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DROUGHT STUDIES FOR KALAHANDI DIST. IN ORISSA

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PREFACE

Drought is a natural, recurring feature of climate; it occurs in virtually all-climatic regimes. Drought differs from other natural hazards in several ways. *First,* it is a "creeping phenomenon", making its onset and end difficult to determine. The effects of drought accumulate slowly over a considerable period of time and may linger for years after the termination of the event. *Second,* the absence of a precise and universally accepted definition of drought adds to the confusion about whether or not a drought exists and, if it does how severe it is ?. *Third,* the societal impacts of drought are less obvious and extend over a larger geographical area than damages that result from other natural hazards. Drought seldom results in structural damage. For these reasons the quantification of impacts and the provision of disaster relief is a far more arduous task than it is for other natural hazards.

Quite for some time Kalahandi has been often in the national media because of the recurring drought-hardship and mass migration in search of livelihood. Perhaps, crop failure and lack of gainful employment have impoverished small and marginal farmers, and landless people in Kalahandi. In order to evince some useful lessons from past events of droughts, the hydrological and agricultural aspects of drought have been studied for Kalahandi district. It is hoped that the scientific views expressed and information provided in this report would lead to better understanding of regional drought phenomena and in planning of drought mitigation activities in the Kalahandi district in Orissa.

This report is a part of research work of Drought Studies Division of this Institute. The study has been carried out by **Shri Rajendra Prasad Pandey**, Scientist C, under the Guidance of **Dr. Bhupendra Soni**, Scientist F & Head of the Dividion. The assistance was provided by **shri Y. K. Dhama**, Research Assistant. I hope, it will point the way towards better understanding of drought and its improved management in the future.

(S.M. Seth)

Director

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ABSTRACT

Agriculture is the main source of people's livelihood in Kalahandi district . Most of the crops are grown there under rainfed condition. The normal rainfall of the district is about 1378.2 mm, out of this about 90% is received during monsoon season. The long breaks of monsoon (dry spells) during the crop growing season and wide variations in the quantum of rainfall from year to year result in frequent failure of crops and consequently the entire district is drought prone.

The hydrological and agricultural aspects of drought have been studied for all the thirteen blocks in Kalahandi district. The 31 years rainfall data for all the blocks has been analysed in order to portend the drought frequency, duration, dates of onset and withdrawal of monsoon and critical dry spells. According to rainfall departure analysis the different parts of the district had experienced drought with an average frequency of 4-8 years. It was observed that the Koksara and Kalampur blocks were least affected. The probability distribution of annual rainfall revealed that the probability of occurrence of 75% of normal rainfall varies from 0.72 to 0.88. Also, the ranges of annual rainfall at 75% probability level varies from 800-900 at Langigarh to 2000-2100 at Th.Rampur. The period between 13th June to 19th September is found as the average length of monsoon in Kalahandi. On an average, the monsoon period incorporates two-to-three intervening critical dry spells per year. Rainfall records witnessed that the distribution of rainfall in time and space, and critical dry spells play major role in crop loss rather than the grass annual amount of rainfall. The crop evapotranspiration (ET_{crop}) has been computed using reference-crop evapotranspiration (ET_p) and crop coefficients (K_c) values. The water requirement for different crops namely paddy, maize, greengram (kharif), greengram (pre-rabi), blackgram, sesamum and minor millet have been estimated as 587 mm, 551 mm, 297 mm, 268 mm, 358 mm, 413 mm and 283 mm respectively. The irrigation requirement for the critical dry spells have been worked out to plan for alternate supplemental irrigation.

The district Kalahandi needs appropriate focus on alternative provisions for supplementary irrigation to the Kharif crop as well as for providing assured water supply at least for one irrigation to Rabi crop. This leads to the need for extending irrigation facilities by conserving the monsoon runoff in tanks/ponds/reservoirs to take care of the requirements in deficit-rainfall months.

The area has vast scope for development and exploitation of ground water. The ground water table records of pre & post monsoon season for a period of last 9 years indicate that the ground water table is almost static (i.e. neither rising nor lowering). A planned development and exploitation of available ground water may not only contribute as a sustainable source of water for supplemental irrigation but also for tackling the situation during drought.

1.0 INTRODUCTION

Substantial areas of our country periodically experience droughts leading to considerable loss of agricultural production and livestock wealth, besides causing misery to people inhabiting these areas. Severe and prolonged water stress due to deficit of rainfall over the prolonged periods with reference to normal rainfall expectation is apt to describe a meteorological drought in general term. According to the National Commission on Agriculture (1976), agricultural drought refers to the inadequate soil moisture during crop growing period and the hydrological drought refers to marked depletion of surface water storage in lakes, reservoirs, rivers and streams etc. In fact the meteorological drought precedes the agricultural and hydrological drought. The agricultural and hydrological drought need not to occur simultaneously but occur subsequent to a meteorological drought (Sastry, 1986).

Drought as such is nothing new for the state Orissa. On an average, the occurrence of drought in the state happens once in every 3-5 years (Ghose Dastidar, 1997; Dutt, 1986; Sahoo, 1993). Orissa, with agriculture as the main source of livelihood, has about 80 percent of its cultivable land dependant on rainfall for agricultural production. Demands of the staggering increase in population have entailed for augmenting food production in turn calls for an assured water availability from rainfall to match rhythm of crop. However, scanty, erratic and fluctuative distribution of rainfall in Kalahandi, Nuapada, Balangir and Koraput districts of Orissa cause crop failures leaving behind devastating effect on its economy and populace. Owing to unstable crop yields and nonavailability of other employment opportunities, there is large scale migration of poor people to other districts of the state and Raipur district in Madhya Pradesh. In Normal years, the migration percentage varies from 30 to 40% and in drought year of 1996, this percentage has been around 70-80% (Times of India, October 1996)

The district Kalahandi is situated adjoining to the Chhattisgarh region in eastern Madhya Pradesh which is known as "Dhan Ka Katora" (a bowl of paddy) i.e. a well known rice producing region. The agricultural activities of the district is dominated by rainfed cropping system except some localised patches of irrigated agriculture. Normally, the rainfed rice and rice-based cropping system is practised in the region, which suffer from water stress mainly due to erratic distribution of seasonal rainfall. The agricultural operations for principal summer crops (kharif) start with the onset of southwest monsoon. One of the important characteristics of the influencing production in such areas is the date of first occurrence of a rain-spell at the beginning of the monsoon season that will go to built a moisture reserve in the soil adequate for commencement of kharif sowing. A correct prediction of the date of onset of effective monsoon may help the farmers to plan cropping strategy and to derive maximum advantages from local soil conditions after monsoon rains.

In order to identify the kharif sowing rains the pre-monsoon showers of high intensity can not be considered as the effective monsoon, particularly, because they are normally followed by long dry spells which may affect the germination of seeds resulting in crop failure if the showing is undertaken immediately after these showers.(Sahoo, 1993).

In literature, no criterion is available for planning a supplemental irrigation to crop based on critical dry spells and critical crop growth stages. The Critical dry spells are those dry spells which exceed certain limiting duration identified to be critical to the crop. Of late, more emphasis is being given to store excess runoff in tanks for supplemental irrigation to crops. However, excess runoff collection and storage of water on dug out ponds or tanks is more expensive than the national resource (Verma and Sarma,1989). Thus, there is a need to develop suitable criteria for planning supplemental irrigation to crops for increasing and stabilizing crop yields during non-drought conditions, and minimising crop damages during drought. The present study is aimed to study hydrological and agricultural aspects of drought based on the analysis of rainfall, evapotranspiration, ground water table, soil characteristics, crop and its critical stages. The study is further aimed at planning of life saving supplementary irrigation requirement for rainfed crops to reduce water stress during critical dry spells.

2.0 ABOUT THE KALAHANDI DISTRICT

2.1 Topography and Physical Features

Kalahandi district is characterised by diverse land forms. However, it may be broadly divided into two distinct physiographic regions, the plain land and the hill tracts. The plain land constitutes the river valleys with isolated hillocks in between and covers about 50 per cent of the total geographical area of the district. Fig. 1 presents the location map of Kalahandi district. The elevation of these plains above mean sea level ranges from 210 to 450 meters. The plain region covers the entire northern portion of the district upto Bhawanipatna and Kesinga and further then westwards through Junagarh and Dharamgarh upto the district boundary. The hill tracts comprise the ranges of hills which run from the north-east to the south-west of the district. The Eastern Ghats hill ranges and the Purana hill ranges having an average altitude of about 700 meters from mean sea level are the principal tracts. The entire hilly regions are covered with dense forests and contain mineral deposits of Manganese, Graphite and Rauxite.

The Tel, Indravati and Jonk which form tributaries of large rivers like the Mahanadi and Godavari may be mentioned among the principal rivers of Kalahandi district. The Indravati, Nagavalli and Vamsadhara rivers owe their origin in this district. There are also some major hill streams like the Sunder, Ret, Hati, Utei, Sagada, Udet, Bolat etc. which flows during the summer season.

2.2 Geological Set-up

A major portion of the district of Kalahandi nestles in the lap of the Eastern Ghats group of rocks of Archaean age, comprising Khondalitic, Charnockitic and granitic suites of rocks. Granite gneisses from the most predominant rock type occurring in the district and usually occupy the undulating plains. Khondalites generally form steep hills and are highly foliated dipping towards south-east.

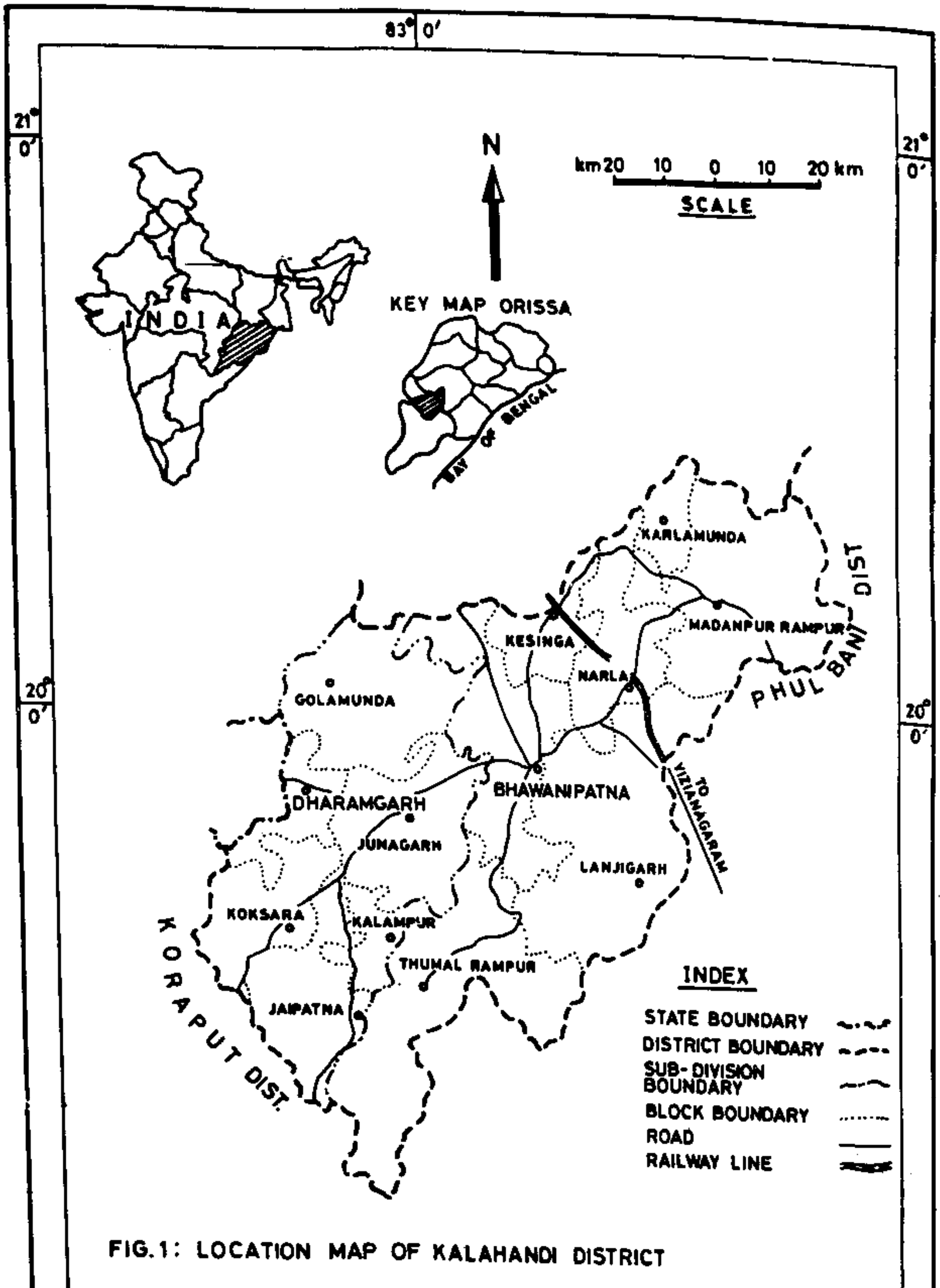


FIG. 1: LOCATION MAP OF KALAHANDI DISTRICT

Overlying the rocks of the Eastern Ghats group occur the less deformed and metamorphosed sedimentary rocks of the Chattisgarh group form the hill ranges. The common rock types include purple shales, quartzite, sandstone, arkosic quartzite and thin bands of limestones.

Other lithostratigraphic units commonly found in the district include leptynite, anorthosite, pegmatite, vein quartz, metadolerite, laterite soil and alluvium. Recent alluvium comprising layers of sand, gravel, clay and silt occurs as thin discontinuous patches along major streams and rivers.

2.3 Climate and Rainfall

The state Orissa is situated in a sub-tropical zone and and exhibits a temperate climate. The climate of the state varies from moist sub-humid to dry sub-humid. The south west monsoon happens to be the single largest contributor of monsoon rains. The climate of Kalahandi district is hot, moist and sub-humid and is known to be of extreme type. It is characterised by a very hot dry summer and extreme cold winter. May is the hottest month when the mean daily maximum temperature is about 41° C and the minimum about 28° C. December is the coldest month of the year with mean daily maximum and minimum temperatures of 28° C and 13° C respectively. The district enjoys 3 distinct seasons, namely winter, summer and rain. The winter commences from November and lasts till end of February. The hot seasons follows thereafter and continues till middle of June when the monsoon sets in and continues till middle of October. The average annual rainfall of the district is 1378.2 mm, out of which around 1259 mm rainfall is received during the period between June 1st to October 31st. Rainfall in this district is mostly erratic and punctuated generally with long dry spells. Due to scanty, erratic and uneven distribution of rainfall the district suffers from frequent drought conditions and almost the entire district is considered drought-prone. The blockwise distribution of mean annual rainfall is given in Table 1.

Table 1 : Blockwise rainfall distribution in Kalahandi district
(averaged over a period of 31 years 1966-996)

Sl. No.	Name of the block	Mean annual rainfall(mm)	C.V. (%)	S.D.	CK/S.E.
1	Bhawanipatna	1445.6	27.68	37.42	2.50
2	Kesinga	1371.0	34.38	43.30	(-)0.05
3	Lanjigarh	1185.4	42.36	48.67	0.13
4	Karlamunda	1238.5	25.76	29.47	2.13
5	Narla	1349.8	24.28	29.67	3.15
6	M.Rampur	1523.4	24.51	36.47	1.84
7	Th.Rampur	2670.2	31.56	85.24	2.59
8	Dharamgarh	1223.7	22.20	27.62	0.24
9	Junagarh	1308.0	25.57	33.75	0.09
10	Jaipatna	1272.4	36.38	45.28	0.23
11	Golamunda	1111.2	32.24	36.40	2.06
12	Kalampur	1554.7	19.09	29.90	3.59
13	Koksara	1586.7	23.42	35.22	3.47

2.4 Area and Population

The district of Kalahandi extends over an area of 8364 sq. km constituting 5.37 per cent of the total area of the state and ranks 4th among the 30 districts of Orissa with regards to size. Its extreme length from east to west is about 140 km and its extreme breadth from north to south is about 120 km . As per the Census Report of 1991 (O), the district accommodates a total population of 1130903 (50.05% males and 49.95% females) which accounts for 3.57 per cent of the total population of the state and occupies 13th position among the 30 districts of Orissa in this respect. The density of population is 135 persons per sq. km. against 202 for the state of Orissa.

The pace of urbanisation of the district is very low and only 6.9 per cent of its population lives in towns. This shows the district is economically backward and rural in character.

In the sphere of literacy and education, the district has registered a lower position and ranks 25th among the 30 districts of Orissa. The per cent literacy of the districts is 31.08 as against the state average of 49.09 per cent.

The backward population consisting of SC/ST forms 45.88 per cent (1991 Census) of the total population of the district. The main tribals in this district belong to Kondha, Gand, Sabar, Bhunya, Paraja and Kutia-Kondha sub-group. The largest concentration of tribal is found in Thumal-Rampur and Lanjigarh blocks. The decadal growth of population in the district of Kalahandi since the beginning of the present century is given in Table 2.

Table 2 :Decadal variation in population and its growth rate in Kalahandi district (Undivided Kalahandi which includes newly created Nuapada district)

Decade	Population	Decennial growth rate of population
1901	449137	--
1911	540495	(+) 20.34
1921	550358	(+) 1.82
1931	655194	(+) 19.05
1941	745313	(+) 13.75
1951	805675	(+) 8.10
1961	946874	(+) 17.53
1971	1163869	(+) 22.92
1981	1339192	(+) 15.06
1991	1591984	(+) 18.88

Source: Census of India 1991, Orissa.

2.5 Soil and Landuse

The soils in the district can be classified into 5 categories, viz. red soil, red and yellow soil, red and black soil. black soil and alluvial soil. Red soil is the predominant among these and occurs in about 48 per cent area of the district. The distribution of the soil types in different blocks of the districts along with their texture is given in Table 3. The soil map of the district is depicted in fig. 2. The cultivated land

FIG.2 : SOILS OF KALAHANDI DISTRICT

map of the district is depicted in fig. 2. The cultivated land of this district have been divided into four categories, viz. At, Mal, Berna and Bahal among which At is the best paddy growing land. Out of the total geographical area of 836.4 thousand hectares, the net area sown is 268.13 thousand hectares (Census-1991). The land use pattern of the district is given in Table 4.

Table 3: Distribution of soil types in different blocks of Kalahandi district.

