role in an iterative **social learning process**. Hence adaptive management is about **flexibility**, about adjusting water management strategies so that they become more resilient under a wide range of future conditions. Various methods, such as forecasting, risk mapping and insurance systems, especially for drought and flood events, have been established to help develop such strategies. Wider **stakeholder involvement** and **transparency** are also required to enhance political support for sharing the burden and possible benefits of the impacts of climate change (Aerts & Droogers 2009; Pahl-Wostl et al. 2005).

Adaptive Water Management, an approach derived from the field of industrial operation theory, is rarely mentioned explicitly in Indian policy documents. However, many of the tenets of adaptive management have been and are increasingly being employed in the management of water resources in India. The National Water Policy and the Common Guidelines for Watershed Development Projects are both indicative of how Adaptive Water Management – when seen as a means to meet the environmental, social, and economic goals of multiple stakeholders in a perpetually changing environment – is being implicitly practised in India.

Adaptive Water Management – examples from India

The **National Water Policy** of 2002 stresses the importance of multi-stakeholder participation and multi-sectoral analysis in planning and implementing water resource projects. It attaches great value to information systems that encourage knowledge generation, management and sharing as well as monitoring projects to ensure necessary corrective action has been mandated. The National Water Policy covers a broad array of water-related issues including groundwater development, drinking water, irrigation, resettlement, and land erosion. It places the stakeholders in the central role and is a good example of how the Indian Government is trying to bring flexibility into the water management policy framework.

Another example of Adaptive Water Management being practised intuitively in India is the **Common Guidelines for Watershed Development Projects** of 2008. The watershed guidelines have been modified over the past two decades, which shows the ability of India's political institutions, with the support of civil society, to adapt practices as circumstances change and people and institutions learn from experience. The most recent iteration, which is certain to be followed shortly by another, places a strong emphasis on the centrality of community participation and capacity development as well as on monitoring and evaluation. The guidelines have even mandated that 2% of the budget for watershed projects should be allocated to monitoring and evaluation and 5% to capacity building. The constant adaptation of the guidelines is not indicative of a trial and error process, but is rather the result of institutional learning by doing to adapt to changing requirements.

A practical example of Adaptive Water Management is the village of **Hiware Bazar** in Maharashtra state, known for its community-based initiatives in enhancing the resilience of communities to climatic variability and extreme weather conditions (Hiware Bazar n.d.). From 1995 to 2005, the efforts of the local leadership were directed towards water conservation, which includes both replenishing the groundwater and creating a surface storage system. Since 2004, Hiware Bazar has been conducting an annual water audit, measuring the total availability of water. The implementation of these development programmes has to a large extent stopped the migration of the villagers. The village has introduced its own water regulations linked to its cropping plans. It began to base cropping patterns on water availability, despite a well-established market for the sugar cane crop. Decisions on cropping intensity are taken annually, ensuring efficient management of the resource and its equitable distribution.

4.4.3 Watershed management

Watershed management

Watershed management is the rational utilisation of land and water resources for optimum production with minimum hazard to natural resources (Tideman 1996).

Watershed management aims to manage water supply, water quality, drainage water runoff and water rights. It also incorporates overall planning processes for watersheds. It comprises the planned, coordinated and sustainable use of:

- water resources,
- agricultural resources,
- grazing land,
- forests, and
- areas with other uses (domestic water supply, irrigation, industrial water use, navigation).

The Indian Government has been supporting the development of watersheds since 1973, when the Drought-Prone Area Programme was introduced. Since then it has evolved with increased experience and knowledge to find answers to two major challenges: soil and water conservation and improvement of livelihoods in rural areas. At first, making significant changes in the original planning and implementation processes was considered too rigid and top-down. In 1994, a government-mandated committee carried out a critical assessment stating that implementation of large-scale soil and water conservation programmes had been 'sub-optimal' thus far. This paved the way for making significant changes in planning and implementation.

In fact, there have been four modifications to the guidelines on watershed management since 1994. Partly as a result of the Indian Government's collaboration with local and international NGOs and international development organisations, there has been a shift towards more transparency, community-participation, and an equitable distribution of benefits. Furthermore, planning of new watershed development projects has become more decentralised.

Watershed development in India is working towards developing watersheds to create sustainable livelihood opportunities. Building on participatory approaches, increasing water availability, improving degraded environments and choosing sustainable agricultural activities are key features. Watershed development is thus directly dependent on climate parameters like rainfall, temperature or evapotranspiration.

On the one hand, watershed development in India contributes significantly to increasing adaptive capacity and reducing the vulnerability of communities and farmers to climate change. On the other hand, unless it is included in development planning processes, the success of watershed development may itself be at risk from climate change. A systematic consideration of observed and expected changes in climate parameters through climate proofing can contribute to optimising watershed development to take account of climate change.

Climate proofing India's Watershed Development Fund

The National Bank for Agriculture and Rural Development (NABARD) initiated the Watershed Development Fund (WDF) in 2001. The WDF is replenished annually and is set to continue for many years to come. This fund has been set up to cover an area of 1.42 million hectares of land. Main activities include drainage line treatment, water harvesting structures, and livelihood interventions.

NABARD and GIZ are starting a process of climate proofing the WDF. Climate proofing should ensure that the activities supported through WDF continue to be appropriate and sustainable, taking into account our changing climate. The exercise of climate proofing could identify possible modifications or additional WDF activities to further increase the adaptive capacities of people living in watershed areas.

As many known and well-proven watershed management measures are already in place in India, it is necessary to first look at the existing measures and activities and evaluate their adaptation potential. A study was conducted that assessed the adaptation and mitigation potential of measures commonly applied in watershed management in India. They were classified according to their potential to adapt to different climatic conditions (e.g. hotter, colder, wetter, drier). The following table shows a selection of measures and their adaptation potential as identified in the study (Hagen et al. 2003).

Preliminary assessment of the adaptation potential for a selection of watershed management measures

Activity	Objective	Impacts	Adaptation potential				No regret
			hotter	colder	dryer	wetter	
Ponds	Groundwater recharge, water for cattle	• Recharge of groundwater • Creation of large open water bodies; as with all open water bodies: more mosquitoes (malaria)	+	++	++	±	+
Silt detention structures, gully plugs, gabions	Primarily to trap sediment/ silt in gullies and stabilise the gully	• Keeps sediment out of downstream areas • Increased water infiltration due to water being slowed down	++	+	++	++	+
Landslide treatment	Stabilise existing slopes to stop landslides	• Reduced erosion • Saving agricultural land or dwellings	+	+	+	++	+
In-situ rain-water harvesting	Increased water availability	• More water available where it falls • Increased biomass • Less runoff and erosion	++	+	++	±	+
Microirrigation	More efficient water use and increased yields	• Less water used and consequently less depletion of groundwater	++	+	++	±	+

+ Helpful, positive
++ Very helpful, positive
- Harming, negative
± Positive & negative effects balanced

(Source: adapted from Hagen et al. 2003)

4.4.4 Agricultural water management

In addition to the first chapter of this publication *(see chapter 1.4.7)*, the following paragraphs describe and evaluate water management techniques associated with agricultural production systems. Agricultural water management is not exclusively concerned with irrigation, but encompasses diverse approaches to increase the effectiveness and efficiency of water management for rain-fed agriculture.

Irrigation

With a net irrigated area of 54 million hectares, India has the largest area of irrigated land in the world (Narayanamoorthy 2006). The extraordinary importance of irrigation for Indian agriculture is bound to increase in the future: due to increasing rainfall variability in the wake of climate change, the demand for irrigation as a means of risk minimisation in agriculture will rise. At the same time, however, water scarcity in many parts of the Indian subcontinent will become more pronounced and competition between the water using sectors will intensify. The main reason for this is the fact that demand for foodgrains will continue to rise (NetIndian News Network 2010).

The most prevalent form of irrigation in India is **groundwater irrigation**. Already 70 % of Indian crop production is dependent on groundwater irrigation. Expanding the irrigation potential through groundwater irrigation is often a priority based on the assumption that it not only reduces the variation in supply and is more reliable, but also provides the flexibility to cope with unforeseen water shortages. This reduces the risks for farmers in purchasing farm inputs and therefore often leads to higher agricultural productivity (Bhaduri et al. 2005). The dependence on groundwater irrigation will further increase with the impacts of climate change, especially in those areas already affected by low and irregular rainfall. Because withdrawal of groundwater often exceeds recharge, if the groundwater resource is not managed well, depletion of groundwater and degradation will pose a serious threat to farmers and the environment alike, as shown in the example from India on the next page.

Options for adaptation to climate change and improving sustainability include improved management and governance of large irrigation systems by focusing on demand management rather than supply management. This includes improving **water use efficiency** and helping to reduce water losses. In addition, alternatives to groundwater irrigation, such as water harvesting and the use of marginal water (see below), must be provided. The easy access to and availability of water for irrigation often leads to higher consumption levels than actually needed by farmers. The inefficiency and lack of water pricing structures that reflect the actual price of water hardly provides any incentive for farmers to conserve their water resources. Improved water use efficiency can be achieved by:

- technical modernisation of the design and operation of new or rehabilitated irrigation systems;
- improved on-farm water management, including water-saving technology (especially drip irrigation);
- volumetric water prices as an incentive to save water;
- cropping patterns, plant breeding and crop-growing practices that are suited to water availability and soil conditions;
- agricultural research that focuses on water saving, e.g. in connection with traditional crops, improved crop-growing practices and increased use of salt-tolerant plants.

The boom in groundwater use in India and its consequences

The use of groundwater for irrigation, as opposed to canals or tanks, has increased from 29 % in 1950/51 to 62 % in 2002/03 (Narayanamoorthy 2006). The so-called groundwater boom is mainly attributed to the absence of large-scale surface irrigation schemes and the availability of low-cost electric and diesel pumps in combination with low or no charges for electricity (Bhaduri et al. 2005). The consequences of this boom in groundwater use are dramatic: the very intensive use of groundwater, combined with low and irregular rainfall, has led to groundwater withdrawal exceeding recharge. While water resource depletion and degradation is a serious threat in India and South Asia, leading to major environmental consequences, the economic consequences for farmers will be equally serious.

Water harvesting

One of the major options for increasing the availability of water lies in the expansion of **water storage facilities** to balance out the discrepancies between periods of peak supply and peak demand. However, such strategies need to take a new and broader view of water storage. Apart from the 'large dam option' – which, with its high economic, social and environmental costs, will come under more severe scrutiny in the future – the whole gamut of water storage options needs to be explored and better utilised. These options range from improved agricultural practices to enhanced water retention in the soil, **small water storage tanks** and other means of water harvesting, and reconstruction and rehabilitation of traditional tanks that were in use in India for centuries, through to new ways of management of ensembles of small, multi-purpose reservoirs and the construction and improved operation of large dams and reservoirs *(see section 4.4.5)*.

In India, water and irrigation tanks are part of an ancient tradition of harvesting and preserving rainfall – primarily for agricultural use and drinking water, but also for hygiene and religious bathing rituals. Small-scale farmers are able to use the stored water for irrigating their fields, watering their livestock and for household needs like cooking. As early as 200 BC, sophisticated systems of drains, wells and storage tanks were constructed, especially in those areas where rainfall is restricted to the monsoon seasons, like South India.

