ANALYSIS OF DROUGHT PHENOMENON OF PRE-DIVIDED KALAHANDI DISTRICT OF ORISSA

BY

Malaya Kumar Sahoo

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF TECHNOLOGY

(AGRICULTURAL ENGINEERING)
IN
SOIL AND WATER CONSERVATION ENGINEERING

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING
College of Agricultural Engineering and Technology
Orissa University of Agriculture and Technology
BHUBANESWAR-751003

OCTOBER, 1993

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Approved by the Advisory Committee

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MY

BELOVED PARENTS

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CERTIFICATE

This is to certify that the thesis entitled " ANALYSIS OF DROUGHT PHENOMENON OF PRE-DIVIDED KALAHANDI DISTRICT OF ORISSA " submitted in partial fulfilment of degree of Master of Technology (Agricultural Engineering) in Soil & Water Conservation Engineering of the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bona-fide research work carried out by Sri Malaya Kumar Sahoo under my guidance and direct supervision. No part of the thesis has been submitted for any other degree or diploma.

The help and information as have been availed of in course of this investigation have been duly acknowledged by him.

8/1/93

(S. D. Sharma)

A C K N O W L E D G E M E N T

I feel immense pleasure to express my deepest sense of reverence gratitude and profound indebtness to my esteemed guide Dr. S. D. Sharma , Dean, College of Agricultural Engineering and Technology, Bhubaneswar who despite his heavy personal and professional engagements has taken keen interest in my research work and has endured much pain in checking the manuscript. It is his pertinent suggestion, genius advice, aurulent guidance and vigilant supervision which made the pursuit a possibility.

It is also a proud privilege for me to record on my heartful obligation and gratefulness to my reverred teacher Prof. S. C. Nayak, Reader, Dept. of Soil and Water Conservation Engineering, CAET, Bhubaneswar who has sacrificed his valuable time for my sake in carrying out the research work and preparing the dissertation and has always treated me with love and affection whenever I approached him for his help and advice. But for his timely help, prolific advice, prudent suggestion and incessant encouragement, the work might not have come to its finality.

I further take this unique opportunity to express my sincere gratitude to Dr. J. C. Muduli, Reader, Dept. of Mathematics, College of Basic Science & Humanities for his valuable advice and constructive comments as and when solicited.

I owe a special debt to Dr. P. C. Senapati, Chief Scientist, Dry Land Agriculture Research Project, Bhawanipatna and Sri B. Panigrahi, Lecturer, Dept. of Soil and Water Conservation Engineering, CAET, Bhubaneswar who have always inspired me to complete the work in time and have rendered me their whole-hearted help and advice everytime I need so.

My sincere thanks are also due to all the teachers and staff of the Dept. of SWCE, CAET for extending their lambent hands of co-operation towards me during the course of the study.

I am extremely obliged to Sri S. sahoo, I.A.S., Commissioner, Special Relief Commission, Board of Revenue, Cuttack, Sri S. Das, Director, CGWB, Bhubaneswar, Sri K. K. Chakravarty, Director, Meteorological Centre, Bhubaneswar, DFOs, Khariar and Bhawanipatna, Sri S. K. Rout, Asst. Engineer, OLIC, Bhubaneswar and Sri M. K. Mohanty, Jr. Scientist, RRS, Bhawanipatna for providing the data for use in this investigation.

I am highly indebted to Dr. B. S. Patro, Prof. & Head, Dept. of Mechanical Engineering , CET, Bhubaneswar for allowing me to carry out the analysis work in his CAD/CAM Laboratory.

Words run shorter to express my indebtness to Sri P. Panigrahi, Programmer, Computer Centre, CET and Sri P. Patra, Programmer, CAD/CAM Laboratory, CET for their valued help and assistance in developing the programs in course of the analysis work.

I can't forget the help and co-operation of Ambika Bhai, Prabhat Bhai, Bhuyan Bhai and many of my friends and natives who contributed in many ways directly or indirectly in making this pursuit a tiny success. I convey all of them a warm "Thank You".

My heartiest appreciation goes to my sisters Mina nani , Runi and Jhuni who have given me a great impetus through their loving service during the entire period of research.

Finally I pay in full my obeissance and tribute from the very core of my heart towards my beloved parents whose supreme sacrifice, eternal benediction and unceasing affection have been a constant source of inspiration all through my study.

Place : Bhubaneswar
Date : 8th Oct.,1993

Malaya Kumar Sahoo
(Malaya Kumar Sahoo)

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LIST OF ABBREVIATIONS

Art.	Article
ASAE	American Society of Agricultural Engineering
Av.	Average
CAET	College of Agricultur Engineering and Technology
^{o}C	Degree Celsius
CDS	Critical Dry Spells
CET	College of Engineering & Technology
CGWB	Central Ground Water Board
D.F.O.	Divisional Forest Officer
D.S.O	District Statistical Officer
EOR	Effective onset Rainfall
et al.	And Other fellows
etc.	et cetra
FAO	Food and Agricultural Organisation
Fig.	Figure
GEC	Ground Water Estimation Committee
GWS & ID	Ground Water Survey & Investigation Division
ha	Hectare
Ha.m	Hectare meter
IARI	Indian Agricultural Research Institute
i.e.	that is
IMD	India Meteorological Department
^{o}K	Degree Kelvin
Kms	Kilometers
m	Meter
MI	Minor Irrigation
mm	milimeter
NF	Normalisation actor
No.	Number
Non-mon.	Non-monsoon
OEM	Onset of Effective Monsoon
OLIC	Orissa Lift Irrigation Corporation
Qty.	Quantity
RIF	Rainfall Infiltration Factor
SWCE	Soil & Water Conservation Engineering
U.S.A.	United States of America
viz.	videlicet

CHAPTER I

INTRODUCTION

I N T R O D U C T I O N

Water is one of the most vital resource for the mankind and like air, is bound up with man's evolution. Since the dawn of civilisation, it has been a boon for the survival and well being for the millions of people in every walk of life. The usage of this natural resource is indispensable not only in agriculture, but also in industry, power production, navigation, recreation etc. Despite rapid strides in technological advances and scientific innovations, variation in the quantum of available water in space and time is still unavoidable. At times, acute water deficit results from sufficiently prolonged lack of precipitation thus imparting serious hydrological imbalance with respect to the various water uses. Such a sitauation of inclement shortage of water is given the name "Drought".

Figuratively drought and flood are two step sisters of nature and implacable enemies who don't see face to face. In other words, while drought forms one extreme end of the hydrological cycle, flood is the other end. Thus they are poles apart. When the country is at the threshold of the 21st century with almost a scientific attitude, let alone the training, it is never preposterous to assume that drought is caused due to the wrath of nature. In that sense it is man's non-perceptible activity that has added fuel to fire.

Without going back to the history and chronology of severity of drought in any part of the world, its origin can be attributed to the aberrations of the global atmosphere. The disorderliness and the disturbances in the atmospheric circulation are but the handiworks of the man. The innumerable benefits achieved by man (which are possible because of the practical application of science) constantly tempt him to recklessly exploit the resources of nature. As a result there is need for large scale felling of trees and denudation of forests. By and large , the demands for harnessing power for various comforts of man are bound to end in air pollution, water pollution and environmental pollution as a whole. Once there is atmospheric disorder, a set of dislocations at various levels occur --- disturbances in the timely occurrence of seasons, unusual rise and fall of temprature ending in the scarcity of rainfall which is but the synonym of drought.

Drought is one of the worst natural hazards that has plagued mankind with untold misery and suffering on many occasions throughout the history leading to serious economic consequences. Amongst all the natural disasters drought affects largest bulk of population in the world. The phenomena of drought can be interpreted in various ways depending on the scientific field involved, purpose and type of water use and extent to which it is perceived to be an expression of water deficiency.

The occurrence of drought in India is not a recent phenomena. In more ancient times (in the late 18th and 19th centuries) conditions of severe scarcity and intense famine in the then North-West Province and the Punjab have been mentioned in the report of the Indian Femine Commission 1880. Reliable information documents reveal that there have been 40 drought years in the country since 1800. Statistics on areal coverage of drought indicate that out of the country's geographical area of 328 million ha., 107 million ha. or about one third of area spread over 99 districts in 13 states and about 29 per cent of the total population are affected by drought. About 39 per cent of the cultivable area of the country witnessed drought conditions (Lohani et al., 1990). During 20th century severe droughts were experienced in the country in 1918, 1965, 1972, 1979 and 1987. It has been reported that from point of view of the area affected of the country , the drought of year 1987 ranks second in severity level, the first one being in year 1918. During 1987-88 the food grains production was reported as 138.41 million tonnes as against 172.0 million tonnes in 1988-89 (Sampath, 1989).

Orissa, with agriculture as the main source of livelihood, has about 80 per cent of its cultivable land dependant on rainfall for agricultural production. Demands of the staggering increase in population have entailed for augmenting food production which in turn calls for an assured water availability from rainfall to match with the growth rhythm of crops. However, scanty, erratic and fluctuative distribution of rainfall in some of its parts causes crop failures leaving behind devastating effect on its economy and populace. This necessiated a study of the agroclimatological analysis of the drought phenomena in the problem rainfall areas. As the geographical area of Orissa is very vast which might not have allowed the scope of the study in a proper perspective, the present effort has deliberatly been limited to Kalahandi district where geographical contour accommodates many mountain ranges with mostly tribal population.

Kalahandi is one of the economically backward districts of Orissa with about 47 per cent of its total population belonging to the weaker sections of the society. Agriculture which is mostly rainfed presents the main facet of economic output of the district employing 80.1 per cent of its total working force (1991 census). So far irrigation facilities in the district have been inadequate and ground water utilisation have also been meagre. Due to scanty, irregular and uneven rainfall distribution and its variation from year to year drought is a regular phenomena here. For more than a decade the district has been the prey of this formidable foe deepening the crisis on its agrarian economy. The femines of 1897, 1899, 1919-20 and the droughts of 1954-55, 1965-66 and 1987 may be considered as the epitomes of her long tale of suffering and form a watershed in history. Till now a perceptible change in the situation is not marked and the poverty of the masses struggling to go upwards from the subsistence level of living standard is not bamished.

In view of recurring droughts and limitation of surface water irrigation , development of ground water resources of the district has become inevitable. Planned and scientific development of ground water resources will go a long way in combating vagaries of drought and extending irrigated agriculture thus improving socio-economic conditions of the people of the district. In this context it is an essential pre-requisite to have an appraisal of the ground water potential of the area.

In the light of the above present study on the "Analysis of drought phenomena of Kalahandi district" was undertaken with the following objectives :

1. To study different characteristics of rainfall associated with occurrence of drought phenomena.
2. To assess the duration and frequency of drought.
3. To study the area under forests and its possible effects on occurrence of drought in the area.
4. To estimate the ground water potential of the study area.
5. To recommend suitable measures of successful cultivation for principal crops in the area.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

This chapter deals with a critical and detailed review of some of the works done by researchers and investigators in the past in India and elsewhere in the fields relating to this study. Starting from the very first concept of a rainy day, attempts have been made to throw light on the previous works associated with onset of effective monsoon, critical dry spells, drought-its definitions and classification, forecasting of dry and wet spells, forest influences on the water cycle, ground water potential study and finally the crop water requirements.

2.1 Rainy Day

A rainy day may be considered as one with one mm or more of rainfall (Raman, 1974). However, 1 mm of rainfall is too meagre to call a day rainy. The India Meteorological department (IMD) defines a rainy day as a day with not less than 2.5 mm of rainfall. Aldabagh et al.(1982) in the course of analysis of rainfall data of 10 stations in Iraq considered a day to be rainy day if the rainfall on that day was at least 2 mm. The definition of rainy day given by the IMD holds better focus and has been used widely in past for agricultural planning.

2.2 Sowing Rains and Effective Monsoon

In rainfed areas in India, agricultural operations for the principal summer crops(kharif) start with the onset of southwest monsoon. One of the important characteristics of rainfall influencing production in such areas is the date of first occurrence of a rainspell at the beginning of the monsoon season that will go to build a moisture reserve in the soil adequate for the satisfactory commencement of Kharif sowing. A correct prediction of the date of effective monsoon will help the farmer to plan his cropping strategy and derive the maximum advantage from the soil conditions after monsoon rains.

2.2.1 Commencement of Sowing Rains

Raman (1974) while analysing the daily rainfall data of the black cotton soil area of Maharashtra suggested criterion for identification of sowing rains at the advent of southwest monsoon. The criterion proposed by him is given below:

> "The commencement of a 7-day spell having a total rainfall of 25 mm or more with showers of at least 1mm on any 5 days of the spell is considered as the commencement of sowing rain."

Stern _et al_.(1982) considered first 10 days after May,1st with three or more rainy days having more than 30 mm rainfall for sowing of Soreghum in semi-arid region of Hyderabad.

2.2.2 Effective Monsoon

It is unlikely that pre-monsoon showers of high intensity can be considered as effective monsoon particularly because they are followed by long dry spells which may effect the germination of seeds resulting in crop failure if sowing is undertaken immediately after these showers. Effective monsoon, so vital for sowing operations, thus must be identified distinctly from premonsoon showers. Any rainfall to be effective from the agricultural standpoint should be high enough so as to have the soil profile charged with sufficient moisture after meeting the evaporation losses and should depend on the characteristics of the soils and the crops grown. In this context, Ashok Raj (1979) defined effective monsoon as that monsoon which leaves enough moisture, in the soil, after meeting evaporation losses, to take up agricultural operations.

2.2.3 Onset of Effective Monsoon (OEM)

India Meteorological Department (1943) prepared charts and maps to show normal onset of monsoon for various stations based on long term average of 5-day total rainfall with the abrupt rise of normal rainfall curve as a basis. However, these charts do not quite serve the purpose in rainfed farming as the criteria used in developing such charts is not based on soil and crop characteristics.

Kowal and Krabe (1972) defined onset of effective rains as the first of the 10-day period having more than 25 mm rainfall provided rainfall of next 10 days exceeds half of the potential evapotranspiration.

Ashok Raj (1979), after experimenting in a pilot study with several factors, defined date of onset of effective monsoon as the date of commencement of a 7-day spell satisfying the following criteria:

(i) The first day's rain in the 7-day spell is not less than e mm, where e is the average daily evaporation.

(ii) The total rain during the 7-day spell is not less than (5e+10) mm.

(iii) At least four out of these seven days are rainy days with not less than 2.5 mm of rain each day.

In all the aforesaid criteria, a particular amount of rainfall is received over a period in the beginning of effective monsoon. This approach, does not provide for considering the importance of soil moisture status which decides the availability of water for workable condition of soil and sowing operation.

Reddy (1985) modified the above approach for studying the monsoon characteristics of Punjab by proposing following criteria for onset of effective monsoon :

(i) The first day's rain in the 7-day spell is not less than e mm, where e is the average daily evaporation of June and July months.

(ii) The total rain during the 7-days rainy spell is not less than the amount of rain which brings the top 30 cm soil layer to the field capacity.

(iii) At least three out of these seven days must be rainy days with not less than 2.5 mm of rain each day.

Verma et al.(1990) while studying the rainfall of "Kandi" belt of northern Punjab with a view to develope criteria of OEM for sowing of rainfed crops pointed out that in the beginning of the monsoon except the first rain there may be some storms which can produce substantial amount of run-off. Hence this hydrological factor should also be considered while deciding criteria for OEM. On the basis of this logic they further modified Reddy's approach and put forth the following criteria for the onset of effective monsoon:

(i) The first day's rain in the 7-day spell should not be less than 'e' mm, where 'e' is the average daily evaporation of the season.

(ii) The total rain during the 7-days spell should not be less than EOR, where EOR is "effective onset rainfall" and can be expressed as

$$EOR = 0.75\ (FC - WP) \times BD' \times d + 5e + RO \quad ----(1)$$

where FC = Moisture content at field capacity (on weight basis)

WP = Moisture content at wilting point (on weight basis)

BD'= Relative bulk density of soil with respect to water

d = Effective seeding zone depth or ploughing depth whichever is more, cm, and

RO = Runoff, mm.

(iii) . At least three out of these seven days are rainy days (having a minimum of 2.5 mm of rain per day.)

(iv) If above three criteria are satisfied in a week of the first fortnight of June , but followed by a prolonged dry spell then it should be considered as a pre-monsoon spell and not OEM.

Unlike the approach of Ashok Raj (1979) and Reddy (1985), this approach assumes that the average daily evaporation 'e' for a week is a variable, particularly in months of June and July and thus uses the average values on monthly basis (June & July) and seasonal basis which are less variable.

2.3 Dry Spell, Critical Dry Spell, Drought

A cursory glance of the records of daily rainfall of various stations of an area reveals that it does not rain continuously for the whole monsoon period starting from its onset till its withdrawal, rather there exists intervening period or periods of low or no rainfall. The length of these periods during the farming season is much critical for crop growth and if exceeds a threshold value, may adversely affect the crop leading to its failure. These periods are given different names by different authors such as dry spell, drought etc. and have been defined accordingly.

2.3.1 Dry Spell and Critical Dry Spell

Ramanath et al.(1973) while determining the influence of climatic factors in agriculture in low rainfall tract of Bellary in Mysore state considered a dry spell as a period of at least 15 consecutive days during which either no rainfall was recorded or less than 6 mm rainfall having been recorded in two consecutive days.

Ashok Raj (1979) , taking into consideration the average daily evaporation 'e' of an area, defined the dry spell as the interval between the end of the 7-day spell beginning with the onset of effective monsoon and another rainy day with 5e mm or more of rain or the commencement of another 7-day rainy spell with a total of at least 5e mm of rainfall and having not less than four rainy days out of these 7 days. If the duration of this dry spell exceeds a certain limiting value depending on the crop-soil complex of the region under consideration then this dry spell is called the first critical dry spell (CDS). On the other hand, such a spell is included in the first wet spell. Subsequent dry spells are defined in a similar fashion.

2.3.2 Wet Spell

The interval between the onset of effective monsoon and the commencement of the first critical dry spell is called the first wet spell. The subsequent wet spells are defined as the interval between the critical dry spells. Thus the wet spells are spells of prolonged rain with possible intervening dry spell of duration less than the value which makes the dry spell critical.

Adopting these definitions of dry and wet spells, Ashok Raj(1979) determined the dates of onset of effective monsoon, the no. of critical dry spells and wet spells and their duration and average dates of onset for six districts, namely Cannanore district (Kerala), Chandrapur district (Maharastra), Mahbubnagar district (Andhra Pradesh), Banswara district (Rajastan), Garo Hills district (Meghalaya) and Kamarup district (Meghalaya). For the first two, a dry spell exceeding 7 days and for the last ones dry spell exceeding 10 days have been considered as critical dry spells based on soil, climate and crops.

In Orissa, Nayak (1985) with a view for irrigation and drainage planning analysed the daily rainfall data of four stations, namely Balasore, Bhubaneswar, Cuttack and Gopalpur and thus found out the date of onset & withdrawal of effective monsoon & critical dry spells using Ashok Raj's criteria. He considered a dry spell of 10 days to be critical.

Das (1992) while analysing the agrometeorological data of Bhubaneswar (Orissa) for crop planning also determined the onset of effective monsoon and the number, date of occurrence and duration of critical dry spells assuming the defining limit of a critical dry spell to be 5 days.

2.3.3 Drought

Drought generally refers to a period of dryness due to lack of rain. It has been defined in various ways by different investigators according to their purpose of study and area of interest.These definitions have been given either on professional standpoints (meteorology, hydrology, geography, water resources development etc.) or on the economic activity affected (agriculture, industry, power production, domestic water supply, navigation etc.). Depending on the normal climatic conditions, available water resources, agricultural practices and economic activity of the region, all concepts and definitions regarding droughts may broadly be classified as precipitation droughts, hydrologic droughts, agricultural droughts and atmospheric droughts (Ram Mohan,1984).