Sl. No.	Soil type	Name of blocks (part/full) fall under various soil group	General texture	Percentage of total area
1	Red soil	M.Ranpur, Th.Rampur, Langigarh and Dharamgarh	Loamy sand to sandy loam	32.05
2	Red & yellow soil	Parts of Narla, M.Rampur, Koksara, Jaipatna Kalampur, and Junagarh	Sandy loam to loam	34.95
3	Red & black soil	Kesinga and Karlamunda	Loam to clay	12.60
4	Black soil	Bhawanipatna, Dharamgarh, parts of Golamunda, Koksara & Kesinga	Heavy clay	13.20
5	Alluvial soil	Parts of Dharamgarh and Karlamunda	loam to silt loam	7.20

Table 4: Land utilization pattern in the Kalahandi district (1996-97)

Sl. No.	Land use	Area ('000 ha)	Percentage of total area
1	Net area sown	268.13	32.06
2	Misc. tree crops & groves	1.55	0.20
3	Current fallow	55.83	6.67
4	Culturable waste	22.29	2.66
5	Land put to non-agril.uses	56.10	6.70
6	Baren & uncultivable land	17.79	2.13
7	Permanent pasture & other grazing lands	21.41	2.56
8	Fallow lands	18.71	2.24
9	Forest lands	253.80	30.34
10	Other lands	120.79	14.44

Source: Districts at a Glance 1998, Deptt. of Economics & Statistics, Bhubaneswer, Orissa

2.6 Forests

Kalahandi district is noted for its rich forests which cover nearly 30.34 per cent of its total geographical area as against the state figure of 37.33 per cent. Timber and Bamboo are the major forest produce of the district. The other important produces from forests include Tendu leaf, Sabai grass and Mahua-flower.

2.7 Major Crops

Food grains constitute the predominate crops of the district which covered about 60 per cent of the gross cropped area of the district. Paddy is the principal crop which alone constituted 38.6 per cent of the gross cropped area. The Kalahandi can be ranked as the second highest rice producing district of Orissa. Other cereals and millet normally grown in the district include wheat, maize, jowar, bajra, minor millet etc. Pulses like arrhar,

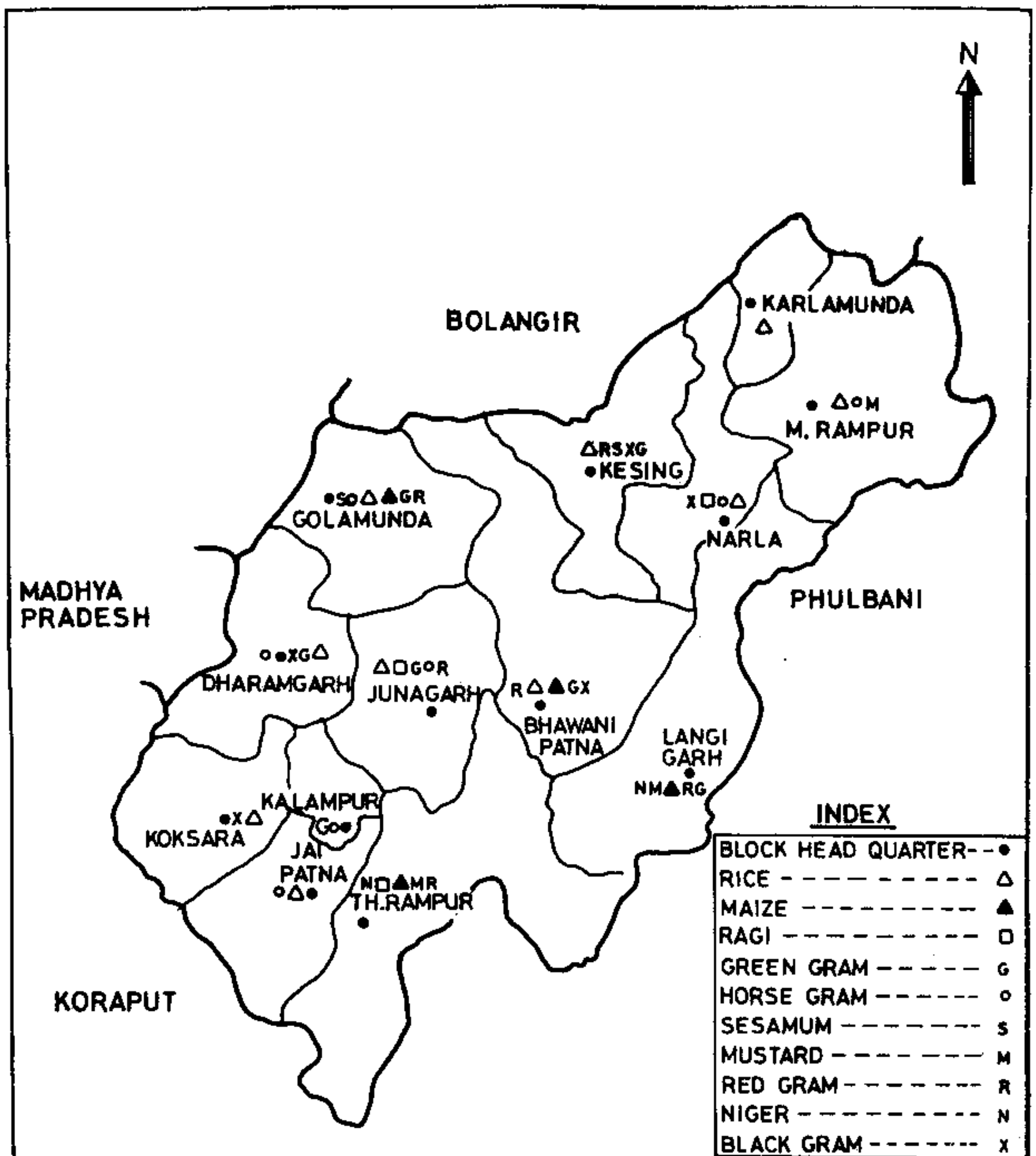


FIG. 3 :CROP MAP AND BLOCK H/Q OF KALAHANDI DISTRICT

mung, biri, kulthi, field pea etc. are also extensively grown which accounted for 31.6 per cent of the gross cropped area. Other commercial crops like sugarcane, sweet potato, potato, onion, garlic, vegetables, tobacco, jute etc. are grown moderately due to lack of irrigation facility. The crop map of the district is presented in Fig. 3.

2.8 Irrigation

Lack of irrigation facility is a major constraint in this district. Although its economy is largely dependent on agriculture, no regular or systematic irrigation facilities have been developed in extensive so far. Only 10.02 per cent of the cropped area was irrigated in kharif in 1996-97. Minor (flow and lift) irrigation projects including C.D. and private sources form the major source of irrigation. Table 5 presents a picture of the net area irrigated by different irrigation sources in the district.

Table 5 : Irrigation potential created Up to 1996-97 ('000 ha.)

Sl. No.	Source	Net area irrigated (in '000 ha.)		
		Kharif	Rabi	Total
1	Major and Medium irrigation projects	54	2	56
2.	Minor irrigation projects	20	5	25
3.	Lift irrigation projects	9	6	15
	Total	83	13	96

[Source: Districts at a glance-1998, Directorate of Economics and statistics, Bhubaneswar, Orissa]

3.0 ASSESSMENT OF GROUND WATER POTENTIAL

The main objective of assessment of groundwater potential is to quantify the available groundwater (dynamic storage) that can be exploited as supplementary source to meet the important demands of the society during water scarcity or drought. The regular monitoring of groundwater level and their evaluation can play an important role in management of this underground resource of water. The fluctuations of water table reflect the effects of infiltration, precipitation and discharge of groundwater to streams or lakes or withdrawal of water from wells. Usually, the change in groundwater storage is a seasonal phenomenon. However, during the period of scarcity of rains or drought, more dependence comes on groundwater storage.

Depending on the type of data available, various approaches can be used for evaluation of groundwater potential of an area. Among these, the recent and more realistic one is the methodology based on the norms framed by the Groundwater Estimation Committee (1983). As per these norms, the groundwater potential of different blocks in Kalahandi district has been estimated by CGWB, Bhubaneswar. Table 6.0 presents the estimates of groundwater potential in different blocks in Kalahandi district.

Table 6: Groundwater potential of different blocks in Kalahandi

Sl. No.	Name of the Block	Total Annual Recharge '000'm^3/yr	Utilizable Ground water '000'm^3/yr	Net Annual Draft '000'm^3/yr	Ground water Balance for Irrigation '000'm^3/yr	level of Groundwater development '000'm^3/yr
	(a)	(b)	(c)	(d)	(e)	(f)
1	Bhawanipatna	52418.30	44555.50	6208.30	38347.20	139.30
2	Kesinga	53607.10	45566.00	5138.00	40428.00	112.70
3	Lanjigarh	38981.10	33133.90	1323.70	31810.20	39.90
4	Karlamunda	40584.60	34496.90	2376.50	32120.40	68.80
5	Narla	50966.80	43321.80	5367.60	37954.20	123.90
6	M.Rampur	46638.90	39643.10	3757.60	35885.50	94.70
7	Th.Rampur	38675.90	32874.50	633.50	32241.00	19.20
8	Dharamgarh	41115.60	34945.30	2653.70	32291.60	75.90
9	Junagarh	55771.60	47405.90	5479.60	41926.30	115.50
10	Jaipatna	47225.30	40141.50	1680.70	38460.80	41.80
11	Golamunda	48643.40	41346.90	3854.90	37492.00	93.20
12	Kalampur	16663.40	14163.90	1587.60	12576.30	112.00
13	Koksara	51200.90	43520.80	3183.60	40337.20	73.70
	Total	**582492.90**	**495116.00**	**43245.30**	**451870.70**	**1109.90**

4.0 ASSESSMENT OF DROUGHT YEARS

Drought implies a deficiency of rainfall of sufficient magnitude over a prolonged duration so as to interfere with some phases of regional economic activities. According to the India Meteorological Department (IMD) an area/region is considered to be drought affected if it receives seasonal total rainfall less than 75% of its normal value (Appa Rao, 1986). The Rainfall records of 31 years (1966-96) for all the thirteen blocks of the Kalahandi district were obtained from the office of Engineer-In-Chief, Department of Water Resources, Bhubaneswar and analysed to study the magnitude and frequency of drought in terms of rainfall deficiency. Rainfall data has been subjected to various kind of analysis including seasonal & annual rainfall departures, probability distribution and dry spell analysis etc.

4.1 Annual Rainfall Departure

In order to identify the drought years and the extent of deficit of annual rainfall, the annual rainfall departure analysis has been carried out. A year is considered as drought year if the total amount of annual rainfall over an area is deficient by more than 25% of its normal value. Blockwise values of annual normal and the annual deficiencies, for the period of 31 years (from 1966 to 1996) are given in Fig 4(a)-4(m). The drought years have been identified and presented in column (3) in the Table 7. The longest duration of drought persistent (i.e. maximum numbers of consecutive drought years) is shown in column (6) in Table 7.

4.2 Seasonal Rainfall Departure

The southwest monsoon contributes about 90% of the average annual rainfall that occurs during June to September in the district (Ghose Dastidar, 1997). In the district Kalahandi the entire paddy cultivation is governed by quantity, distribution and time of onset of effective monsoon . The agricultural droughts in this region is the result of variable rainfall and its irregular distribution. The long dry spells occur within the rainy season and their effect is more severe on agriculture and normal life pattern of the region concerned. In order to compute the deficiency of seasonal rainfall, the seasonal rainfall analysis has been carried out. Normal rainfall of the monsoon season was calculated as the arithmetic average of rainfall during June to September, over the period of record, for all the thirteen blocks in the districts. A seasonal drought can be defined if actual rainfall is deficient by more than twice of the mean deviation of the season (Ramdas 1960). A simple approach to delineate good or bad monsoon years have been suggested by Banerjee and Raman (1976). They considered a year to be a bad monsoon year if in more than two-third number of meteorological stations the seasonal rainfall is deficient. India Meteorological Department (IMD) defined seasonal drought as the period with the seasonal rainfall deficiency more than 25% from its normal value (Appa Rao, 1986). Blockwise values of seasonal normal and the seasonal deficiencies, for the period of 31 years (from 1966 to 1996) are given in Fig 5(a)-5(m). The years during which various blocks of the district Kalahandi experienced seasonal drought are identified and given in column (5) in the Table 7.

Table 7 :Identification drought years in different blocks in Kalahandi

Sl. No.	Name of the block	Mean annual rainfall (mm)	Drought years	Average drought frequency	Years with more than 25% deficiency in monsoon rains	Longest spell of Consecutive Drought years
	(1)	(2)	(3)	(4)	(5)	(6)
1	Bhawanipatna	1445.6	68,74,75,87, 88,89,96	4	66,68,74,75,81,87,96	2
2	Kesinga	1371.0	68,74,75,79, 87,88,89,96	4	74,75,87,88,96	3
3	Lanjigarh	1185.4	74,79,81,82, 84,87,88	4	74,81,82,84,87,88	3
4	Karlamunda	1238.5	72,73,74,83, 87,96	5	72,74,83,87,96	3
5	Narla	1349.8	70,71,73,74, 75,77,87,96	4	70,71,73,74,77,87,88,96	3
6	M.Rampur	1523.4	74,83,87,88, 96	6	74,83,87,88,96	2
7	Th.Rampur	2670.2	74,75,76,80, 83,88	5	68,74,75,76,78,80,83,88	3
8	Dharamgarh	1223.7	74,83,86,88, 89,96	5	74,83,88,89,96	2
9	Junagarh	1308.0	74,79,86,87, 88,89,92	4	74,86,87,88,89,96	4
10	Jaipatna	1272.4	74,82,83,85, 86,87,88,89	4	74,81,82,83,85,86,87,88	5
11	Golamunda	1111.2	70,74,79,80, 82,96	5	70,71,74,79,80,82,96	2
12	Kalampur	1554.7	74,80,86,88	8	74,80,86,88	1
13	Koksara	1586.7	68,74,79,82	8	68,74,81,82,83,95	1

5.0 PROBABILITY DISTRIBUTION OF ANNUAL RAINFALL

The probability analysis of annual rainfall is important to predict the relative frequency of occurrence in different group interval of annual rainfall with reasonable accuracy. The probability distribution curves have been drawn by plotting the values of percentage of cumulative probability in respect of various range-groups of annual rainfall at their corresponding midpoint. The graphs of probability distribution of annual rainfall for all the thirteen blocks in Kalahandi district are shown in Fig. 6(a)-6(m). The blockwise average range of annual rainfall has been worked out and presented in column (3) in Table 8. The percentage probability of occurrence of 75% of mean annual rainfall has been worked out to delineate the drought proneness of various blocks of the district Kalahandi. An area can be considered as drought prone if the probability of occurrence of 75% of normal rainfall is less than 80% (CWC,1982: Ramakrishna 1986). Percentage probability of occurrence of rainfall equivalent to the 75% of normal is presented in column (4) in Table 8.

Table 8: Blockwise probability distribution of annual rainfall in Kalahandi

Sl. No.	Name of the block	Mean annual rainfall (mm)	Range of rainfall at 75% Probability level (mm)	probability of occurrence of rainfall equivalent to 75% of normal (in %)
	(1)	(2)	(3)	(4)
1	Bhawanipatna	1445.6	1100-1200	85 (1084)
2	Kesinga	1371.0	1000-1100	75 (1028)
3	Lanjigarh	1185.4	800-900	74 (889)
4	Karlamunda	1238.5	900-1000	78 (929)
5	Narla	1349.8	900-1000	67 (1012)
6	M.Rampur	1523.4	1200-1300	80 (1142)
7	Th.Rampur	2670.2	2000-2100	81 (2003)
8	Dharamgarh	1223.7	1000-1100	78 (918)
9	Junagarh	1308.0	1000-1100	72 (981)
10	Jaipatna	1272.4	900-1000	80 (954)
11	Golamunda	1111.2	900-1000	77 (833)
12	Kalampur	1554.7	1300-1400	86 (1166)
13	Koksara	1586.7	1300-1400	87 (1190)

Note: Rainfall values equivalent to 75% of normal are shown in parenthesis in column (4).

6.0 ONSET OF EFFECTIVE MONSOON AND CRITICAL DRY SPELL

Paddy is the principal crop which alone constitute about 39% of the gross cropped area of the district Kalahandi. Also, the other major crops like maize, greengram, mung, kutki etc. are grown during kharif season. The selection of crop varieties and time for seed bed preparation are governed by onset and length of monsoon. Therefore, the onset, termination, and distribution of rains during monsoon season plays very significant role in the success of agricultural crops in this region.

In order to identify the onset and withdrawal of effective monsoon and critical dry spells, the daily rainfall records have been analysed using the methodology as described below.

6.1 Onset of Effective monsoon (EMO)

The date of onset of effective monsoon (EMO) can be defined as the date of commencement of a 7-day dry spell satisfying the following criteria (Varma and Sarma, 1989; Ashok Raj, 1979; Sahoo, 1993)

(i) The first day's rain in 7-days spell is not less than average daily evapotranspiration (ET).
(ii) At least four out of seven days are rainy days with not less than 2.5 mm of rain each day.
(iii) The total rain during the 7-day spell is not less than (5ET+10) mm.

Using above definition the rainfall record have been analysed to identify the date of EMO in respective years.

6.1.1 Mean date of EMO

The mean date of onset of effective monsoon is calculated as follows:

$$D_m = \sum_{i=1}^{n} \frac{X_i}{n} \qquad (1)$$

Where, D_m = mean date of effective monsoon

X_i = date of onset of effective monsoon in i^{th} year ($i= 1,2,\ldots n$)

n = total number of years for which rainfall data is being analysed

6.1.2 Standard Deviation (σ) of EMO

Standard Deviation (σ) of the date of onset of effective monsoon from its mean date is calculated as follows:

$$\left[\frac{\sum_{i=1}^{n} X_i^2-\left(\sum_{i=1}^{n}\frac{X_i}{n}\right)^2}{n-1}\right]^{\frac{1}{2}} \qquad (2)$$

6.1.3 Median date of EMO

The dates of EMO X_i ($i=1,2,..n$) for n number of years are arranged in ascending order. If n, the number of years is odd, the middle value is considered as the median date of EMO. In case n is even, the median date is the arithmetic mean of two middle values.

6.1.4 Quartile Deviation (q)

The quartile deviation (q) or semi-inter-quartile-range can be calculated as follows:

$$q=\frac{q_3-q_1}{2} \qquad (3)$$

Where,

q_1 = first quartile dividing the observation X_i ($i=1,2,\ldots n$) in to fourth q_1 and three-fourths above.

q_3 = third quartile dividing the observations into a fourth above and three-fourth below.

6.1.5 Earliest and latest probable date of EMO

If a variate X which takes the values $X_1, X_2, \ldots X_n$ follows a normal distribution with mean (D_m) and standard deviation (σ), then the probability density function of the variate can be calculated as follows.

$$P(X) = \frac{1}{\sigma\sqrt{2\pi}} \exp -\frac{(X-D_m)^2}{2\sigma^2} \qquad (4)$$

The probability that X lies between ($D_m-\sigma$) and ($D_m+\sigma$) is given by the following relationship.

$$P[(D_m-\sigma)<X<(D_m+\sigma)] = \int_{(D_m-\sigma)}^{(D_m+\sigma)} P(X)dx \qquad (5)$$

As X follows a normal distribution with mean D_m and standard deviation σ, the standardised normal variate (Z)

$$Z = \frac{X-D_m}{\sigma} \qquad (6)$$

follows a normal distribution with mean 'zero' and standard deviation 1. The probability of X lies between ($D_m-\sigma$) and ($D_m+\sigma$) is the same as that of Z lying between -1 and 1 which is given by the relation.

$$P(-1<Z<1) = \int_{-1}^{1} \phi(Z)dZ \qquad (7)$$

$$= 2\int_{0}^{1} \phi(z)dz \qquad \text{because of symmetry}$$

$$= 2 \times 0.3413 \qquad \text{(from table)}$$

$$= 0.6826$$

In other words the least and highest values that X can be assumed in the domain ($D_m-\sigma$) to ($D_m+\sigma$) are ($D_m-\sigma$) and ($D_m+\sigma$) respectively, each with the probability of approximately 68%. Thus it is assumed that the dates of onset of effective monsoon X_i (i=1,2,..n) follow a normal distribution with mean D_m and standard deviation σ, then the least value of X_i is ($D_m-\sigma$) at a probability of 0.68 and the highest value is $(D_m+\sigma)$ with same probability level.