Over time, many ancient water harvesting structures fell into disuse and disrepair. However, in recent years, villages have started to re-build and re-use the ancient systems. NGOs play a major role in supporting villages in their efforts, providing technical assistance and knowledge management. Modernising the ancient tank irrigation systems, even though they are severely degraded, is likely to have higher pay-offs than constructing new and additional channels, wells and tanks. The systems are regarded as less capital-intensive and have a wider geographical distribution than large projects (Palanisami 2006). However, to ensure the long-term usage of these irrigation tanks, sustainable tank management practices must be put into place. Storing water during times of higher availability as a result of precipitation events augments its supply in times of water shortage and drought. Using the traditional knowledge and adapting it to current conditions and future challenges supports the large number of marginal and small-scale farmers essentially dependent on tank irrigation. This is demonstrated in the following example.

Building on India's traditions

The Development of Humane Action (DHAN) Foundation is an Indian development organisation. In 1992, it initiated the Vayalagam Tankfed Agriculture Development Programme, reaching approximately 12,000 farmers in 192 villages in Tamil Nadu, Andhra Pradesh and Karnataka. The programme's main emphasis is on organising water tank users and involving them in rehabilitation works. It consists of the following key components:

- organising the farmers around the tanks and later on at the level of cascades, and promoting tank-based farmers' associations at block and district level;
- rehabilitating water;
- involving farmers in setting up harvesting structures to restore system efficiency, increase water use efficiency and thus improve access to water;
- promoting traditional tank-based watershed development to harvest all the rainwater within the watershed boundary;
- reviving and strengthening the tradition of appointing *Neerkattis* (water managers). A water manager is responsible for the supply of water to every field at the farm level, safeguarding the tank structures, ensuring water management on the basis of available water and crop needs, and managing the distribution of water in times of scarcity and high demand.

(Source: CSE n.d.)

Use of marginal water

In countries suffering from water scarcity, the use of marginal water is common in agriculture, posing great risks to human health for farmers and consumers. However, this approach may offer a viable option for optimising the use of limited water resources, when handled in a proper manner. Marginal-quality water can be broken down into the following categories (Wichelns et al. 2007):

- urban wastewater (domestic wastewater from commercial and industrial effluent and wastewater from commercial establishments);
- agricultural drainage water (surface runoff and deep percolation, often containing salts, agricultural chemicals and nutrients);
- saline or sodic surface water and groundwater (the reactions of water moving through the soil profile).

Because marginal water contains various pollutants, use of wastewater needs to be carefully managed. Both the quality management of water according to the technical, economic and social possibilities and the sustainable use of marginal-quality water need to be documented and experiences shared among water professionals and practitioners. Below are three examples of how to improve the quality of marginal water:

- leaching and drainage to balance salt in the soil profile;
- blending saline and sodic waters with freshwater;
- establishing property rights for wastewater and creating economic incentives.

4.4.5 Optimisation and planning for multi-purpose dam development

During recent decades, there has been a debate over whether large-scale infrastructure projects, such as dams, are inflexible approaches to water management, with the costs (direct and indirect) in some cases outweighing the benefits. This has certainly been the case in some instances. Under changing climate conditions, the variability of water flow in the future will make maintaining electricity supply a more complex job for hydro planners, institutions and engineers. Adaptation to climate change, especially in monsoon regions of the Indian sub-continent, will also require more effective measures to deal with droughts and floods. Although today far greater attention is being given to other storage options such as natural wetlands, small tanks, groundwater aquifers and enhanced soil moisture, large dams could nevertheless be beneficial if used in a more flexible and multi-purpose way.

Appropriate reservoir management techniques could contribute to an efficient linkage between energy and water supply, food security, poverty alleviation, and climate change adaptation. Adopting standards for evaluating the sustainability of hydropower projects under different climate change scenarios is stipulated as an important criterion for decision-making in hydropower governance, with special emphasis put on ensuring compliance with them in the Himalayan region. Along with the political and institutional strategies to address this issue, multi-purpose planning and management can provide a useful approach to adaptation to climate change.

Dams for irrigation and hydropower in India

India has more than 4,300 large dams in operation. Although their primary function is irrigation (96 %), they also contribute to hydroelectric power generation (25 GW accounting for 23 % of the total installed generation capacity in India and 31 % of the total hydropower potential), flood control, and water supply. A number of hydropower schemes are more than 40 years old, and have been identified for renovation and upgrading. At the same time, to keep pace with India's rapid economic development, the Indian Government plans to build an additional 20 GW of hydro capacity in the next five years (GoI 2008; World Bank 2010). Here it is important to assess the sustainability of the proposed developments. In addition, an analysis needs to be carried out to establish whether the expected rainfall, taking projected climatic changes into account, will be sufficient to fill all the planned dams and for the range of intended water uses.

Multi-purpose dams combine several advantages: the production costs for electricity are relatively low and the reservoirs provide additional benefits such as irrigation, drinking water supply, and flood protection – benefits which can also be used as options for adaptation to climate change. Multi-purpose dams should apply core Integrated Water Resources Management principles, such as planning at the river basin level, strong inter-sectoral cooperation, public participation and making the best use of water resources. Furthermore, in order to avoid or at least minimise the negative impacts of building large-scale infrastructure, dam projects should be planned and managed in compliance with international standards and guidelines.

Multi-purpose planning can also be applied to existing dams. The rehabilitation of existing dams is a crucial first step to sustainable water management in the context of climate change. Inadequate infrastructure can lead to major risks of water waste, thus exacerbating water stress and increasing the risks of major accidents. There are three general improvement options:

- upgrading and rehabilitating facilities associated with the dam;
- optimising operation of reservoirs, e.g. by managing daily and seasonal water levels and release patterns for single or multi-purpose uses;
- optimising the role of the dam within the larger system it services, e.g. by introducing new water uses.

4.4.6 Capacity building for adaptation in water resources management

Adapting water management to climate change will require building capacity of people and institutions, e.g. by training engineers, hydrologists, planners and many other professionals. Strengthening the ability of people to manage their water resources more efficiently and equitably is vital. This can be achieved by integrating climate change adaptation into watershed management planning processes. Making resources available for strengthening both institutional and individual capacities is a critical early step in adapting to climate change.

Viable options for capacity building are as follows (GTZ 2008):

- identifying priority adaptation measures and institutional responsibilities for implementing them in a participatory process;
- identifying alternative crops that are better adapted to expected future climate conditions;
- designing water-saving irrigation schemes;
- organising exhibitions to raise public awareness of expected changes in climate;
- introducing climate change into the curriculum for all school levels;
- integrating knowledge of expected hydrologic impacts of climate change into watershed management.

In view of its vulnerabilities to climate change, the Indonesian Government, for example, is actively promoting adaptation programmes across the country. Challenges faced in adaptation planning include the availability of relevant information and planning tools and the active involvement of line ministries, local level administrations and other stakeholders that are key to implementing adaptation. Since 2007, GIZ (then GTZ) has been implementing a pilot project supporting an interministerial working group on adaptation in the water sector and providing decision-making support. The methodological focus is on assessing vulnerability to climate risks and its impacts, as well as on economic assessment and prioritisation of adaptation options. Climate and hydrological modelling and cost-benefit analyses are being performed in a pilot district and helping to identify efficient adaptation options. The project thus contributes to enhancing the capacity of policymakers to incorporate climate change issues into routine planning in the water sector (GTZ 2008).

4.5 Linking adaptation and mitigation

Mitigation and adaptation need to be viewed as complementary responses to climate change in general, and more particularly to its impact on the water sector. The interactions between an increasing demand for water, the need to adapt to the effects of climate change and the need to reduce greenhouse gas emissions are stimulating integrated energy and water use within water resources management, regulatory frameworks and adaptation planning. This also reaffirms the importance of integrated energy, land and water management strategies to ensure that both adaptation and mitigation measures deal adequately with climate change impacts.

Tests revealed that many water reservoirs produce a certain amount of greenhouse gas emissions. In shallow, tropical reservoirs, where the natural carbon cycle is most productive, high levels of methane emissions from the anaerobic decomposition of organic substances were even recorded (Bates et al. 2008).

Possible conflicts between adaptation and mitigation might arise over water resources. In regions where hydropower stations use a large part of existing water resources for energy production, the competition for water might increase. Water shortages are, for example, often experienced in villages that are located downstream from areas where upstream damming is taking place. In cases like this, feasible strategies could incorporate irrigation schemes to cope with climate change impacts in agriculture (Bates at al. 2008).

Furthermore, the recent emphasis on introducing non-conventional energy devices and energy conservation measures clearly has considerable mitigation potential. Withdrawal of groundwater, for instance, is very energy-intensive. Pumps are often inefficient and waste generated power. The high, and often subsidised, energy use in groundwater irrigation causes greenhouse gas emissions. In India, such emissions account for at least 6 % of the country's overall greenhouse gas emissions (Rothausen & Conway 2011). The use of drip irrigation and efficient pump sets means that less water is needed for irrigation and electricity consumption is lower, which in turn reduces emissions. To minimise the effects of climate change, adaption and mitigation measures need to be implemented alongside each other.

A preliminary assessment identifying the potential of different measures for both mitigation and adaptation was conducted in Indian watershed programmes (Hagen et al. 2003). According to the findings, activities related to water, soil and land conservation contribute to adaptation, and some of them even to mitigation. They include afforestation, reforestation, agroforestry, use of biogas, and improved agricultural practices as it can be seen in the table below.

Mitigation measures in other areas such as industry, agriculture and forests, have positive effects on the reduction of climate change impacts within the water sector. For example, reducing forest degradation and deforestation, combined with afforestation and reforestation measures, may significantly contribute to avoiding emissions and storing carbon. Further positive outcomes in connection with water resources management could include conserving water resources and preventing flooding, reducing runoff, controlling erosion, reducing siltation of rivers, protecting fisheries and investing in hydroelectric power facilities, and, last but not least, preserving biodiversity.

Preliminary assessment of the adaptation and mitigation potential of watershed management measures

Activity	Objective	Impacts	Adaptation potential				Mitigation	No regret
Contour/ boundary trenches/ bunds	Stop runoff and sediment from farmer's fields	• Increased water availability and therefore increased agricultural production • Reduced loss of especially fertile soils	++	+	++	±	+	+
Afforestation[1] and reforestation[1]	Stabilise degraded areas	• Less erosion • Higher availability of wood and other products	++	+	++	+	++	+

Agro-forestry	Increase wood and fruit production in existing agricultural businesses	• See objective; • Stabilisation of bunds and fields	++	+	++	+	+	+
Horti-culture	Increase production of fruit and vegetables	• Improved quality of food • Increased income if produce is sold • Higher employment	+	+	++	+	+	+
Improved agricultural methods and seeds[2]	Increase agricultural production	• Increase in quantity and quality of production • Fewer diseases and pests	++	+	++	+	+	+
Biogas	Promote renewable energy	• Less fuel wood needed	++	++	++	++	+	+

+ Helpful, positive
++ Very helpful, positive
- Harming, negative
± Positive & negative effects balanced

[1] Use of a robust mix of species supposed
[2] Selection of suitable mix of species supposed

(Source: adapted from Hagen et al. 2003)

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ADAPTATION IN COASTAL ZONES

Abstract

One of the most visible impacts of climate change can be seen in coastal zones. The potential for severe damage along the coastline from salinisation, strong coastal storms, heavy rain, strong winds, and associated storm surges and inundation will increase dramatically.

India has a long, densely populated coastline of more than 7,500 kilometres, which is very exposed to the impacts of climate change. These impacts are threatening the livelihoods of hundreds of thousands of people living in India's coastal areas. Rising sea levels and storms, which are likely to increase in frequency and intensity, will aggravate erosion – with serious consequences for the economy and the environment in the coastal states. Integrated Coastal Zone Management and Marine Protected Areas are two current answers to that huge challenge. In the past, climate change has scarcely featured in coastal zone management, let alone adaptation to climate change. This is no longer the case.