2.3.3.1 Precipitation Drought

According to Webster(1953) drought is "1.dryness,want of rain; 2.a dry spell especiallly when protracted."

Thornthwaite and Mathur (1955) have defined drought as " a lack of rainfall so great and long continued as to affect injuriously the plant and water supplies both for domestic purposes and for the operation of the power plants, especially in those regions where rainfall is normally sufficient for each purposes". They pointed out that drought cannot be defined in terms of rainfall deficiency alone, without taking into account the water need of the region and the role of soil moisture, and identified the following types of droughts:

The first type is "permanent drought" which characterises the arid climates. The second type of drought is a seasonal phenomena which occures in regions with well defined rainy and dry seasons. The third type of drought is called " invisible drought", which is based on the fact that a rain, sufficient to maintain the plant growth may not be adequate to overcome water loss by evaporation and transpiration. The fourth type of drought is due to the basic irregularity in rainfall and is not limited to season and region. It can occur in practically all the climatic zones, but is generally most important in the marginal zones between arid and moist climates.

Banerji and Chhabra (1963) in course of their analysis of drought conditions in the Telengana Division (Andhra Pradesh) during the south-west monsoon season defined drought taking rainfall deficit from normal as the indicator. They characterised three types of droughts, namely slight drought, moderate drought, and severe drought as follows :

It is slight drought if the rainfall deficit from normal lies between 11 to 25 per cent . It is moderate drought if the rainfall deficit from normal lies between 26 to 50 per cent. It is severe drought if the rainfall deficit from normal is greater than 50 per cent.

Herbst et al. (1966) defined drought duration , deficit and the onset and termination of a drought event basing on precipitation. They also introduced an index of drought duration and deficit. Gupta and Duckstein(1975) used rainfall for a stochastic analysis of extreme drought events.

Correia (1978) reported that drought has various implications, advanced on different considerations, in different parts of the world. In Bali (Indonesia) drought means a period of six days without rain. In Egypt, any year the river Nile does not flood is a year of drought, regardless of amount of rainfall. He recognised precipation drought as meteorological drought, i.e. a long period of significantly below normal rainfall. On the basis of dry days the drought classification as quoted by Corriea is as follows:

(i) Absolute drought - a period of 15 consecutive days none of which received as much as 1/4 mm rain. (ii) Partial drought - a period of at least 29 days in which the mean daily rainfall was below 1/4 mm rain. (iii) Dry spell - a period of at least 15 consecutive days none of which received as much as 1 mm of rainfall.

He also characterised drought severity considering the rainfall deficiency. The three categories are large deficiency, Serious deficiency and disastrous deficiency of water if the rainfall is 30 to 40 per cent , 45 to 60 per cent and above 60 per cent, respectively of the normal rainfall.

Sharma _et al_.(1979) while analysing the rainfall data of Pantnagar for crop planning described the following definitions for identifying drought :

(i) Drought Month - Any month receiving rainfall less than 50 per cent of the average monthly rainfall .

(ii) Drought Year - Any year receiving rainfall less than the mean yearly rainfall minus its standard deviation.

Sharma (1983) noticed drought to be the direct result of departure from normal rainfall. He defined drought as the fixed period of time with rainfall less than the minimum accompanied with adequate stream flow.Irrigation Commission India has also defined drought on the basis of deficit rainfall. An area where annual rainfall is less than 100 cm and even 75 per cent of this rainfall is recorded in not 20 per cent or more of the years, and where irrigation is less than 30 per cent of the cropped area is considered as a drought area.India Meteorological Department has also defined drought on frequency distribution of deficit rainfall. Here a area is considered to be drought affected if probability of rainfall equivalent to 75 per cent of normal is below 80 per cent indicating that more than 20 per cent of years, the area experienced scarcity of rain.

Smart (1983) undertook a drought analysis based on daily rainfall and evaporation inputs and predicted soil moisture at given level of drought , frequency duration and severity. Ram Mohan (1984) studied the droughts during the period 1901-1975 over Tamilnadu and viscinity and analysed their spread and severity. Ray et al. (1987) while stastically analysing the 70 years (1901-1970) rainfall data of Gopalpur, Orissa attempted for investigation of drought months and years using the definitions proposed by Sharma et al.(1979) and reported that there would be one drought year in every eight year period. Liakatas and Nianiors (1988) made meteorological analysis of a drought which occurred during the winter and spring of 1977 in Greece. Wind, temperature and humidity data were also taken into account along with rainfall in their study.

Kumar et al. (1989), with a view to identify droughts in two districts each in Gujurat and Rajastan analysed the rainfall data by using the rainfall based drought index evolved by India Meteorological Department. For precise study of drought various types of analys s viz. rainfall departure analysis using monthly data, probability analysis using annual data, dry spell analysis using daily data were performed. It was seen that from rainfall deficiency point of view , the study areas witnessed drought conditions more severe during 1985 than earlier years.

Subramainiam and Rao(1989) examined the occurrence of different intensities of drought during annual, Kharif and Rabi seasons based on the aridity index over south coastal Andhra Pradesh and concluded that the chances of experiencing a severe drought during rabi season is more than Kharif.

Patel(1992) attempted a climatological analysis to examine the incidence of drought, its spread and dissipation over Rourkela, Orissa. The analysis indicated that there were moderate droughts during 1969,1970,1971; large droughts during 1982 &1985; severe droughts during 1972,1974,1976 and 1979; and no disastrous drought till date.

2.3.3.2 Hydrologic Drought

To hydrologists drought means a depression of surface and underground water levels and diminition of streamflow below some threshold value.

Gumbel (1963) defined drought as the smallest annual value of daily streamflow. By this definition a drought event occures exactly once a year. Palmer (1965) described drought as a significant deviation from the normal hydrologic conditions of an area. Gooch (1966) used three components to characterise a drought and net reservoir-surface evaporation during drought. Yevjevich (1967) defined the hydrologic drought as "the deficiency in water supply or the deficiency in precipitation , run off or accumulated water in various storage capacities. He formulated drought events based on stationary time series and the theory of runs. A study of severity of Hydrologic drought was studied by Beard and Kubic (1972) based on water supply dependancy. Linsley et al.(1975) defined hydrologic drought as a period during which stream flows are not adequate to provide the required water supply for a given water management system. Corriea (1978) recognised the hydrological drought as the period when water levels in wells, lakes and reservoirs is below normal level.

Klugman (1978) adopted the Palmer drought severity index to study the spatial and temporal characteristics of drought in the Upper Midwest area.

Dracup et al. (1980) discussed different definitions of droughts in terms of their impact and concluded the selection of water deficit, averaging period, truncation level and regionalisation are critical in drought analysis. Sen (1980) developed a drought generating mechanism and an analytic formulation of the probabilistic behaviour of extreme droughts by the theory of extremes. Cordery (1981) used probabilistic forecasting of soil water deficit as a measure of predicting hydrologic drought.

The Central Water Commission of India (1982) while studying drought in 99 districts of the country considered drought as a situation when annual runoff for the year under consideration is less than 75 per cent of the normal values.

Zaporzec (1984) studied statistical relationship regarding effects of precipitation on ground water levels in Wisconsin, U.S.A. and developed relationship between ground water level and precipitation in a bid to characterise hydrologic drought. Ben-Zvi (1987) has developed indices of hydrologic drought in Israel considering annual volumes of streamflow. He has further classified the period of scarcity as deep shortage, continuous shortage and widely extended shortage based on mean and standard deviation of the recorded flow data. Chang (1989,1990) using daily stream flow data developed the hydrologic drought intensity function and the method of truncation level to investigate drought characteristics and its effects on stream flows.

2.3.3.3 Agricultural Drought

According to Corriea (1978) agricultural drought is a situation when such conditions prevail so as to result in insufficient moisture balance in the root zone of crops leading to permanent injury to the plants.

Subramanian and Rao (1989) examined the occurrence of different intensities of agricultural drought for seven crops viz., rice, bajra, jowar, groundnut, tabacco, ragi and cotton during kharif and rabi seasons in Prakasham and Nellore district of Andhra Pradesh ,and concluded that the per centage drought occurrence is more to cotton and groundnut compared to other crops grown in the region.

Panigrahi et al.(1990) formulated a model for depletion of soil moisture in the root zone during periods of no rainfall and to determine the critical drought period for a number of selected crops in three types of soils i.e. sandy, sandy loam and clay soils. They observed that the critical drought period for different crops to sustain the drought is more for clay soil and these values decreases for sandy loam and sandy soil in order.

2.3.3.4 Atmospheric Drought

Atmospheric drought refers to the study of severity and areal extent of a drought and may deal with meteorological ,hydrological or agricultural drought. Nevertheles,the concept of such a drought is clearcut.

2.4 Forecasting of Dry and Wet Spells

For successful production of rainfed crops,particularly in areas where the monsoonic rainfall is much erratic and vagarious interspersed with highly variable dry periods ,it is an important criteria to know in advance the distribution and pattern of rainfall and the probable dry periods of 2 or 3 consecutive weeks during the monsoon season . This will go a long way in helping the farmers to plan in safety and quality of their cropping strategy and to carry out the agricultural operations accordingly. Forecasting of dry and wet spells,therefore ,warrants much importance.

Victor and Sastry (1979) made use of Markov chain probability model to find the long term frequency behaviour of wet or dry weather spells.

Robertson (W.M.O.,1982) applied the Markov chain model to daily rainfall data and forecasted the probabilities of wet and dry decades,i.e.10-days periods.He defined a dry decade as one with total rainfall less than 30mm and a wet decade as one having equal to or more than 30mm of rainfall. The formulae used in the calculation of probability read as follows:

$$(i)\ P(D) = \frac{F(D)}{n}$$

$$(ii)\ P(DD) = \frac{F(DD)}{F(D)}$$

$$(iii)\ P(W) = \frac{F(W)}{n}$$

$$(iv)\ P(WW) = \frac{F(WW)}{F(W)}$$

Where, P(D)= probability of a dry decade

F(D)= Total no. of dry decades

P(DD)= Probalility of a dry decade preceeded by another dry decade.

F(DD)= Total no. of dry decades which are preceeded by dry decades also

n = Total no of decades taken for analysis .

P(W), F(W), P(WW) and F(WW) have the same meaning as P(D), F(D), P(DD) and F(DD) respectively except that here the decade is wet.

The probalility of a certain number of consecutive dry or wet decades beginning with any one decade of a certain year can now be calculated with the following formulae given by Robertson(1982):

$$P(D_2) = P(D) \times P(DD)^{2-1}$$

$$P(W_2) = P(W) \times P(WW)^{2-1}$$

Where, $P(D_2)$ and $P(W_2)$ denote the probabilities of two consecutive dry decades and wet decades respectively.

Pandarinath (1991) also adopted the Markov chain model for forecasting of dry and wet spells during monsoon period over Andhra Pradesh on weekly basis. He defined a dry week as one in which the total rainfall is less than 20 mm and a wet week in which rainfall is equal to or more than 20 mm.

The various formulae used for the analysis are as follows:

(i) $P(d) = \frac{F(d)}{n}$ where P(d)=probability of a certain week being dry, F(d)= frequency of dry weeks, and n=total no of years for which analysis is being carried on.

(ii) $P(dd) = \frac{F(dd)}{F(d)}$ where, P(dd)= conditional probability of a dry week preceeded by a dry week, and F(dd)=total no. of dry weeks which are also preceeded by dry weeks.

(iii) 2D = P(dw1) x P(ddw2), where 2D= probability of two consecutive dry weeks, P(dw1)= probability of the 1st week being dry, P(ddw2)= conditional probability of 2nd week being dry, given the 1st week i.e. its preceeding week is dry.

(iv) 3D =P (dw1) x P(ddw2) x P(ddw3), where 3D = probability of three consecutive dry weeks, P(ddw3) = conditional probability of 3rd week being dry, given the preceeding 2 weeks are dry.

Similarly, P(w),P(ww), 2W and 3W are calculated, with having the same meaning as P(d), P(dd), 2D and 3D. However, here the weeks are no more dry, rather wet.

Dalabehera and Sahoo (1993) analysed the daily rainfall data of Bhawanipatana of Kalahandi district for a period of

20 years (1970-1990) with a view to find out the initial and transition probabilities of various sequences of dry and wet days by using a Markov Probability model. The definition of a wet day or dry day given by IMD was adopted for the study. It was assumed that the transition probability for a given day depends only on the weather (dry or wet) of its previous day. The relations suggested by Dalabehera and Sahoo (1993) for the aforesaid study are as follows:

(i) $P(W_i) = 1 - P(D_i)$

(ii) $P(W_i / D_{i-1}) = 1 - P(D_i / D_{i-1})$

(iii) $$P(D_i / W_{i-1}) = \frac{P(D_i) - P(D_{i-1}) \times P(D_i / D_{i-1})}{P(W_{i-1})}$$

(iv) $P(W / W_i) = 1 - P(D_i / W_{i-1})$

in which , P(Di) and P(Wi) are the initial dry and wet probabilities respectively of the ith day subjected to weekly averages, P(Di-1) and P(Wi-1) are the initial dry and wet probabilities for the (i-1)th day, P(Wi/Di-1) is the transition probability that the ith day is dry given that the previous day i.e. (i-1)th day is wet. The definitions for other notations automatically follow in a similar fashion.

2.5 Influences of Forests on Water Cycle

The influences of forests on their environment and water cycle forms part of a vast and complex relationship between environment and forest vegetation. Many workers have been trying for past several decades to assess the influence of forests on various hydrological parameters and components of water cycle viz. rainfall, infiltration, soil moisture, evapotranspiration, ground water, flood etc. However, as yet the findings of these studies have not been very coherent and are mainly confined to small experimental watersheds.

2.5.1 Effect of Forests on Rainfall

No literature has been to hand to show that any extensive study has been conducted to relate forest cover directly with the precipitation amount. However, it is a general conception that increase in green mass attracts precipitation.

2.5.2 Effect of Forests on Infiltration

Studies have been attempted to find out effects of forest cover on infiltration rates. Malchanov (1960), based on the observations in various areas in U.S.S.R., has deduced that the forest soils have a higher moisture absorptive capacity than soils on treeless terrains.

Regarding infiltration under forests, Burger(1954) observed in Switzerland that the infiltration through a 25cm layer sandy soil covered with grass amounts to 22 per cent of total precipitation, it is 44 per cent on bare soil and 60 per cent in forest, on the same soil, but covered with mossy vegetation. Kittredge(1948) reported that undistributed natural forest canopy and floor maintain infiltration at a maximum for a given situation. He also concluded that the influence of forest on infiltration is least on sands or other highly permeable soils.

In India, studies have been carried out to determine infiltration rates under varying forest cover. Pattnaik and Virdi(1962) reported higher infiltration rates (5.87,3.78 and

3.63 cm/hr for first 3 hours) for forested area than for crop lands (3.7,1.94 and 1.91 cm/hr) taking maize as the test crop in Dhilkot. Ghosh(1974) indicated the infiltration rates under forests, natural grass land and terraced cultivation as 5.16, 3.00 and 1.40 cm/hr, respectively for black cotton soil in Bellary. In Bihar, Mistry and Chatterjee(1965) recorded infiltration rates under forest land, permanent grass and croplands as 26.0, 12.0 and 9.0 cm/hr respectively. The Environmental Research station, Simla has also conducted studies on the same field and has reported that the forest land has higher initial infiltration rate than the agricultural lands (cited in Lohani,1985)

The above studies confirm that infiltration rates are higher under forest. The percentage increase, however, depends on soil type, extent of forest cover, species and biotic interference.

2.5.3 Effect of Forests on Soil Moisture

Soil moisture performs vital functions in dissolving nutrients and supporting plant life, but hydrologically it represents a rapidly fluctuating storage reservoir from which water is extracted by plant roots for transpiration and by direct evaporation from the surface. As reported by Lee(1980), the forest cover generally reduces the levels of soil moisture and ground water compared with corresponding levels under other vegetation types especially during the negative water balance.

In India, studies on soil moisture monitoring under forest cover has been done by CSWCRTI, Dehradun and its other centres. Gupta (1980) reported that soil moisture remains at a higher level under forest than under grass. Dhruvanarayana and Shastri (Anon,1983) mentioned that in forest watershed relatively higher soil moisture values were observed in top 45 cm soil depth as compared to agricultural watershed.

2.5.4 Effect of Forests on Ground Water

The effect of forest cover on ground water storage can be inferred from evapotranspiration, soil moisture and discharge relationships. It depends partly on the depth and proliferation of rooting system and on growing season length.

Ototskii(1925) found that wherever ground water is not deep, the water table is always shallow on open, treeless terrain than in forest. Based on the studies conducted in shipov forest, Russia, Morozov(1900) concluded that water table lies at a greater depth under forest than under field. Basov(1948) showed that there is no progressive sinking of the ground water forest strips. Yadovlev(1925) reportedd the seasonal fluctuation of water lable are not simultaneous in forest and on fields. In the former water table rises slowly where as on fields it is sinking.

Aside from cloud forest, increasing heights of water table have usually followed cutting of forests in areas where permanent water table are found (Wicht,1949). Guillerme (1980) reported that direct influence of deforestation on the lowering of water table does not seem as historical evidence. Boughton (1970) found increase in ground water level when trees were replaced with any native grasses. Melzer(1962) has indicated water table rise of 10 metre following conversion of forest to

On the other hand reforestation of open land usually leads to decreased water table, with effects most pronounced in the dry season. In northern Thailand, Chunkao (quoted by Hamilton and king,1983) reported a decrease in well levels in dry season following reforestation. Increase in the water table due to afforestation has been evidenced in C.R. halli, Chittardurga (Anon, 1983).

Forest influence on groundwater regime has been a controversial issue and due to lack of wide spread and systematic studies it may not be possible to arrive at definite conclusions.

5.5 Effect of Forests on Evapotranspiration

Evapotranspiration denotes the quantity of water transpired by plants during their growth, or retained in the plant tissue, plus the moisture evaporated from the surface of the soil and vegetation. Forest cover has more or less influences on evaporation as well as transpiration.

Evaporation:

The presence of plant cover greatly reduces evaporation from the soil surface as plants withdraw water themselves. Continuous tree cover is particularly effective in reducing soil evaporation. The evaporation of soil covered with forest floor is 10 to 80 per cent of that from bare soil. The reduction increases as the floor becomes thicker at least up to a thickness of 2 inches (Kittredge,1948).

Transpiration:

Lohani(1985) reported that amount of transpiration depends significantly on the type of vegetation and its rooting depth. Other studies show higher transpiration for forest area, but depend on species.

It can thus be said that the evapotranspiration is more in forest than other land use. The rate of evapotranspiration much depends on soil moisture. The evaporation on bare soil is reported equal to the evaporation from free water surface.

2.6 Ground Water Potential

It is needless to say that not only for irrigation but also for domestic and industrial utilisation ground water is a very valuable commodity. Particularly in view of the reccurring droughts and limitations of surface water irrigation, ground water resource plays a key role in extending irrigated agriculture and providing sustained drinking water source. It has, therefore, been essential to investigate the total ground water potential of any place and to predict how much of this stored amount can be utilised to meet the present day demand.

A vast work on the ground water resource development has been done throughout the country and abroad. Saksena(1983) carried out an extensive study on the ground water potential of India and the status of its development . Central Ground Water Board has undertaken detailed exploration for ground water in different parts of the country with different hydrological situations. Sharma et al. (1989) investigated and evaluated the ground water potential of Bhubaneswar. Das and Sar (1990) estimated the blockwise ground water potentials of Kalahandi district, Orissa and reported the prospects for the development of this potential. The Ground Water Survey and Investigation Division of OLIC has also performed similar works in different areas. Nayak (1991) used remote sensing technique to evaluate the ground water potential of Athagarh block of Puri district basing on the G.E.C. norms (1983).