Similarly based on median, the earliest and latest probable dates of onset of effective monsoon are q_2-q and q_2+q respectively each with 0.50 probability level, where q_2 is median and q is quartile deviation.

6.2 Critical dry spell (CDS)

Normally, a dry spell is defined as the interval of dry days (none of the day have rainfall more than 2.5 mm) between two consecutive wet spells. After the onset of effective monsoon, a wet spell can be defined either as a day with rainfall not less than 5ET, or the commencement of another 7-day rain spell with a total of at least 5ET of rainfall and having not less than three or four rainy days out of 7-days spell (Varma and Sarma, 1989; Ashok Raj,1979; Sahoo, 1993). If a single rainy day having at least 5ET rainfall after a dry spell can wet the soil profile upto the desired depth and is taken as a wet day for breaking the dry spell, then two consecutive rainy days whose total rainfail is 5ET or more can be considered as two-day wet spell for the same purpose (Varma and Sarma, 1989). This is based on the following fact derived from experirnce:

" that an effective wet spell of two consecutive rainy days can leave more moisture in the soil profile than that of one effective rainy day having equal amount of total rainfall". This is because of more chances of water loss as surface runoff in the later case.

Further, three or more rainy days occurring in a week, not necessarily consecutively, having at least a total of rainfall of 5ET are also considered to constitute a wet spell. In view of the above discussions, The definition of a wet spell can be summarised as:

**- A rainy day with rainfall equal to or more than 5ET,

Or

**- A spell of two consecutive rainy days with rainfall totalling at least 5ET,

Or

**- A 7-day period having at least 3 or 4 rainy days with a total rainfall not less than 5ET.

The intervening period of dry days between any two consecutive wet spells is considered as dry spell. Based on the above definition, all the dry spells after the date of onset of effective monsoon are identified for first year of record. Similarly, depending on the crop variety and crop duration all the dry spells during crop growing season are identified. If the duration of these dry spells exceeds certain limiting period when the moisture stress is experienced by crops (under rainfed conditions), then the dry spell is called as 'critical dry spell'. Occurrence of critical dry spells depend upon the rainfall pattern, crop-soil complex of the region under consideration (Ashok Raj,1979; Sahoo, 1993). Subsequently, the critical dry spells are identified in the similar manner for all the 31 years of record.

For calculating the duration of CDS, an appropriate approach is to divide the crop growth period into some important growth phases according to water demand as evapotranspiration of crop varies according to growth stages. For paddy crop the critical stages for water demand are (i) tillering and (ii) flowering while for maize crop the critical stages are (i) early vegetative stage and (ii) tasselling and silking stage, the later being the most critical (Hiler, 1974; Waldren, 1982). In order to predict probable period of CDS the Median dates of begining of 1st, 2nd and 3rd CDSs for crop growing season have computed. The corresponding week of the month to which median date belongs, has been taken as the probable period of commencement of critical dry spells. The probable period of commencement of critical dry spells and their duration are presented in the Table 11.

Since paddy is the principal crop of the district Kalahandi and the most parts of the district have red and red-mixed soils (i.e. light soil). The rooting system of paddy is inherently incapable of efficiently using moisture from deeper layers, which explains why paddy is so extraordinarily susceptible to short drought period of 10-15 days (Sharma and Nayak, 1990). On the basis of crop-soil combination the minimum length of a dry spell is considered as 10-days that becomes critical to the crop.

Table 9: Average dates of onset and withdrawal of effective monsoon based on mean in different blocks of Kalahandi

Sl. No.	Name of the block	Mean date of onset of monsoon	Standard deviation of onset (days)	Mean date of withdrawal of monsoon
	(1)	(2)	(3)	(4)
1	Bhawanipatna	18 June	18	20 Sept.
2	Kesinga	20 June	22	19 Sept.
3	Lanjigarh	17 June	14	18 Sept.
4	Karlamunda	21 June	13	23 Sept.
5	Narla	15 June	15	25 Sept.
6	M.Rampur	19 June	19	20 Sept.
7	Th.Rampur	14 June	15	22 Sept.
8	Dharamgarh	16 June	19	18 Sept.
9	Junagarh	17 June	12	16 Sept.
10	Jaipatna	15 June	15	20 Sept.
11	Golamunda	16 June	13	13 Sept.
12	Kalampur	14 June	14	16 Sept.
13	Koksara	14 June	15	19 Sept.

Table 10: Median date of onset and withdrawal of effective monsoon in different blocks of Kalahandi

Sl. No.	Name of the block	Median date of onset of monsoon	Semi-inter quartile range of date of onset (days)	Median date of withdrawal of monsoon
	(1)	(2)	(3)	(4)
1	Bhawanipatna	15 June	8	18 Sept.
2	Kesinga	14 June	11	19 Sept.
3	Lanjigarh	12 June	10	16 Sept.
4	Karlamunda	19 June	7	16 Sept.
5	Narla	18 June	8	20 Sept.
6	M.Rampur	15 June	11	14 Sept.
7	Th.Rampur	14 June	9	18 Sept.
8	Dharamgarh	15 June	7	15 Sept.
9	Junagarh	15 June	8	16 Sept.
10	Jaipatna	12 June	8	15 Sept.
11	Golamunda	16 June	7	14 Sept.
12	Kalampur	14 June	6	16 Sept.
13	Koksara	12 June	8	13 Sept.

Table 11: Occurrence of critical dry spell (CDS) during monsoon season in different blocks in Kalahandi

Sl. No.	Name of the block	First CDS		Second CDS		Third CDS		Average number of CDS/yr.
		Probable period of comencement	Average Length in days	Probable period of comencement	Average Length in days	Probable period of comencement	Average Length in days	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Bhawanipatna	Jly-IInd week	14	Aug-Ist weeK	16	Sep-Ist week	22	2
2	Kesinga	Jly-Ist week	16	Aug-IInd week	15	Aug-IVth week	19	2
3	Lanjigarh	Jly-Ist week	15	Aug-Ist weeK	17	Aug-IIIrd week	21	2
4	Karlamunda	Jly-Ist week	19	Jly-IVth week	20	Aug-IVth week	16	2
5	Narla	Jly-IInd week	16	Aug-IInd week	18	Aug-IVth week	17	2
6	M.Rampur	Jly-Ist week	18	Aug-Ist week	21	Aug-IVth week	22	2
7	Th.Rampur	Jly-IInd week	13	Aug-IIIrd week	14	Sep-IInd week	14	2
8	Dharamgarh	Jly-Ist week	21	Aug-Ist week	15	Aug-IIIrd week	18	3
9	Junagarh	Jly-IInd week	17	Aug-IInd week	18	Aug-IVth week	15	2
10	Jaipatna	Jly-IInd week	16	Aug-IInd week	22	Aug-IVth week	15	2
11	Golamunda	Jly-Ist week	21	Jly-IVth week	15	Aug-IVth week	17	3
12	Kalampur	Jly-Ist week	15	Aug-IInd week	16	Sep-Ist week	16	2
13	Koksara	Jly-IInd week	14	Aug-Ist week	18	Aug-IVth week	20	2

7.0 ESTIMATION OF CROP EVAPOTRANSPIRATION AND IRRIGATION REQUIREMENT

7.1 Crop Evapotranspiration

The potential reference crop evapotranspiration (ET_p) has been estimated using modified Penman (1963) method. The ET_p (mm/day), for 52 standard weeks, has been calculated based on mean air temperature (maximum & minimum), dry bulb and wet bulb temperature, wind velocity, relative humidity (maximum & minimum), sun shine hours and using the standard tables values given by Doorenbos and Pruitt (1977). The ET_p estimates are made using meteorological data for Bhawanipatna station. The Estimates of ET_p for 52 standarded weeks are given in Table 12.

Table 12: Average daily reference crop evapotranspiration for 52 standard weeks in mm/day (averaged over 12 years)

Week No.	ET_p	Week No.	ET_p	Week No.	ET_p
1	5.64	19	8.59	37	5.62
2	5.48	20	8.85	38	5.69
3	5.65	21	8.78	39	6.43
4	5.88	22	8.73	40	5.81
5	6.32	23	8.77	41	6.44
6	6.21	24	7.68	42	5.92
7	6.38	25	6.44	43	6.53
8	6.97	26	5.84	44	5.76
9	7.32	27	6.51	45	5.31
10	7.46	28	5.65	46	5.54
11	7.48	29	5.733	47	5.48
12	8.23	30	5.58	48	5.48
13	8.24	31	5.59	49	5.36
14	8.42	32	5.69	50	5.27
15	8.40	33	5.59	51	5.34
16	8.423	34	5.57	52	5.46
17	7.89	35	5.49		
18	8.84	36	5.56		

In order to account for the effect of crop characteristics on ET_p, the crop coefficients for the selected crops are used and the estimates of crop-evapotranspiration (ET_{crop}) are made as follows.

$$ET_{crop} = K_c \times ET_p \qquad (8)$$

Where,

ET_{crop} = crop-evapotranspiration mm/day

ET_p = reference evapotranspiration mm/day

K_c = crop coefficient

The factors affecting the value of he crop coefficient (K_c) are mainly the crop characteristics, crop planting or sowing preiod, rate of crop development, length of growing season and climatic condition. Particularly following sowing and during the early growth stage, the frequency of rain or irrigation is important. The crop growing season has been divided in to four stages (i) initial stage, (ii) crop development stage, (iii) mid-season stage and (iv) late season or ripening stage. Table 13 presents the duration of different growth phases of selected crops in Kalahandi. As per the guidelines suggested in FAO Irrigation and drainage Paper no. 24 (Doorenbos and Pruitt, 1977), the crop coefficient curves for selected major crops like (rice, maize, greengram, blackgram, minor millet and sesamum were developed for Kalahandi area at Orissa University of Agriculture and Technology (by Sahoo, 1993). These crop coefficient curves have been utilized to obtain K_c values for different growing phases of crops (Table 14).

The sample estimates of consumptive use (ET_{crop}) for different time interval during growing period of upland rice crop (95-to-100 days crop duration varieties) are presented in Table 15. Similarly, the consumptive use (ET_{crop}) for other selected crops have been computed and given in Appendix I(a)-I(f).

Table 13: Probable periods of different growth phases of selected crops for a normal year in Kalahandi

Sl. No.	Name of Crop	Crop duration (days)	Crop growth Phases			
			initial stage	crop development stage	mid-season stage	late-season stage
1	Rice	95-100	Jun 15 to Jly 14	Jly 15 to Aug 14	Aug 14 to Sep 7	Sep 8 to Sep 25
2	Maize	110	Jly 5 to Jly 25	Jly 26 to Aug 25	Aug 26 to Sep 30	Oct 1 to Oct 25
3	Greengram (Kharif)	70	Jun 15 to Jun 30	Jly 1 to Jly 25	Jly 26 to Aug 15	Aug 16 to Aug 25
4	Greengram (pre-rabi)	65	Aug 20 to Sep 5	Sep 6 to Sep 30	Oct 1 to Oct 15	Oct 16 to Oct 25
5	Blackgram	85	Jun 25 to Jly 9	Jly 10 to Aug 15	Aug 16 to Sep 10	Sep 11 to Sep 20
6	Sesamum	90	Jun 15 to Jun 30	Jly 1 to Jly 25	Jly 26 to Aug 29	Aug 30 to Sep 15
7	Minor millet	65	Jun 20 to Jun 30	Jly 1 to Jly 15	Jly 16 to Aug 10	Aug 11 to Aug 25

Table 14: Crop coefficient (K_c) values during the growing phases of different crops in Kalahandi.

Standard Week No.	K_c Values						
	Rice	Maize	Green gram (Kharif)	Green gram (pre-Rabi)	Black gram	Sesamum	Minor millet
24	--	--	0.27	--	--	0.19	--
25	1.10	--	0.27	--	0.28	0.19	0.28
26	1.10	0.42	0.27	--	0.28	0.19	0.28
27	1.10	0.42	0.47	--	0.30	0.42	0.42
28	1.10	0.42	0.70	--	0.47	0.69	0.79
29	1.10	0.42	0.93	--	0.63	0.96	1.05
30	1.05	0.55	1.10	--	0.79	1.15	1.08
31	1.05	0.63	1.10	--	0.93	1.15	1.08
32	1.05	0.89	1.10	--	1.10	1.15	1.08
33	1.05	1.06	0.79	--	1.10	1.15	0.66
34	1.05	1.14	0.32	0.29	1.10	1.15	0.34
35	0.95	1.14	--	0.29	1.10	1.10	--
36	0.95	1.14	--	0.38	0.80	0.67	--
37	0.95	1.14	--	0.60	0.36	0.40	--
38	0.95	1.14	--	0.80	--	--	--
39		1.05	--	1.02	--	--	--
40		0.90	--	1.05	--	--	--
41		0.75	--	1.05	--	--	--
42		0.63	--	0.68	--	--	--
43		---	--	0.30	--	--	--

Table 15: Weekly crop water requirement (ET_{crop}) in mm/day during the growing period of rice crop (98 days).

Sl.No.	Standard Week No.	Duration	ET_p mm/day	K_c	ET_{crop} mm
1	25	June 18-24	6.44	1.10	49.59
2	26	June 25 - July 1	5.84	1.10	44.99
3	27	July 2 - 8	6.51	1.10	50.13
4	28	July 9 - 15	5.65	1.10	43.51
5	29	July 16 - 22	5.73	1.10	44.12
6	30	July 23 - 29	5.58	1.05	41.01
7	31	July 30 - Aug 5	5.59	1.05	41.09
8	32	Aug 6 - 12	5.69	1.05	41.82
9	33	Aug 13 - 19	5.59	1.05	41.09
10	34	Aug 20 - 26	5.57	1.05	40.94
11	35	Aug 27 - Sept 2	5.49	0.95	36.51
12	36	Sept 3 - 9	5.56	0.95	36.97
13	37	Sept 10 - 16	5.62	0.95	37.37
14	38	Sept 17 - 23	5.69	0.95	37.84
Total Water requirement for a rice crop in mm =					**586.98**

7.2 Effective Rainfall (ER)

Crop water needs can be fully or partly met by the rainfall. Rainfall for any period vary from year to year and therefore, rather than using mean rainfall data (saying roughly one year is drier, the next is wetter), a dependable level of rainfall should be selected i.e. the depth of rainfall that can be expected 3 out of the 4 years or 4 out of 5 years(Doorenbos and Pruitt, 1977). Not all the rainfall is effective as part may be lost by surface runoff, deep percolation and evaporation etc. With a dry soil surface and little or poor vegetative cover rain up to 8 mm/day may all be lost by evaporation; rains of 25 to 30 mm may be only 60% effective with a low percentage of vegetative cover (USDA, 1969; Doorenbos and Pruitt, 1977; Sahoo, 1993). In the present study, the monthly rainfall at 80% probability level has been taken as dependable rainfall. As per the guidelines suggested by U.S. Department of Agriculture,(1969), monthly effective rainfall has been computed using evapotranspiration/precipitation ratio method (*table 34* in FAO Paper No. 24, by Doorenbos and Pruitt, 1977). Effective rainfall during the probable duration of critical dry spells (CDS) for differen blocks in Kalahandi has been estimated using interpolation techniquet. These estimates of effective rainfall are presented in Table 16.

Table 16: Effective rainfall during three critical dry spells (CDS) in different blocks of Kalahandi

Sl. No.	Name of the block	Duration of CDS			Effective Rainfall during critical dry spell (mm)		
		Ist CDS	IInd CDS	IIIrd CDS	Ist CDS	IInd CDS	IIIrd CDS
1	Bhawanipatna	14	16	22	45.50	23.00	24.00
2	Kesinga	16	15	19	46.00	43.00	41.00
3	Lanjigarh	15	17	21	35.00	24.00	38.00
4	Karlamunda	19	20	16	25.50	32.00	37.00
5	Narla	16	18	17	34.00	31.50	29.00
6	M.Rampur	18	21	22	41.00	46.00	28.00
7	Th.Rampur	13	14	14	50.00	30.00	47.00
8	Dharamgarh	21	15	18	41.00	28.00	22.00
9	Junagarh	17	18	15	43.00	32.00	28.00
10	Jaipatna	16	22	15	33.00	36.00	21.00
11	Golamunda	21	15	17	52.00	53.00	34.00
12	Kalampur	15	16	16	28.00	35.00	30.00
13	Koksara	14	18	20	36.00	34.00	38.00

7.3 Irrigation requirement (IR)

The crop failure in kharif season, normally, happen due to water stress during critical dry spells. The crop water requirement (ET_{crop}) for first three critical dry spell has been estimated as given in Table 17. The irrigation requirement (IR) of crop has been obtained as the difference between crop water requirement (ET_{crop}) and the effective rainfall. The irrigation requirements of selected crops have been estimated for effective critical dry spell durations and the results are presented in Table 18.

$$IR = ET_{crop} - ER \qquad (9)$$

For appropriate planning of a supplemental irrigation (specially for Kharif crops), it is important to have careful considerations of crop variety and its critical stages, analysis of critical dry spells and availability of stored water etc. A decision on the timing of a supplemental irrigation to Kharif crop is difficult to take due to unpredictable occurrence of rain. If irrigation is provided at critical stages associated with higher probability of drought, a heavy rain during or at the end of irrigation may drastically reduce the beneficial effects of applied water. Hence irrigation to kharif crop at pre-decided times may not lead to achievement of full benefit of applied water. It will be prudent to wait for the dry spell to enter into the critical stage of crop growth and start irrigation. This irrigation should be completed in as short a time as possible preferably in 7 to 10 days. The full benefit of applied water can only be obtained if the dry spell continues upto at least one week after irrigation (Verma and Sarma,1989). However, taking a decision for supplemental irrigation in the post rainy season period is quite simple because of very low probability of wet days in October and November. In areas of low and medium moisture retentive soils, pre-sowing irrigation to wheat becomes essential. A pre-sowing irrigation can be skipped only if there is rain of at least 20 mm during the week preceding sowing. There is only 4.1 per cent probability of occurrence of such condition.