Integrated Coastal Zone Management offers mechanisms for adaptation through an attempt to balance environmental, economic, and social objectives. Adaptation mechanisms include afforestation of mangroves, and the declaration and stewardship of protected areas, be it coral reefs, seagrass meadows or fish spawning grounds. Such measures are combined with policy adjustments and incentive structures to encourage the protection and sustainable management of valuable coastal ecosystems.

By focusing on different aspects of adaptation in coastal zones and implementing pilot projects in several locations with unique characteristics, GIZ has acquired a wide range of experience from its own projects and those of partner organisations, which we describe in the following pages.


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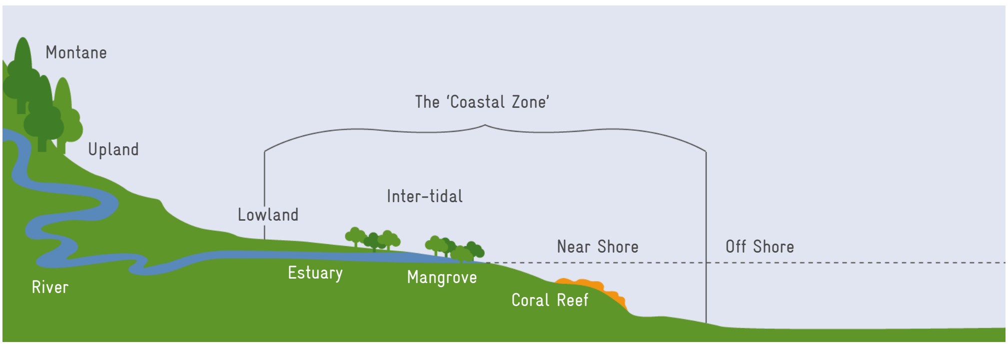
ADAPTATION IN COASTAL ZONES

5.1 How does climate change impact coastal zones?

Coastal zones are among the most densely populated regions on Earth, and that trend is increasing. Around 50 % of the world's population now lives in coastal regions and that figure is expected to rise to 75 % by 2020 (BMVBS 2009). The development of human settlements, the expansion of coastal and near-coastal infrastructure and increased economic activities are posing a growing threat to the ecological and social equilibrium of coastal areas and intensifying the pressure on their resources.

Coastal zones



(Source: Brown 1997)

Climate change impacts are already beginning to alter the nature of coastal and ocean ecosystems, threatening the livelihoods of millions of people living in coastal areas. The rise in marine and coastal water surface temperatures is causing coral bleaching and the widespread death of coral reefs. Salt-water intrusion is leading to the spread of brackish estuarine systems, which has severe consequences for agriculture and aquaculture. Coastal erosion is worsening due to the gradual disappearance of mangrove belts and seagrass beds. The decline of coastal and marine ecosystems such as the coral reefs and mangrove wetlands could have a severe impact on marine biodiversity and fisheries production.

General impacts of climate change on coastal zones

Climate change phenomenon	Potential impact on coastal zones
Increase in air temperatures	• Heat waves • Drought • Wildfire • Invasive species range expansion • Changes in timing of ecological events • Loss of sea ice • Reduction in snowpack
Rising sea levels (accelerated rise in sea level of up to 0.6 metres or more by 2100)	• Coastal inundation • Erosion • Storm surge flooding • Rising water tables • Saltwater intrusion • Nonpoint source pollution • Introduction of toxic substances
Increasing storm intensity/frequency	• Flooding • High wind, high waves • Erosion • Salinity shifts • Nonpoint source pollution • Introduction of toxic substances
Increase in water temperatures (a further rise in sea surface temperatures by up to 3 °C)	• Coral bleaching • Hypoxia • Pathogens and disease • Harmful algal blooms • Invasive species, shift in species range • Changes in timing of ecological events
Ocean acidification	• Dissolution of calcium carbonate in shell-forming marine organisms

(Source: adapted from NOAA 2010)

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ADAPTATION IN COASTAL ZONES

Coastal zones are complex ecosystems. This means that climate change impacts such as warming temperatures, sea-level rise, and changing precipitation patterns will severely affect them (Murray 2005). According to today's predictions, climate change will increasingly 'endanger the food security, water security, health, and livelihoods of coastal populations' (Michel 2010).

Management of coastal zones is particularly crucial in India. Overall, India's coastline is 7,525 kilometres long, 20 % to 25 % of the population lives within 50 kilometres of the coast, and 70 % of that total in rural areas (ADB 2010). The Indian coastline can be categorised into three classes – emergent coast, submergent coast and neutral coast (NATCOM 2004). When the dominant agent in shaping the coastline is the submergence of the land relative to the sea then it is called submergent coast and when it is emergence of the coastline relative to the sea then it is called emergent coast. The Indian coastal zone is inhabited by more than 100 million people in nine coastal states. The east coast comprises West Bengal, Orissa, Andhra Pradesh, Tamil Nadu; the west coast Kerala, Karnataka, Goa, Maharashtra, Gujarat. There are also two coastal union territories (Pondicherry, Daman and Diu), and two groups of islands (Andaman and Nicobars, Lakshdweep).

The lives of over 40 million people living along the Indian coastline will be affected by the impacts of climate change. Not only do these people have their homes on the coast, many of them are also dependent on it to make a living, above all in climate-sensitive sectors like agriculture and fisheries (INCCA 2010). The main impacts of climate change are listed in the following box.

Threatened embankments in the Sundarbans, West Bengal, India. (photo: Dr B.K. Chand)

How climate change impacts coastal zones in India

- All coastal states and territories in India are affected by coastal erosion.
- About 26 % of the mainland coastline is already seriously eroded and much of the coastline is actively retreating. In the state of Karnataka, for example, erosion has affected 249.6 kilometres of the state's total coastline of 280 kilometres.
- Rising sea levels and storms that are likely to increase in frequency and intensity will aggravate erosion – with serious consequences for the economy and the environment in the coastal states.
- By the middle of the century, the sea level in the Indian subcontinent will have risen 15-38 centimetres.
- A 1-metre rise in sea level would displace 7.1 million people in India as 5,764 square kilometres of land and 4,200 kilometres of roads would be lost.

(Source: adapted from ADB 2010)

5.2 What does adaptation in coastal zones mean?

Adapting to climate change requires an assessment of how current and anticipated climate variability and change is likely to affect societies and ecosystems. Based on this analysis, possible adaptation measures can be identified. Apart from the effectiveness of addressing climate change risks, the financial and economic costs of the measures need to be estimated, using cost-benefit analyses to define priority measures. Aspects of governance must also be considered. For instance: who could most appropriately tackle which areas, and what risk management interventions should be used?

In responding to climate change, the specific nature of coastal areas calls for special approaches. On the one hand, these areas are highly vulnerable to climate change impacts; on the other hand, healthy coastal wetland ecosystems, such as mangrove forests, can reduce that vulnerability as they provide protection from climate impacts like storms or sea level rise. Climate change is not only bringing new challenges, it is also exacerbating the human-induced pressures that already existed.

In the past, climate change issues were rarely considered in coastal zone management. For the past decade, a more holistic, multi-disciplinary approach is being advocated, which also takes climatic changes into account (Murray 2005). It is known as **Integrated Coastal Zone Management** (ICZM).

Integrated Coastal Zone Management

The European Commission defines Integrated Coastal Zone Management (ICZM) as

'a dynamic, multi-disciplinary and iterative process to promote sustainable management of coastal zones. It covers the full cycle of information collection, planning (in its broadest sense), decision making, management and monitoring of implementation. ICZM uses the informed participation and co-operation of all stakeholders to assess the societal goals in a given coastal area, and to take actions towards meeting these objectives. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural and recreational objectives, all within the limits set by natural dynamics.'

(Source: European Commission 2000)

Former coastal zone management approaches were often sector-based, short-term and geared towards small-area management systems. They did not really address the broader issues of ecological sustainability and long-term community interest (Kenchington & Crawford 1993). ICZM, however, is based on **cross-sector planning** and pays greater attention to interactions among component parts of natural and human systems. It also aims at a balance between economic development and protecting the environment and social values (ibid.). Moreover, it works on the principle of constructing partnerships so that individuals, non-governmental organisations and different levels of governments are all able to participate in decision-making and management (ibid.).

The relatively unpredictable changes in wave action, frequency and intensity of storms, and the extent of sea level rise due to global warming is a major challenge for today's coastal managers who are implementing ICZM approaches in an effort to adapt to climate change. These managers therefore have to devise adaptation strategies for different extreme event and wave impacts and for a variety of sea level rise scenarios. Strategies will also need to be adjusted in the future as forecasting improves (CSO 2008).

5.3 Governance and policies for adaptation in coastal zones

Policy development and global governance for adaptation to climate change belong to the core business of institutions like the Intergovernmental Panel on Climate Change (IPCC), the International Union for Conservation of Nature (IUCN) or the United Nations Framework Convention on Climate Change (UNFCCC). The list of policy options for adaptation in coastal zones shown on the following page can be seen as offering general guidelines to address the impacts of climate change in this sector.

India has already developed its **National Action Plan on Climate Change** (NAPCC), which, among other things, sets up a programme for coastal zones with a focus on coastal protection and early warning systems. The NAPCC identifies several priority areas for India's coastal zones (GoI 2008):

- developing an air-ocean circulation modelling system especially for the Bay of Bengal and the Arabian Sea, to simulate regional climate change and, in particular, monsoon behaviour;
- carrying out high-resolution ocean-atmosphere variability studies in tropical oceans, in particular the Indian Ocean;
- engineering a high-resolution storm surge model for coastal regions;
- developing salinity-tolerant crop cultivars;
- raising community awareness on coastal disasters and necessary action;
- establishing timely forecasting and cyclone and flood warning systems;
- increased planting and regeneration of mangroves and coastal forests.

Policy options for adaptation in coastal zones

Policy option	Potential impacts and target points
Integrate adaptation into development planning	• Advancing both adaptation and development goals • Ensuring a community-based and cross-sector Integrated Coastal Zone Management (ICZM) approach
Increase awareness of and knowledge about adaptation	• Enabling individuals and decision-makers to take action • Activating individuals, communities, NGOs and the private sector to invest and participate in the ICZM approach
Strengthen the roles of local and national institutions with regard to adaptation issues	• Enabling institutions on all levels to make their contribution to the ICZM approach • Strengthening certain positions that increase the chances of implementing ICZM in a cross-level and cross-sector manner
Rehabilitate natural resources and protect them from climate-related damage	• Buffering against future climate change impacts • Mitigating climate change impacts
Involve at-risk stakeholders in adaptation planning and implementation	• Optimising emergency preparedness and coastal zone response mechanisms • Improving disaster management and preparedness for weather phenomena such as storm surges and cyclones
Use location-specific strategies	• Ensuring appropriateness of strategies for the individual contexts of particular areas
Adapt now	• Preventing rising costs for adaptation in the future

(Source: adapted from Shea & Dyoulgerov 1997 and Wong 2010)

5.4 Adaptation options in coastal zones

In general terms, adaptation options for coastal zones can be divided into two categories: **structural** and **non-structural interventions**. Technological interventions like building dykes around islands and mangrove plantations, or beach restoration, would fall under the category of structural interventions. Non-structural interventions would involve, for example, information dissemination, land use control programmes and risk insurance. Of course, there are programmes that include both categories. Furthermore, the options can also be either **reactive or anticipatory**. Reactive options would include measures taken after the impacts are observed while anticipatory options would include measures taken before the impacts are observed.