Water Requirement of Crops

Information on water requirements of different crops is essential for optimum use of the scarce irrigation water during the crop growing season. It can be compared with rainfall and soil moisture to select the appropriate crops and planting dates to avoid or minimise drought vulnerability. Hence for crop planning , estimation of crop water requirements is eminently important.

Water requirement of crops is defined as the depth of water needed to meet the water loss through evapotranspiration of a disease free crop, growing in large fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment (Doorenbos and Pruitt, 1977)

Michael (1978) defined crop water requirement as the quantity of water, regardless of its source, required by a crop or diversified pattern of crops in given period of time for its normal growth under field conditions at a place. Water requirement includes the losses due to evapotranspiration (ET) or consumptive use (Cu) plus the unavoidable losses during the application of irrigation water and the quantity of water required for special operations such as land preparation, transplanting, leaching, etc. It may thus be formulated as follows:

WR = ET or Cu + application losses + special needs.

.7.1 Reference Crop Evapotranspiration

Doorenboos and Pruitt (1977) defined reference crop evapotranspiration, ETo as the rate of evapotranspiratin from an extended surface of 8 to 15 cm tall green grass cover of uniform height, actively growing, completely shading the ground and not short of water. Based upon alphalfa (Medicage Sativa,L) Jansen et al. (1971) defined ETo as the upper limit or the maximum evapotranspiration that occurs under given climatic conditions with field having a well watered agricultural crop with an aerodynamically rough surface, such as alfalfa, with 30 to 50 cm of top growth.

Based on intensive studies of the climatic and measured grass evapotranspiration data, Doorenbos and Pruitt (1977) proposed four methods for the calculation of reference crop evapotranspiration (ETo) viz. Modified Blaney - criddle method, modified radiation method, modified Penman method and pan evaporation method.

2.7.1.1 Modified Blaney Criddle Method

The recommended formulas is $ETo = C \times [P(0.46\ T + 8)]$

Where ETo = Reference crop evapotranpiration in mm/day for the month considered.

T = Mean daily temperature in ^{o}C over the month considered.

P = Mean daily percentage of total annual day time hours, and

C = Adjustment factor depending on minimum relative humidity, sunshine hour and day time wind estimates.

Doorenbos and Pruitt(1977)pointed out that the above method should normally be applied for periods not shorter than one month and for each calender month for each year of record.

.7.1.2 Modified Radiation Method

The relationship suggested for this method, representing mean value over the given period is expressed as

$$ETo = C(WRs)$$

where, ETo = reference crop evapotranspiration in mm/day for the period considered

Rs = solar radiation in equivalent evaporation in mm/day

W = Weighting factor which depends on temperature and altitude,

C = adjustment factor which depends on mean humidity and day time wind conditions.

.7.1.3 Modified Penman Method

The recommended relationship as applicable to this method reads as

$$ETo = C\ (WRn + (1-W) \times f(u) \times (e_a - e_d)$$

Where, ETo = reference crop evapotranspiration in mm/day

W = temperature related weighting factor

Rn = net solar radiation in equivalent evaporation in mm/day

f(u) = wind related function

$(e_a - e_d)$ = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in bar.

C = Adjustment factor to compensate for the effect of day and night weather conditions.

2.7.1.4 Pan Evaporation Method

The equation is of the form

$$ETo = Kp \times Epan$$

where, ETo = Reference crop evapotranspiration in mm/day

Epan = pan evaporation in mm/day and represents the mean daily value of the considered period and

Kp = Pan coefficient which depends on the type of pan, humidity, wind condition and pan environment.

2.7.2 Adjustment Factor

The adjustment factor 'c' of Blaney Criddle method modified radiation method and modified Penman method is somewhat difficult to be calculated from the graphs and tables as proposed by Doorenbos and Pruit (1977). To overcome this Allen and Pr (1991) have suggested easier solution for the calculation of the adjustment factor. They have replaced the graph or tables by regression equations depending on climatic factors like humidity, wind velocity, radiation, sunshine hours etc.

2.7.2.1 Adjustment Factor for Modified Blaney-Criddle Method

The equation for calculation of 'c' in Blaney-Criddle method is a seven-parameter regression model and reads as follows.

$$c = 0.908 - 0.00483\ RHmin + 0.7949\ n/N + 0.0768\ [\ln(Ud + 1)]^2 - 0.0038\ RHmin - 0.000433\ RHmin \times Ud + 0.281\ \ln(Ud + 1) \times \ln(n/N + 1) - 0.00975\ \ln(Ud + 1)\ [\ln(RHmin + 1)]^2 \times \ln(n/N+1)$$

where, RHmin = minimum daily relative humidity in per cent

n/N = mean ratio of actual to possible sunshine hour

Ud = day time wind speed in m/sec.

2.7.2.2 Adjustment Factor for Modified Radiation Method

Frevert et al. (1983) developed a regression model for calculation of the 'C' factor in radiation method which was also recommended for use by Allen and Pruitt (1991)

The relationship, with coefficients rounded to significant digits is as follows:

$$c = 1.066 - 0.00128\ RHmean + 0.045\ Ud - 0.002\ RHmean \times Ud - 0.0000315\ (RHmean)^2 - 0.001103\ (Ud)^2$$

Where, RHmean = mean daily relative humidity in per cent

Ud = day time wind speed in m/sec.

.7.2.3 Adjustment Factor for Modified Penman Method

The adjustment factor 'C' for modified penman method can be best estimated using a nine-parameter regression model based on four variables and has the following form as suggested by Allen and Pruitt (1991).

$$c = 0.892 - 0.0781\ Ud + 0.00219\ Ud \times Rs + 0.000402\ RHmax \times Rs + 0.000196\ (Ud/Un) \times Ud \times RHmax + 0.0000198\ (Ud/Un) \times Ud \times RHmax \times Rs + 0.00000236\ (Ud)^2 \times Rhmax \times Rs - 0.0000086(Ud/Un)^2\ Ud \times RHmax - 0.0000000292\ (Ud/Un) \times (Ud)^2 \times (RHmax)^2 \times Rs - 0.0000161\ RHmax \times (Rs)^2$$

Where, Ud = mean daily day time wind speed over the month considered in m/sec.

RHmax = mean daily maximum relative humidity over the month considered.

Ud/Un = ratio of day time & night time wind speeds (generally taken as 2 if unknown)

Rs = daily global solar radiation in equivalent evaporation in mm/day.

2.7.3 Crop Coefficient

The values of ETo, the reference crop evapotranspiration estimated by the above methods are based on climatological parameters and need to be adjusted for actual crop evapotranspiration (ETcrop) to account for the effect of the crop characteristics. For converting ETo value into ETcrop, suitable crop coefficients (Kc) should be evolved for different crops, time of planting or sowing, and also for different stages of growth for the same crop. Doorenbos and Pruitt (1977) have given tables showing crop coefficients for given stages of crop development and different climatic conditions.

2.7.4 Crop Evapotranspiration

The crop evapotranspiration, ETcrop of different crops are determined by the following equation suggested by Doorenbos and Pruitt (1977).

$$ETcrop = Kc \times ETo$$

Where ETcrop = crop evapotranspiraion or water requirement in mm/day

ETo = reference crop evapotranspiration in mm/day

Kc = crop coefficient

2.8 Length of record

The decision regarding the length of record puts a typical problem before a research worker at the time he takes into hand a project. For more realistic representation of the picture a minimum length of the record should always be advisable.

Manhor (1980) reported that coefficient of variation will lie within confidence limits if the series includes a minimum of 20 to 30 variates. Bhattacharya and Sarkar (1982) suggested that a 20 year period data should be the minimum requirement for agricultural drainage design.

.9 Closure of Review

All collected literatures concerning the relevant works in the field of drought analysis from different sides have been reviewed in the foregoing pages. It is seen that analysis of daily rainfall data for prediction of onset and withdrawal of effective monsoon, length and duration of critical dry spells and their probable dates of occurrence has not been carried out so far in the most drought prone Kalahandi district, though the same work has been done for some coastal areas in Orissa. Moreover works to relate the forest area with rainfall and other components of water cycle are yet to see light in the district and the state as well.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

This chapter deals with the description of the study area, the materials used and the methods employed for the study.

3.1 Description of Study Area

The area selected for the purpose of the study is the predivided district of Kalahandi of Orissa State. It is needless to say that this district has recently been splitted up into two districts, namely Kalahandi district and Nawapara district. In the present study, however, the district of Kalahandi wherever used means the predivided district since the study was initiated prior to this division.

3.1.1 Origin and Ancient Background

The district of Kalahandi was in ancient times a part of South Kosala in form of a princely state. After independence of the country, this district was formed taking into its fold the Ex-states of Kalahandi and the Ex-Zamindary area of Khariar on 1st November, 1949. Subsequently in 1962, Kashipur police station was taken out from this district and was merged with Koraput district.

3.1.2 Location and Boundaries

The district of Kalahandi occupies the south western portion of Orissa and is located between North latitudes $19^{\circ} 03'$ and $21^{\circ} 05'$ and East longitudes $82^{\circ} 20'$ and $83^{\circ} 47'$. It is bounded on the north by the districts of Balangir, Sambalpur and Raipur (M.P.) ; on the south by the district of Koraput; on the west by the districts of Koraput and Raipur (M.P.) and on the east by the districts of Koraput and Phulbani.

3.1.3 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. The elevation of these plains above mean sea level ranges from 210 to 450 meters. The plain region covers the entire Nawapara sub-division and then runs southwards 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 and the western portion of the Nawapara sub-division. 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 Bauxite.

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 flow during monsoon and almost dry up during the summer season. The topographical map of the district is given in fig.3.1 and the contour map in fig. 3.2.

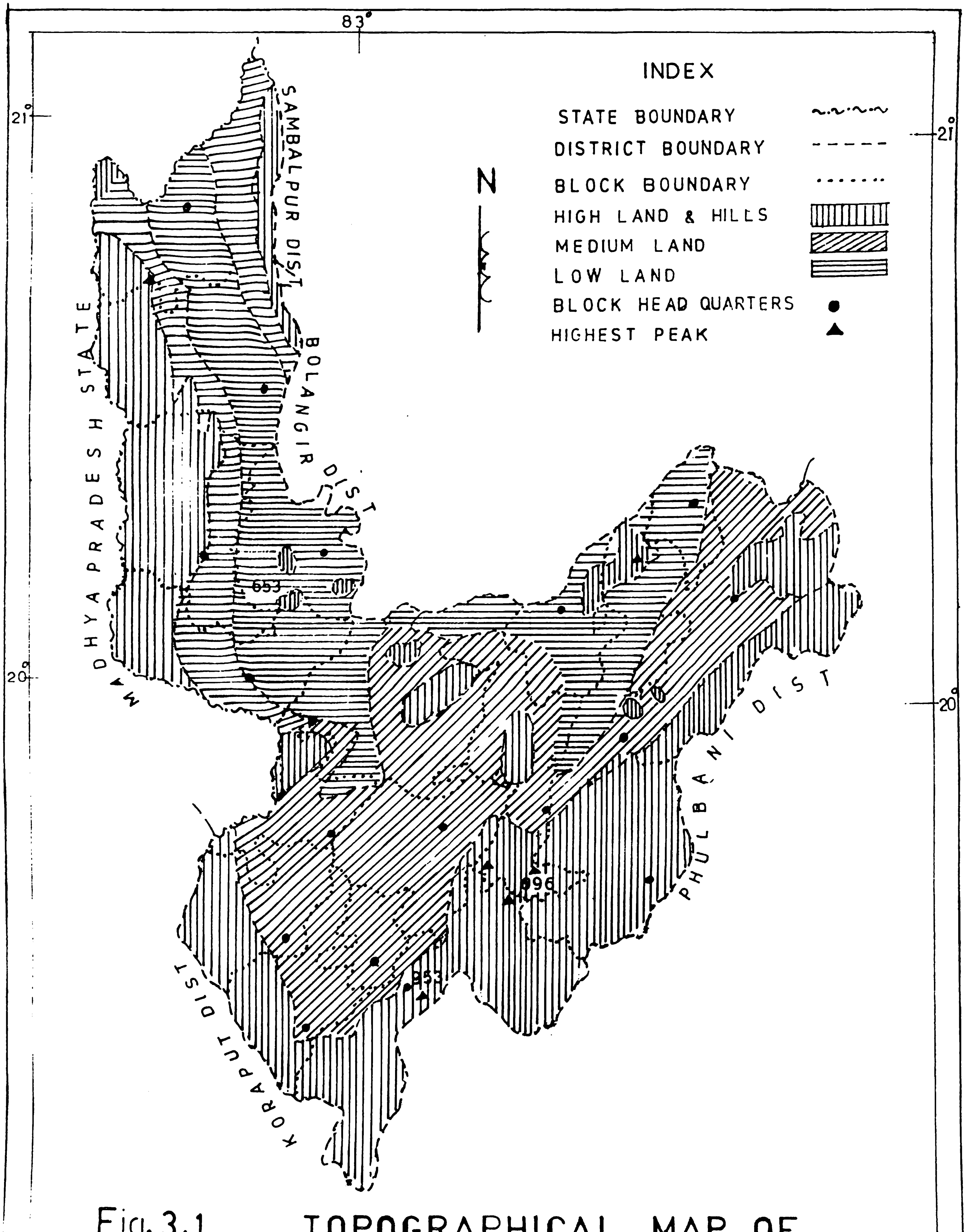


Fig. 3.1 TOPOGRAPHICAL MAP OF KALAHANDI DISTRICT

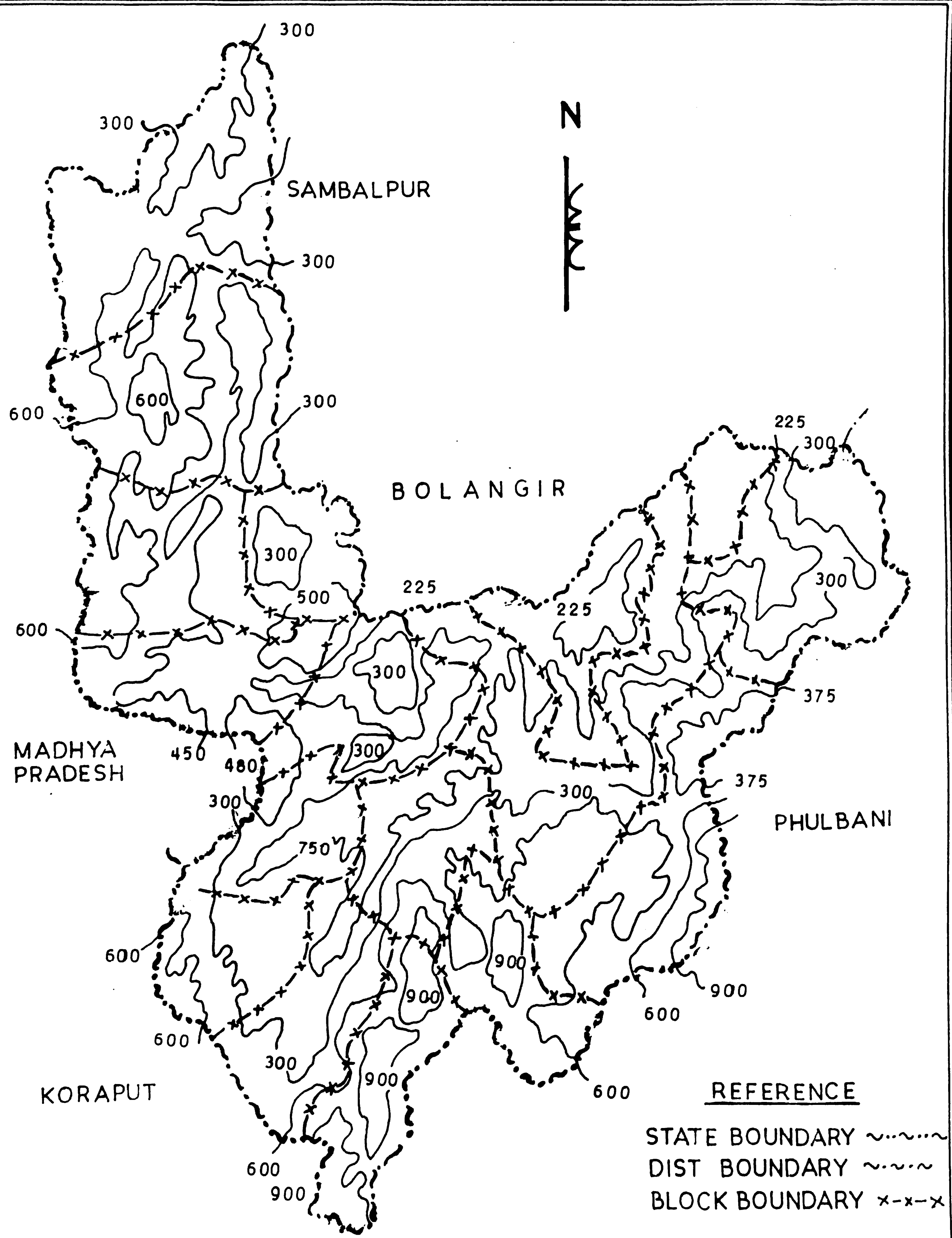


Fig. 3.2 CONTOUR MAP OF KALAHANDI DISTRICT

.1.4 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 form 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.

Overlying the rocks of the Eastern Ghats group occur the less deformed and metamorphosed sedimentary rocks of the Chattisgarh group in the western parts of Nawara sub-division forming the hill ranges. The common rock types include purple shales, quarzite, sandstone, arkosic quarzite 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.

The geological map of the district is depicted in Fig. 3.3.

3.1.5 Climate and Rainfall

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 hotest 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

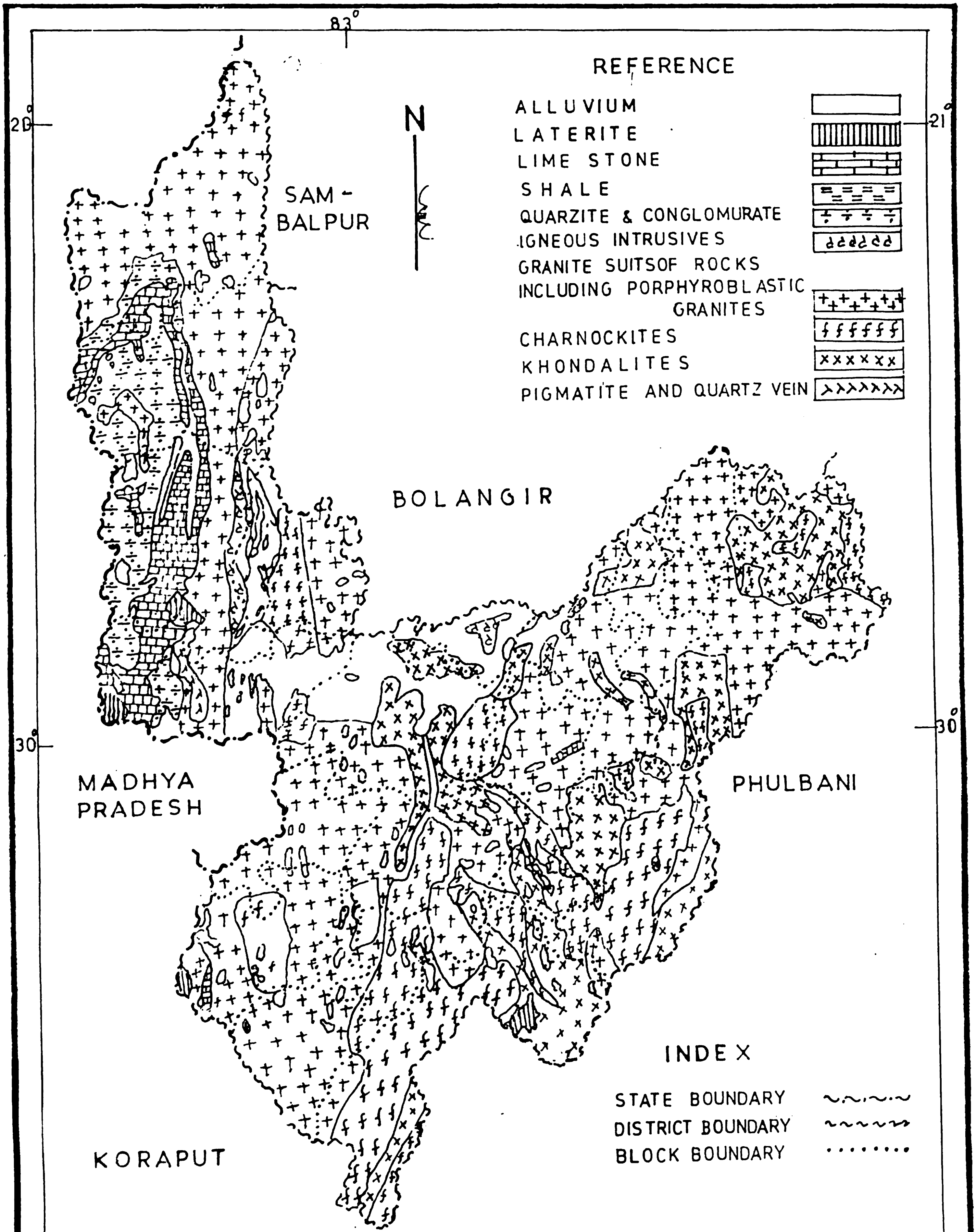


Fig. 3.3 GEOLOGICAL MAP OF KALAHANDI DISTRICT

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 season 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 rainfall between the period 1st June to 31st October averages around 1259 mm. 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 rainfall map of the district is given in fig. 3.4 and the blockwise distribution of rainfall in Table A-1 (Appendix A). Fig.3.5 depicts the departure of yearly rainfall from the normal in the district.