Table 17 : Water requirement (ET_{crop}) for selected major crops during effective critical dry spells in different blocks in Kalahandi

Sl. No.	Name of the block	Effective CDS	Water requirement (ET_{crop}), mm						
			Rice	Maize	Greengram (kharif)	Greengram (pre-rabi)	Blackgram	Sesamum	Minor millet
1	Bhawanipatna	1st	87.63	33.46	64.99	--	43.86	65.80	73.36
		2nd	94.61	71.95	95.69	--	92.24	103.67	88.96
		3rd	117.74	142.23	--	38.59	79.87	51.70	--
2	Kesinga	1st	[illegible]06.25	38.16	59.77	--	39.48	54.43	59.30
		2nd	88.76	83.28	80.29	--	99.11	97.22	70.74
		3rd	100.18	111.98	8.90*	31.00	96.36	92.67	--
3	Lanjigarh	1st	99.94	38.68	54.44	--	48.24	51.93	56.40
		2nd	100.52	77.89	100.11	--	86.36	106.09	92.66
		3rd	118.54	124.65	39.00*	23.91	121.50	124.41	--
4	Karlamunda	1st	125.16	51.05	75.76	--	50.31	73.93	80.48
		2nd	117.95	76.45	112.53	--	104.81	129.19	121.32
		3rd	84.16	92.96	8.90*	24.65	88.34	86.87	--
5	Narla	1st	99.35	39.58	82.96	--	52.68	78.64	85.41
		2nd	106.30	102.69	81.84	--	111.37	116.45	76.41
		3rd	93.29	99.30	--	22.54	87.44	85.24	--
6	M.Rampur	1st	117.08	45.39	70.43	--	46.25	68.43	74.46
		2nd	124.00	101.58	117.76	--	80.21	135.81	111.1
		3rd	123.85	126.50	--	38.59	102.40	97.17	--

TABLE : 17

Contd .....

7	Th.Rampur	1st	81.77	30.40	59.66	--	40.25	61.90	67.34
		2nd	82.03	85.93	43.39	--	77.46	79.41	39.06
		3rd	75.21	90.26	--	55.46	45.30	23.20	--
8	Dharamgarh	1st	137.76	52.60	86.41	--	57.53	84.94	92.50
		2nd	88.78	66.03	91.27	--	86.34	84.27	86.62
		3rd	98.58	106.41	34.55*	16.53*	105.69	94.33	--
9	Junagarh	1st	103.21	48.83	83.41	--	57.09	85.09	91.48
		2nd	106.30	102.33	81.89	--	111.37	116.42	76.41
		3rd	78.82	86.62	--	22.54	81.91	83.14	--
10	Jaipatna	1st	99.35	39.58	92.57	--	52.67	78.64	85.42
		2nd	129.07	128.10	87.20	--	129.94	140.59	82.08
		3rd	78.82	86.62	--	22.54	80.23	80.46	--
11	Golamunda	1st	137.76	52.60	86.41	--	57.53	84.94	92.50
		2nd	88.08	51.15	104.79	--	73.52	96.46	88.97
		3rd	93.30	99.30	--	26.76	86.36	87.92	--
12	Kalampur	1st	99.94	38.16	54.44	--	35.87	63.15	56.40
		2nd	94.61	89.62	78.28	--	99.11	103.63	72.63
		3rd	85.15	102.20	--	47.49	45.30	41.82	--
13	Koksara	1st	87.63	33.46	64.99	--	43.86	65.80	73.43
		2nd	106.39	83.82	102.80	--	104.81	104.67	100.04
		3rd	109.14	118.24	--	33.11	102.47	99.08	--

Note: *- water requirement estimated for the part of CDS duration

Table 18: Irrigation requirement (IR) for selected major crops during effective critical dry spells in different blocks in Kalahandi

Sl. No.	Name of the block	Irrigation requirement (IR) during effective cirtical dry spells mm						
		Rice	Maize	Greengram (kharif)	Greengram (pre-rabi)	Blackgram	Sesamum	Minor millet
1	Bhawanipatna	207.48	167.18	92.18	14.59	125.11	128.67	75.32
2	Kesinga	165.19	111.26	51.06	--	111.47	114.32	43.04
3	Lanjigarh	222.0	144.22	95.55	--	159.10	185.43	62.06
4	Karlamunda	232.77	125.96	130.79	--	148.96	195.491	114.80
5	Narla	204.44	147.07	99.30	--	156.99	85.83	74.82
6	M.Rampur	249.93	158.47	101.19	10.59	113.86	206.91	98.56
7	Th.Rampur	112.01	99.19	23.05	8.46	47.46	61.31	26.40
8	Dharamgarh	214.36	134.04	121.23	--	158.56	172.54	110.12
9	Junagarh	185.33	134.78	90.30	1.54	147.37	181.65	92.89
10	Jaipatna	217.24	164.30	110.77	--	172.84	209.69	98.50
11	Golamunda	180.14	65.90	86.20	--	78.41	130.32	76.47
12	Kalampur	186.70	136.98	69.72	17.49	87.28	115.60	66.03
13	Koksara	195.16	130.06	93.79	--	143.14	161.55	103.47

8.0 A BRIEF REVIEW OF REPORTED NATURAL CALAMITIES IN KALAHANDI IN LAST THIRTY TWO YEARS:

(based on discussions with the officials, local peoples and few available official documents)

The Kalahandi district in Orissa has had no respite from droughts, floods and cyclones for last few decades. Due to scanty rainfall in the months of June, August, and October in 1965, the kharif paddy crop was very severely affected in all the blocks of the district (Department of Revenue, 1976) . Also the other districts of Orissa namely Balangir, Koraput Surendragarh, Sambalpur and Phulbani had been badly affected by this drought. The impact of which continued to be felt during 1966-67 also. Again during 1966, drought conditions had developed due to insufficient rainfall in the months of August, September and October.

During the year 1967 there was heavy rainfall in the months of July, August and September resulting in a flood in the Mahanadi system, affecting the district of Kalahandi. Again during the year 1968 a severe cyclone and heavy rainfall caused flood conditions. In the year 1969 two spells of heavy rainfall in the months of July and August lead to flood situation twice. Also the flood in Mahanadi system partially affected the district in the years 1970 and 1971. In 1972 there was scanty rainfall during June and October, leading to failure of agricultural crops again followed by a flood in the August-September. Due to scanty and erratic rainfall in 1973, drought had taken grip of a sizable area of the district followed by a more severe drought affecting entire district in 1974. The drought of 1974 caused severe losses to the agricultural crops in all the blocks of the district. Long dry spells prevailed during early part monsoon season which badly affected the kharif operation. With the failure of rains in the Kalahandi and also in many other districts of the state of Orissa, almost all the water resources like ponds, tanks , streams, wells etc. had either dried up or the water level had gone down abnormally. The availability of water had become so scare that there was mounting demand even for drinking water supply. However, there was few events of intense showers during late-monsoon season and caused partial flood also. These showers had helped to some extent for Rabi crop operations. But, after these showers, the drought situation worsen and had tended towards acute severity (Department of Revenue, 1974). Water stress conditions prevailed during early part of the monsoon season in 1975 due to delayed arrival of monsoon. There was heavy rainfall in late July and first part of August and caused flood. In the year 1976 the monsoon started late and rainfall in the month of June was only about 40% of the normal. The preliminary agricultural operations were therefore delayed. Rainfall was rather concentrated in July-August and brought in two phases of floods in the 'Tel' and 'Hati' rivers system (Department of Revenue, 1976). The years 1977 and 1978 were wet years and relatively good from agriculture point of view. During 1979, rainfall was inadequate again and caused severe water stress in some of the blocks of the Kalahandi district. Rainfall was good in the year 1980 and the paddy crop was least affected from dry spells. The mixed conditions of partial drought prevailed in few blocks of the district during the years 1981, 1982 and 1983. Total rainfall was again enough during the years 1984 and 1985. A severe and wide spread drought occurred due to failure of monsoon during the year 1987. The kharif crops had experienced severe damage due to deficit rainfall in the months of June(-83%), July(-49%), August(-69%) and September (-43%). During 1988 and 1989, rainfall was again below normal in many blocks of Kalahandi, but the intensity of drought was moderate. In the years 1990, 1991, 1992 and 1993 the total amount of annual rainfall was more or less satisfactory (in relative terms) in many blocks of the district except few long dry spells of water stress and events of partial flood during 1990 and 1992. Most of the blocks had received enough rainfall (above normal) causing partial flood during the 1994 and 1995. Monsoon started very late during 1996 and due to scanty and very erratic monsoon rains throughout, the agricultural crops faced severe damages . Again a delayed arrival of subsequent weak monsoon during 1997 worsen the situation and forced the people of Kalahandi to face severe drought hardship.

Thus, there has been recurring occurrence of natural calamities (droughts and floods) one after the other and the cumulative effect of all these had been acute distress for the people of Kalahandi.

In view of the above reported episodes of natural calamities, it can be stated that the drought and flood cycle recur on an average after every 3-4 years in Kalahandi district. It is clear from the above descriptions that in a flood or wet year also, the agricultural system had experienced drought in different parts due to water stress caused by intervening long dry spells during crop growing season.

9.0 DISCUSSIONS

1. **General:** Frequent failure of major agricultural crops had been reported in Kalahandi due to water stress in the years 1965-66, 1974, 1977,1979, 1987, 1989, 1990, 1994, 1996-97. The 1965-66 drought was reported to be worst, which was responsible for the loss of nearly 3/4th of total production. The drought of 1996-97 was reported to be comparable to that of the 1965-66.

Mean annual rainfall of the district Kalahandi (for district as a whole) amounts to be in the order of about 1378.2 mm. In general, it may be considered as nearly enough (if evenly distributed) to achieve atleast a moderate agricultural output of kharif crops even under rainfed cultivation. Also, this amount of mean annual in totality seems be relatively better as compare to that of the other drought prone districts in the country. However, uneven distribution of rainfall and under development of available water potential forced the people of Kalahandi to face severe drought hardship time to time.

2. **Assessment of drought years**: Annual rainfall departure analysis for the period from 1966-96 (Fig. 4a-4m) shows that the deficiency of annual rainfall varied from 0-62% in the different blocks of Kalahandi. There had been many occasions (years), when one block had received more than its normal rainfall and during the same year another block had experienced severe rainfall deficiency. Out of the above 31 years of rainfall records analysed for, there had been about 10 years during which at least 1/3 number of blocks of Kalahandi were affected by drought. The analysis indicate that more than 2/3 numbers of blocks had been affected by drought in the years 1974, 1987, 1988 and 1996. Also the seasonal rainfall analysis indicate that the years 1974, 1987, 1988 and 1996 had been the bad monsoon years. In these years the monsoon rainfall was deficient by 40-66% in more than 1/2 number of blocks in Kalahandi. Magnitudes of seasonal rainfall deficiencies in different blocks are shown in Fig. 5a-5m). The summary of identified drought years for different blocks is given in Table 7.

3. **Distribution of annual rainfall**: The mean annual rainfall in different blocks of Kalahandi varies from 1111.2 mm at Golamunda to 2670.2 mm at Th. Rampur (See *column 2* in Table 7). About 90% of mean annual rainfall is received between 3rd week of June to the 4th week of September. The probability distribution analysis of annual rainfall (Fig. 6a-6m) shows that the probability of occurrence of rainfall equivalent 75% of normal in different blocks of the district varies from 67% to 87% (See Table 8). The average value of probability of occurrence of rainfall equivalent 75% of normal, for Kalahandi district as a whole, is estimated in the order of about 79.5%. Which indicates that the area has good overall chances of receiving a moderate quantity of total annual rainfall for crop survival in kharif season . However, this area had been suffering from frequent failure of crops and severe water scarcity conditions. Thus, from the above points, it is quite understandable that the distribution of rainfall in time and space, and intervening dry spells during cropping season are responsible for most crop loss events in Kalahandi.

4. **Cropping System:** The majority of the formers in Kalahandi belong to illiterate group of people and they believe on traditional type of cropping pattern. The formers are used to grow long duration (95 to 110 days) paddy crops during monsoon season. Due to inherent characteristic of the rooting system, paddy is incapable of efficiently using moisture from deeper layers of soil and therefore paddy is so extraordinarily susceptible to short drought period of 10-15 days. According to a study for Chattisgarh region it was found that a dry spell of 15 days during monsoon season is sufficient enough to reduce rainfed rice production by more than even 40%. Often, the monsoon rainfall in the Kalahandi is either inadequate or erratic with relatively long intervening dry spells and cause frequent losses to rice production. Thus, the traditional cropping system also, plays its role to some extent, in advancing a mild-drought condition towards severe one. Therefore, some changes in cropping pattern are necessary to reduce the extent of agricultural losses during drought.

5. **Ground Water Assessment:** Based on data for the year 1992-93, the estimates made by the Central Ground Water Board, indicate that the region is having adequate ground water resource potential, but a significant quantity of this resource is unutilized. Only 8% of the total replenishable ground water is being used for irrigation at present. The estimates of ground water balance are summarised below:

	(thousand m^3/yr)
1. Total replenishable ground water resource	582493
2. Provision for domestic & industrial uses	87377
3. Utilizable ground water for irrigation	495116
4. Net ground water draft	43245
5. Balance ground water resource	451871
Percentage of balance ground water available for irrigation	91.26%

(The blockwise details are given in Table 6),

The above estimates witness that there is enough scope for development of ground water resources both for irrigation as well as for domestic purposes.

The plots of depth to water table for last 10 years (1988-1997) shows that the ground water table had not depleted much from the average position even during drought years. The plots of depth to water table against time, for selected wells falling in various blocks in the Kalahandi, are shown in Fig. 7a-7n. A comparison of ground water table depths between 1995 (an excess rainfall year) and 1996 (a drought year) showed that the water level has not gone down much during drought years. In other words, the water table was more or less static in all the thirteen blocks during the severe drought year of 1996-97. These plots of ground water regime are witnessing to believe that the ground water may provide a sustainable source of water in this area. According to information furnished by State Ground Water Board, the underground water bearing layers-the phreatic aquifer is quite extensive and fairly thick to facilitate storage and movement of water. Thus, there is a vast scope for development and exploitation of ground water. A planned tapping of ground water can not only meet the domestic requirement but also may contribute for supplemental surface irrigation demands during drought conditions.

6. Effective monsoon and critical dry spells: The definition and methodology described in *section 6.0* has been used to identify the dates of onset and withdrawal of effective monsoon and critical dry spells. Blockwise results on mean and median dates of onset and withdrawal of effective monsoon are presented in Table 9 and 10 respectively. The mean duration and mean period of beginning (probable week of commencement) for first three critical dry spells during monsoon season are shown in Table 11.

From Table 9, it may be observed that the mean date of onset of effective monsoon (EMO) in different blocks of Kalahandi varies from June 14th at Th. Rampur to 21st at Karlamunda with an average standard deviation of 15.7 days (ranging from 13 to 22 days). This shows that there is a lot of variation in the dates of EMO in different years. The knowledge of mean date of arrival of monsoon is important to the farmers to be prepared for primary tillage operations and timely seed bed preparation. This information is very useful to complete the sowing in time and to take maximum advantage of monsoon rains. It is also observed during the analysis that the earliest probable date of EMO in different blocks based on the mean varies from May 28th Dharamgarh to June 8th at Karlamunda with a probability of 0.68 and the latest date varies from June 29th at Th. Rampur to July 12th at Kesinga. The median dated of EMO in different blocks of Kalahandi Varies from June 12th to 19th with quartile deviation (semi inter-quartile range) varying from 6 to 11 days. The average length of monsoon period (based on mean) in different blocks varies from 91-102 days. Therefore, under rainfed condition in Kalahandi, farmer should adopt only such paddy varieties whose crop growth duration is not more than 100 days.

The average number of critical dry spells (CDS) during monsoon season was observed only two CDS per year. However, in some years there were more than two CDS. In 13 out of 31 years of rainfall records, there were more than two CDS. It was also observed that number of CDS in different blocks was not same during a year. Using the definition described in *section 6.2*, the dates of commencement and duration of first, second and third CDS per year in different block were identified for the total period of records (31 years). Based on the average dates of beginning of different CDS , the corresponding weeks of commencement of Ist IInd and IIrd CDS were identified and the average duration of these CDS were computed for different blocks. The blockwise results on the probable week of commencement and average duration of first three CDS are shown in Table 11. These predictions about CDS are of great practical value in selecting suitable crops and their varieties to achieve required level of drought tolerance or to plan for supplemental irrigation at appropriate times of crop need. In order to prevent the crops from moisture stress and to achieve better production, it is essential that the provision for supplemental irrigation are made for critical dry spell period.

7. Crop water requirement: The crop evapotranspiration (ET_{crop}) has been estimated using the methodology described in *section 7.2*. Table 15 presents the sample estimates of water requirement (ET_{crop}) for rice crop. Similar estimates for other selected major crops are shown in presented in Appendix I(a)-to-I(f). These estimates of water requirement of the crops viz. upland rice, maize, greengram (kharif), greengram (pre-rabi), blackgram, sesamum and minor millet are summarised below (in Table 19).
It was found from the above estimates that the amount of water required to grow the crops of rice (597 mm) and maize (551 mm), were almost twice of that of the greengram (kharif) and greengram (pre-rabi)(i.e. 297 mm and 269 mm respectively). Therefore, in case of delayed onset of monsoon the crops of greengram (kharif) and greengram (pre-rabi) may be more profitable as compare to the crops of rice and maize. Since, the rice crop is very sensitive to water stress and the intervening critical dry spells may cause great loss to it even during a normal year. Therefore, the provisions of supplemental irrigation for rice crop are must.

Table 19: Water Requirement for different crops in Kalahandi

Sl. No.	Crop	Crop duration and sowing period	Water Requirement
1	Rice	95-100 (June 18)	587 mm
2	Maize	110 (July 5)	551 mm
3	Greengram (kharif)	70 (June 15)	297 mm
4	Greemgram (pre-rabi)	65 (August 20)	269 mm
5	Blackgram	85 (June 25)	358 mm
6	Sesamum	90 (June 15)	413 mm
7	Minor millet	65 (June 20)	283 mm

8. Irrigation Requirement: In order to compute irrigation requirement of a crop, it is important to have realistic estimates of effective rainfall for the period for which supplemental irrigation is needed. The effective rainfall for the first three critical dry spell periods during monsoon were computed using the methodology described in the *Section* 7.2 and the results are shown in Table 16. The water requirements as obtained above (Table 17) were compared with effective rainfall during critical dry spells (Table 16) for recommendation of quantum of supplemental irrigation for different crops. The irrigation requirements (IR) of selected crops were obtained as the difference between crop water requirement (ET_{crop}) and the effective rainfall for effective critical dry spell durations as shown in Appendix-II. Also, the blockwise results of estimated irrigation requirements (IR) are presented in Table 18.

From Table 18, it can be observed that for the principal rice crop, the total irrigation requirement during first three critical dry spells (CDS) varied from a lowest value of 112.01 mm at Th.Rampur to a highest value of 249.93 mm at M.Rampur. It can also be seen that the maize crop has maximum irrigation requirement during the third effective CDS (varied from 118 mm highest at Bhawanipatna to 43.26 mm lowest at

Th.Rampur (See Appendix-II). It is also clear from the Table 18 that during Ist CDS, maize crop needs no irrigation in Bhawanipatna, Kesinga, Th.Rampur, Koksara and Golamunda. However, very little irrigation is required for maize during Ist effective CDS in Langigarh, Narla, M.Rampur, Junagarh, Jaipatna, Kalampur, Dharamgarh and Karlamunda (i.e. 3.68, 5.50, 4.39, 5.83, 6.58, 10.16, 10.60, 25.55 mm respectively). The greengram (kharif) and minor millet crops need irrigation during first two CDS only. The greengram (pre-rabi) needs only one irrigation (in very small amount) during 3rd CDS in Junagarh, Th.Rampur, M.Rampur, Bhawanipatna and Kalampur (1.54, 8.46, 10.59, 14,59 and 17.49 mm respectively). In order to insure full benefit of atleast one-season crops in this region, the Table 17 and 18 can be referred as guidelines for the planning of supplemental irrigation.