The three projects from India described in the following are examples of these different types of intervention:

Communities engaging in mangrove restoration – an example from Tamil Nadu, India

Background: Pichavaram mangrove wetland is located at the northernmost end of the Cauvery delta in Tamil Nadu. It covers a total area of about 1,470 hectares, consisting of about 50 small, yet inhabited islands. Due to extensive felling of mangrove trees to generate revenue, the whole area has experienced a number of problems like increased salinity, loss of biodiversity and complete degradation of the Pichavaram wetland.

Approach: The M.S. Swaminathan Research Foundation (MSSRF), with the support of the State Forest Department (Government of Tamil Nadu) and the participation of local mangrove user communities, started a programme of mangrove restoration on a small area of 10 hectares. Artificial canal systems were built, enabling tidal water to flow freely to and from the degraded areas, increasing the soil moisture and decreasing soil and groundwater salinity. This made the area suitable for mangroves to be planted with good chances of survival.

Outcome: These efforts led to an increase in mangrove cover and a decrease in salinity of groundwater in the tested area. The success of this project led to a community-based joint mangrove management scheme being set up in this area and to the restoration of the Pichavaram wetland.

(Source: Selvam et al. 2003)

Communities replanting and restoring mangroves – an example from Gujarat, India

Background: The Indian state of Gujarat has a 22.5 % share in the country's total mangrove cover. In order to restore the declining mangrove cover, the state forest department started to support mangrove plantations in the districts of Kutch and Jamnagar. In 2001, the Gujarat Ecology Commission (GEC), which is an autonomous body under the state government, started a community-based project for mangrove restoration with financial help from the India-Canada Environment Facility (ICEF).

Approach: The project covered a total of 10 villages in Gujarat. Its key feature was building capacity in the communities to promote regeneration and sustainable management of the mangrove resources. In addition to mangrove plantation activities, awareness programmes were also conducted to educate people about mangroves and their ecological and economic importance. The state government had a very proactive role in this project.

Outcome: Under this project, which ended in 2007, a total of 4,000 hectares of mangroves were planted. The project also helped to establish a pool of local experts who are able to sustainably manage the restored mangrove forests and create large-scale awareness among local communities about the significance of mangroves.

(Source: GEC 2010)

In India, the **Coastal Regulation Zone Notification 1991** developed by the Indian Ministry of Environment and Forests is the government programme for protecting and conserving the country's coastal environment, including the islands of Andaman and Nicobar, and Lakshadweep. The latest amendment to the notification was proposed in 2010 and is still under discussion. This amendment would divide the coastal area into four coastal regulation zones (CRZ):

- ecologically sensitive areas (CRZ-I);
- built-up municipal areas (CRZ-II);
- rural areas, whether developed or not developed (CRZ-III);
- aquatic areas (CRZ-IV).

Under the notification, all development activities proposed in these zones are regulated according to specific guidelines. Special focus would be put on ecologically sensitive areas such as Sundarbans in West Bengal and on vulnerability and hazard mapping. This will be taken into consideration when framing coastal zone management plans for each state. Each coastal state has a designated coastal zone management authority under the Coastal Regulation Zone Notification and is responsible for implementing the regulation and drawing up a coastal zone management plan (MoEF 2010).

Towards sustainable water management – an example from Tamil Nadu, India

Background: Kadaikadu, a coastal town in the Nagapattinam district of Tamil Nadu, is home to 300 people. Its close proximity to the sea and low-lying lands makes it vulnerable to sudden climatic changes. Lately, the town's freshwater supply has started to become scarce due to flooding and changing rainfall patterns as water storage ponds are either turning saline or running dry. This is threatening the livelihoods of the agriculture-based communities of Kadaikadu.

Approach: To address these challenges, GIZ Advisory Services in Environmental Management initiated the CapCoast pilot project for Kadaikadu with funding from the German Federal Ministry for Economic Cooperation and Development. One of its aims is to climate proof a fresh water pond in the village, that is anticipate climate impacts on its usage and respond in ways that minimise risk and utilise opportunities. The intention is to increase the capacity of water reservoirs and support groundwater recharge, which will in turn enhance well water sources. The technological interventions are accompanied by capacity development and knowledge transfer in water resource management, and include limiting groundwater extraction to an amount that can be replenished.

Outcome: These efforts made it possible to prevent salinisation of the water sources and nearby fields that provide the main source of livelihood. In addition, bunds were constructed to protect the pond from the intrusion of brackish water during cyclones and flooding.

(Source: GIZ 2011)

Adaptation options in coastal zones

<table>
<tr><th>Adaptation option</th><th>Potential impacts and target points</th></tr>
<tr><td>Protect and maintain important coastal ecosystems</td><td>Coastal ecosystems like mangroves, seagrass beds, and coral reefs are able to protect coastlines and mitigate climate change impacts.</td></tr>
<tr><td>Enhance physical infrastructure</td><td>Infrastructure can be improved through appropriate dyke design, use of barriers to break waves, limitation of erosion, increase of sedimentation, and rehabilitation of mangroves under relatively sheltered conditions behind the wave breaking barrier.</td></tr>
<tr><td>Identify coastal areas at risk</td><td>Once areas at risk are identified, emergency preparedness and coastal zone response mechanisms can be strengthened and optimised.</td></tr>
<tr><td>Enhance flexibility</td><td>Flexibility combined with know-how allows for the development of new strategies that can provide a buffer against the negative impacts of climate change by improving the chances of adapting more smoothly and painlessly.</td></tr>
<tr><td>Integrate programmes and plans for economic development, environmental quality management, and land use</td><td rowspan="6">All these adaptation options aim to guarantee the integration aspect of coastal zone management as described in section 5.2. Furthermore, these adaptation options ensure the inclusion of environmental and climate change impacts into future coastal zone management approaches.</td></tr>
<tr><td>Integrate programmes for certain sectors such as food production (including agriculture and fishing), energy, transportation, water resources, waste disposal, and tourism</td></tr>
<tr><td>Integrate coastal management tasks – from planning and analysis, to implementation, operation and maintenance, and monitoring and evaluation</td></tr>
<tr><td>Integrate responsibilities for various management tasks among different government levels, i.e. local, state/provincial, regional, national, international</td></tr>
<tr><td>Integrating responsibilities among different stakeholders from the public and private sector</td></tr>
<tr><td>Integrate different disciplines, e.g. sciences (ecology, geomorphology, and marine biology), economics, engineering (technology); political science (institutions), law</td></tr>
</table>

(Source: adapted from Shea & Dyoulgerov 1997 and Wong 2010)

Integrated Coastal Zone Management

Integrated Coastal Zone Management (ICZM) combines interventions in different sectors and eco-systems within coastal zones and also includes policy adjustments. It can therefore be regarded as an ideal strategy for adaptation to climate change in coastal zones *(see also section 5.2)*. The following list pinpoints a number of sectors and interventions that ICZM encompasses:

- safeguarding usage rights for and access to aquatic resources (especially to exclusive economic zones[1] and for marginalised fishers and women);
- management of conflicts of interests between nature conservation, the safety of shipping, tourism and the fishing industry;
- analysis of ecological, social and economic processes and perspectives in coastal regions;
- research into the development of sustainable land use systems (e.g. opportunities for multiple use);
- evaluation of coastal subsidence rates to facilitate better land use planning in sensitive coastal regions;
- using coastal protection structures (e.g. dykes, water retention basins) and boosting the natural resilience and protective function of coastal ecosystems (e.g. mangrove forests, coral reefs, flood plains);
- extending coastal countries' spatial plans to encompass the 12-nautical-mile zone[2] and the exclu-sive economic zone;
- reducing habitat fragmentation and developing buffer zones and migration corridors for different species;
- contingency plans for human migration in response to sea level rise;
- emergency preparedness for weather extremes (e.g. cyclones and storm surges);
- developing financing strategies for the protection and sustainable use of aquatic resources and coastal zones (e.g. eco-tourism);

[1] Under the law of the sea, an exclusive economic zone (EEZ) is a sea zone over which a state has special rights over the exploration and use of marine resources. It stretches from the seaward edge of the state's territorial sea out to 200 nautical miles from its coast (Wikipedia 2011a).

[2] Territorial waters, or a territorial sea, are defined by the 1982 United Nations Convention on the Law of the Sea as a belt of coastal waters extending at most 12 nautical miles (22 kilometres or 14 miles) from the baseline (usually the mean low-water mark) of a coastal state. The territorial sea is regarded as the sovereign territory of a state, although foreign ships (both military and civilian) are allowed 'innocent passage' through it; this sover-eignty also extends to the airspace over and seabed below (Wikipedia 2011b).

- creating income-generating measures for marginalised coastal populations;
- designation and management of marine protected areas and no-take areas where fishing is not permitted;
- reforestation and management of mangroves.

ICZM's adaptation strategy is characterised by its integrated approach, which attempts to balance environmental, economic, and social objectives (Wong 2010). The integrated aspect of the approach includes at least five different dimensions of integration (Cicin-Sain et al. 2000):
1) **intersectoral:** integration among different coastal and marine sectors, such as off-shore fisheries, coastal fisheries, oil and gas development;
2) **intergovernmental:** integration among different levels of government – national, provincial, and local;
3) **spatial:** integration between the land and ocean sides of the coastal zone;
4) **science-management:** integration among the different disciplines important in coastal and ocean management (natural sciences, social sciences, and engineering);
5) **international:** integration across countries, e.g. when a nation borders enclosed or semi-enclosed seas or when there are international disputes over fishing activities, transboundary pollution, establishment of maritime boundaries, or passage of ships.

The ICZM approach is also characterised as a **continuous and dynamic process** that has the goal of achieving 'sustainable use, development, and protection of coastal and marine areas and resources' (Cicin-Sain et al. 2000). ICZM acknowledges the interrelations that exist between use of the coast (tourism, agriculture, land-based industries, harbours) and the ocean (fisheries, aquaculture, oil exploitation, shipping) by humans, on the one hand, and environment, on the other hand.
Due to its holistic approach and its promising climate change adaptation potential, a wide variety of organisations are involved in ICZM, ranging from government agencies to universities and non-governmental organisations (Crawford et al. 1993).

ICZM also has two sub-approaches, the **community-based adaptation** approach and the **ecosystem-based adaptation** approach.

Community-based adaptation (CBA) can be understood as an 'innovative approach enabling communities to enhance their own adaptive capacity and empowering them to increase their resilience to climate change impacts. CBA focuses on activities carried out by highly vulnerable and poor communities, mostly in developing countries' (Wong 2010). Community-based adaptation ensures the population is included and receives information in order to facilitate a bottom-up implementation of ICZM.

Ecosystem-based adaptation (EBA) in coastal zones is based on the assumption that climate change will entirely transform coastal and marine ecosystems in ways that today's management systems are often unprepared for and unable to accommodate. The EBA for coastal zones approach was developed to make it possible to respond to the total transformation of coastal and marine ecosystems. EBA 'takes a broader view of management decisions in order to understand the ecosystems themselves' (Wong 2010). The approach prepares 'to take account of potential future changes that may be greater than those induced by present stresses, adopting a longer perspective that includes non-climate issues' (ibid.).

New paths for India's coastal zone management

In India, integrating adaptation to climate change into coastal zone management is gaining momentum. One example is the **Integrated Coastal Zone Management Project** to be coordinated by the Society of Integrated Coastal Management (SICOM), which was established by the Indian Government in September 2010 (MoEF 2010). It plans to establish a National Centre for Sustainable Coastal Management at Anna University, Chennai, within the next few years. The centre will be working with the collaborating institutes in each of the coastal states and union territories. The programme will start in three states (Orissa, West Bengal and Gujarat) and will then be extended to other states (MoEF 2009, 2010).