3.1.6 Area and Population

The district of Kalahandi extends over an area of 11,772 sq. km constituting 7.56 per cent of the total area of the state and ranks 4th among the 13 districts of Orissa with regards to size. Its extreme length from north to south is about 220 km and its extreme breadth from east to west is about 140 km. As per the Census Report of 1991 (P), the district accommodates a total population of 15,91,984 (7,95,939 males and 7,96,045 females) which accounts for 5.05 per cent of the total population of the state and occupies tenth position among the 13 districts of Orissa in this respect. The density of population per sq.km is 135 as against 202 for Orissa.

The pace of urbanisation of the district is very low and only 6.53 per cent of its population live in the 5

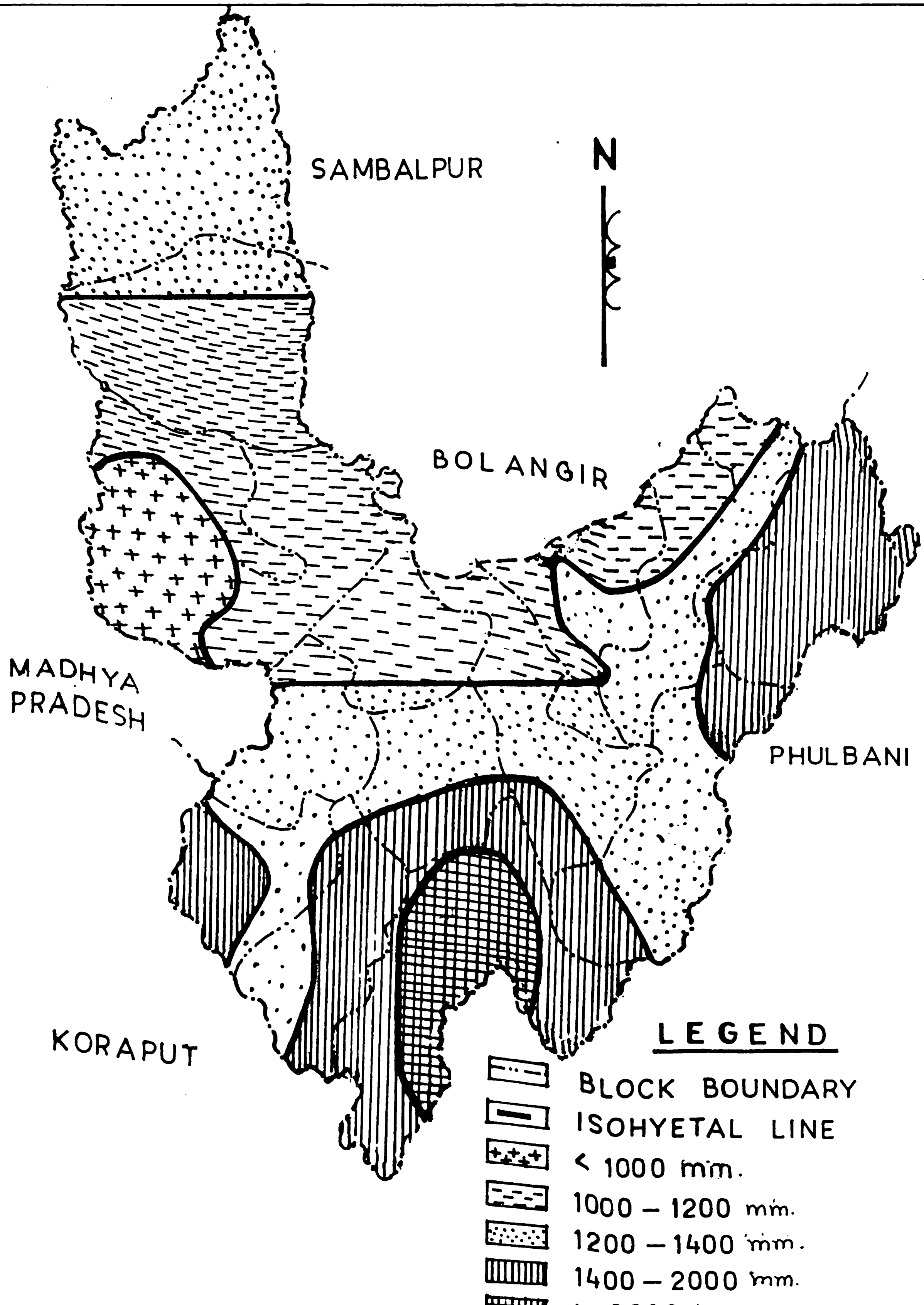
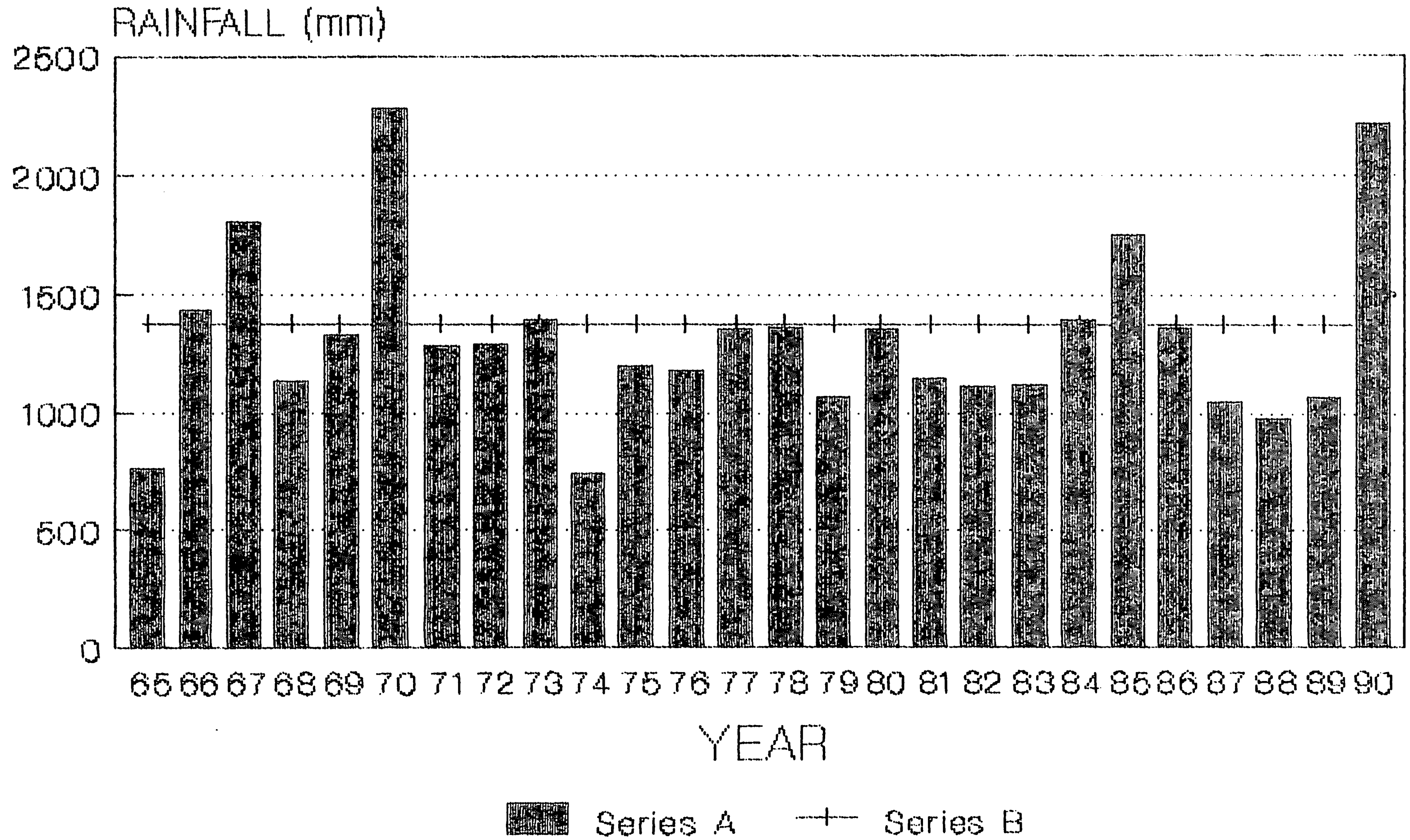


Fig. 3.4 RAINFALL MAP OF KALAHANDI DISTRICT

NORMAL & ANNUAL RAINFALL
IN KALAHANDI DISTRICT



SERIES A - ANNUAL RAINFALL
SERIES B - NORMAL RAINFALL

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 12th among the districts of Orissa. The per cent literacy of the districts is 25.32 as against the state average of 40.97 per cent.

The backward population consisting of SC/ST forms 47.1 per cent (1981 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 tribals is found in Thumal-Rampur and Lanjigarh blocks. The decedal growth of population beginning from the present century in Orissa as also in the district of Kalahandi is given in Table A-2 (Appendix A).

3.1.7 Administrative Set-up

For administrative convenience, the district has been divided into 3 sub-divisions, viz. Bhawanipatna, Dharamgarh and Nawapara and 7 Tahsils. Three of the Tahsil headquarters are located in the sub-division headquarters and the rest four are located at Jaipatna, Khariar, Madan Rampur and Lanjigarh. The district also has 18 C.D. blocks, 249 Grama Panchayats and 2840 villages out of which 2695 are inhabited. For implementation of agricultural programme smoothly, the district has been divided into two agricultural districts, viz. Bhawanipatna and Khariar. The district has been delimited with 8 Assembly and one Parliamentary constituencies. The administrative map of the district is given in fig. 3.6.

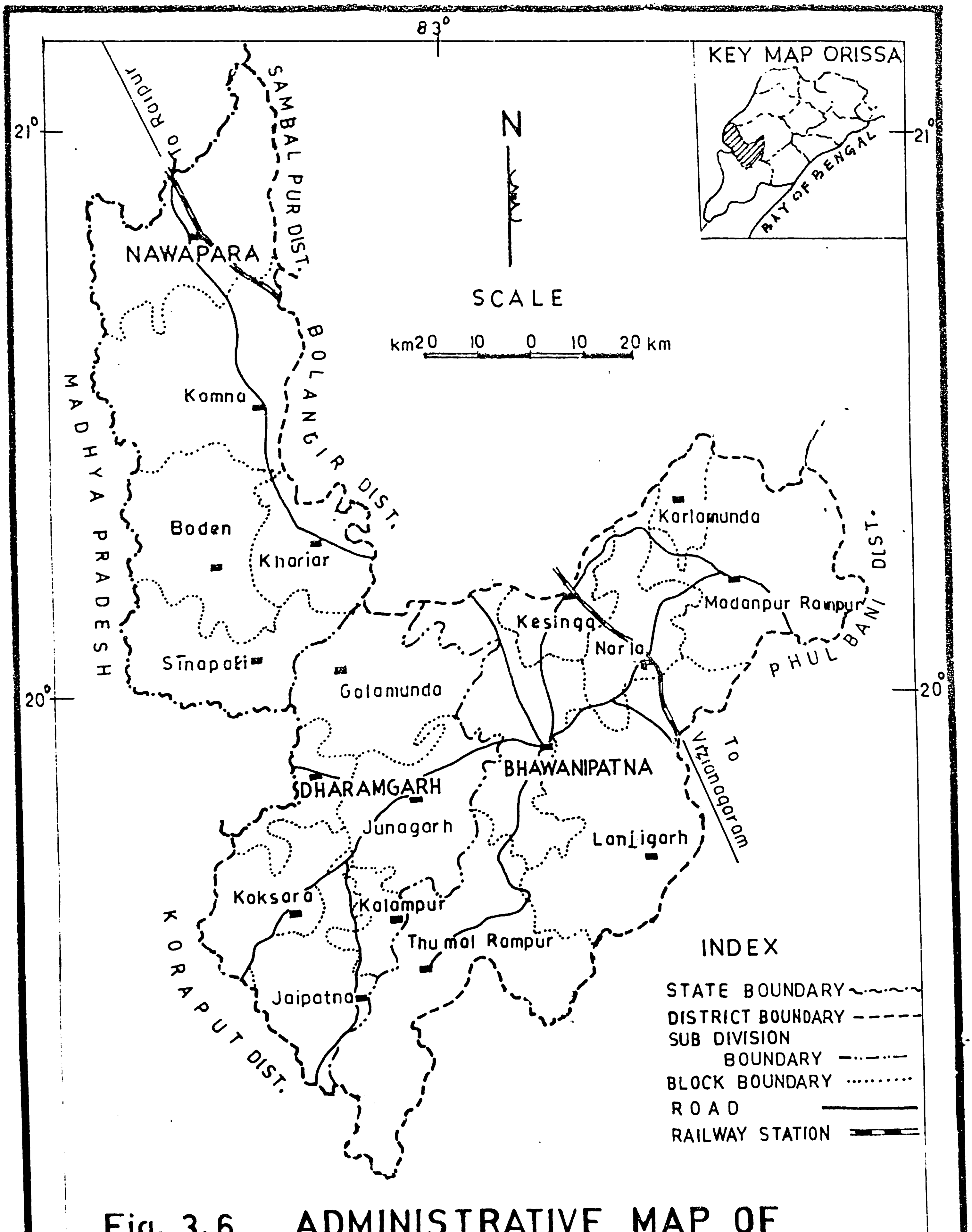


Fig. 3.6 ADMINISTRATIVE MAP OF KALAHANDI DISTRICT

3.1.8 Soil and Land

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 occures 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 A-3 (Appendix A).The soil map of the district is depicted in fig. 3.7. 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 1158 thousand Ha.m, total cropped area (excluding fruits) is 828 thousand Ha. and the net area sown is 564 thousand ha. as per 1989 data. The land use pattern of the district is given in Table A-4 (Appendix A).

3.1.9 Forests

Kalahandi district is noted for its rich forests which cover nearly 48.1 per cent of its total geographical area as against the state figure of 35.4 per cent. In 1989-90, it extended over an area of about 5660.83 sq. km. comprising 1448.13 sq. km. of reserved, 2527.86 sq.km. of protected and 1684.84 sq.km. of unclassed forests. Timber and Bamboo are the major forest produce of the district. The other important produces from forests include Kendu leaf, Sabai grass and Mahua-flower.

3.1.10 Land Holding Pattern

About 64 per cent of the land holdings in the district belong to the marginal and small farmers which constitute 28.8 per cent of total area whereas 12.4 per cent of

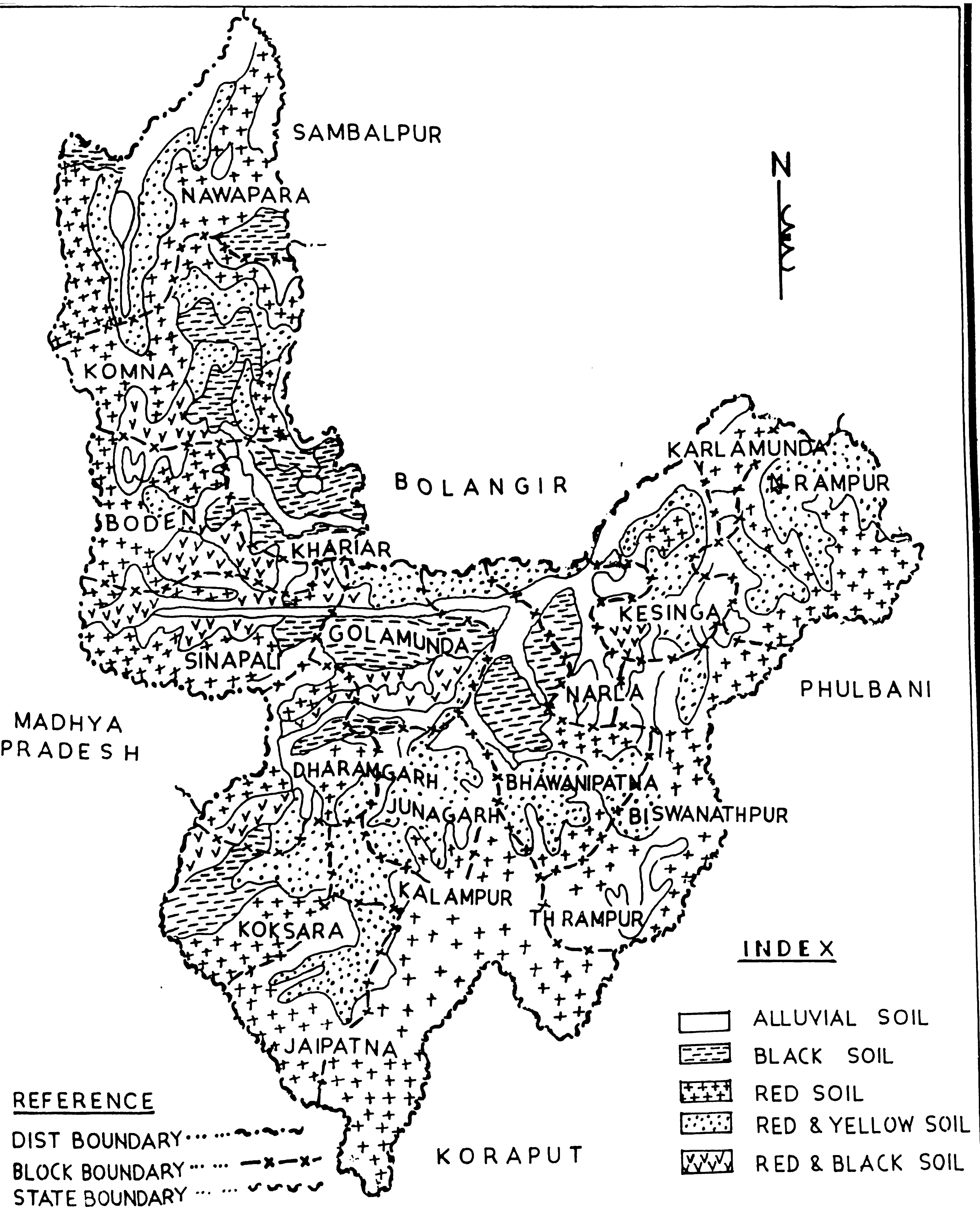


Fig. 3.7 SOILS OF KALAHANDI DISTRICT

total holdings are of more than 4Ha size and alone account for 40.8 per cent of total area. The size distribution of land holdings in Kalahandi district for 1985-86 is given in Table A-5 (Appendix A).