Fig. 4a-4m: Percentage annual rainfall departure in different blocks in Kalahandi

Fig. 4a: GOLMUNDA

Annual Normal =1111.2 mm

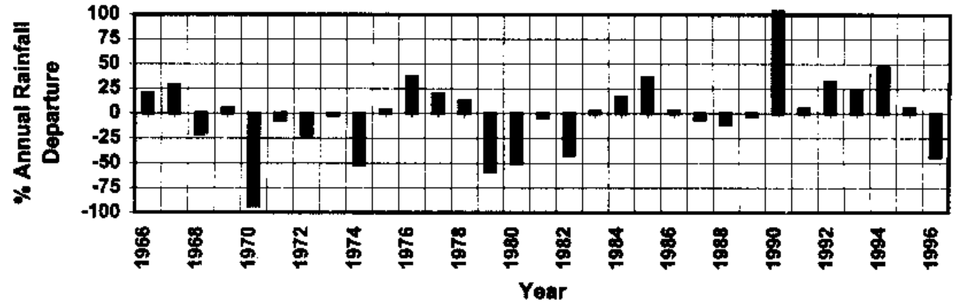


Fig. 4b: DHARMAGARH

Annual Normal =1223.7 mm

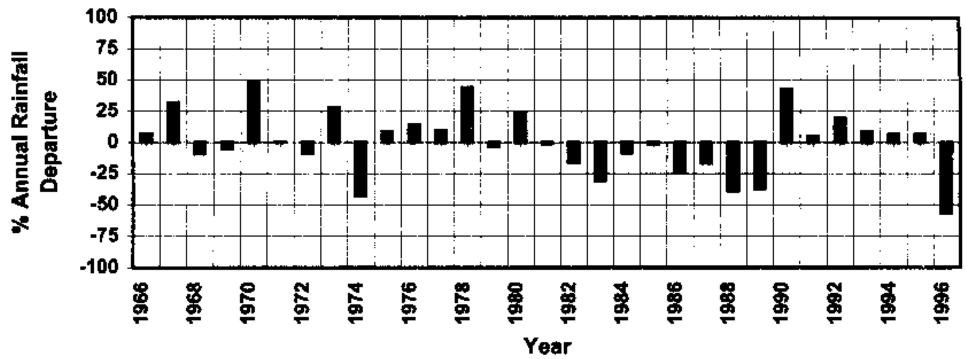


Fig. 4c: JUNAGARH

Annual Normal =1308.5 mm

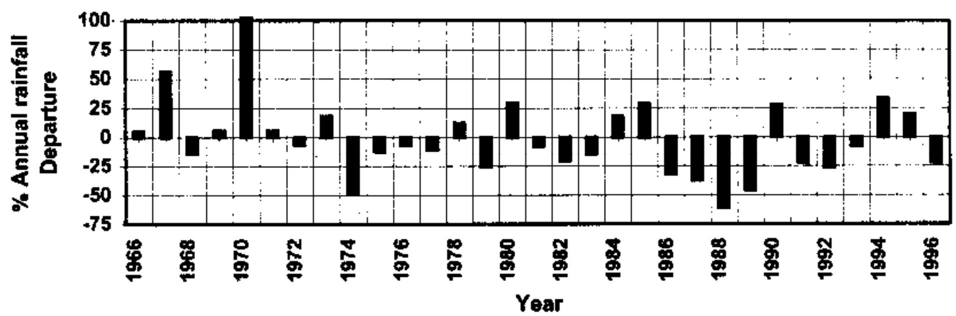


Fig. 4a-4m: continue.....

Fig. 4d: KOKSARA Annual Normal =1586.5 mm

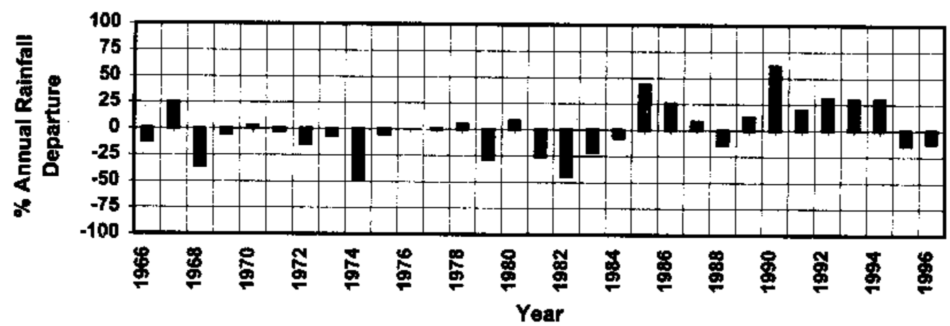


Fig. 4e: KALAMPUR Annual Normal =1554.7 mm

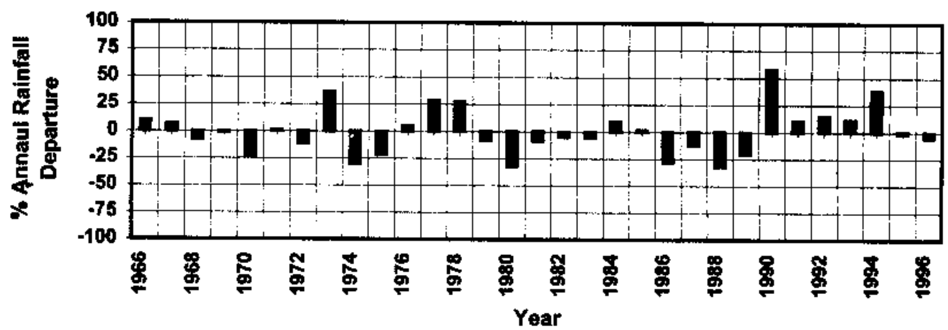


Fig. 4f: JAIPATNA Annual Normal =1272.4 mm

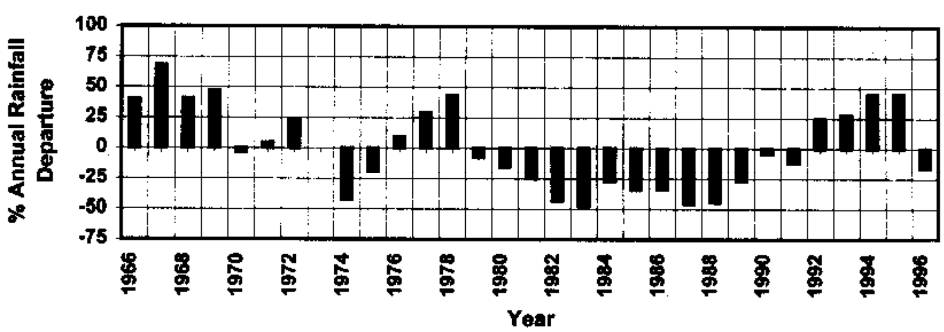


Fig. 4a-4m: continue.....

Fig. 4g: KARLAMUNDA

Annual Normal =1232.5 mm

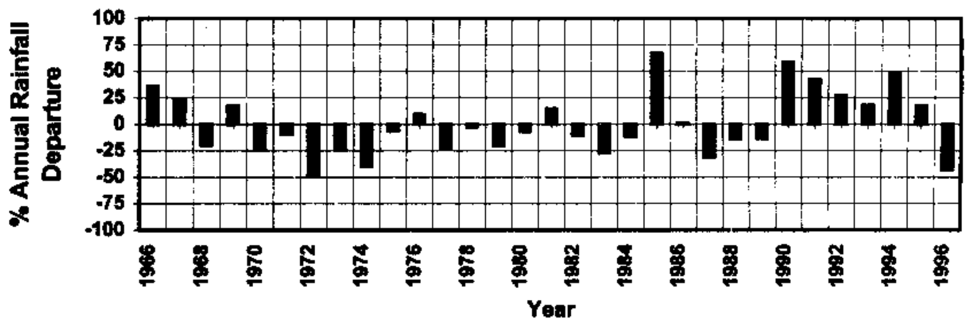


Fig. 4h: MADANPUR-RAMPUR

Annual Normal =1523.4 mm

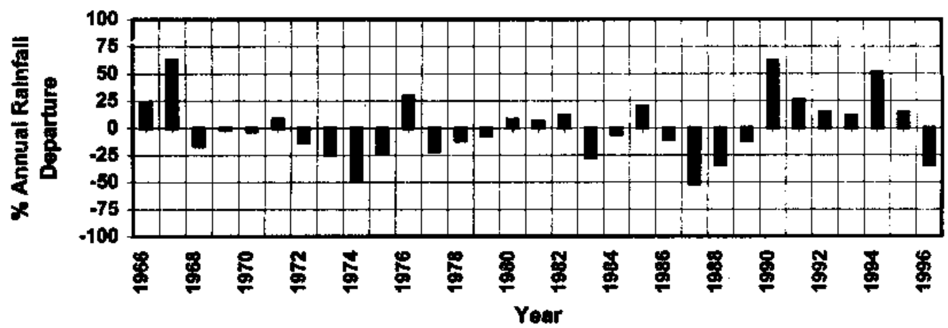


Fig. 4i: NARLA

Annual Normal =1349.8 mm

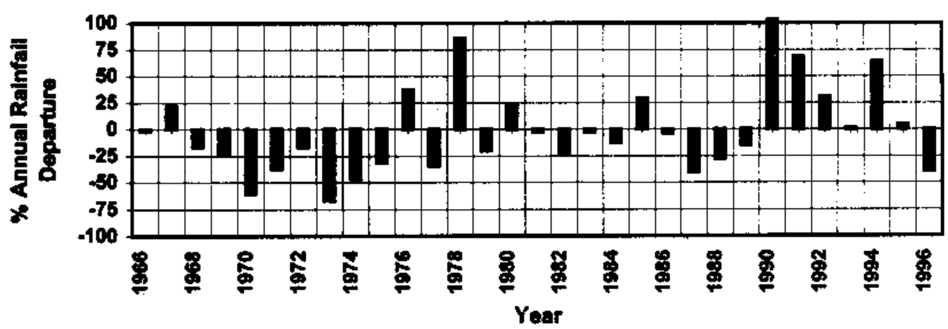


Fig. 4a-4m: continue.....

Fig. 4j: KESINGA Annual Normal =1371.0 mm

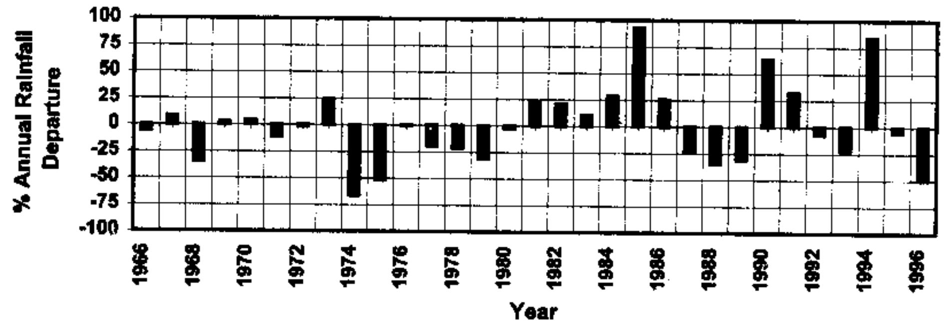


Fig. 4k: LANGIGARH Annual Normal =1185.4 mm

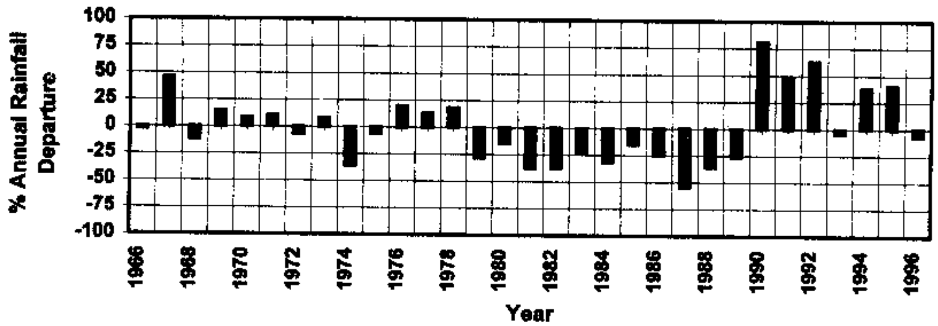


Fig. 4l: THUAMUL-RAMPUR Annual Normal =2670.2 mm

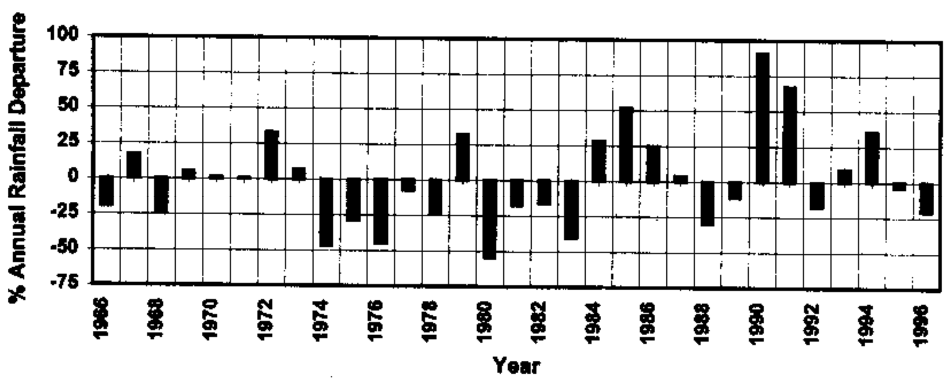


Fig. 4a-4m: continue.....

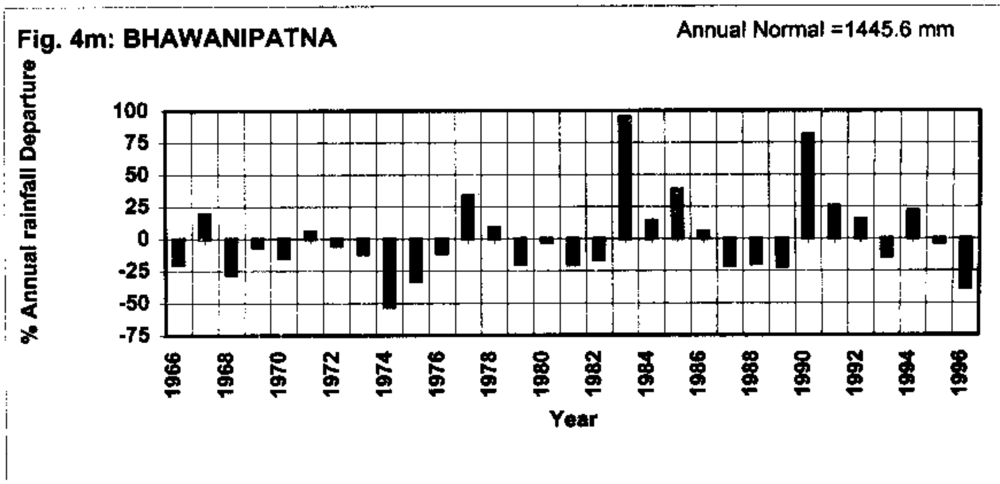
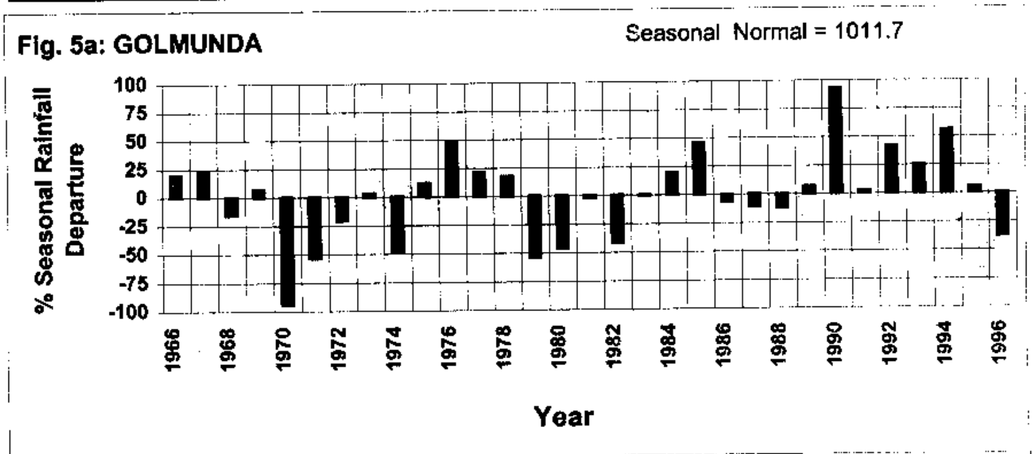
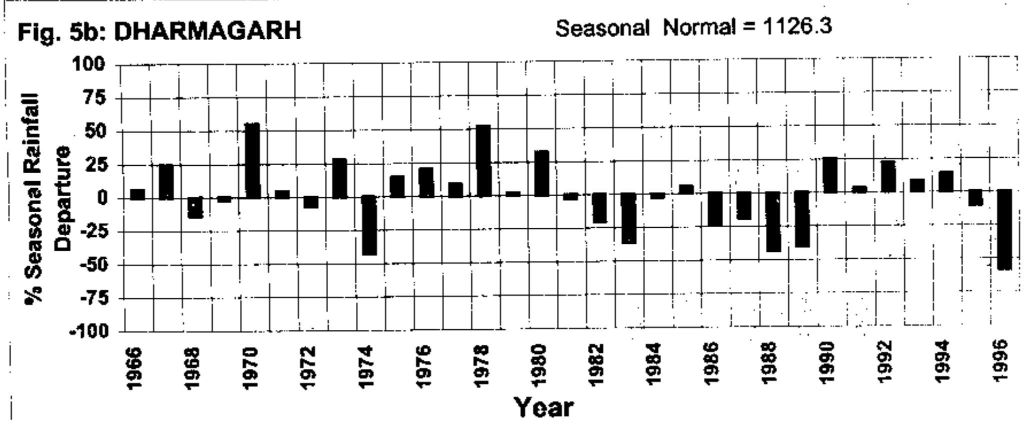


Fig. 5a-5m: Percentage seasonal rainfall departure in different blocks in Kalahandi.





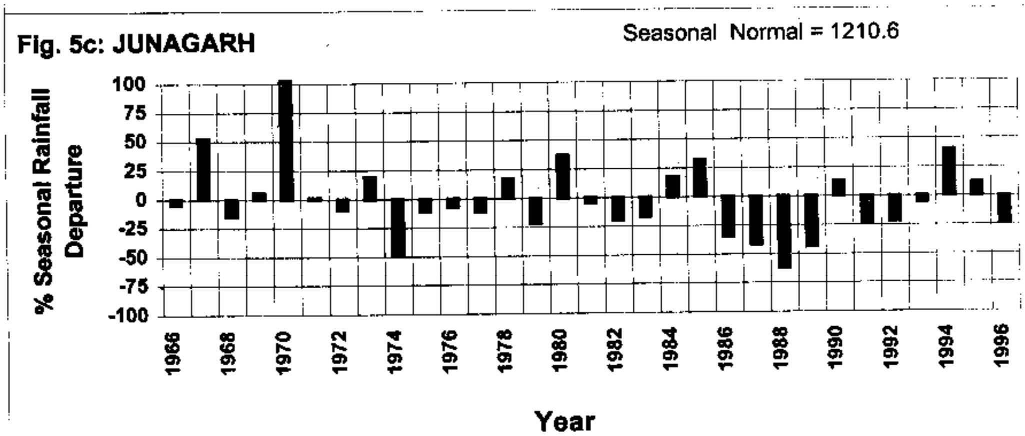


Fig. 5a-5m: continue......