Another programme in India is the **Sustainable Coastal Protection and Management Investment Programme**, which will be coordinated by the Ministry of Water Resources with financing from the Asian Development Bank (ADB 2010). The Asian Development Bank's environmental assessment report published in March 2010 promises: 'The approach to coastal protection and management will significantly change, in a well-planned and programmed transition from environmentally harmful protection (...) to environmentally appropriate and sustainable solutions' (ibid.).

To gain further understanding of different ways of successfully implementing ICZM approaches, it can also be useful to take a look at some good examples from other countries.

GIZ offers two good examples of climate change adaptation projects in coastal areas – one in the Philippines, one in Viet Nam. GIZ supports both countries in implementing ICZM, which involves:

- diversifying and rehabilitating coastal forests to increase biodiversity and enhance the protection of the coasts from climate change impacts such as storms and erosion;
- establishing co-management schemes in mangrove forests to improve the incomes of the poor and reduce conflicts of interests between economic development, sustainable management and protection of natural resources;
- improving the management of protected areas and coastal forests;
- identifying the most effective means of stabilising eroding coastal shorelines;
- establishing marine protected areas, including mangrove forests, coral reefs and seagrass beds;
- introducing disaster risk management, i.e. community-based early flood warning systems.

In the Philippines, GIZ is supporting two projects on ICZM: Adaptation to Climate Change and Protection of Biodiversity in the Philippines and Environment and Rural Development Programme Philippines (GTZ 2009; GTZ DENR n.d.).

Like many South Asian and South-East Asian countries, the Philippines has a long coastline. Its coastal and marine ecosystems consist of beaches, mangrove forests, coral reefs, seagrass beds, soft-bottom communities, open marine waters and small islands. A large proportion of the population lives in coastal areas, depending largely on coastal ecosystems. Coral reefs, mangroves, and seagrass beds provide food, building materials and coastal protection from storm surges and heavy monsoon winds. They also serve industries such as fishing and tourism.

Climate change impacts can already be felt and seen in the Philippines. Rising sea surface temperature has affected the open coastal waters and coral reefs, resulting in episodes of coral bleaching. Coral reefs provide a considerable amount of harvestable fish species in the country, but they have already lost 90 to 95 % of their fish biomass and their species richness, particularly the top carnivores.

Sea level rise is also affecting coastal communities. During times of strong monsoon winds and storm surges, which are often accompanied by high tides, coastal flooding and erosion of beaches have occurred in some low-lying areas on small, flat islands off southern Palawan and in Central Visayas. This caused displacement of coastal communities and destruction of infrastructure.

Through the Environment and Rural Development Programme in the Philippines, GIZ has supported 37 cities and municipalities in the Visayas Region in establishing 40,000 hectares of marine protected areas. Additional protected areas are planned. Support has also been given to national initiatives such as the Marine Protected Area Network and inter-regional initiatives like the Coral Triangle Initiative, which covers six countries and their territorial waters, which are known to have the highest marine biodiversity in the world.

In Viet Nam, GIZ is supporting three projects: Management of Natural Resources in the Coastal Zone of Soc Trang Province, Integrated Conservation and Development of the Biosphere Reserve in Kien Giang Province, and Sustainable Management of Forest Ecosystems for Coastal Protection in Bac Lieu Province. Apart from that, GIZ is implementing a pilot project on integrating climate change risk assessment into local development planning in the Mekong Delta of Viet Nam.

The Mekong Delta, although relatively small in size in relation to the entire country, plays an important role as the 'rice bowl' for the whole of Viet Nam. However rapid expansion in shrimp farming and economic interests in aquaculture have brought about unsustainable use of natural resources in the coastal zone of Soc Trang Province. This is threatening the protection function of the mangrove forest belt and reducing income for local communities. The coastal zone will moreover be affected by the impacts of climate change, which will cause increased intensity and frequency of storms and floods as well as rising sea levels. In addition, the flow regime of the Mekong River, the tidal regime of the South China Sea, and the coastal longshore currents driven by monsoon winds together produce a dynamic process of accretion and very severe erosion in some areas along the coast of Soc Trang Province.

GIZ's project on Management of Natural Resources in the Coastal Zone of Soc Trang Province (GIZ 2010) is supporting the Forest Protection Department and the Soc Trang Provincial People's Committee by:

- planting, rehabilitation and management of mangroves with emphasis on resilience to climate change;
- developing models for sustainable co-management of coastal areas;
- setting up an erosion control model that combines dyke design, computer-based current and erosion modelling, wave barriers and mangrove planting schemes;
- raising environmental awareness with the aim of promoting positive change;

Coastal erosion in Soc Trang Province, Southern Viet Nam. (photo: Klaus Schmitt)

- increasing income along aquaculture value chains, such as shrimp farming, through public-private-partnerships, co-management and certification;
- developing a participatory environmental impact monitoring system;
- devising concepts for the sustainable financing of ecosystem services provided by coastal wetlands.

5.5 Linking adaptation and mitigation

Apart from planting coastal forests, the most promising approach for linking adaptation and mitigation in coastal zones is the conservation of Marine Protected Areas (MPAs).

Marine Protected Areas

Kelleher (1999) defines Marine Protected Areas as:

'(…) any areas of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which have been reserved by law or other effective means to protect part or all of the enclosed environment.'

According to this definition, MPAs include mangroves, coral reefs and seagrass beds. MPAs serve different purposes: they prevent further destruction of marine and coastal ecosystems and conserve vital parts of them. They also contribute to high biodiversity and genetic diversity (GTZ 2002). As mentioned earlier, coastal ecosystems, especially mangrove forests and coral reefs, also act as buffers against extreme weather conditions and natural disasters, thereby reducing the vulnerability of coastal communities and their investments. However, in the context of mitigation, the most important quality of MPAs is their ability to reduce CO_2 emissions substantially. They can help nature and society to mitigate climate change by sequestering and storing carbon in natural ecosystems. They are able to store huge amounts of carbon, particularly in coastal zones where capture is equivalent to 0.2 gigatonnes per year. Salt marshes, mangroves and seagrass beds all have important potential to sequester carbon. But all these systems are currently under pressure and 'without better protection they could switch from being sinks to sources of emissions. There is an urgent need both for new protected areas to be established and for better implementation and management of existing protected areas' (Dudley et al. 2010).

The potential of Marine Protected Areas for climate change mitigation

Mangroves

It is estimated that mangroves sequester large amounts of carbon – approximately 25.5 million tonnes every year. Mangroves also provide more than 10 % of the essential dissolved organic carbon that is supplied to the global oceans from land. Their role as a carbon sink is a service of particular global importance – mangroves and their soils are the second largest repository of terrestrial sequestered carbon after tropical forests. Mangroves affect sediment carbon storage both by direct inputs as a result of production and by increasing sedimentation rates. Conversely, clearing mangroves can rapidly decrease this storage capacity (Mangroves for the Future n.d.).

Seagrass meadows

Although standing biomass of seagrasses is relatively low, the absolute rate of net production and therefore carbon uptake is comparatively high. Furthermore, seagrass leaves degrade slowly and through their root and rhizome system, and seagrasses deposit large amounts of underground, partly mineralised carbon. Thus, they constitute an important CO_2 sink, responsible for about 15 % of the total carbon storage in the ocean.

Coral reefs

Coral reefs do not sequester carbon. Unmanaged reef metabolism is a net CO_2 source, because of side-effects from calcium carbonate precipitation. If calcification declines due to climate change (e.g. because of warmer waters or ocean acidification), this could in theory reduce CO_2 emissions from corals, because dead corals do not emit CO_2. But the huge ecological side effects from these losses would more than cancel out any advantages. The role of coral reefs is more one of reefs being likely beneficiaries of CO_2 management. They also protect coastal communities and terrestrial ecosystems from incursions from the sea.

(Source: adapted from Dudley et al. 2010 and Ong 1993)

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6

ADAPTATION AND DISASTER RISK MANAGEMENT

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6

ADAPTATION AND DISASTER RISK MANAGEMENT

Abstract

Climate change has clearly changed our perception of disasters. More and more often, the increasing occurrence of weather-related hazards is not seen as 'natural' anymore, but as of our own making. Disasters can undo decades of development efforts and reverse poverty reduction achievements. Therefore, there is a growing awareness among development practitioners and the private sector alike that we have to systematically assess, reduce and manage risks and find synergies between disaster risk management (DRM) and climate change adaptation efforts.

Climate change and DRM are interconnected because climate change is causing an increase in the magnitude and frequency of extreme events such as storms, floods and droughts. Furthermore, climate change is increasing societies' vulnerability to such events, creating stresses on agriculture, reductions in water and food availability, and changes to livelihoods. India is especially vulnerable to climate change impacts. The economy is greatly influenced by monsoons and these are likely to be affected by climate change, resulting in a variation in their patterns and intensity. DRM aims to prevent the emergence of new risks and reduce societies' vulnerability by increasing their capabilities to cope with them. DRM provides tools to mitigate the impacts of present and future climate risks by determining possible impacts and the resulting vulnerabilities. It also helps identify the measures that need to be taken to adapt to existing and new risks.

Promoting good governance, identifying adequate policy options, building legal and institutional frameworks and developing strategic instruments play key roles in integrating climate change adaptation into DRM. Community initiatives and financial mechanisms are two measures that can make adaptation and DRM efforts not only cost-effective, but above all sustainable.

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ADAPTATION AND DISASTER RISK MANAGEMENT

6.1 How does climate change impact disaster risks?

Key messages

- There are going to be more extreme weather events in the future due to climate change. These are likely to increase the number and scale of hydro-meteorological disasters.
- Climate change impacts increase the vulnerability of communities to natural hazards.
- In India, it is predominantly changes in the patterns and intensity of monsoons, flooding and droughts that will increase disaster risks.

Climate change increases disaster risk. The effects of climate change on disaster risk management (DRM) stem, on the one hand, from the likely increase in weather and climate hazards and, on the other hand, from an increase in the vulnerability of communities to natural hazards, particularly as a result of ecosystem degradation, reductions in water and food availability, and changes to livelihoods (UNISDR 2008).

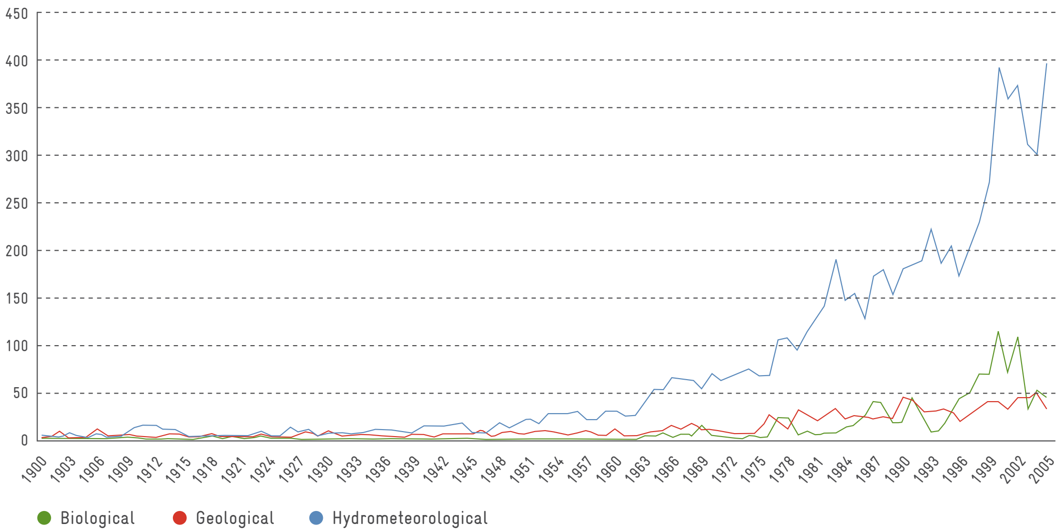
Disasters

The United Nations International Strategy for Disaster Reduction (ISDR) defines a disaster as: 'a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental impacts (damages and losses) which exceeds the ability of the affected community or society to cope using its own resources.'