3.1.11 Major Crops

Food grains constitute the predominate crops of the district which covered 56 per cent of the gross cropped area of 828thousand Ha. in 1989-90. Paddy is the principal crop which alone constituted 38.6 per cent of the gross cropped area . Other cereals and millets normally grown in the district include wheat, maize, jowar, bajra, minor millets etc. Pulses like arhar, 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 area under different crops, their production and yield rate for 1989-90 and 1990-91 is given in Table A-6 (Appendix A). Fig. 3.8 gives the crop map of the district.

3.1.12 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 13.08 per cent of the net area sown was irrigated in kharif in 1989-90. Minor (flow and lift) irrigation projects including C.D. and private sources form the major source of irrigation .

Table A-7 (Appendix A) presents a picture of the net area irrigated by different irrigation sources in the district.

Fig. 3.8 CROP MAP AND BLOCK H Q OF KALAHANDI DISTRICT

3.2 Data Used

For the sake of the present study, a variety of data have been used which are collected from various sources. For rainfall analysis , 26 years' continuous daily rainfall data for 8 blocks of Kalahandi district, viz. Bhawanipatna, Kesinga, Nawapara, Khariar, Narla, Boden, Golamunda and Dharamgarh are collected from Regional research Station, Bhawanipatna (1967-1987) and Board of Revenue, Cuttack (1988-1992). Monthly evaporation data for 10 years (1981-1990) for Kesinga station are obtained from office of the Assistant Engineer, Data Division, O.L.I.C., Bhubaneswar. As no data on evaporation was available for Bhawanipatna station and Kesinga is situated very near to Bhawanipatna (35 km away), these data are used for finding out the daily average evaporation (e) of Bhawanipatna. Daily data on maximum and minimum temperature, relative humidity, wind speed and cloudiness for Bhawanipatna station are collected over 9 years (1976,1978,1981-83,1986-89) from Meteorological Centre, Bhubaneswar for calcualtion of crop water requirements. The yearwise data on area under forests in the district of Kalahandi for 26 years (1965-1990) are obtained from the offices of D.F.O., Bhawaipatna and D.F.O., Khariar and the yearly rainfall data for these years are gathered from the office of D.S.O., Kalahandi. The data used for estimation of ground water potential of Bhawanipatna block are collected from the office of the Senior Geologist, G.W.S. & I.D., O.L.I.C.,Bhawanipatna which include water table fluctuation, area suitable for ground water recharge, specific yield, length, wetted perimeter and running days of canals, area irrigated under differnt crops, numbers of irrigation wells etc.

3.3 **Assessment of Drought Years**

The drought years in the eight blocks under study were identified according to the approach given by Sharma et al. (1979). The criteria for this is that a year is said to be drought year if the annual rainfall is less than ($\bar{X}$ - σ), where $\bar{X}$ is the average yearly rainfall and σ is the standard deviation.

3.4 **Onset of Effective Monsoon and Critical Dry Spells**

For the analysis of the daily rainfall data with a view to identify the onset and withdrawal of effective monsoon, occurrence of critical dry spells etc. the methodology which is adopted in the present study is described below.

3.4.1 **Onset of Effective Monsoon (OEM)**

The date of commencement of a 7-day spell satisfying the following criteria can be defined as the date of onset of effective monsoon (Ashok Raj,1979).

(i) The first day's rain in the 7-day spell is not less than e mm, where e is the average daily evaporation.

(ii) The total rain during the 7-day spell is not less than (5e+10) mm.

(iii) At least four out of these seven days are rainy days with not less than 2.5 mm of rain each day.

This definition regarding the onset of effective monsoon is used in the present study. The average daily evaporation (e) for Kesinga station is calculated to be 10.3 mm/day. As no data were available regarding the daily evaporation at other stations, this value of e has been taken for other stations.

3.4.2 Mean Date of OEM

When the date of onset of effective monsoon Xi (i=1,2...n) in the ith year for a particular raingauge station is identified, the mean date (m) is then calculated as follows :

$$m = \sum_{i=1}^{n} Xi/n$$

Where n is the total number of years for which the anlysis is being carried on.

3.4.3 Standard Deviation (σ) of OEM

After determining the Xi (i=1,2 ...n) dates of onset of effective monsoon, their standard deviation (σ) is calculated as follows :

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

3.4.4 Median Date of OEM

Median is defined as that value which divides observations into two equal parts. If n, the number of years is odd and the dates of onset of effective monsoon Xi(i=1,2,...n) are arranged in ascending or descending order of magnitude, the middle value is the median date. In case n is even, median date is the arithmetic mean of the two middle values.

3.4.5 Quartile Deviation (Q)

The quartile deviation (Q) or the semi-inter-quartile- range is defined as follows :

$$Q = \frac{Q_3 - Q_1}{2}$$

Where Q_1 is the first quartile dividing the observations Xi (i=1,2 .... n) into a fourth below Q_1 and three-fourths above, and Q_3 is the third quartile dividing the observations into a fourth above and three-fourths below.

3.4.6 Earliest and Latest Probable Date of OEM

If a variate **X** which takes the values $X_1, X_2, \ldots X_n$ follows a normal distribution with mean(m) and standard deviation (σ), then the probability density function of the variate is given by

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

The probability that x lies between (m - σ) and (m + σ) is given by the relation

$$P(m - \sigma < X < m + \sigma) = \int_{m-\sigma}^{m+\sigma} P(X)\, dX$$

As X follows a normal distribution with mean m and standard deviation σ, the standardised normal variate

$$Z = \frac{X - m}{\sigma}$$

follows a normal distribution with mean O and standard deviation 1. The probability that X lies between (m - σ) and (m + σ) is the same as that of Z lying between -1 and 1 which is given by the relation.

$$P(-1 < Z < 1) = \int_{-1}^{1} \emptyset(Z)dZ$$

$$= 2 \int_{0}^{1} \emptyset(Z)dZ \text{ because of symmetry}$$

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

$$= 0.6826$$

In other words the least value that X can assume in the domain $(m - \sigma)$ to $(m + \sigma)$ is $m - \sigma$ and the heighest value $m + \sigma$ each with a probability of approximately 0.68. Thus it is assumed that the dates of onset of effective monsoon Xi (i=1,2...n) follow a normal distribution with mean m and standard deviation σ, then the least value Xi can take with a probability of 0.68 is $m - \sigma$ and the highest value is $m + \sigma$ with the same probability. These values $m - \sigma$ and $m + \sigma$ are taken as the earliest and latest probable dates of OEM with a probability 0.68. Similarly based on median earliest and latest probable dates of onset of effective monsoon are $Q_2 - Q$ and $Q_2 + Q$ respectively each with probability 0.50, where Q_2 is the median and Q the quartile deviation.

3.4.7 Critical Dry Spell (CDS)

The interval between the end of the 7-day spell beginning with the onset of effective monsoon and another rainy day with 5e mm or more of rain or the commencement of another 7-day rainy spell with a total of at least 5e mm of rain and having not less than four rainy days during this spell is called the first dry spell. If the duration of this dry spell exceeds a certain limiting value depending on the crop-soil complex of the region under considertation, then this spell is called the first critical dry spell (Ashok Raj, 1979). Subsequent critical dry spells are defined in the same manner. The above definition for identification of critical dry spells is used in this study. Paddy is the principal crop of the district of Kalahandi for most parts of which the soil is red or mixed red. On the basis of this crop-soil combination the minimum length of a dry spell was assumed to be 7 days for making it critical. The 120th day of each year is considered to be the approximate date in which rains are likely to start.For analysis of the daily rainfall data to identify the OEM and critical dry spells, a computer programme in Fortran-IV language has been developed by Ashok Raj (1979). A modified form of this programme in Fortran-77 for Unix System with 3 sub routines is used for the purpose of this study. The daily rainfall data of 26 years of the selected stations are fed to the computer along with the data regarding average daily evaporation, defining length of a critical dry spell and the average date of starting of rains in a year for carrying out the analysis.

Since the durations of the critical dry spells are likely to differ from year to year, the average duration of the critical dry spells is taken as effective critical dry spell duration.

3.5 Forecasting of Dry and Wet Spells

For forecasting of dry and wet spells, the method suggested by Pandarinath (1991) is applied in this study. A week with less than 20 mm of rainfall is considered as a dry week and that with 20 mm or more of rainfall as a wet week. The procedure and the formulae used for calculation are as follows :

(i) $P(d) = F(d)/n$

(ii) $P(dd) = F(dd)/F(d)$

(iii) $2D = P(dw1) \times P(ddw2)$

(iv) $3D = P(dw1) \times P(ddw2) \times P(ddw3)$

Where $P(d)$ = Probability of the week being dry

$F(d)$ = Frequency of dry weeks

n = Total number of years for which data are being analysed.

P(dd) = Conditional probability of dry weeks preceed by another dry week.

F(dd) = Frequency of dry weeks preceed by another dry week.

2D = Probability of two consecutive dry weeks

3D = Probability of three consecutive dry weeks

P(dw1) = Probability of the week being dry (1st week)

P(ddw2) = Probability of the 2nd week being dry given the preceeding week (i.e 1st week) is dry.

P(ddw3) = Probability of the 3rd week being dry given the preceeding two weeks (i.e 1st and 2nd weeks) are dry.

In a similar fashion , P(w),P(ww) , 2W and 3W can be calculated as P(d), P(dd), 2D and 3D and the notations used have the same meaning except the weeks being wet.

For the present analysis, the daily rainfall data are fed to the computer and by a simple DBASE programme these are converted to weekly data. In order to cover the whole year, the 52nd week of each year is considered to be of 8 days (9 days in case of a leap year). The weekly rainfalls for all the 26 years are arranged under respective weeks and then the dry and wet weeks are identified. F(d) and F(w) are obtained by simply counting separately the numbers of dry and wet weeks as identified from the 26 values for a certain week. Similarly dry weeks preceeded by dry weeks and wet weeks preceeded by wet weeks are counted to get the values of F(dd) and F(ww) respectively.

Using the formula as described above, probabilities of dry weeks and wet weeks, conditional probabilities of dry weeks and wet weeks preceeded by dry weeks and wet weeks and probabilities of consecutive 2 and 3 dry or wet weeks with a dry or wet week at the beginning are calculated.

3.6 Evaluation of Ground Water Potential

Depending on the types of data available, various approaches can be used for evaluation of ground water prtential 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). The groundwater potential of Bhawanipatna block of Kalahandi district is estimated as per these norms for the present study, keeping in view the data collected. The area suitable for ground water recharge in this block is found to be entirely crystalline (consolidated). Hence the expressions for sendimentary and alluvial zones in the above approach have been discarded. The stepwise procedure of calculation is given below in detail.

EVALUATION OF GROUND WATER POTENTIAL OF BHAWANIPATNA BLOCK, KALAHANDI DISTRICT BASED ON GROUND WATER ESTIMATION COMMITTEE (G.E.C.) NORM, 1983.

ANNUAL RECHARGE
(WATER TABLE FLUCTUATION APPROACH)

A. MONSOON RECHARGE

(a)	Total geographical area	96530 Ha
(b)	Area not suitable for ground water recharge	55582 Ha
(c)	Net area suitable for ground water recharge (a-b)	40948 Ha
(d)	Year of observation	1992
(e)	Water table fluctuation observed in the crystalline zone	2.16 mm
(f)	I.M.D. normal yearly rainfall	1457.1 mm

(g) I.M.D. normal monsoon rainfall 1348.5 mm

(h) I.M.D. normal non-monsoon rainfall 108.6 mm

(i) Monson rainfall received during 1992 (June-October) 1560.06 mm

(j) Non-monsoon rainfall received during 1992 38.0 mm

(k) Specific yield in the zone (crystalline) of water table fluctuation expressed as fraction 0.025

(l) Rainfall Infiltration Factor (R.I.F.) for the crystalline zone 0.08

B. RECHARGE FROM SURFACE SOURCE

I. Recharge due to seepage from canals = length of canal x av. wetted perimeter x av. running days x seepage factor. A seepage factor of 20 Ha. m / day/10^6 m^2 of wetted area is considered for this study.

Calcualtion of this part is presented in table 3.1

Table 3.1 Recharge due to seepage from canals

Name of canal	Length (m)	Av. Wetted perimeter (m)	Av.running days		Seepage (Ha.m)		
			non-monsoon	mon-soon	non-monsoon	mon-soon	yearly
M.I. canal	30270	4.2	20	30	50.85	76.28	127.83
Total					50.85	76.28	127.83

II. Recharge due to return flow from surface water irrigation = crop area irrigated x av. depth of water application x seepage factor for the crop considered.

The detailed calculation for this part is given in the following table.

Table 3.2 Recharge due to return flow from surface water irrigation.

source	Crop grown	Area irrigated (Ha.)	Av. depth of water (m)	Total Qty. of water applied (Ha.m)	Seepage factor (%)	Seepage (Ha.m) non-mon.	mon-soon	yearly
MIP	Kharif (Paddy)	1911	0.3	573.3	40	-	229.32	230.89
	Rabi (Veg.)	12	0.375	4.5	35	1.57	-	
DLP	Kharif (Paddy)	585	0.3	175.5	40	-	70.2	146.98
	Rabi (Veg.)	585	0.375	219.37	35	76.78	-	
Total						78.35	299.52	377.87

III. Recharge due to seepage from tanks/ponds etc = total waterspread area x seepage factor

The following table gives the necessary calculation for the estimation of this part of recharge.

Table 3.3 Recharge due to seepage from tanks & ponds.

source	Total waterspread area (Ha.)	Seepage factor m/yr	Seepage (Ha.m) non-mon.	mon-soon	yearly
Tanks & Ponds of the block	470.69	0.6	162.5	119.9	282.4
Total			162.5	119.9	282.4

C. ANNUAL GROUNDWATER DRAFT

I. Gross yearly draft = Number of irrigation wells x unit draft.

The calculation of the gross yearly draft is reported in the following table.

Table 3.4 Gross yearly ground water draft.

Type of irrigation well	Total nos. (as on 3/92)	Unit draft (Ha.m)		Gross draft (Ha.m)		
		non-monsoon	monsoon	non-monsoon	monsoon	yearly
Dugwell with tenda	2413	0.2	0.1	482.6	241.3	723.9
Dugwell with pumpset	163	0.6	0.4	97.8	65.2	163.0
Total				580.4	306.5	886.9

II. Net annual groundwater draft

= 70 % of gross yearly draft

= 0.7 x 887.9

= 620.83 Ha.m

CALCULATION OF MONSOON RECHARGE

(a) Change in ground water storage (Δs)

= Net area suitable for recharge x water table fluctuation x specific yield

=40948 x 2.16 x 0.025

=2219.19 Ha.m

(b) Gross ground water draft during monsoon (Dw)

= 306.5 Ha.m (from table 3.4)

(c) Recharge due to seepage from canals during monsoon (Rs) = 76.28 Ha.m (from Table 3.1)

(d) Recharge due to return flow from surface irrigation during monsoon (Ris) = 299.52 Ha.m (from Table 3.2)

(e) Return flow from ground water irrigation during monsoon (Rigw) = 30 % of Dw

= 0.3 x 306.5
=91.95 Ha.m

(f) Normalisation Factor (NF)

$$= \frac{\text{Normal monsoon rainfall}}{\text{monsoon rainfall received during 1992}}$$

$$= \frac{1348.5}{1560.06}$$

= 0.864

Therefore the total monsoon recharge

= [(s + Dw - Rs - Ris - Rigw) x NF + Rs + Ris

= [(2211.19+306.5-76.28-299.52-91.95)x0.864 +76.28+299.52]

= 2146.95 Ha.m

(D) NON-MONSOON RAINFALL RECHARGE

This is calculated as follows :

Total non-monsoon rainfall reacharge

= net area suitable for ground water recharge (Ha) x
av.non-monsoon rainfall received during 1992 (mm) x
rainfall infiltration factor x 1/1000

= 40948 x 38.0 x 0.08 x 1/1000

= 124.48 Ha.m

(E) TOTAL ANNUAL RECHARGE

(a) Monsoon recharge	2146.95 Ha.m
(b) Non-monsoon rainfall recharge	124.48 Ha.m
(c) Recharge due to seepage from canals during non-monsoon (Table 3.1)	50.85 Ha.m
(d) Recharge due to return flow from surface water irrigation during non-monsoon period (Table 3.2)	78.35 Ha.m
(e) Recharge due to non-monsoon seepage from tanks and ponds (Table 3.3)	162.50 Ha.m

(f) Potential recharge (recharge from flood prone areas & shallow water table areas) nil

Therefore, total annual recharge

= (a)+(b)+(c)+(d)+(e)+(f)

= 2146.95+124.48+50.85+78.35+162.50

= 2563.13 Ha.m

(F) CHECK OF MONSOON RECHARGE BY WATER TABLE FLUCTUATION METHOD

(a) Monsoon recharge due to rainfall only as per water table fluctuation approach

= (s + Dw -Rs - Ris - Rigw) x N.F.

= (2211.19+306.5-76.28-299.52-91.95)x0.864

= 1771.15 Ha.m

(b) Monsoon rainfall recharge as per adhoc norms (rainfall penetration norms)

= Net area suaitable for ground water recharge (Ha)

x I.M.D. normal monsoon rainfall (mm)

x rainfall infiltration factor x 1/1000

= 40948 x 1348.5 x 0.08

= 4417.47 Ha.m

(c) Variation between (a) and (b) above

$$= \frac{(a)-(b)}{(b)} \times 100$$

$$= \frac{1771.15-4417.47}{4417.47} \times 100$$

= (-) 59.91 %

REMARK : As the variation is found to be greater than 20 per cent, the rainfall penetration approach (adhoc norm) is accepted for the estimation of annual recharge (G.E.C.Norm,1983)

G ANNUAL RECHARGE ON ADHOC NORM

(a) Annual recharge from rainfall

= Net area suitable for ground water recharge (Ha)
x I.M.D. normal yearly rainfall (mm)

x infiltration factor x 1/1000

= 40948 x 1457.1 x 0.08 x 1/1000

= 4773.23 Ha.m

(b) Yearly recharge due to seepage from canals (Table 3.1)	127.13 Ha.m
(c) Yearly recharge due to return flow of surface water irrigation (Table 3.2)	377.87 Ha.m
(d) Yearly recharge due to seepage from tanks and ponds (Table 3.3)	282.40 Ha.m
(e) Potential recharge	nil

Hence, total annual recharge

= (a)+(b)+(c)+(d)+(e)

= 4773.23+127.13+377.87+282.40

= 5560.63 Ha.m

(H) UTILISABLE GROUND WATER RESOURCE FOR IRRIGATION

Annual utilisable ground water resource for irrigation

= 85% of total annual recharge

= 0.85 x 5560.63

= 4726.53 Ha.m

(I) GROUND WATER BALANCE

Ground water balance for irrigation

= Annual utilisable ground water resource for irrigation - net annual ground water draft

= 4726.53 - 620.83.

= 4105.70 Ha.m

(J) PRESENT LEVEL OF GROUND WATER DEVELOPMENT

$$= \frac{\text{Net annual ground water draft}}{\text{Annual utilisable ground water resource for irrigation}}$$

$$= \frac{620.83}{4726.53} \times 100$$

$$= 13.13\ \%$$

The blockwise groundwater potential of Kalahandi district as obtained from Central Ground Water Board, Bhubaneswar is given in table A-8 (Appendix A)

3.7 Influence of Forest on Water Cycle

For studying the influence of forest cover on yearly rainfall, a vital component of the water cycle in the district, 26 years' data on area under forest as collected from the D.F.O.s, Bhawanipatna and Khariar and the annual rainfall have been taken into account. Table 3.5 gives the data on these two parameters for a period from 1965 to 1990.