Fig. 5d: KOKSARA

Seasonal Normal = 1451.1

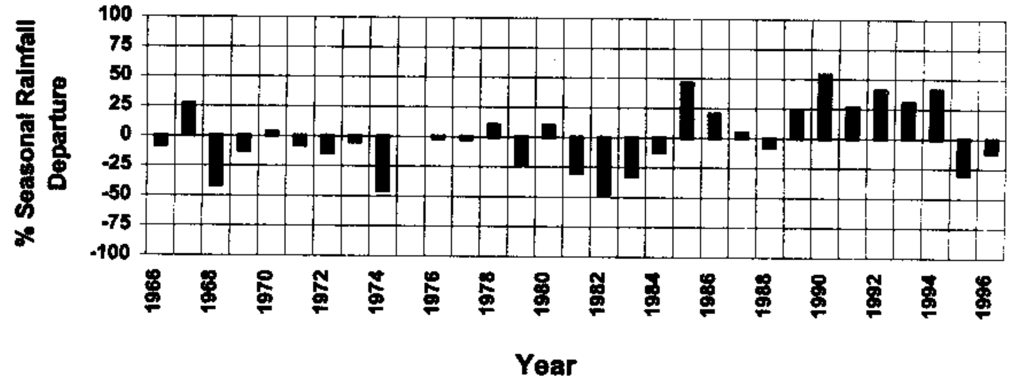


Fig. 5e: KALAMPUR

Seasonal Normal = 1434.9

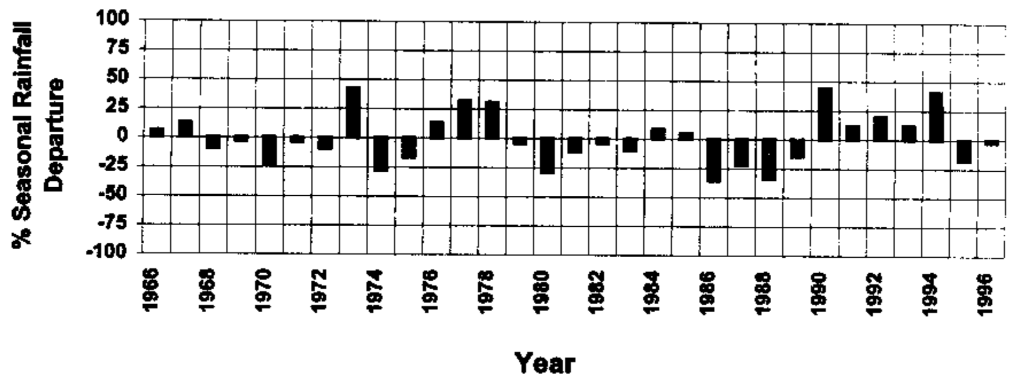


Fig. 5f: JAIPATNA

Seasonal Normal = 1148.5

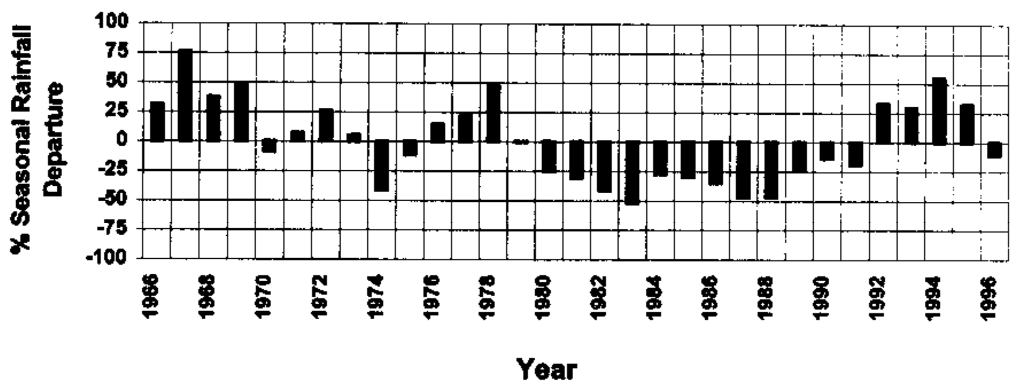


Fig. 5a-5m: continue.......

Fig. 5g: KARLAMUNDA

Seasonal Normal = 1153.2

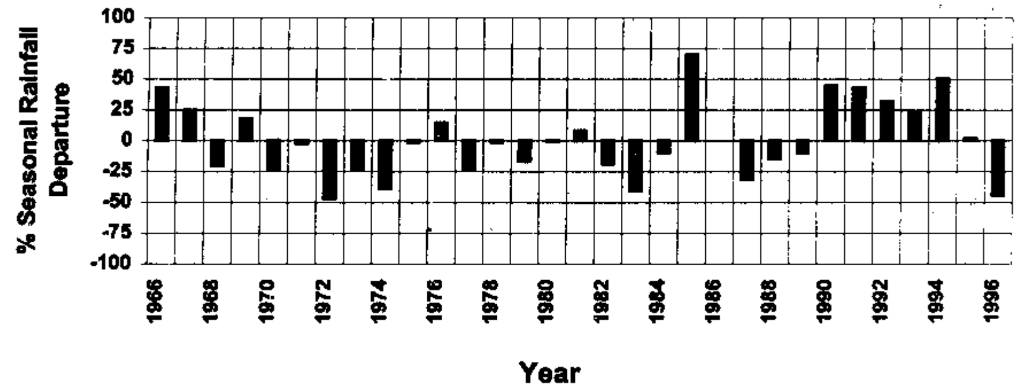


Fig. 5h: MADANPUR-RAMPUR

Seasonal Normal = 1402.6

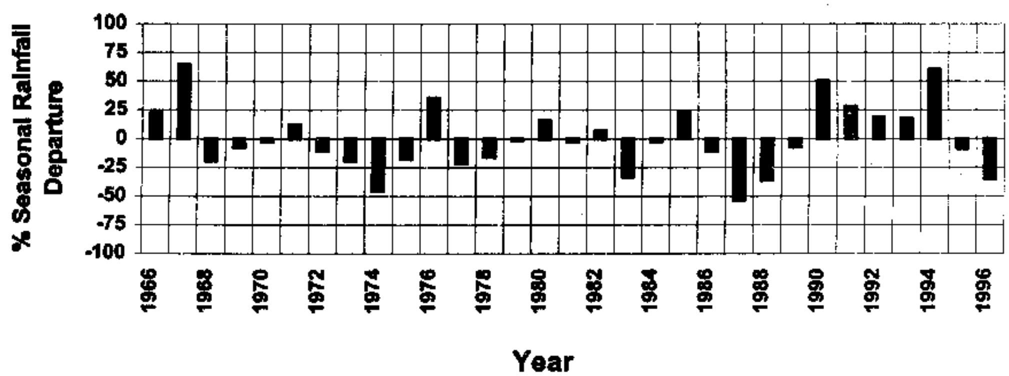


Fig. 5i: NARLA

Seasonal Normal = 1221.6

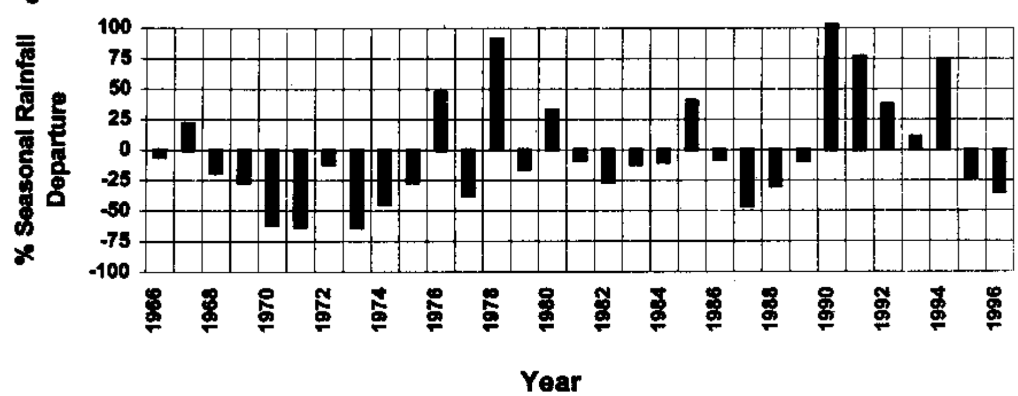
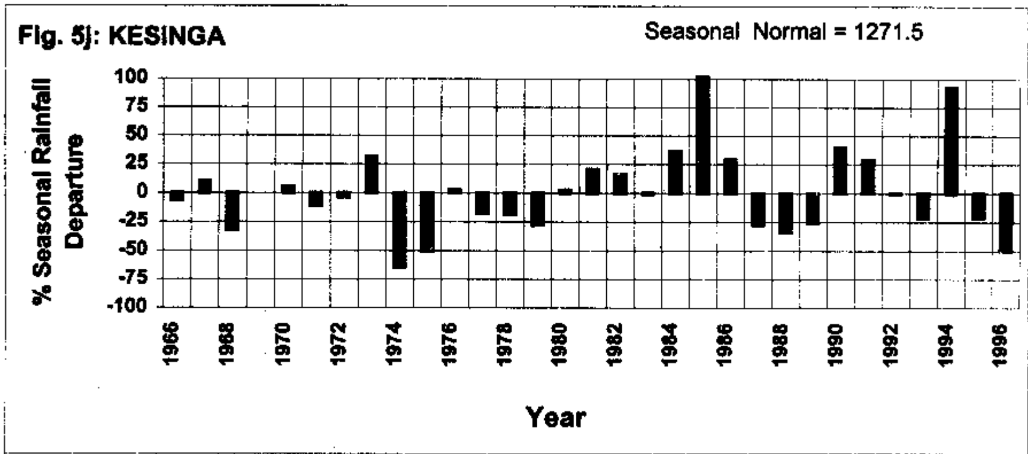
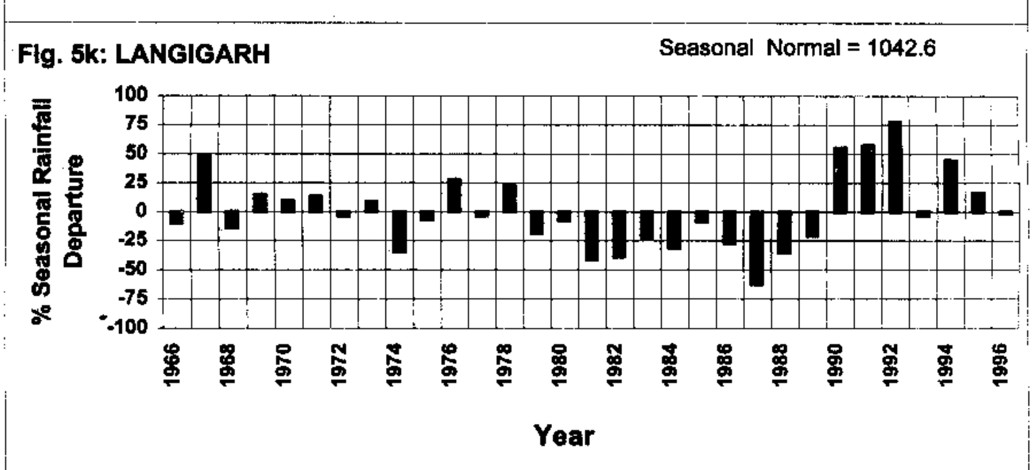
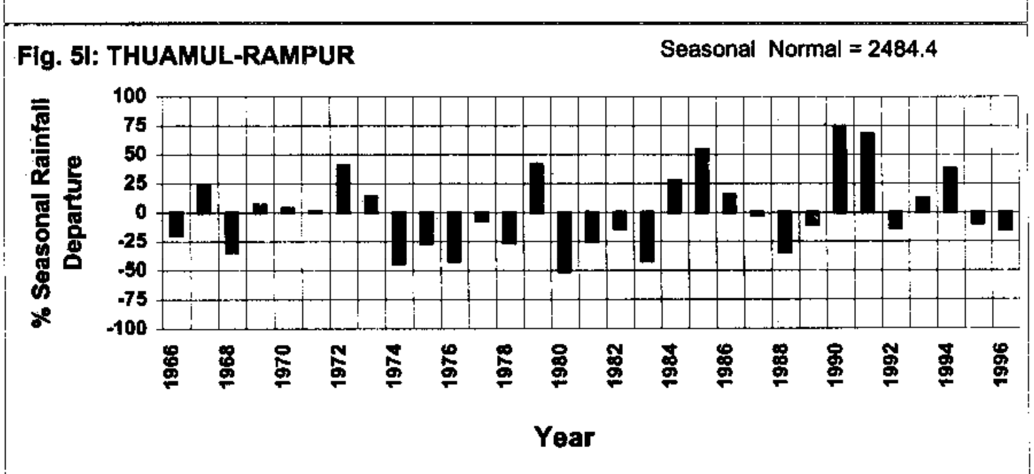


Fig. 5a-5m: continue......







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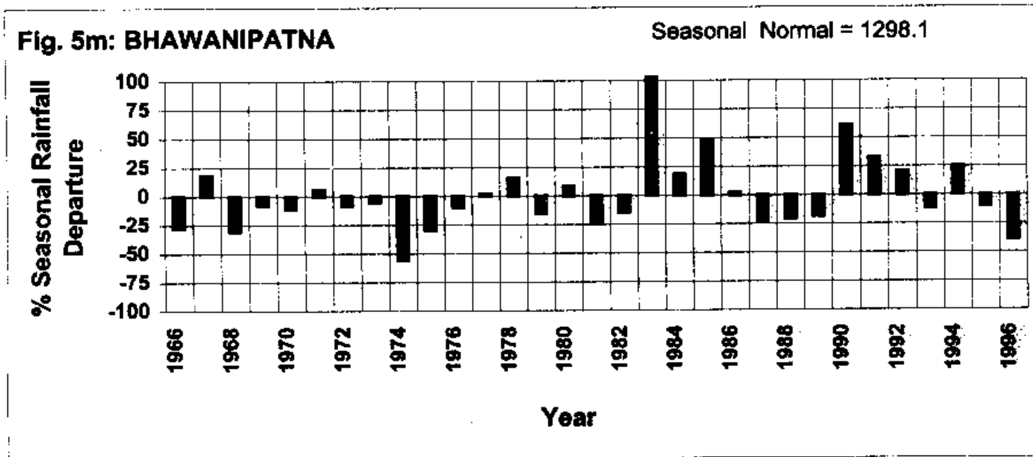


Fig. 6a-6m: Probability distribution of annual rainfall in different blocks in Kalahandi

Fig. 6a: Probability distribution of annual rainfall at Golmunda

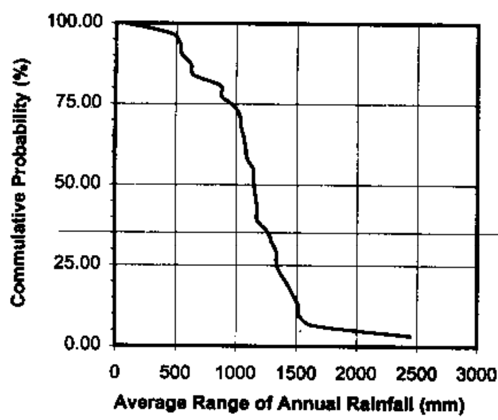


Fig. 6b: Probability distribution of annual rainfall at Dharamgarh

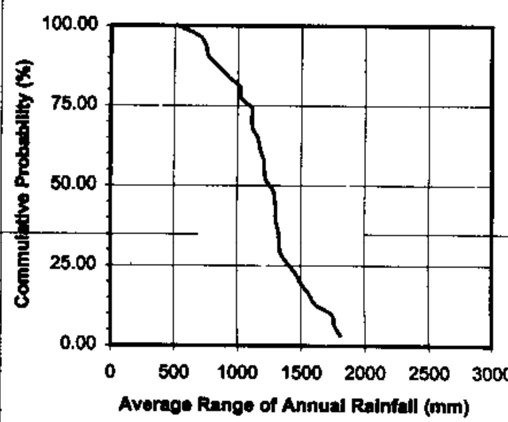


Fig. 6c: Probability distribution of annual rainfall at Junagarh

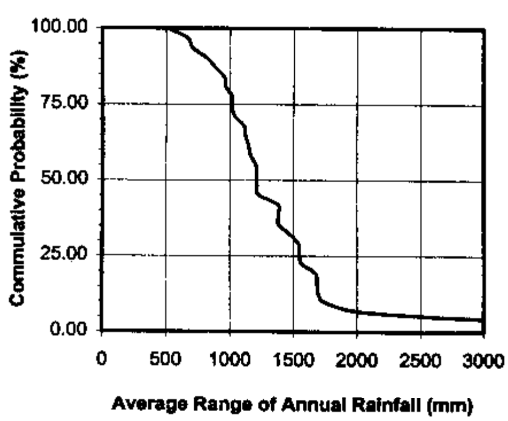


Fig. 6d: Probability distribution of annual rainfall at Koksara

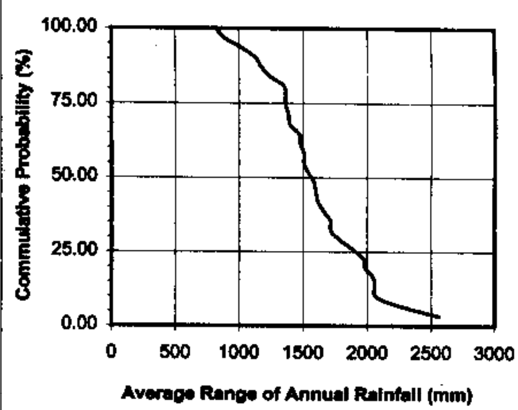


Fig. 6a-6m: continue.....