Over the past decades, the frequency and impact of natural disasters have increased substantially around the globe, as can be seen in the chart on the next page. The Intergovernmental Panel on Climate Change (IPCC) believes that, as a result of climate change, hot extremes, heat waves and heavy precipitation are very likely to continue to become more frequent, and that tropical cyclones – typhoons

and hurricanes – will become more intense (IPCC 2007a). Precipitation is very likely to increase in frequency in high latitudes and is likely to decrease in most subtropical land regions, continuing recent observed trends. These changes may lead to an increase in storms, droughts, floods and landslides (IPCC 2007b), but also to an increased risk from forest fires due to increased dry spells (Greenpeace India 2010).

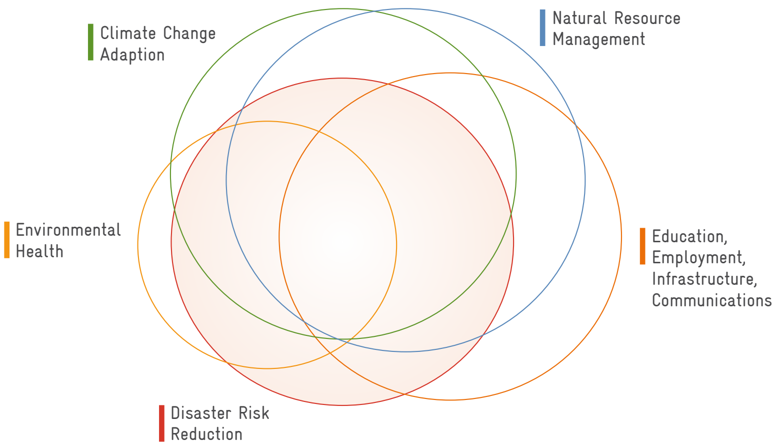
Number of natural disasters on a global scale (1900–2005), registered in the international disaster database EM-DAT



(Source: UNISDR 2005a)

Extreme events can be especially devastating for developing countries where a great number of poor people are forced to settle in hazardous areas and have less capacity to adapt (Ravindranath & Sathaye 2002; IPCC 2007a). This undeniably creates an unholy alliance between climate change, disasters, and development as can be seen in the chart on the next page.

Environment-development interface for disasters and adaptation



(Source: Gupta et al. 2011)

The continent of Asia is particularly vulnerable to climate change and disasters. Between 1991 and 2000, 83 % of people affected by disasters worldwide were in Asia. Within Asia, 24 % of deaths due to disasters occur in India – a result of its size, high population and extreme vulnerability.

For the period between 1998 and 2008, the international disaster database EM-DAT used by the Centre for Research on the Epidemiology of Disasters (CRED) indicates that 75,731 people in India were reported killed by disasters, with a further 650,393,577 people affected by them. Disasters are estimated to currently cause up to 13 % GDP loss every year in India (CRED n.d.)

Climate change is driven by increased greenhouse gas emissions and exacerbated by the loss of carbon sinks. Environmental modifications, including intensive land use and overexploitation of natural resources, reduce the ability of natural systems to act as a buffer against extreme weather events, hence increasing disaster risk at regional/local levels. As well as intensifying hydro-meteorological hazards and the risk of complex emergencies, environmental degradation also increases the vulnerability of socio-economic systems, ecosystems and livelihoods.

How climate change is intensifying disasters in India

There is considerable evidence that economic damage caused by extreme weather events has increased substantially over the last few decades. For a country like India with over 70 % of its population relying directly or indirectly on agriculture for their livelihoods, the impact of extreme weather events is critical. People often live in areas of high ecological vulnerability and relatively low levels of resource productivity and have limited and insecure rights over productive natural resources. These combined factors are significant forces contributing to vulnerability to natural disasters (Baumann et al. 2003).

Changes in the precipitation patterns and any intensification of the monsoons will contribute to flood disasters and land degradation and will thus have far-reaching consequences for the entire economy (Stern 2006). In the last decade, India has been repeatedly battered by successive monsoons, flooding and droughts. For example, the state of Orissa has experienced floods in 49 of the last 100 years, droughts in 30 and cyclones in 11 years. The occurrence of droughts, floods and cyclones in a single year is not unusual. In addition, the number of villages in India experiencing drought is increasing (Tompkins 2002). India's water supply depends not only on monsoon rains but also on glacial melt water from the Hindu Kush and the Himalayas. Rising temperatures will cause snowlines to retreat further, increasing the risk of floods during the summer monsoon season (Greenpeace India 2010).

Currently, as much as 68 % of India is drought-prone and 12 % – i.e. more than 40 million hectares – is flood-prone. India has a long coastline of about 7,516 kilometres of flat coastal terrain and shallow continental shelf with high population density and is extremely vulnerable to cyclones and its associated hazards like storm tide, high velocity wind and heavy rains. Although the frequency of tropical cyclones in the North Indian Ocean, including the Bay of Bengal and the Arabian Sea, is the lowest in the world (7 % of the global total), their impact on the east coast of India is more devastating in relative terms (Mittal 2010). About 8 % of the area in the country is prone to cyclone-related disasters. The number of storms with more than 100 millimetres of rainfall in a day is reported to have increased by 10 % per decade (UNEP 2009).

6.2 What does adaptation in disaster risk management mean?

Key messages

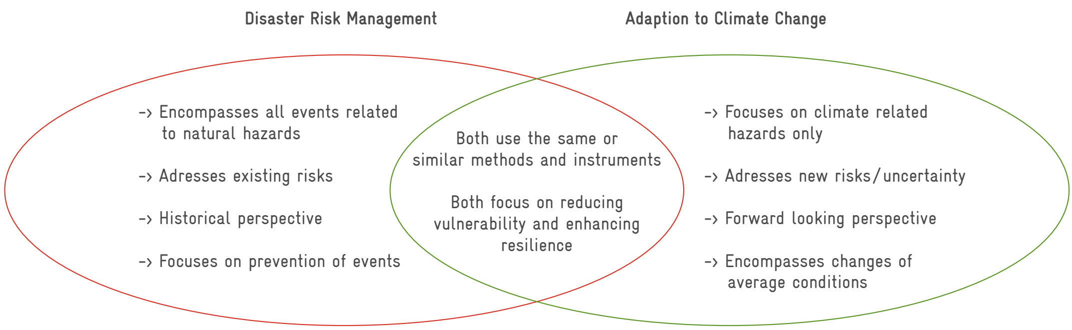
- Adaptation to climate change and disaster risk management both seek to build resilience in the face of hydro-meteorological hazards.
- There is a significant overlap of instruments and stakeholders between the two disciplines.
- Disaster risk management helps reduce future climate change impacts on society by strengthening the necessary capacities.

Disaster risk management (DRM) aims to reduce disaster risk, prevent the emergence of new risks and decrease a society's vulnerability (UNISDR 2008). The focus is therefore on reducing the vulnerability of the population to events such as earthquakes, floods and storms; or even averting the impacts of new hazards, such as landslides caused by inappropriate land use or deforestation (BMZ 2008).

DRM and adaptation to climate change both pursue similar aims in terms of seeking to build resilience in the face of hazards and to reduce or avert social and economic consequences. There is a certain overlap in terms of challenges and courses of action, as natural disasters and climate change both pose a threat to sustainable development, increase the vulnerability of affected populations and contribute to poverty, especially in developing countries. This overlap can be seen in the diagram on the next page. Furthermore, neither climate change nor disaster risk stop at political or country borders, so both require cross-border actions. Drivers of climate-change and associated disasters, and strategies to address them are related to environmental processes, ecological systems and natural resources, and thus, have the environment as a common background. This involves addressing the same actors and sectors, such as ministries, by using similar or familiar instruments (GTZ 2010).

Nevertheless, there are differences between adaptation to climate change and DRM. DRM focuses on present-day vulnerabilities based on past experience and deals with multiple hazards, not only hydro-meteorological events. Such hazards include technical and geological risks not caused by climate change. In contrast, increases in extreme weather events are just one of the many impacts of climate change that require adaptation on the part of affected societies. Furthermore, adaptation to climate change deals with slow changes over a longer time period, using projections and scenarios, in an attempt to anticipate future impacts.

Overlap between DRM and adaptation to climate change



(Source: Venton & La Trobe 2008)

DRM for adaptation to climate change implies that response mechanisms and economic planning for disasters based on past vulnerabilities may no longer suffice (Sperling & Szekely 2005). In an attempt to deal with current and future climate variability and climatic extremes, classical disaster management, which draws its lessons from past events, has evolved into DRM, which adopts a more **anticipatory and forward-looking approach** (Thomalla et al. 2006). DRM has recognised the importance of adaptation to climate change and incorporates measures to promote climate change adaptation by addressing the drivers of vulnerability, building response capacity and managing climate risks. By adopting measures to mitigate existing disaster risks and anticipate future ones, DRM can be seen as part of adaptation to climate change in regions where traditionally there has been no disaster risk but where new risks may arise due to climate change, e.g. coastal flooding (GTZ 2008).

In the context of climate change, DRM is regarded as an adaptation option (Sperling & Szekely 2005). DRM has also been seen as a way to achieve sustainable development (Boulle et al. 1997) and contributes towards adaptation and mitigation by reducing pressure on and damage to ecosystems.

One of the best ways to **mainstream climate change concerns into DRM** is to understand possible current and future impacts and address them in development and risk reduction planning. For this, it is necessary to look at a range of climate scenarios and overlay them with future socio-economic scenarios to obtain an idea of future risks. However, there are limitations, such as lack of availability of dependable high-resolution climate change scenarios and uncertainties that even the best available scenarios and projections have not addressed. Hence, there is a need to look for alternative means of addressing uncertain climate risks. One way to do this is to identify no-regret or win-win options, as these would be beneficial in reducing vulnerabilities to a range of possible changes in climate (Lomborg 2007).

The Hyogo Framework for Action 2005-2015

In 2005, prompted by an increasing number of environmental hazard-induced disasters, the international community called for a substantial reduction in disaster risks with the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters. This framework identified climate change as one of the major threats to the world's future and determined DRM as one of the key entry points for tackling climate change threats. The words of the framework linking the two spheres of DRM and climate change adaptation read as follows: 'Promote the integration of risk reduction associated with existing climate variability and future climate change into strategies for the reduction of disaster risk and adaptation to climate change, which would include the clear identification of climate-related disaster risks, the design of specific risk reduction measures and an improved and routine use of climate risk information by planners, engineers and other decision-makers.'

(Source: UNISDR 2005)

6.3 Governance and policies for adaptation in disaster risk management

Key messages

- Various conventions agreed upon by the international community in the last two decades emphasise disaster management as a major environmental concern.
- The Government of India has established an institutional framework on disaster risk management.
- Disaster risk management and adaptation can be integrated strategically into environmental and natural resource policies and legislation.

The relevance of adaptation to climate change for disaster risk management (DRM) is growing. In order to harness the synergy effects between the two, policies need to be developed to heighten awareness, intensify trans-boundary cooperation and improve governance through capacity development. Institutional and policy frameworks for disaster and climate risk management must be developed at regional and national level to strengthen the links and collaboration between national DRM and climate change programmes and platforms. This will ensure a consistent approach and an exchange of information on issues of common interest. Governments need to prepare and qualify the relevant organisations for their governance tasks and to mainstream disaster risk reduction measures appropriately across sectors and levels. The following table gives an overview of policy options in DRM.