3.8 Crop Water Requirments

The water requirments of the selected crops are determined on weekly basis by using modifed enman method since this is the best method as suggested by Doorenbos and Pruitt (1977).

3.8.1 Reference Crop Evapotranspiration

The equation used to calculate reference crop evapotranspiration by modified Penman method is given below.

$$ET_o = c(A+B)$$

where,

ET_o = reference crop evapotranspiration in mm per day

$A = (1 - w)\ f(u)\ (e_a - e_d)$, aerodynamic term

Table 3.5 Yearwise variation of rainfall and forest area in Kalahandi District.

YEAR	NORMAL RAINFALL (mm)	ACTUAL RAINFALL (mm)	DEPARTURE OF ACTUAL RAINFALL FROM NORMAL RAINFALL (mm)	(%)	FOREST AREA (Sq.kms.)
1965	1378.20	760.99	- 617.21	- 44.78	6137.66
66	-do-	1435.31	+ 57.11	+ 4.14	-do-
67	-do-	1805.30	+ 427.10	+ 30.99	-do-
68	-do-	1135.90	- 242.30	- 17.58	-do-
69	-do-	1332.82	- 45.38	- 3.29	-do-
70	-do-	2279.20	+ 901.00	+ 65.37	-do-
71	-do-	1284.21	- 93.99	- 6.82	-do-
72	-do-	1288.04	- 90.16	- 6.54	5859.57
73	-do-	1395.83	+ 17.63	+ 1.28	6406.03
74	-do-	739.70	- 638.50	- 46.33	-do-
75	-do-	1200.70	- 177.50	- 12.88	-do-
76	-do-	1182.00	- 196.20	14.24	6406.94
77	-do-	1354.70	- 23.50	- 1.71	6405.05
78	-do-	1360.10	- 18.10	- 1.31	6260.06
79	-do-	1068.80	- 309.40	- 22.45	6261.01
80	-do-	1353.70	- 24.50	- 16.72	6260.66
81	-do-	1147.80	- 230.40	- 18.96	-do-
82	-do-	1116.90	- 261.30	- 18.87	8358.85
83	-do-	1118.10	- 260.10	+ 1.28	8363.94
84	-do-	1395.90	+ 17.70	+ 1.18	-do-
85	-do-	1755.20	+ 377.00	- 27.35	6899.30
86	-do-	1362.00	- 16.20	- 1.18	5653.59
87	-do-	1048.70	- 329.50	- 23.91	-do-
88	-do-	978.00	- 400.20	- 29.04	-do-
89	-do-	1072.00	- 306.20	- 22.22	5660.83
90	-do-	2214.00	+ 835.80	+ 60.64	-do-

Table 3.6 Duration of different growth phases of crops under study

Crops	Duration, days	Initial stage	Crop development stage	Mid season stage	Late season stage
Upland rice	95	Jun 10 to July 9	July 10 to Aug 9	Aug 9 to Sept 2	Sept 3 to Sept 22
Maize	110	Jun 1 to July 20	July 21 to Aug 19	Aug 20 to Sept 23	Sept 24 to Oct 18
Greengram (kharif)	70	Jun 15 to Jun 29	Jun 30 to July 24	July 25 to Aug 15	Aug 14 to Aug 23
Greengram (pre-rabi)	65	Aug 20 to Sept 3	Sept 4 to Sept 28	Sept 29 to Oct 13	Oct 14 to Oct 23
Blackgram	85	Jun 20 to July 4	July 5 to Aug 8	Aug 9 to Sept 2	Sept 3 to Sept 12
Sesamum	90	Jun 15 to Jun 29	Jun 30 to July 29	July 25 to Aug 28	Aug 29 to Sept 12
Minor millet	65	Jun 20 to Jun 29	Jun 30 to July 14	July 15 to Aug 8	Aug 9 to Aug 23

B = $W \times Rn$, Radiation term

W = temperature related weighting factor

$f(u)$ = wind dependent function

= $0.27(1+u/100)$

u = 24 hours wind velocity in km per day

e_a = saturation vapour pressure in mbar at mean air temperature

e_d = mean actual vapour pressure of the air in mbar

= $(e_a \times RHmean) / 100$

Rn = net radiation

= $Rns - Rnl$

Rns = net incoming shortwave radiation

= $(1 - \alpha)(0.25 + 0.5\, n/N)\, Ra$

α = reflection coefficient the value of which is taken as 0.25 for most of crops

n/N = ratio of actual sunshine hours to maximum possible sunshine hours during a day

Ra = extra terrestrial radiation expressed in equivalent evaporation in mm/day

Rnl = net incomig longwave radiation

= $f(t).f(e_d).f(n/N)$

$f(t)$ = temperature dependent function = σTa^4

σ = Boltzmann's constant

= 2.01×10^{-9} mm/day

Ta = mean air temperature in $^{\circ}K$

= $273 + {}^{\circ}C$

$f(e_d)$ = function related to effect of vapour pressure on longwave radiation

= $0.34 - 0.044 \sqrt{e_d}$

f(n/N)= function related to effect of the ratio of actual and maximum expected sunshine hours on longwave radiation

$= 0.1 + 0.9\ (n/N)$

c = adjustment factor to account for the effect of day and night weather condition and is given by Allen et al. (1991) as follows :

$c = 0.892 - 0.0781\ Ud + 0.00219\ Ud.Rs + 0.000402 RHmax.Rs + 0.000196\ (Ud/Un).\ Ud\ .\ RHmax + 0.0000198\ (Ud/Un).Ud.\ RHmax.\ Rs + 0.00000236\ (Ud)^2.\ RHmax.\ Rs - 0.0000086 (Ud/Un)^2.Ud.RHmax - 0.0000000292 (Ud/Un).(Ud)^2.(RHmax)^2.Rs - 0.000016\ RHmax.(Rs)^2$

Where, Ud = mean daily day time wind velocity over the month considered in m/sec.

Rs = mean solar radiation

$= (0.25 + 0.5 n/N) Ra$

Ra = extra terrestrial radiation expressed in equivalent evaporation in mm/day for the given month and latitude

RHmax = mean daily maximum relative humidity over the month considered in per cent.

(Ud/Un) = ratio of the day time wind velocity to night time wind velocity. In absence of night time wind velocity data, (Ud/Un) is considered as 2.

Daily ET_o value for 9 years (1976,1978,1981-83, 1986-89) were calculated based on daily mean air temperature, maximum and minimum relative hmidity, wind velocity and (n/N) ratio and using the equations and standard tables given by Doorenbos and Pruitt (1977). Since data on Rs were not available, (n/N) ratios were first found out from the cloudiness data (oktas) from which Rs values were computed. No correction factor was multiplied to the wind velocity data as these are measured at 2 m height. The whole computation was made using a prepared Fortran computer programme in DOS system. Weekly average reference crop evapotranspiration values were computed from the daily values.

3.8.2 Crop Evapotranspiration

The method described in the previous article, though predicts the effects of climate on reference crop evapotranspiration (ET_o), does not consider the effect of crop characteristics on it. To account for this crop cofficients are to be estimated.

Crop coefficients for the selected crops are estimated using the procedure given by Doorenbos and Pruitt (1977).

Water requirement (ETcrop) of the crops for which the crop coefficients are developed are then calculated using the relation

$$ETcrop = Kc \times ET_o$$

Where , ETcrop = crop evapotranspiration or water requirement of crop in mm/day.

Kc = crop coefficient

ETo = reference crop evapotranspiration in mm/day

3.9 Estimation of Effective Rainfall and Irrigation Requirement

In the present study, rainfall at 80 percent probability level is taken as dependable rainfall. It is assumed that 60 per cent of the dependable rainfall is available for crop growth. This is referred to as effective rainfall. The difference between the consumptive use or evapotranspiration and the effective rainfall is the irrigation requirement which is to be met by suitable source.

Since there is likelihood of crop failure due to water scarcity during critical dry spells, the irrigation requirement is estimated for the effective critical dry spell durations explained in Art.3.4.7 taking into consideration the per day effective rainfall during the critical dry spells and the consumptive use of different crops.

CHAPTER IV

RESULTS
AND
DISGUSSIONS

RESULTS AND DISCUSSION

This chapter pertains to presentation of results as obtained from various analysis in course of the study and their critical discussions.

4.1 Assessment of Drought Intensity in the Study Area

In the light of the criteria given in Art 3.3 for investigation of overall drought intensity , drought years were identified for each of the 8 selected blocks, and the results are presented in Table 4.1 . It is seen from Table 4.1 that all these blocks have, more or less witnessed droughts in the choosen period of 26 years in the study. Amongst them, however, Dharmagarh block has experienced most frequent occurrence of drought with as many as 5 drought years in 26 years period followed by the blocks Khariar and Boden each with 4 drought years. Narla block has been least affected in this regard with only one drought year during the same period. It is also seen that in the year 1974, all the 8 blocks had to face drought. This information reveals that Dharamgarh should be given priority attention in implementing measures with limited resources for combating drought. In addition, more indepth analysis of rainfall regarding onset of effective monsoon (OEM), critical dry spells etc. has been done in these blocks for planning agricultural field operations at farmer's level. Results of such analysis have been presented in subsequent articles.

4.2 Onset of Effective Monsoon and Critical Dry Spells

Dates of onset and withdrawal of effective monsoon and critical dry spells were identified for each block as per the definitions and methodology described in the previous chapter under Art 3.4. The results so obtained are given in Appendix B (Table B-1 to B-11). Tables B-1 to B-8 give the blockwise information on dates of onset of effective monsoon (OEM), dates of withdrawal of monsoon, dates and duration of first three critical dry spells (CDS), number of CDS for each year and the mean value of the above characterstics . The standard deviation associated with the mean dates of OEM , the quartile deviation (semi inter-quartile range) associated with the median dates of OEM , the earliest and the latest probable dates of OEM based on mean and median with associated probabilities are also given for each block in these tables.

From Table B-1 , it may be observed that the mean date of OEM at Bhawanipatna was 19th June with a standard deviation of 18 days. This information will help the farmer to go for seed bed preparation and other primary tillage operations so that he could complete the sowing by this date to take advantage of monsoon rains . It is also seen that the earliest probable date of OEM based on mean was 1st June with a probability of 0.68 and the latest probable date was 7th July. This shows that there is a lot of variation in the dates in different years. The median date of OEM was 15th June with a quartile deviation (semi inter-quartile range) of 8 days and the earliest and latest probable dates based on median were 8th June and 23rd June respectively, each with a probability of 0.5. The difference between the respective dates of onset and withdrawal of monsoon in this block was found to be 96 days. The farmer should, therefore, adopt paddy varieties having growth period not more than this duration (96 days) in rainfed areas of this block. The average no. of critical dry spells (CDS) per year was only two in this block. However in some years there were more than 2 CDS. The 1st CDS of 14 days duration began, on an average, on 10th July. The 2nd CDS started on 6th August and lasted for 16 days. In 10 out of 26 years, there were more than 2 CDS. The average date of commencement and duration of the 3rd CDS, based on these 10 years values, were 30th Aug. and 22 days respectively. Prior knowledge on these informations will be of great practical value in selecting crops and their varieties to obtain the required level of drought tolerance or to provide irrigation at appropriate times in irrigated tracts. In order to save the crop from deficiency of moisture, it is essential that provision for supplemental irrigation are made for the critical dry spell periods.

The similar information with respect to the other seven blocks can readily be obtained from Tables B-2 to B-8.

Tables B-9 , B-10 and B-11 give in a consolidated and comparable form the above informations for all the 8 blocks. It can be seen from Table B-9 that based on the mean values the effective monsoon started in the 3rd week of June in all the blocks and ended by the 4th week of September. The earliest probable date of OEM for Kesinga, Boden and Narla blocks was in the last week of May while in other blocks it was towards first week of June. The latest probable date ranged from 31st June at Dharamgarh to 13th July at Kesinga.

Table B-10 reveals that the median date of OEM for all the blocks fell under 3rd week of June. The earliest probable date based on median values for all the blocks was 2nd week of June except at Kesinga where it was as early as 4th June and the latest probable date was 4th week of July.

The first critical dry spell commenced in Khariar block as early as 29th June with a duration of 20 days and as late as 13th July in Narla block with a duration of 16 days (Table B-11). In Khariar and Boden, the 2nd CDS began towards end of July and lasted for about half a month while in other blocks it set in the 1st week of August and continued for a period ranging from 15 to 18 days. The date of start of 3rd CDS was earliest (12th Aug.) in Khariar and latest (30th Aug.) in Bhawanipatna. All the blocks have an average no. of CDS per year equal to 2.

The weekly observed minimum, maximum and normal rainfall and also the probability of the weekly rainfall in a year equalling or exceeding the weekly normal for each of the 8 blocks are presented in Appendix C (Tables C-1 to C-8). It can be seen from Table C-1 that in Bhawanipatna the observed weekly minimum rainfall is zero in all the standard weeks except 29th, 32nd & 37th weeks. The highest weekly observed maximum of 526.1 mm occurred in the 33rd week. The weekly normal rainfalls upto 23rd were negligibly small so also from 41st week onwards, and hence quite insufficient for crop production. Irrigation facility must be rendered if a crop is to be grown during this period (i.e. for Rabi crop) . Therefore in rainfed area of this block, it is not advisable to raise rabi crops. The highest weekly normal of 109.6 mm was observed during 31st week and the probability that in any particular year the weekly rainfall equaled or exceeded this rainfall of 109.6 mm in the same week was 38.46 per cent. This information will be helpful in planning cropping pattern and irrigation scheduling.

Similar informations can be gathered for other blocks from Tables C-2 to C-8.

4.3 Forecasting of Dry and Wet Spells

The computer processed weekly data of rainfall for the individual blocks were analysed with a view to forecast dry and wet spells based on the method given under Art 3.5 of Chapter III . The results are described in Appendix D (Table D-1 to D-8).

From Table D-1, it can be conferred that in Bhawanipatna the probability of occurrence of a dry week was above 80 per cent upto 21st week so also after 43rd week. In the mid weeks (24th to 37th) it, however, seldom exceeded 30 per cent. The conditional probability of a dry week was high (71% to 96%) in the first 21 weeks, In subsequent weeks it came down and again increased remarkably from 43rd week. The probability of occurrence of 2 consecutive dry weeks was also high (> 60%) upto 20th week and that of 3 consecutive dry weeks was high only upto 15th week. These probalities also were beyond 60 per cent from 41st and 43rd weeks respectively. It was also observed that the probability of occurrence of wet week was much less (below 23%) upto 21st week and also after 43rd week. In the period starting from 31st to 34th weeks, it reached its peak with an average value of 85 per cent therein. This information will help the farmer to perform the wet field operations without any risk. The conditional probability of wet week preceeded by wet week was zero in the first 21 weeks except weeks 6 & 16, then increased to maintain a value greater than 60 per cent between 24th to 37th week and again reduced to zero from 43rd week. The probability of occurrence of 2 consecutive wet weeks remained less than 2 per cent upto 21st week, it increased to attain a maximum value of 66 per cent in the 32nd week. After 42nd week it was zero always. The probability of occurrence of 3 consecutive dry weeks remained zero in 31 out of the 52 weeks and its maximum value (51%) was in 31st & 32nd weeks.

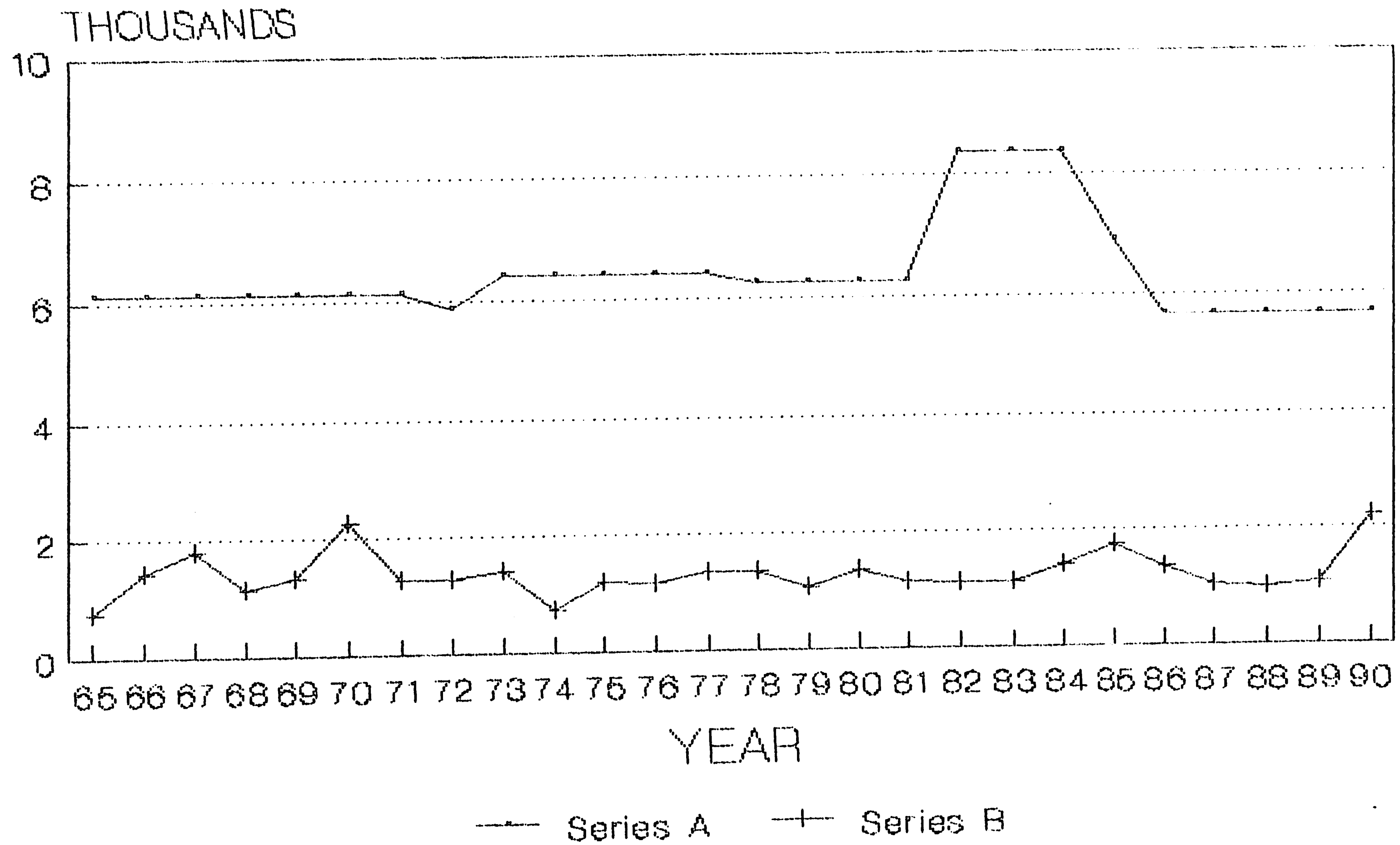
Tables D-2 to D-8 gave similar informations for other 7 blocks of the district.

4.4 **Forest Area and Rainfall**

Table 3.5 giving yearwise area under forests and corresponding annual rainfall for individual years revealed that there is no direct relationship between these two parameters. The data of Table 3.5 was also presented graphically in Fig.4.1. It can be observed that the yearly rainfall increased from 760.99 mm in 1965 to 1805.3 mm in 1967, then decreased to 1135.0 mm in 1968 and again increased to 2279.2 mm in 1970. However the forest area remained unchanged during this period. Similarly when forest area increased from 6260.66 sq km. to 8358.85 sq km in 1982, the rainfall increased slightly, but again when forest area remained unaltered from 1986 to 1988, rainfall decreased remarkably.