Fig. 6e: Probability distribution of annual rainfall at Kalampur

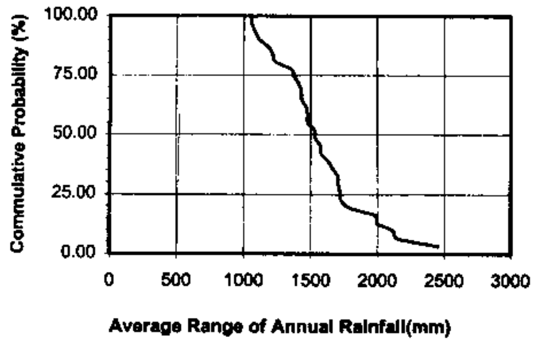


Fig. 6f: Probability distribution of annual rainfall at Jaipatna

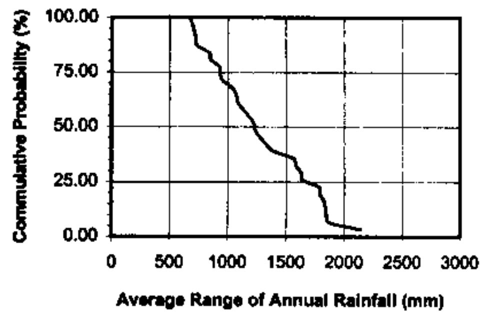


Fig. 6g: Probability distribution of annual rainfall at Karlamunda

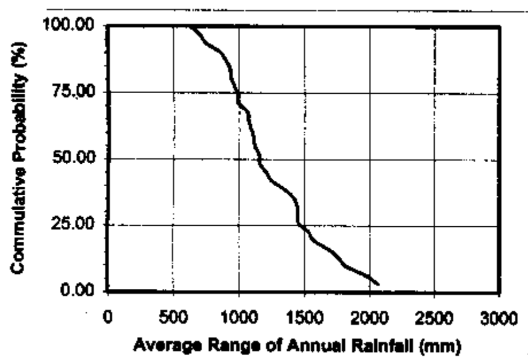


Fig. 6h: Probability distribution of annual rainfall at Madanpur-Rampur

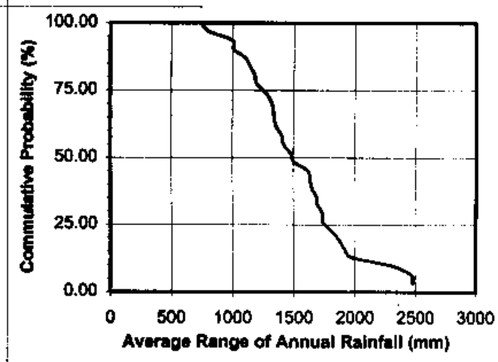


Fig. 6i: Probability distribution of annual rainfall at Narla

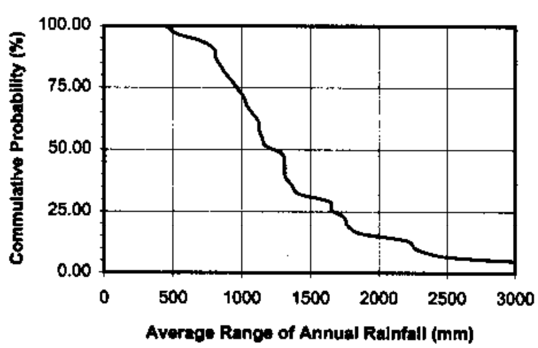


Fig. 6j: Probability distribution of annual rainfall at Kesinga

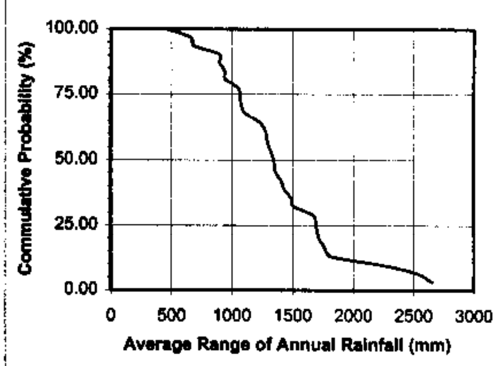


Fig. 6a-6m: continue.....

Fig. 6k: Probability distribution of annual rainfall at Langigarh

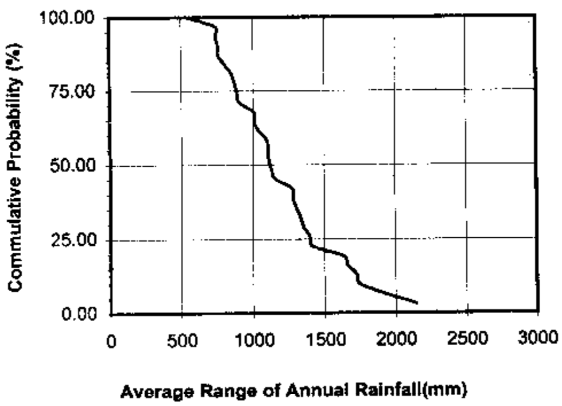


Fig. 6l: Probability distribution of annual rainfall atThuamul-Rampur

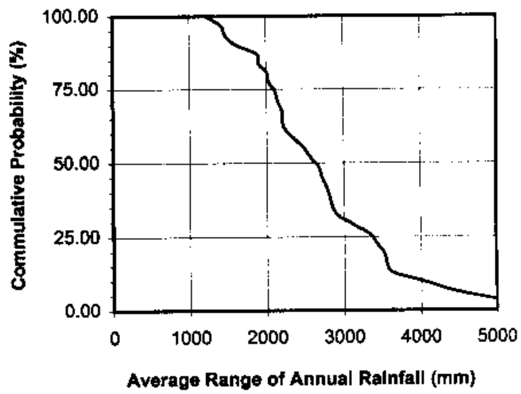


Fig. 6m: Probability distribution of annual rainfall at Bhawanipatna

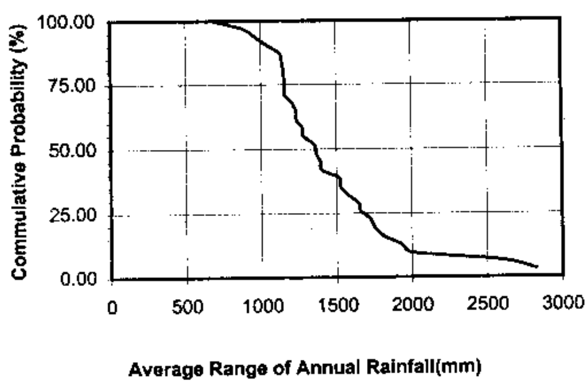


Fig.7a-7n: Groundwater table fluctuation in diffirent blocks in Kalahandi

Fig. 7a: Bhawanipatna (well-1 at Deypore)

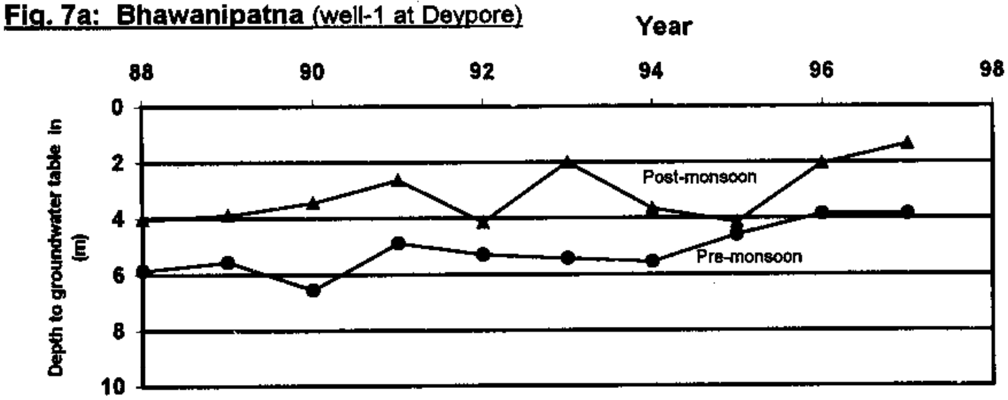


Fig. 7b: Bhawanipatna (well-2at Bhawanipatna)

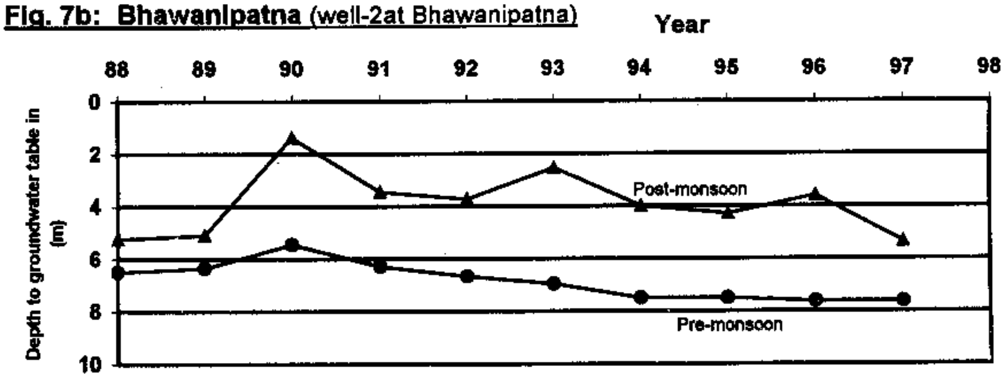


Fig. 7c: Junagarh (at Charabahal)

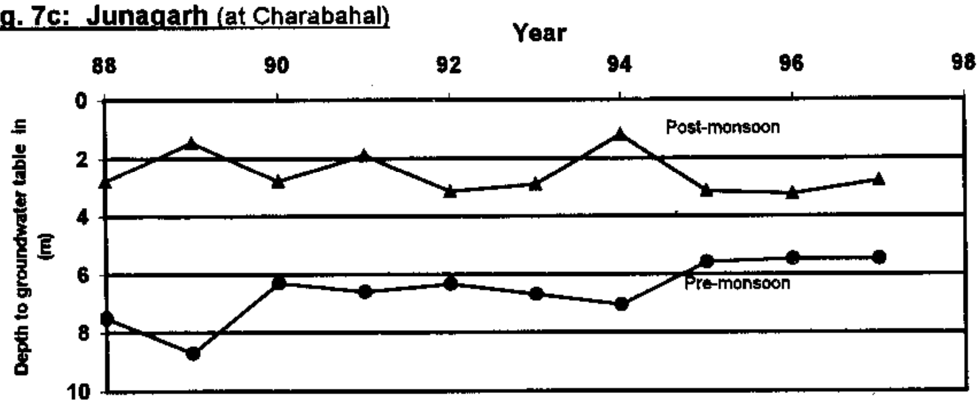


Fig.7a-7n: Continue...

Fig. 7d: Jaipatna (at Bandigaon)

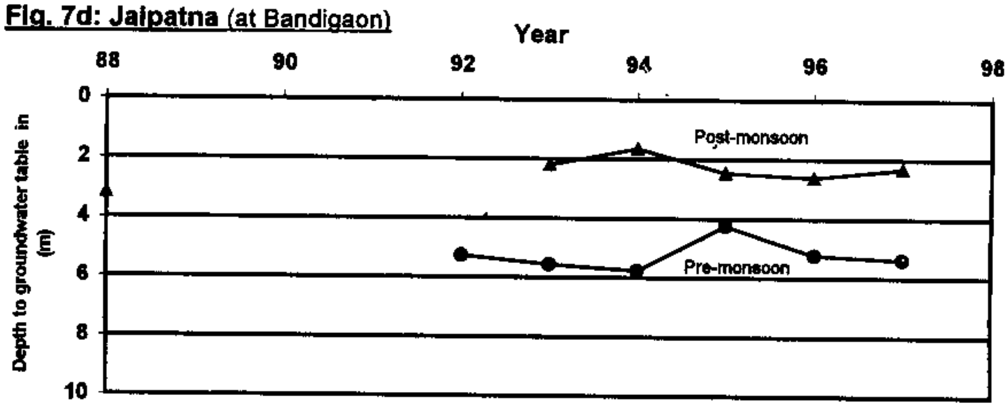


Fig. 7e: Kesinga (at Badipata)

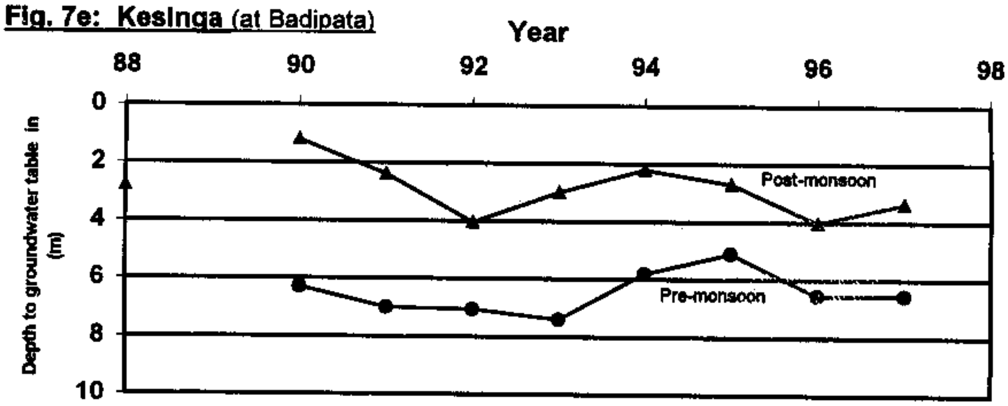


Fig. 7f: Kesinga (at Kashrupara)

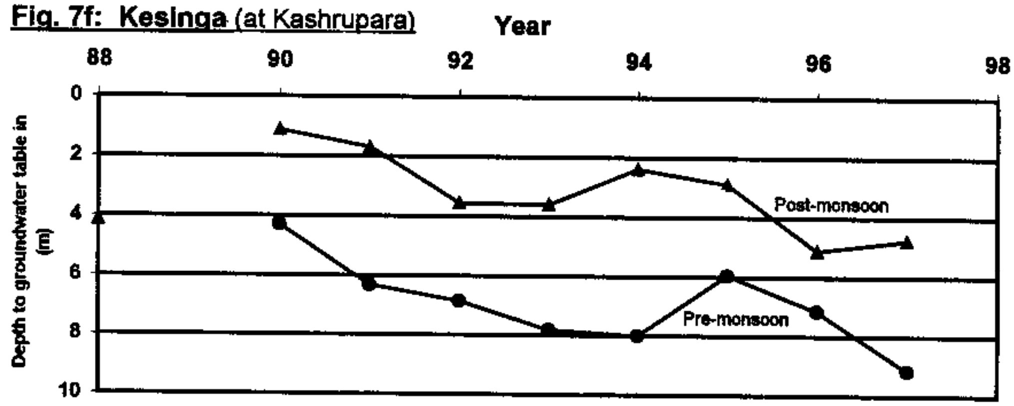


Fig. 7a-7n: Continue.....

Fig. 7g: Karlamunda (at Badadungrigadal)

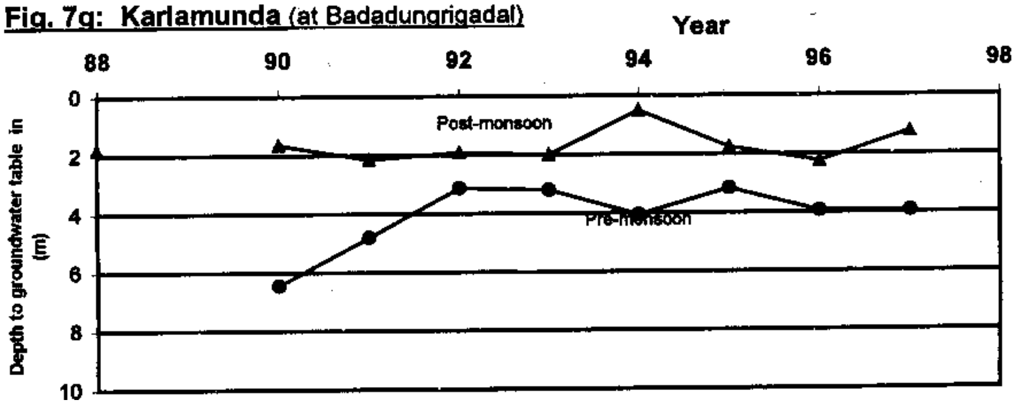


Fig. 7h: Karlamunda (well-2 at Karlamunda)

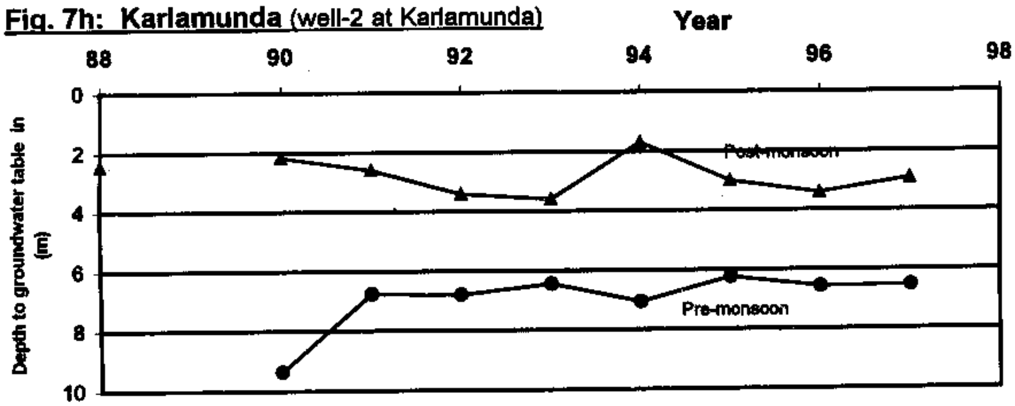


Fig. 7i: Madanpur Rampur (at Ramud)

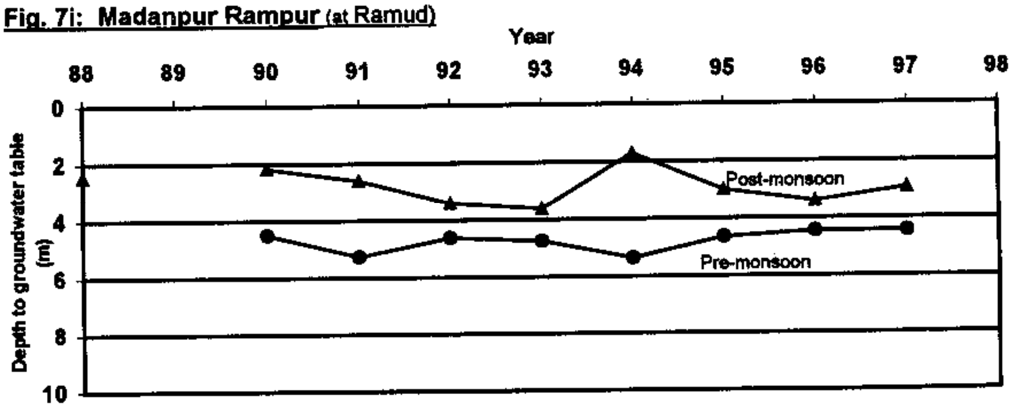


Fig. 7a-7n: Continue....