Policy options for adaptation in disaster risk management

Policy option	Potential impacts and target points
Mainstream DRM on all administrative levels	• Strengthening capacities of institutions at all levels • Mainstreaming DRM into climate change adaptation policies and activities (National Adaptation Programmes of Action – NAPAs) • Formalising collaboration and the coordination of climate-related risk reduction activities through a multi-sector mechanism • Developing mechanisms to actively engage and empower communities and local governments in the assessment of vulnerability and impacts • Formulating local adaptation activities containing DRM measures
Promote DRM research	• Investing in better information and forecasts • Selecting and evaluating information on future disasters, the effects of climate change and the resulting impacts • Conducting assessments of vulnerability and identifying particularly vulnerable groups
Enhance early warning systems	• Developing and disseminating high-quality information about climate hazards and their likely future changes • Implementing procedures to ensure warnings reach vulnerable groups • Developing local capacities for understanding and disseminating warning messages in a proper manner • Undertaking public information activities to help people understand the risks they face
Reduce underlying risk factors	• Incorporating climate risk-related considerations into development planning processes and sector plans • Integrating climate risk-related information in city planning, land use planning and water management • Strengthening and maintaining protective works such as coastal wave barriers and flood ponds • Constructing shelters to protect people and livestock
Build a culture of resilience through awareness and education	• Creating participatory risk maps • Developing education curricula on climate adaptation and risk reduction • Incorporating adaptation activities into plans for recovery from specific disasters • Supporting the diffusion of information

Institutions in connection with India's Disaster Management Act

The Disaster Management Act of 2005 set up a mechanism for creating a number of institutions in India:

- The **National Disaster Management Authority** (NDMA) is an apex authority of the Indian Government, with the Prime Minister as its chair. NDMA is mandated to develop policies and national guidelines on disaster management. This includes promoting various functions associated with prevention, mitigation, preparedness, response and recovery in case of a disaster.
- State **Disaster Management and District Disaster Management Authorities** are key functional units in the planning and discharge of disaster prevention and mitigation activities. These authorities at state and district level have similar functions to NDMA at national level.
- The **National Executive Committee** (NEC) is the executive committee of NDMA. NEC was set up to coordinate the response in the event of a disaster, prepare the National Plan for Disaster Management based on the National Policy on Disaster Management, and monitor the implementation of guidelines issued by NDMA.
- The **National Institute of Disaster Management** (NIDM) is a statutory body for capacity building. It is responsible for promoting training, research, documentation and networking. NIDM functions through its headquarters in New Delhi and a network of universities, research and training institutes as well as multilateral and international agencies.
- In addition, a **National Disaster Response Force** (NDRF) has been set up.

India's paradigm shift in DRM, which is also envisaged in the National Disaster Management Policy 2009, is based on the conviction that development cannot be sustainable unless it takes disaster mitigation into account. State governments have therefore converted their Relief Codes into Disaster Management Codes by including aspects of prevention, reduction and preparedness.

Various pieces of environmental legislation – particularly on atmosphere, water, waste, biodiversity, climate, land use, wetlands, and desertification – contain significant provisions for promoting a culture of disaster prevention and management, and facilitating options for integrating adaptation into DRM. Concerns have also been raised about the need to focus on indigenous and local capacities for preparedness and emergency response rather than depending on external support or calling on central response forces to handle disasters only.

Disaster management, as outlined in the National Action Plan on Climate Change (NAPCC) launched by the Government of India in 2008, comprises of:

- reducing risk to infrastructure through better design and engineering;
- strengthening communication networks and disaster management facilities;
- protecting coastal areas among key initiatives for addressing climate change.

The three NAPCC Missions – for a Green India, for Sustainable Agriculture and for Sustaining the Himalayan Ecosystem – are relevant to DRM since intact ecosystems can greatly attenuate hazards.

Financial mechanisms for disaster risk reduction and relief in India

The **Calamity Relief Fund** (CRF) was created at state level with contributions from both central and state governments (3:1 ratio) and is used to pay for relief measures in the event of droughts, floods, cyclones, hailstorms, tsunamis, etc.

The **National Calamity Contingency Fund** (NCCF) was created at central level with 100 % central government funding. It is used for any relief operations not covered by the CRF.

India is also administering a crop insurance programme that is the largest in the world in terms of the number of farmers insured. The **National Agricultural Insurance Scheme** (NAIS) annually insures approximately 18 million farmers, or 15 % of all farmers and approximately 17 % of all farmed land. **Weather-based crop insurance**, which began in India in 2003, is available under the umbrella of NAIS. At present, the Agriculture Insurance Company of India (AIC), along with two private insurers, is providing weather insurance. Although until 2007 most of these activities were based on the initiative of particular insurers, in 2007 the Government began offering an alternative to NAIS by initiating pilot projects in selected areas for selected crops. **Livestock insurance schemes** began as long ago as the early 1970s. However, they are still in need of substantial improvement in terms of scope and coverage.

Micro-insurance (MI) has also evolved in India, primarily with the aim of supporting poverty alleviation and helping marginalised people, especially farmers. There have been three distinct phases in the Indian development of micro-insurance. The first phase coincided with the introduction of target-oriented poverty alleviation programmes such as the Integrated Rural Development Programme (IRDP). The second phase of MI growth can be seen in conjunction with the growth of credit disbursement to the poorer segments of society through Self Help Groups (SHGs). However, most MI products on the market are related to health insurance, with only a few offering insurance for assets such as houses and tools, livestock or crops. In a third phase, the Government launched specific funds such as an **income stabilisation fund** in 2002 for small farmers cultivating four plantation crops: coffee, tea, rubber and tobacco. The fund works as a savings account, with the Government contributing to the account during distress years, farmers contributing during boom years and both parties sharing the contribution equally during normal years. Recently a **Central Food Security Fund** has been proposed.

The need to institutionalise the **economic evaluation of environmental impacts** of disasters and of overall damage and losses has also found recognition in India recently. Cost-benefit analysis methodologies for decisions regarding choice of technology or disaster risk reduction options have been piloted in certain cases of flood and drought risk management. These methodologies help especially in assessing structural measures and their sustainability.

6.4 Adaptation options in disaster risk management

Key messages

- Disaster risk management for adaptation to climate change involves risk analysis, disaster prevention and mitigation, disaster preparedness and disaster-preventive reconstruction, and ecosystem management.
- To facilitate the integration of adaptation into disaster risk management, capacities need to be strengthened on all levels. This can be achieved by involving authorities and the communities and by using a multi-tier and interdisciplinary approach.
- Capacity development is essential for integrating climate-change adaptation into disaster risk management. Teaching on adaptation to climate change and disaster risk management needs to be incorporated into environmental degree courses and research.

The main task in responding to climate change, apart from mitigating it, is to manage its impacts. The elements of disaster risk management (DRM) – risk analysis, disaster prevention and mitigation, disaster preparedness and disaster-preventive reconstruction – are all designed to reduce, or even prevent, damage and losses resulting from natural hazards that are exacerbated by climate change. This means that DRM also offers options for adaptation to climate change.

The aim of **risk analysis** is to determine the vulnerability of a group or community to a natural hazard. It gathers information on past natural hazards and their impacts and goes on to identify future geological, meteorological and climatic threats to society. A specific assessment of vulnerable groups is conducted so that their needs can be targeted accordingly. Risk maps are developed and updated based on all the above-mentioned information and with the participation of local authorities, community members and experts. Through the community-based approach, risk analysis makes use of local information and observations, thus helping to downscale global trends and identify local impacts.

The information derived from risk analysis can be used in further planning for disaster prevention and preparedness. Risk maps can also help make risks more visible to the community concerned and highlight the need for action by local governments and the population. It is important to use a community-based approach to gather information that is specific to the area in danger and to strengthen a community's self-help capacity. In terms of adapting to climate change, risk analysis should incorporate long-term climate change predictions (where they are available on the appropriate scale), take their possible impacts into account and integrate them into the analysis (BMZ 2008).

The aim of **disaster prevention** is to minimise the possible adverse impacts of a natural event and its consequences and provide permanent protection against its effects. The long-term perspective of all the following disaster prevention and mitigation instruments makes them suitable for use in adaptation to climate change:

- establishment and implementation of land plans;
- regulation of building design and construction;
- education and training measures for the population and employees of municipalities and other authorities;
- establishing and strengthening local and national disaster preparedness structures by setting up disaster committees, promoting sustainable resource management and improving infrastructure (more stable and risk-adapted design).

Disaster preparedness seeks to avoid or reduce loss of life and damage to property and to provide an immediate response to an upcoming natural event on the basis of a risk analysis. At local level, mobilisation of self-help resources is supported by preparing participatory emergency and evacuation plans, training and upgrading, infrastructural and logistical measures. Included in the latter are establishing emergency accommodations, conducting disaster protection exercises, and setting up and monitoring early warning systems. Disaster preparedness actions also include revising contingency plans to take into account the projected changes in existing hazards and new hazards not experienced before.

The role of modern science and technology in India's disaster risk management

There are several areas of science and technology where modern interventions play a significant role in different stages of disaster management – both internationally and in India. In India they are primarily space technology, environment & earth science, forestry, agriculture, ecology, system dynamics, engineering, geography, and health science. Specific and integrated efforts have been made in risk assessment, mitigation planning and disaster response. Disaster risk management begins with risk information and its appropriate dissemination. The advances in **information and communication technologies** (ICT) that have emerged over the last two decades lend themselves to greater possibilities of integration in different communication systems. Lessons learnt so far have proven that community-owned ICT-based approaches have a greater impact and are more sustainable.

Knowledge about the environment holds the key to risk assessment, preparedness and recovery planning. Three major environmental aspects are crucial in DRM: climate change, land use and natural resources. Satellite-based decision support systems, integrating **satellite meteorology** with forecasting and communication devices, enable early warning for disasters. The Indian Space Research Organisation (ISRO) has disaster management system software specifically for this purpose. It was way back in 1975 when satellite technology started to reveal its huge social and educational potential. The biggest satellite-based education experiment took place in 2,500 rural villages across six Indian states under the first phase of the **Satellite Instructional Television Experiment** (SITE). The experiment that made educational television programmes available for rural India was jointly designed by the US-based National Aeronautics and Space Association (NASA) and ISRO. SITE was followed by similar experiments in various countries, which showed the important role satellite TV could play in providing information and education.

Two of the major information resource networks in India today are the **India Disaster Resource Network** (IDRN) and the **India Disaster Knowledge Network** (IDKN). They have been developed with support from the United Nations Development Programme's (UNDP) disaster risk management programme. IDKN is now part of the **South Asia Disaster Knowledge Network** (SADKN).

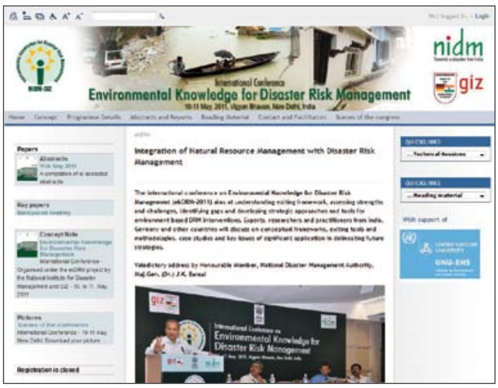
The **National Natural Resource Data Management System** (NNRDMS), the **Environmental Information System** (ENVIS) and initiatives by the **Central Statistical Organisation** (CSO) deliver important information for DRM and climate change adaptation (Nair & Gupta 2009). However, the availability of weather data in forms that are directly useful to stakeholders in rural contexts is still underdeveloped. Knowledge management is an area where greater intervention is needed to facilitate resilience to climate-related disaster. Emphasis is now placed on weather data products and translating information into knowledge that can be put to use by stakeholders for field-level decisions and actions.