Thus no distinct relationship can be said to exist between the forest area and rainfall of a limited region. It might be that the forest area of the adjoining districts /state or even the region might be having the effect on rainfall. However, the established fact that the forest allows more of the rainwater to be retained in the area and in soil mass can go a long way to help conserve the moisture. This moisture can be available in the form of springs or in other form of ground

YEARWISE VARIATION OF FOREST AREA AND RAINFALL



SERIES A - FOREST AREA IN SQUARE KMS.
SERIES B - ANNUAL RAINFALL IN MM

68a

water flow. Thus it is suggested that deforestation in the area should be checked and effective measures be taken to go for afforestation in the area.

4.5 Estimation of Ground Water Potential

The ground water potential of Bhawanipatna block is estimated based on adhoc norms (rainfall penetration approach) as described in Chapter III under Art.3.6. For estimation of dynamic ground water resources or annual ground water recharge, the average yearly rainfall has been taken into account. The total annual recharge from rainfall was found to be 4773.23 Ha.m. The total annual ground water recharge including other racharges like recharge due to return flow of irrigation water etc. is estimated to be 5560.63 Ha.m. The net annual ground water resource for irrigation is found to be 4726.53 Ha.m while the present net annual ground water draft taking into account the existing ground water structures in the block as on March,1992 is calculated to be 620.83 Ha.m. Thus there is a balance of 4105.70 Ha.m of ground water which is available in the block . The present level of utilisation of ground water for irrigation is only 13.13 per cent of the annual utilisable ground water resource and hence, there is vast scope for further development of ground water in the block to augment the irrigation potential.

Although almost the entire block is underlain by hard crystalline rocks and sedimentaries there is favourable hydrological situations in the undulating plains and valleys where weathered zone is moderately thick and rocks are intensely fractured. In this terrain ground water exploitation is feasible through both dugwells and borewells. The ground water use can help in advancing the kharif period thereby increasing the yield. It also can do a lot in mitigating drought conditions and vagaries of monsoon as well as in diversification of rabi crops.

The ground water potential of other blocks of Kalahandi district as obtained from CGWB, Bhubaneswar are given in Table A-8. It can be seen that the present level of ground water development is highest in Khariar (20.69 %) while it is as low as 1.92 % in Thumal Rampur. Thus there is enough scope for ground water development in the whole district.

4.6 Estimation of Crop Evapotranspiration

Using the developed computer programme based on the methodology described under Art.3.7, the reference crop evapotranspiration (ETo) values were estimated on daily basis. Yearwise average weekly values of ETo in mm/day for a period of 9 years are presented in Appendix E (Table E-1). The weakwise daily average values of reference crop evapotranspiration for the 52 standard weeks are given in Table 4-2. These values have been taken later on for estimation of crop evapotranspiration (ETcrop).

The crop coefficient curves for some principal crops of the district like maize, greengram, blackgram, sesamum and minor millet (gulji) were developed as per the guidelines suggested by Doorenbos and Pruitt (1977) and are presented in Fig. 4.2 to 4.7. The crop evapotranspiration values were then estimated for the above crops making use of these coefficients. The weekly values of crop evapotranspiration for upland rice, maize, blackgram, sesamum, minor millet in kharif season and greengram in both kharif and pre-rabi season are presented in Tables E-3 to E-8. It was found from these tables that the

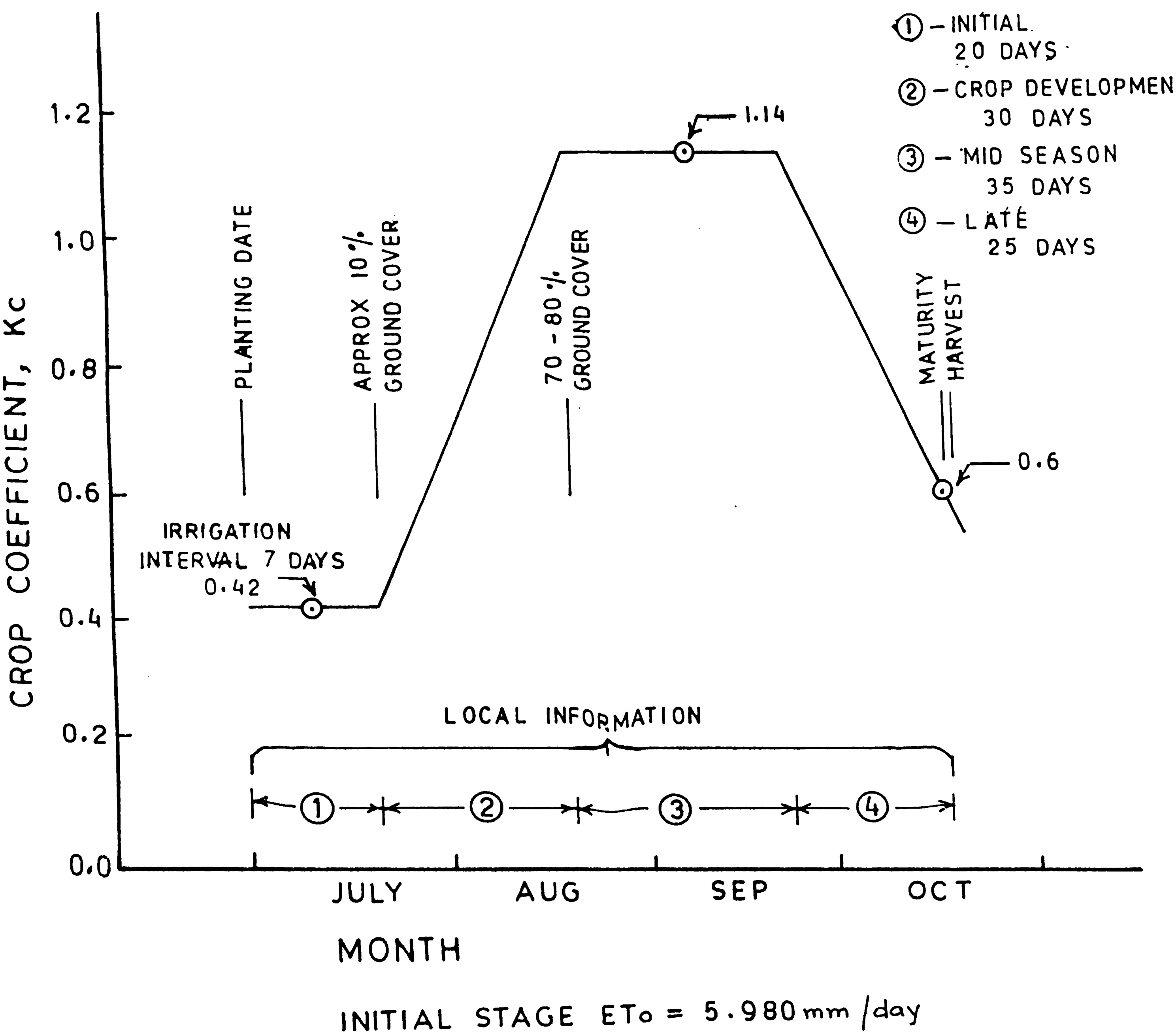
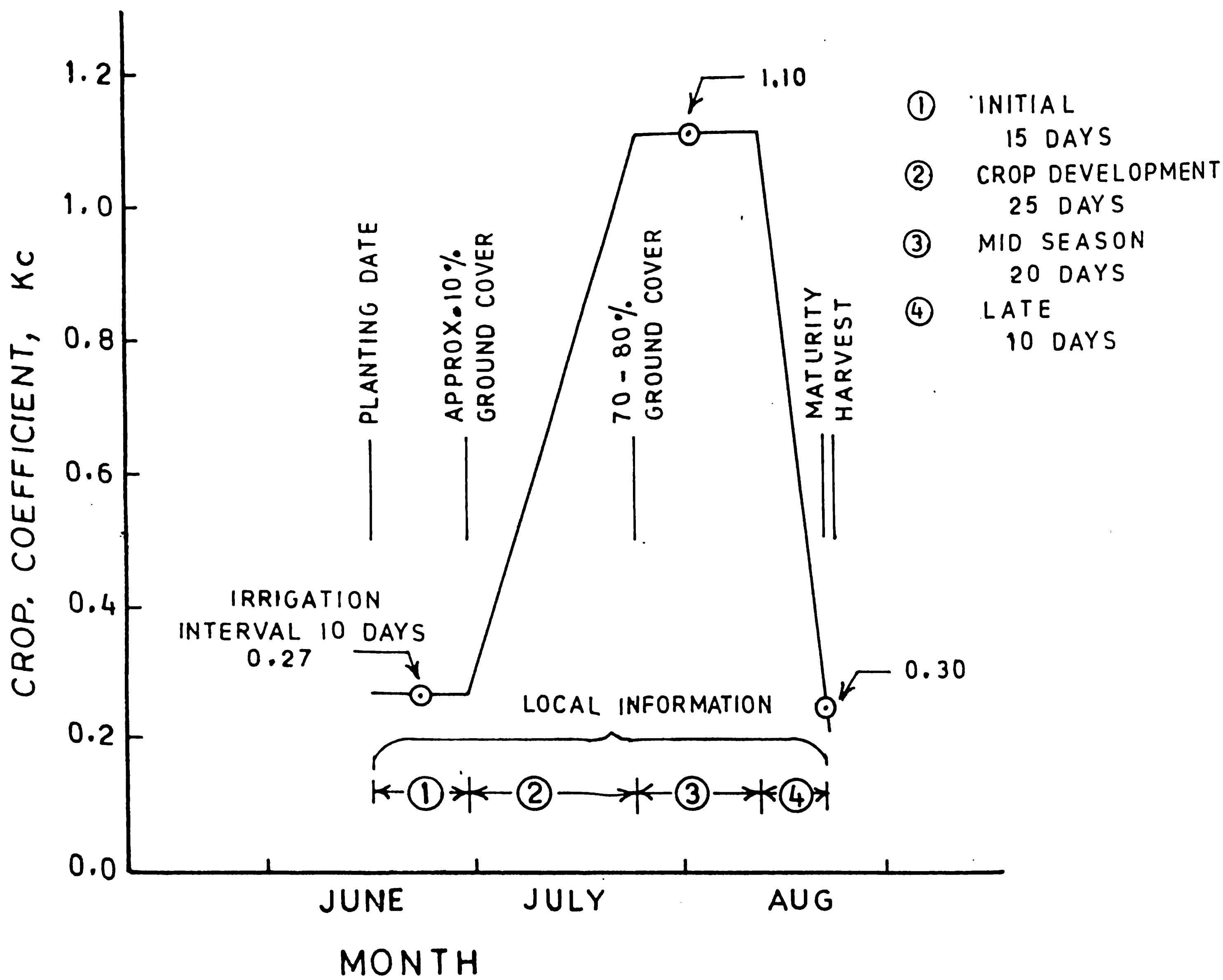


Fig. 4.2 CROP COEFFICIENT CURVE FOR MAIZE



INITIAL STAGE ET_o = 6.158 mm/day

Fig. 4.3 CROP COEFFICIENT CURVE FOR GREENGRAM (Kharif)

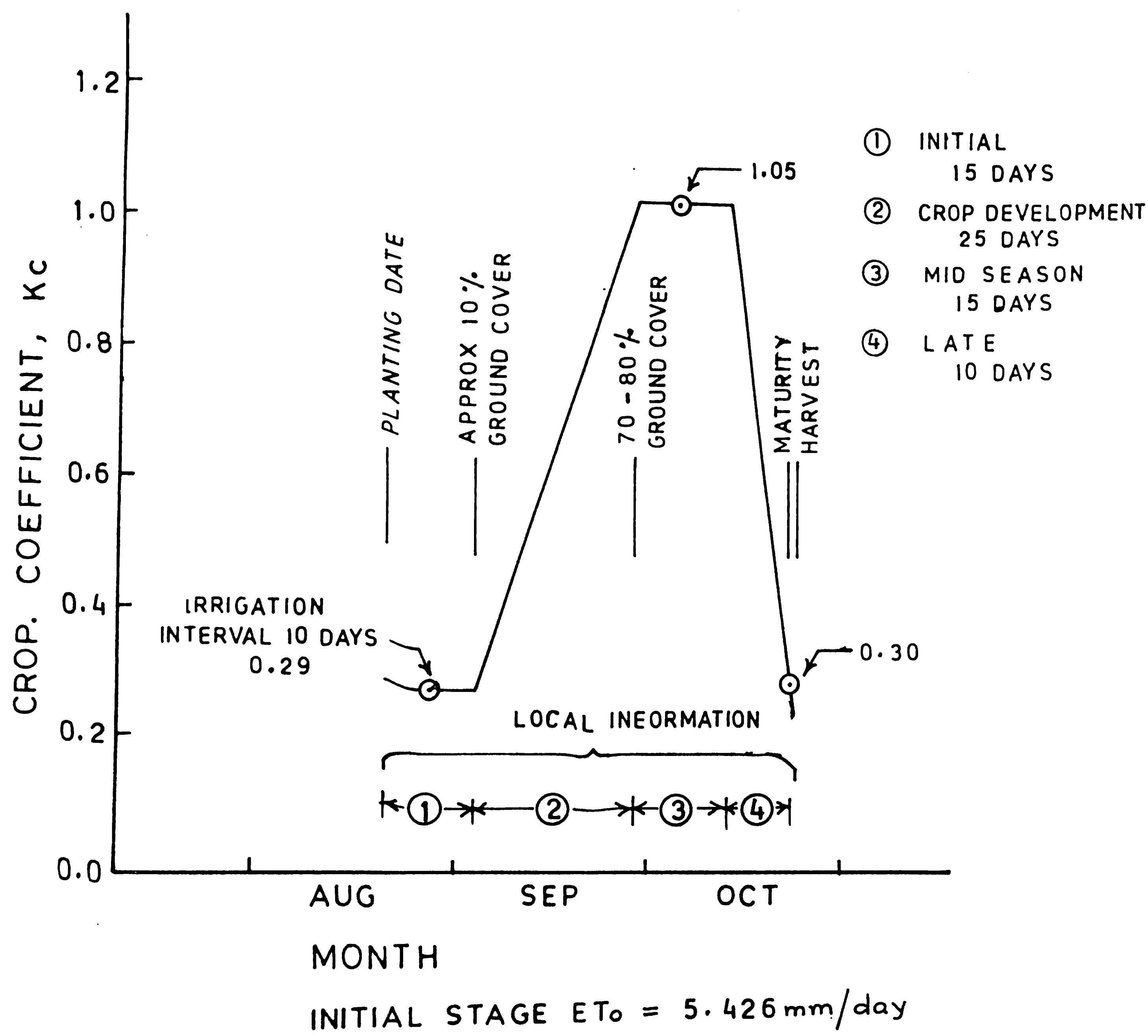


Fig. 4.4 CROP COEFFICIENT CURVE FOR GREENGRAM (Pre-rabi)

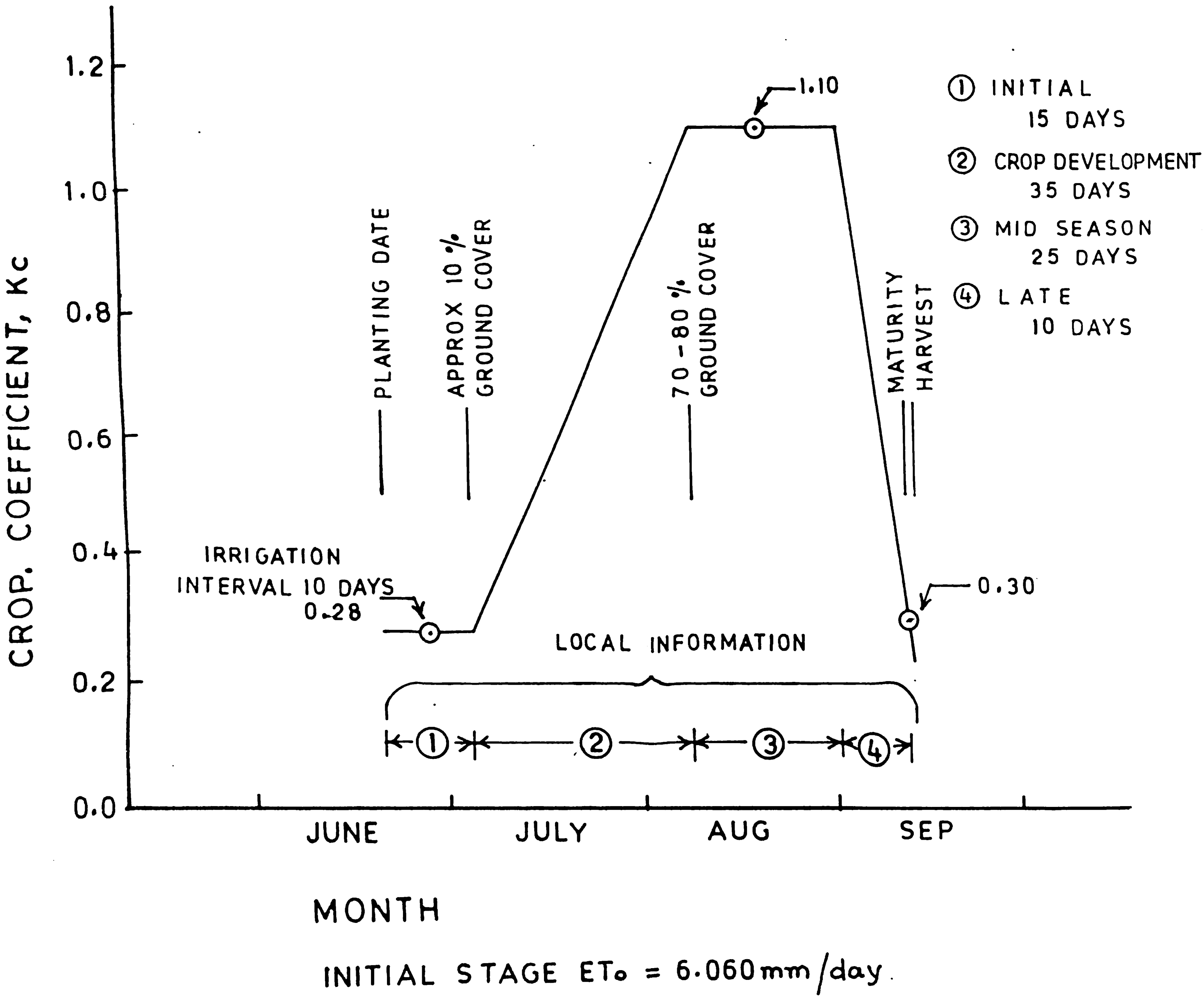
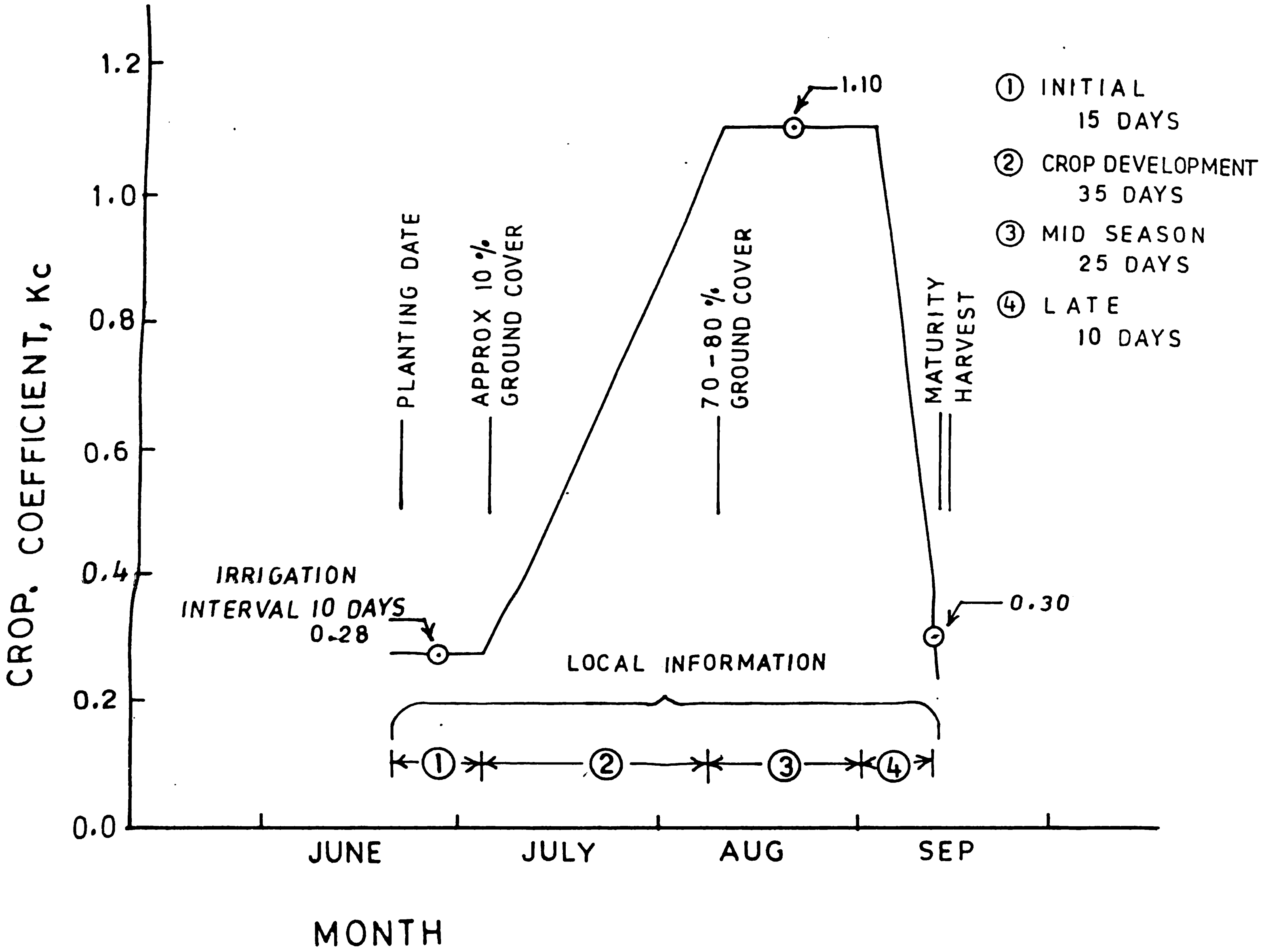


Fig. 4.5 CROP COEFFICIENT CURVE FOR BLACKGRAM (Kharif)



INITIAL STAGE ET_o = 6.060 mm/day.