Fig. 7j: Narla (at Serapur)

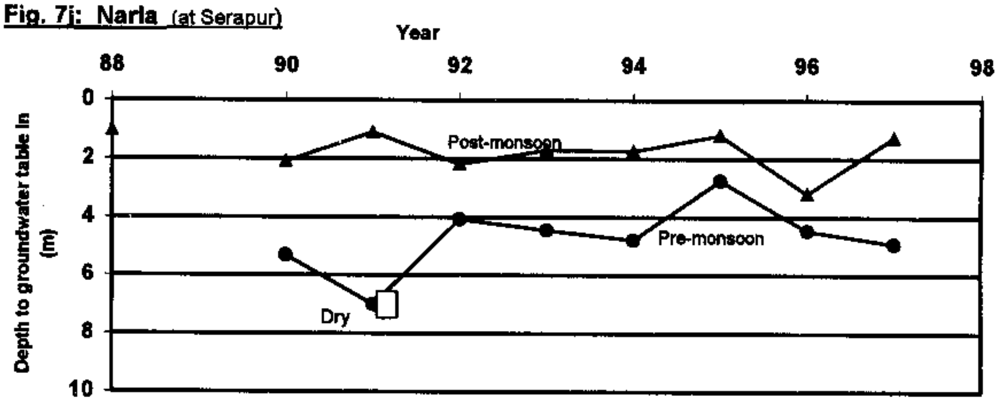


Fig. 7k: Langigarh (at Biswanathpur)

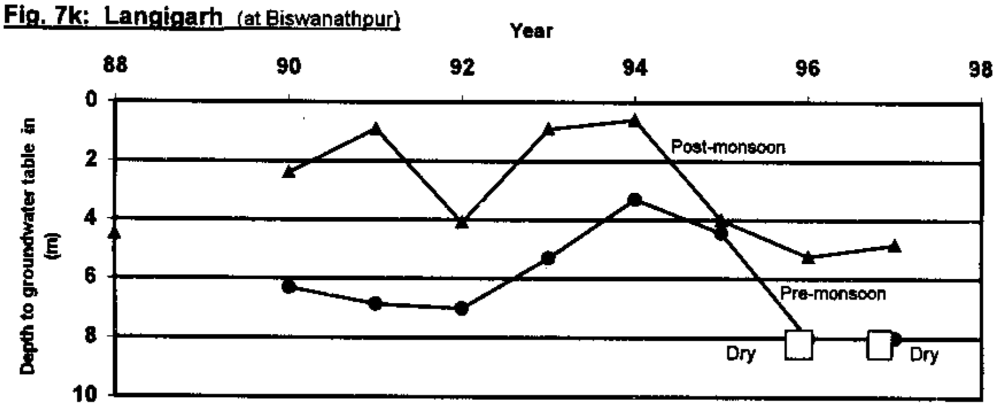


Fig. 7l: Dharamgarh (at khamarhaldi)

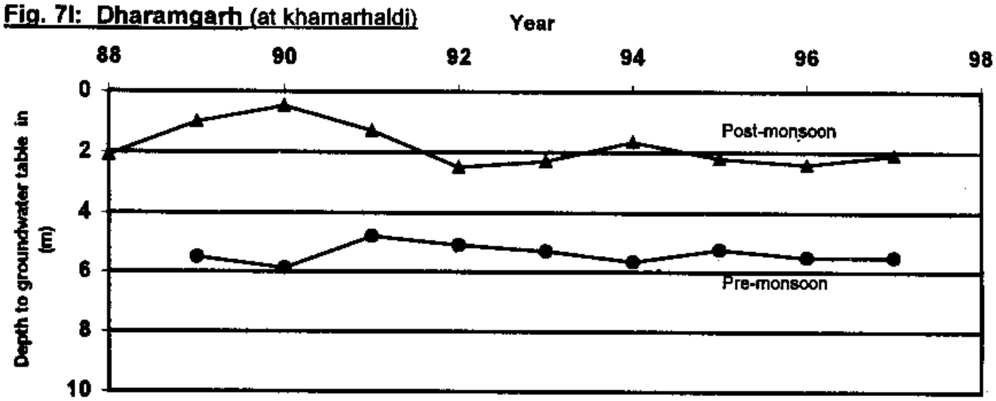


Fig. 7a-7n: Continue....

Fig. 7m: Dharamgarh (at Chhendia)

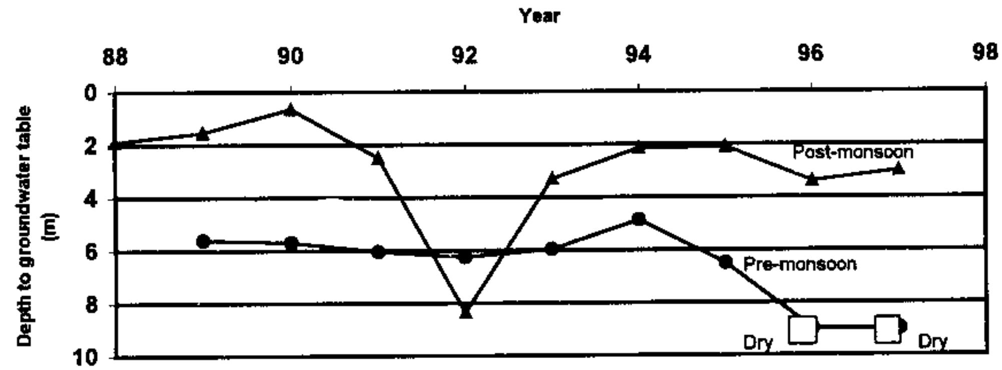
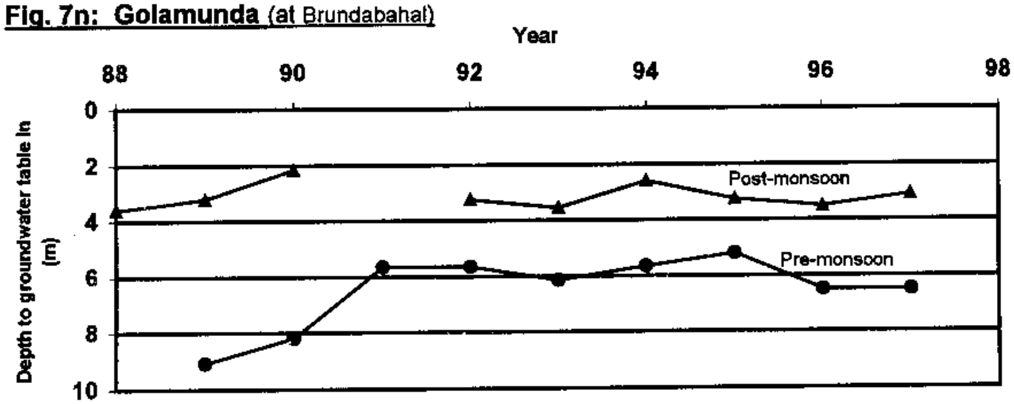


Fig. 7n: Golamunda (at Brundabahal)



10.0 CONCLUSIONS

1. The majority of formers belong to uneducated and backward class of people and they, normally, believe on use of traditional system of cropping. The traditional rice cropping system under rainfed conditions increases the risk of crop loss during drought.

2. The Kalahandi had been suffering from frequent failure of crops and severe water scarcity conditions. Droughts of moderate to severe intesity had been observed with average frequency of 4-to-8 years in different blocks of Kalahandi. The years 1974, 1987, 1988 and 1996 had been the bad monsoon years with seasonal rainfall deficiency in the order of 40-66% and had caused severe water stress and crop loss in more 2/3 number of blocks in Kalahandi.

3. The results of preliminary analysis of rainfall records indicate that the drought had occurred in Bhawanipatna, Kesinga, Langigarh, Junagarh and Jaipatna blocks with an average frequency of every 4 years. In the other four blocks namely Karlamunda, Th. Rampur, Dharamgarh and Golamunda the average frquency of drought had been about 5 years. Kalampur and Koksara blocks had experienced minimum number of droughts (i.e. once in every 8) during the period from 1966-96. However, M.Rampur block had been facing drought after every 6 years.

4. The district has good overall probability of receiving a moderate quantity of total annual rainfall, but its erratic distribution in time and space had played major role in advancement of drought hardship in Kalahandi. Also, it is clear from annual rainfall analysis that there was no meteorological drought during the year 1996 in five blocks of Kalahandi namely Th.Rampur, Junagarh, Jaipatna, Kalampur and Koksara because, these blocks had received more than 75% of their normal rainfall during the wel known drought year of 1996. However, the people of this region had faced severe crop loss and water stress in the year 1996

5. The district Kalahandi has sufficient length of wet season (on average about 96 days) to grow a rainfed crop of 95 to 100 days duration. The period between 14th June to 21st september is found as the average length for south-west monsoon season.

6. The intervening dry spells during cropping season had been responsible for most crop loss events and seasonal water scarcity conditions in Kalahandi On an average the monsoon period incorporates two-to-three intervening critical dry spells for average duration ranging from 14 to 22 days. The area needs provisions for life saving irrigation to meet the crop water requirement during the dry spell periods.

7. The water requirement of crops viz. upland rice, maize, greengram (kharif), greengram (pre-rabi), blackgram, sesamum and minor millet were estimated to be 587 mm, 551 mm, 297 mm, 268 mm, 358 mm, 413 mm and 283 mm respectively.

8. This study provides the estimated irrigation requirement for different crops for the first three critical dry spells in each block in Kalahandi. These estimate may be used for the planning of supplemental irrigation to ensure a success of crops in one season.

9. The available information revealed that there is a vast scope for development and exploitation of ground water. A planned development and exploitation of available ground water may not only contribute as a sustainable source of water for suplemental irrigation but also for tackling the situation during drought.

11.0 RECOMMENDATIONS

1. The efforts are needed to promote crop diversification. The traditional rice cropping system under rainfed conditions may be suitabily substituted by low water dependent crops like pulses, oilseeds and horticulture crops.

2. In view of the average length of monsoon period and soil characteristics of this area, the farmers should be advised not to adopt the paddy varieties with crop duration more than 96 days.

3. There is a urgent need to focus on alternative provisions for supplimentary irrigation to the Kharif crop as well as for providing assured water supply at least for a success of single season crops. This leads to the need for extending irrigation facilities by conserving the monsoon runoff in tanks/ponds/reservoirs to take care of the requirements in deficit-rainfall months.

4. Both the surface and ground water resources are much underutilized. There is a need for some planned water resources development to check the severe drought hardship in this region.

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APPENDIX-I(a)

Crop water requirement (ET_{crop}) for different time interval during growing period of maize crop (110 days).

Sl.No.	Standard Week No.	ET_p mm/day	K_c	ET_{crop} mm
1	26	5.84	0.42	17.17
2	27	6.58	0.42	19.14
3	28	5.65	0.42	16.61
4	29	5.73	0.42	16.85
5	30	5.57	0.55	21.44
6	31	5.59	0.63	24.65
7	32	5.69	0.89	35.45
8	33	5.59	1.06	41.48
9	34	5.57	1.14	44.45
10	35	4.49	1.14	35.83
11	36	5.56	1.14	44.37
12	37	5.62	1.14	44.85
13	38	5.69	1.14	44.41
14	39	6.43	1.05	47.26
15	40	5.81	0.90	36.60
16	41	6.44	0.75	33.81
17	42	5.92	0.63	26.11
Total Water requirement for a maize crop in mm = 551.48				

APPENDIX-I(b)

Crop water requirement (ET_{crop}) for different time interval during growing period of greengram (kharif) crop (70 days).

Sl.No.	Standard Week No.	ET_p mm/day	K_c	ET_{crop} mm
1	24	7.68	0.27	14.52
2	25	6.44	0.27	12.17
3	26	5.84	0.27	11.04
4	27	6.51	0.47	21.42
5	28	5.65	0.70	27.69
6	29	5.73	0.93	37.30
7	30	5.58	1.10	42.97
8	31	5.59	1.10	43.04
9	32	5.69	1.10	43.81
10	33	5.59	0.79	30.91
11	34	5.57	0.32	12.48
Total Water requirement for a greengram(kharif) crop = 297.35 mm				

APPENDIX-I(c)

Crop water requirement (ET_{crop}) for different time interval during growing period of greengram (pre-rabi) crop (65 days).

Sl.No.	Standard Week No.	ET_p mm/day	K_c	ET_{crop} mm
1	34	5.57	0.29	11.31
2	35	4.49	0.29	9.12
3	36	5.56	0.38	14.79
4	37	5.62	0.60	23.60
5	38	5.69	0.80	31.86
6	39	6.43	1.02	45.91
7	40	5.81	1.05	42.70
8	41	6.44	1.05	47.33
9	42	5.92	0.68	28.18
10	43	6.53	0.30	13.71
Total Water requirement for a greengram(pre-rabi) crop =268.51 mm				

APPENDIX-I(d)

Crop water requirement (ET_{crop}) for different time interval during growing period of blackgram crop (85 days).

Sl.No.	Standard Week No.	ET_p mm/day	K_c	ET_{crop} mm
1	25	6.44	0.28	12.62
2	26	5.84	0.28	11.45
3	27	6.51	0.30	13.67
4	28	5.65	0.47	18.59
5	29	5.73	0.63	25.27
6	30	5.58	0.79	30.86
7	31	5.59	0.93	36.40
8	32	5.69	1.10	43.81
9	33	5.59	1.10	43.04
10	34	5.57	1.10	42.89
11	35	4.49	1.10	34.57
12	36	5.56	0.80	31.14
13	37	5.62	0.36	14.16
Total Water requirement for a blackngram crop = 358.47 mm				

APPENDIX-I(e)

Crop water requirement (ET_{crop}) for different time interval during growing period of sesamum crop (90 days).

Sl.No.	Standard Week No.	ET_p mm/day	K_c	ET_{crop} mm
1	24	7.68	0.19	10.21
2	25	6.44	0.19	8.57
3	26	5.84	0.19	7.77
4	27	6.51	0.42	19.14
5	28	5.65	0.69	27.29
6	29	5.73	0.96	38.51
7	30	5.58	1.15	44.92
8	31	5.59	1.15	45.00
9	32	5.69	1.15	45.81
10	33	5.59	1.15	45.00
11	34	5.57	1.15	44.84
12	35	4.49	1.10	34.57
13	36	5.56	0.67	26.08
14	37	5.62	0.40	15.74
Total Water requirement for a sesamum crop = 413.45 mm				

APPENDIX-I(f)

Crop water requirement (ET_{crop}) for different time interval during growing period of minor millet crop (65 days).

Sl.No.	Standard Week No.	ET_p mm/day	K_c	ET_{crop} mm
1	25	6.44	0.28	12.62
2	26	5.84	0.28	11.45
3	27	6.51	0.42	19.14
4	28	5.65	0.79	31.24
5	29	5.73	1.05	42.12
6	30	5.58	1.08	42.19
7	31	5.59	1.08	42.26
8	32	5.69	1.08	43.03
9	33	5.59	0.66	25.83
10	34	5.57	0.34	13.26
Total Water requirement for a minor millet crop = 283.13 mm				

Appendix--II

Irrigation requirement (IR) for selected major crops during effective critical dry spells in different blocks in Kalahandi

Sl. No.	Name of the block	Effective CDS	Irrigation requirement (IR) during effective cirtical dry spells mm						
			Rice	Maize	Greengram (kharif)	Greengram (pre-rabi)	Blackgram	Sesamum	Minor millet
1	Bhawanipatna	1st	42.13	--	19.49	--	--	20.30	32.36
		2nd	71.61	48.95	72.69	--	69.24	80.67	42.96
		3rd	93.74	118.23	--	14.59	55.87	27.70	--
		Total	207.48	167.18	92.18	14.59	125.11	128.67	75.32
2	Kesinga	1st	60.25	--	13.77	--	--	8.43	18.30
		2nd	45.76	40.28	37.29	--	56.11	54.22	24.74
		3rd	59.18	70.98	--	--	55.36	51.67	--
		Total	165.19	111.26	51.06	--	111.47	114.32	43.04
3	Lanjigarh	1st	64.94	3.68	19.44	--	13.24	16.93	15.40
		2nd	76.52	53.89	76.11	--	62.36	82.09	46.66
		3rd	80.54	86.65	--	--	83.50	86.41	--
		Total	222.00	144.22	95.55	--	159.10	185.43	62.06
4	Karlamunda	1st	99.66	25.55	50.26	--	24.81	48.43	39.48
		2nd	85.95	44.45	80.53	--	72.81	97.19	75.32
		3rd	47.16	55.96	--	--	51.34	49.87	--
		Total	232.77	125.96	130.79	--	148.96	135.491	114.80
5	Narla	1st	65.35	5.58	48.96	--	18.68	44.64	44.41
		2nd	74.80	71.19	50.34	--	79.87	84.95	30.41
		3rd	64.29	70.30	--	--	58.44	56.24	--
		Total	204.44	147.07	99.30	--	156.99	185.8	74.82

APPENDIX : II

Contd....

6	M.Rampur	1st	76.08	4.39	29.43	--	5.25	34.43	33.46
		2nd	78.00	55.58	71.76	--	34.21	104.31	65.10
		3rd	95.85	98.50	--	10.59	74.40	68.17	--
		Total	249.93	158.47	101.19	10.59	113.86	206.91	98.56
7	Th.Rampur	1st	31.77	--	9.66	--	--	11.90	17.34
		2nd	52.03	55.93	13.39	--	47.46	49.41	9.06
		3rd	28.21	43.26	--	8.46	--	--	--
		Total	112.01	99.19	23.05	8.46	47.46	61.31	26.40
8	Dharamgarh	1st	96.76	11.60	45.41	--	16.53	43.94	51.50
		2nd	60.78	38.03	63.27	--	58.34	56.27	58.62
		3rd	56.82	84.41	12.55	--	83.69	72.33	--
		Total	214.36	134.04	121.23	--	158.56	172.54	110.12
9	Junagarh	1st	60.21	5.83	40.41	--	14.09	42.09	48.48
		2nd	74.30	70.33	49.89	--	79.37	84.42	44.41
		3rd	50.82	58.62	--	1.54	53.91	55.14	--
		Total	185.33	134.78	90.30	1.54	147.37	181.65	92.89
10	Jaipatna	1st	66.35	6.58	59.57	--	19.67	45.64	52.42
		2nd	93.07	92.10	51.20	--	93.94	104.59	46.08
		3rd	57.82	65.62	--	--	59.23	59.46	--
		Total	217.24	164.30	110.77	--	172.84	209.69	98.50
11	Golamunda	1st	85.76	0.60	34.41	--	5.53	32.94	40.50
		2nd	35.08	--	51.79	--	20.52	43.46	35.97
		3rd	59.30	65.30	--	--	52.36	53.92	--
		Total	180.14	65.90	86.20	--	78.41	130.32	76.47
12	Kalampur	1st	71.94	10.16	26.44	--	7.87	35.15	28.40
		2nd	59.61	54.62	43.28	--	64.11	68.63	37.63
		3rd	55.15	72.20	--	17.49	15.30	11.82	--
		Total	186.70	136.98	69.72	17.49	87.28	115.60	66.03
13	Koksara	1st	51.63	--	28.99	--	7.86	29.80	37.43
		2nd	72.39	49.82	64.80	--	70.81	70.67	66.04
		3rd	71.14	80.24	--	--	64.47	61.08	--
		Total	195.16	130.06	93.79	--	143.14	161.55	103.47

ABBREVIATION

CDS	Critical Dry Spell
CGWB	Central Ground Water Board
CWC	Central Water Commission
D_m	Mean date of onset of monsoon
EMO	Onset of Effective Monsoon
ER	Effective Rainfall
ET_{crop}	Crop Evapotranspiration
ET_p	Potential Evapotranspiration for reference crop
IMD	India Meteorological Department
IR	Irrigation Requirement
K_c	Crop Coefficient
mm	Millimetre
m	Metre
m^3	Cubic meter
NIH	National Institute of Hydrology
USDA	United States Department of Agriculture
Yr.	Year
%	Percentage

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