Making know-how available for India's disaster risk management

The Indo-German cooperation project on Environmental Knowledge for Disaster Risk Management (ekDRM), implemented by the National Institute of Disaster Management (NIDM) and GIZ, which places emphasis on hydro-meteorological disasters, was launched in 2010.

The ekDRM project focuses on climate change, land use and natural resources degradation as the key aspects of environmental change driving the disasters. Specific interventions include training, research, publications and use of information in the following areas:

- role of environmental statistics in DRM;
- decision support systems and space technology in DRM;
- environmental/natural resource legislation in DRM;
- environmental services in disasters and emergencies;
- integration of natural resource management and disaster risk reduction.



The website of the Indo-German project Environmental Knowledge for Disaster Risk Management (ekDRM).

(Source: ekDRM n.d.)

Disaster-preventive reconstruction aims to draw appropriate lessons from natural disasters and includes disaster reduction criteria and measures directly in the reconstruction process (BMZ 2008). Disaster-preventive reconstruction involves carrying out risk assessments in different sectors such as:

- infrastructure (e.g. flood-resistant construction, provision of shelter);
- institutions (responsibility and cooperation of actors);
- local structures (strengthening organisations and structures);
- future prevention (e.g. protection of resources, creation of flood concepts).

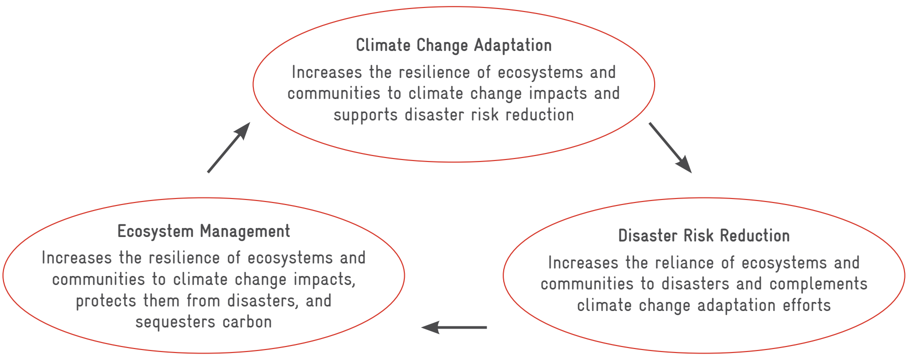
Disaster-preventive reconstruction measures are designed to be included in long-term development activities following the reconstruction and rehabilitation phase. Aspects of climate change should be incorporated at the reconstruction and rehabilitation stage, particularly if the natural disaster appears to be due to changed climate conditions.

Natural disasters are environmental processes and can be understood as 'environmental extremes'. The vicious conundrum of 'climate change – ecosystem degradation – accelerated disasters' causes severe economic and ecological dislocation and disruption, including loss of life, property and biodiversity. **Ecosystem management** therefore constitutes an essential part of a global climate change adaptation strategy. Healthy ecosystems act as natural buffers and/or barriers to the impacts of extreme weather events. They protect infrastructure (e.g. mangroves protecting dykes and housing), and increase the resilience of human systems to climate-related disasters. Healthy and diverse ecosystems also recover faster from disasters and can adapt more easily to climate change themselves. Natural ecosystems offer a cost-effective and proven way for climate change adaptation and disaster risk reduction (UNDP India 2010).

A failure to address environmental risks and the insufficient inclusion of environmental considerations in relief operations can undermine the relief process. This can cause additional loss of life, displacement, aid dependency and increased vulnerability (Delrue & Sexton 2009).
Over the past decade, there has been greater focus on the interface between the environment, livelihoods and disasters. The consequences are a more robust conceptual understanding of ecosystem services for both sustainable development and DRM, and increased empirical evidence to reinforce

concepts. However, there is still a long way to go before environmental management policies become an integral part of DRM. The following chart outlines how climate change adaptation, ecosystem management and disaster risk reduction are interlinked.

Linkage of climate change adaptation, ecosystem management and disaster risk reduction



(Source: UNEP 2009)

When the Indian Ocean tsunami hit the Indian Andaman and Nicobar islands in December 2004, more women died than children or men – not due to chance, but due to gender inequalities. Even though tsunamis are not directly linked to climate change, this example shows how women's roles as carers and mothers meant that, when the disaster hit, they put the safety of their children and belongings before their own survival. Furthermore, the women had spent their lives in the home and had very limited experience of interacting with others outside this private space. Food security and family well-being are threatened when the resource base on which women

It is women and children in rural areas who are the hardest hit by natural disasters. Their potential for community resilience to climate change and disasters is not yet being utilised efficiently. (photo: Anil Kumar Gupta) rely to carry out their critical roles and obtain supplementary incomes is undermined. In rural areas in many parts of the world, women's insecure land tenure can cause unsustainable practices and be a critical factor in constraining their potential for recovery in the aftermath of disasters. Research on gender and sustainable development should give greater attention to land tenure and its impact on natural disasters (Fourth World Conference on Women 1995). Without the full participation and contribution of women in decision-making and leadership, real community resilience to climate change and disasters simply cannot be achieved (UNISDR 2008).


Community-based participatory assessment in DRM. (photo: Anil Kumar Gupta)

Effective risk assessment and management, particularly in the rural areas, requires the active involvement of local communities and civil society groups. **Community-based disaster risk management** aims at combining the objectives of decreasing the occurrence of disasters and reducing losses and costs if disasters do occur. In India, the 73rd Constitutional Amendment of 1993 institutionalises three tiers of local government at district (usually called *Zilla Parishad*), block and village (*Gram Panchayat*) levels, collectively called *Panchayati Raj* institutions. *Gram Panchayats* have been vested, among other things, with the responsibility for preparing plans for managing and developing natural resources within their boundaries. This system of devolved natural resource management has key and significant potential for disaster risk reduction and management strategies at field levels. Here once more, the gender issue plays a role, since risk management is a task for both men and women in rural contexts.

Community-based risk and vulnerability assessment practices using Community Geoinformatics (C-GIS) have begun to appear in DRM practice in India. GIZ's experience in countries like Mozambique and Nicaragua can serve as examples of good practice and support community-based approaches in India.

One example of successful integration of adaptation measures into DRM systems in cooperation with local communities comes from Mozambique (GTZ 2005). This East African country is one of the poorest in the world; it is also one of the world's top ten hotspots for floods, droughts and cyclone disasters. It was in this context that in 2001 GIZ (then GTZ) set up an early warning system for the catchment area of the Rio Búzi. The pilot project was developed on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) with support from the Munich Re Foundation. The creation of local DRM committees has meant that the local communities are now better prepared for emergency situations and know how to reduce disaster risk. This is an important step for climate change adaption, since recent studies on climate change indicate that disaster risk will rise in the future.

Emergency simulations are exercises to train and sensitise local communities. The photograph shows an evacuation operation in a flood simulation exercise organised by the local DRM committee of Monamicua community in the Búzi District. (photo: Konstanze Kampfer)

The implementation of DRM components began with a participatory risk analysis, which identified a third of the district's population as being particularly disaster-prone. Detailed risk maps were developed, depicting high-risk areas and elevated ground for emergency evacuation. In terms of disaster prevention and mitigation, the project focused on people-centered early warning systems, integration of disaster prevention into district planning, and sensitisation of both the population and the local political and administrative decision-makers. The local DRM committees are responsible for warning the population by radio before a disaster occurs and for organising transportation and evacuations. As a result of the project, climate-driven disasters and threats can now be effectively met by concerted, decentralised community action and self-organisation.

After implementing simple and effective measures at local level, a follow-on programme is now focusing on upscaling DRM to higher levels. It advises the institutions involved on how to incorporate DRM into policymaking. Legislation to institutionalise DRM is under development and should be completed within the next years.

Another successful example of adaptation through DRM comes from Nicaragua, where climate change is making itself felt with increasing storms, floods, hurricanes, drought and irregularities in the rainfall cycle. In 2004, GIZ (then GTZ) initiated a project with selected rural communities entitled Adaptation to Climate Change through Risk Management. The aim was to improve the communities' capacity to adapt to climate change by means of strengthened DRM and to integrate this capacity into their planning processes.

The main issue was to raise awareness among those affected and those in charge at community level and to provide them with a plan and the means to manage disaster risk. To ensure collaboration at community level, multiple participatory risk analyses were conducted, relying on information provided by 550 individuals from different communities. In addition, special risk analysis training for employees from municipalities and local authorities helped ensure preparedness. The next step was to integrate the identified risks into the local land management plans and define the necessary steps to reduce them. Early warning systems were installed or improved in the pilot communities. To ensure fast communication and information exchange, hands-on training on how to use the equipment was organised for around 150 individuals. The early warning systems substantially improved the preparedness and speed of evacuation during the 2005 hurricanes Wilma and Beta. To ensure that these pilot projects have a sustainable impact, they have been integrated into GIZ's long-term Programme for Sustainable Resource Management and Entrepreneurial Capacity Building in Nicaragua.

6.5 Linking adaptation and mitigation

An important part of addressing climate change is dealing with its root causes by reducing greenhouse gas emissions from human activity. Examples of mitigation actions include managing natural carbon sinks such as forests, vegetation and soils so that they absorb carbon dioxide (UNISDR 2008). **Afforestation and reforestation** are two instruments of disaster risk management (DRM) that can reduce risk. Trees and other vegetation help to lessen the impact of floods and avoid soil erosion. These DRM measures also indirectly contribute to mitigating global warming: forests and other vegetation have the capacity to absorb carbon dioxide and store it for decades even after trees have been felled. Furthermore, replacing oil and other fossil fuels with wood as biomass energy can reduce CO_2 emissions, bringing about a slowdown in global warming (Venton & La Trobe 2008).

Another factor contributing to the intensification of anthropogenic greenhouse effects is forest fires. DRM creates and strengthens the necessary infrastructure to **extinguish wildland fires and forest fires**. It makes it possible to fight forest fires more effectively by setting up fire prevention and firefighting units and by providing the necessary training and education. In addition, the use of existing communication structures and the development of fire management concepts help suppress fires and thus avoid further CO_2 emissions. A GIZ project in Mongolia illustrates how this can work.

Instruction in the use of hand tools at the First Central Asian Forest Fire Experiment in Mongolia. (photo: GIZ)

In Central Asia, in particular, existing changes in climate, in combination with changes in land use, are already causing more intense forest and wildland fires, threatening ecosystems, the livelihoods of the local population and the economy. The aim of the project is to reduce disaster risk through integrated fire management measures and at the same time minimise the negative impacts of forest fires on people, property and climate.

Mongolian firefighting specialists controlling a fire. (photo: GIZ)

The project covered different levels and approaches to integrated fire management. Key aspects included identifying affected areas, developing a risk analysis and recommendations on incorporating the results into the National Round Table on Fire Management. A round table initiated by GIZ supported the establishment of an Inter-Agency Fire Management Board with the participation of civil organisations and associations. Improvements in fire management structures and capacities at community, state and national level and cross-border cooperation were fostered by targeting representatives of the different levels. The knowledge generated from this project is expected to help prevent fire risk due to climate change.

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