Fig. 4.5 CROP COEFFICIENT CURVE FOR BLACKGRAM (Kharif)

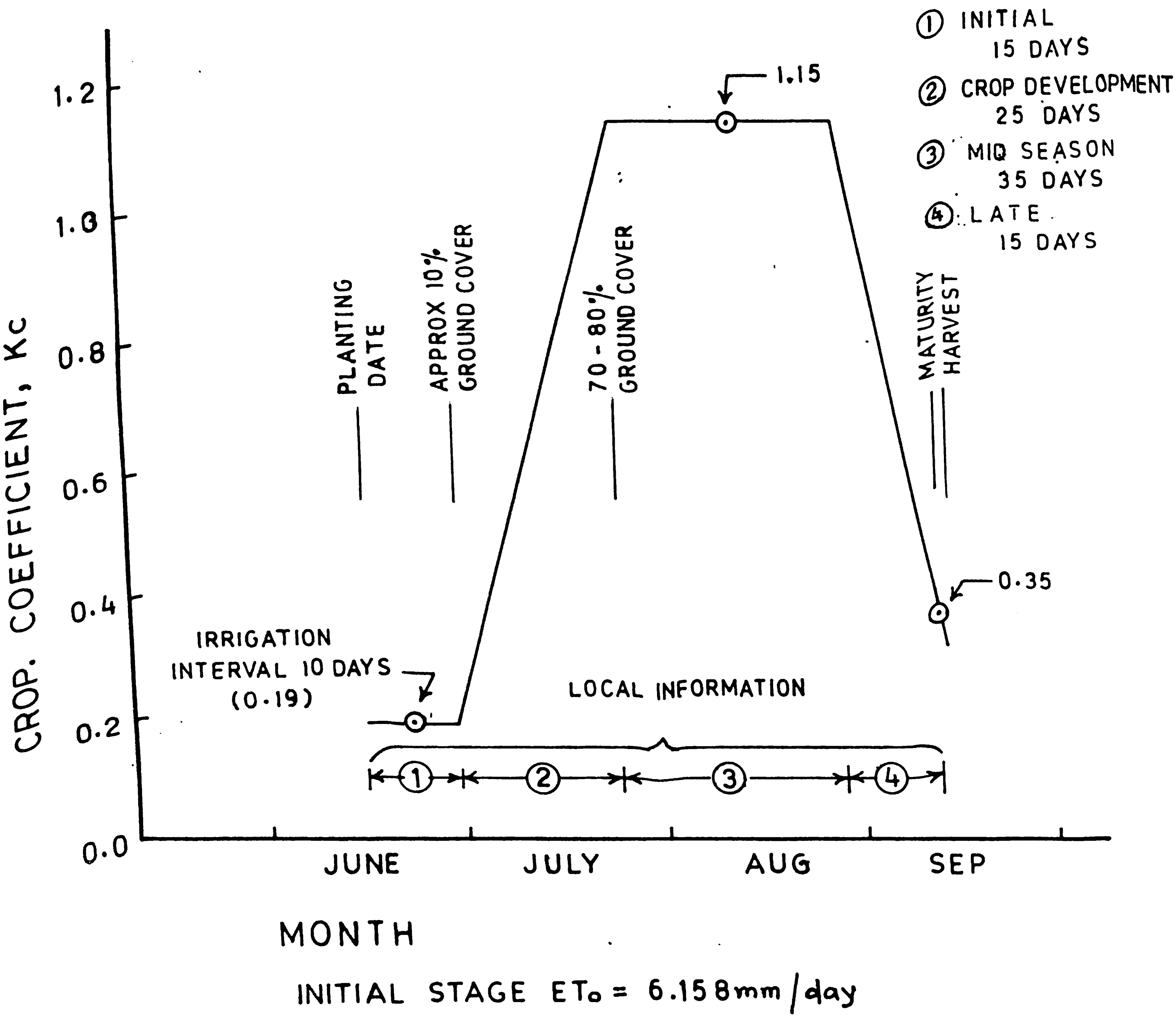
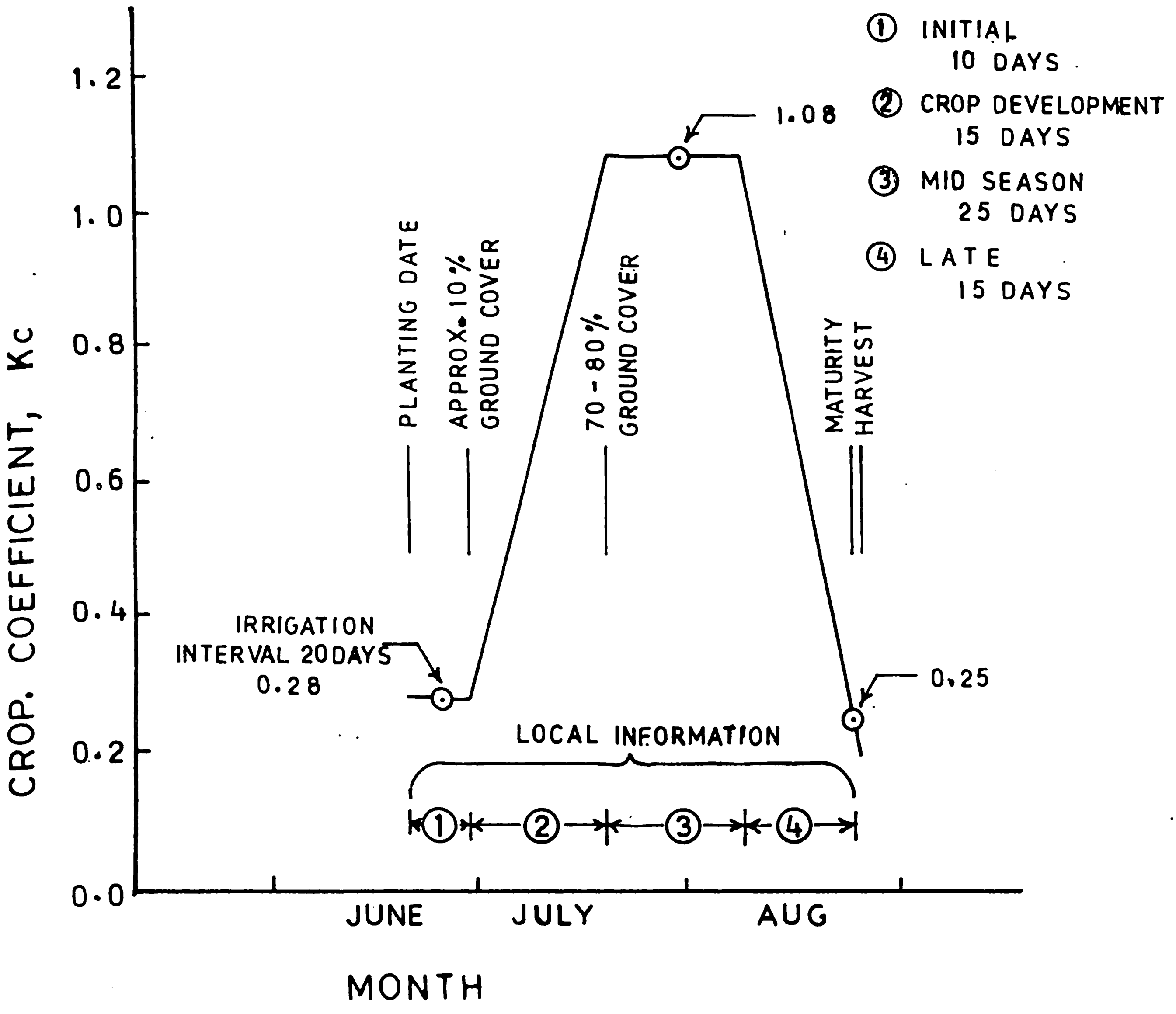


Fig. 4.6 CROP COEFFICIENT CURVE FOR SESAMUM



INITIAL STAGE $ET_o = 6.014$ mm/day

Fig. 4.7 CROP COEFFICIENT CURVE FOR MINOR MILLETS (Gulji) consumptive use of water or water requirement of the crops viz. upland rice, maize, greengram(kharif), greengram(pre-rabi), blackgram, sesamum & minor millet were 557.855 mm , 524.406 mm, 279.786 mm, 255.720 mm , 348.776 mm, 396.087 mm and 296.085 mm respectively.

4.7 Estimation of Irrigation Requirement

The crop water requirements as obtained in the previous sections are compared with the effective rainfall during critical dry spells for recommendation of quantum of supplemental irrigation for different crops in the block. The rainfall at 80 per cent probability has been taken as the dependable rainfall. The effective rainfall is considered to be 60 per cent of this dependable rainfall in view of irrigation planning. The average duration of a critical dry spell has been considered as effective duration. The irrigation requirement as obtained for the choosen crops during the first three critical dry spells are given in Table 4.2.

From Table 4.2 it can be seen that for the principal crop rice (upland), the irrigation requirement varied from a lowest value of 51.79 mm in Bhawanipatna to a highest value of 102.23 mm in Dharamgarh during the first effective CDS. In 2nd and 3rd CDS , however, it was highest in Bhawanipatna (79.25 mm & 98.43 mm respectively) and lowest in Khariar (40.98 mm) and Kesinga (35.21 mm) respectively. It can also be observed that the maximum irrigation requirement was for maize during the 3rd effective CDS in the blocks Bhawanipatna, Nawapara, Khariar, Golamunda and Narla (121.51, 62.93, 77.91, 76.86 and 88.90 mm respectively). In Boden and Dharamgarh , it was for upland rice during the 1st effective CDS (96.40 & 102.23 mm respectively) and in Kesinga it was for sesamum during the 2nd effective CDS(61.23 mm).

Table 4.2 thus can be referred as guidelines to appproximately fix in the water requirement of a farm for both main and supplemental irrigation under single as well as multicrop planning.

Table 4.1 Identification of drought years in different blocks under study.

Blocks	Average annual rainfall in mm ($\bar{x}$)	Standard deviation (σ), mm	($\bar{x}-\sigma$), (mm)	Drought years
Bhawanipatna	1455.13	446.41	1008.72	1968,1974,1975
Kesinga	1309.58	432.21	877.37	1968,1974,1975
Newapara	1214.68	326.04	888.64	1974,1989,1991
Khariar	1097.44	267.53	829.91	1974,1987,1989, 1992
Boden	1083.29	323.90	759.39	1972,1973,1974, 1979
Golamunda	1191.99	417.42	774.57	1974,1979,1982
Dharamgarh	1247.47	311.09	936.38	1974,1983,1986, 1988,1989
Narla	1359.24	565.10	794.14	1974

Table 4.2 Irrigation requirements of different crops during the first three effective critical dry spells in different blocks under study

Block	Effective CDS	Irrigation requirement, mm						
		upland rice	maize	greengram (kharif)	greengram (pre-rabi)	blackgram	sesamum	minor millet
Bhawanipatna	1st	51.79	-	30.62	-	10.16	35.62	39.20
	2nd	79.25	74.28	65.00	-	53.68	84.17	57.73
	3rd	98.43	121.51	-	46.19	44.71	40.36	-
Kesinga	1st	64.06	-	20.82	-	0.03	18.98	24.46
	2nd	52.96	50.29	32.50	-	57.08	61.23	27.25
	3rd	35.21	53.66	-	-	26.26	22.65	-
Nawapara	1st	69.05	2.09	34.25	-	15.85	34.07	41.57
	2nd	61.12	58.03	36.98	-	65.80	70.49	31.73
	3rd	48.47	62.93	-	3.28	44.55	39.78	-
Khariar	1st	78.55	10.53	48.51	-	21.91	49.21	55.93
	2nd	40.98	38.80	16.57	-	45.39	49.79	11.43
	3rd	61.93	77.91	-	9.05	59.09	54.60	-
Boden	1st	96.40	10.60	34.57	-	12.85	31.01	38.06
	2nd	62.58	60.40	38.17	-	66.99	71.39	33.03
	3rd	62.94	73.05	22.30	-	73.84	77.92	-
Golamunda	1st	70.40	5.51	27.16	-	6.37	25.32	30.80
	2nd	49.39	29.30	50.16	-	47.94	12.54	47.28
	3rd	60.23	76.86	-	3.28	57.64	53.44	-
Dharamgarh	1st	102.23	17.61	51.07	-	22.42	49.59	57.10
	2nd	61.31	48.33	56.97	-	62.67	65.71	52.28
	3rd	80.39	93.20	-	8.85	82.64	87.92	-
Narla	1st	56.88	1.78	45.06	-	18.95	47.75	-
	2nd	53.33	50.73	23.55	-	58.29	63.25	18.30
	3rd	65.00	88.90	-	-	36.70	33.16	-

CHAPTER V

SUMMARY
AND
CONCLUSION

SUMMARY AND CONCLUSION

Kalahandi district of Orissa is primarily an agrarian one where agriculture is the main source of people's livlihood. Most of the crops are grown there under rainfed condition during monsoon season. The normal annual rainfall of the district is 1378.2 mm out of which about 92 percent is received during the south-west monsoon period. It is a matter of irony that long breaks of monsoon during the growing rainy season and the 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. Since the drought is caused solely due to erratic nature of the south-west monsoon, a prophecy of onset and withdrawal of monsoon and also occurrence of interspersed critical dry spells is of prime importance for successful agriculture. Such a knowledge in advance will help in timely preparation of seedbed and planning of sowing activity in a bid to derive maximum advantage of monsoonic rains and to provide for contingency planning for supplemental irrigation during the critical dry spells in the irrigated tracts.

In view of the above, analysis of the drought phenomena was carried out for eight blocks of the district namely, Bhawanipatna, Kesinga, Nawapara, Khariar, Boden, Golamunda, Dharamagarh and Narla. The 26 years' daily rainfall data of each of these blocks were analysed in order to portend the dates of onset of critical dry spells and their durations during the monsoon season. In addition to it, the weekly values of rainfall were examined critically for forecasting wet and dry spells throughout the year.

In general, taking into account the rainfall information only the 52 standard weeks of the year were identified as dry and wet weeks on the basis of recommendation of Pandarinath (1991). It was observed that there is much likelihood of occurrence of consecutively 2 to 3 dry weeks in the period ranging from 43rd to 52nd week and 1st to 18th week of a year. This information speaks that there is no possiblity of raising crops, in general within this period i.e mid October to end of April without any adequate source of irrigation. The rainfall data were further subjected to analysis in reference to the local evaporation rate and the soil- crop complex for critical assessment of adequacy of rainfall meeting the crop water demand on the basis of the model formulated by Ashok Raj (1979) leading to identification of onset of effective monsoon (OEM), withdrawal of monsoon(WM) ,onset of critical dry spells (CDS) and their durations in the growing season. The average daily evaporation rate for the district was estimated to be 10.3 mm/day which was taken for use in the above analysis.

In the present study forest area and its effect on annual rainfall was studied taking into account 26 years of data of rainfall and areal distribution of forest.

Further the ground water potential of Bhawanipatna block was estimated as per G.E.C. norms (1983).

The crop evapotranspiration (ETcrop) of different crops like upland rice , maize, greengram, blackgram, sesamum and minor millet (gulji) were estimated using modified Penman method as per the guidelines suggested by Doorenbos and Pruitt

(1977) to recommend quantum of supplemental irrigation during the critical dry periods.

Based on the above study following conclusions were drawn :

1. A preliminary examination of 26 years' rainfall data of above eight blocks in the district revealed that all of them faced droughts more or less.Dharmagaraha was the most frequently affected block with as many as 5 drought years in the choosen period , Narla being the least affected.

2. The mean dates of OEM for the above eight blocks viz.Bhawanipatana , Kesingha , Nawapara , Khariar ,Boden , Golamunda , Dharmagarh and Narla were found to be 19th Jun ,21st Jun,18th Jun, 19th Jun, 16th Jun, 16th Jun, 15th Jun, and 23rd Jun respectively. Hence it is advisable to take up seed bed preparation by this period in these blocks.

3. The mean dates of withdrawal of effective monsoon for the said blocks were found to be 23rd Sep, 18th Sep, 23rd Sep, 20th Sep, 18th Sep, 13th Sep and 25th Sep respectively. Hence crops of duration not exceeding about 90 to 95 days are to be selected in these blocks as the effective monsoon lasts for this period. Neela, Sankar, Rudra, CR-666-78, CR-666-18, DR-92 etc. are some of the promising early and ultra early rice varities of 85 to 95 days duration which are suggested for adoption in the blocks.

4. In the above blocks , on an average there occurred two numbers of CDS during the course of south-west monsoon season.

5. The average dates of onset and durations of 1st CDS in the above blocks were 10th July (14 days), 3rd July (16 days), 6th July (17days), 7th July (18 days), 29th June (20 days), 3rd July(16 days), 2nd July (21 days) and 13th July (16 days) respectively.

6. The average dates of onset and durations of 2nd CDS in the blocks Bhawanipatna, Kesinga, Nawapara, Khariar, Boden, Golamunda, Dharamgarh and Narla were found to be 6th Aug (16 days), 8th Aug (15 days), 7th Aug(17 days), 8th Aug(16 days), 29th July (16 days), 31st July (15 days),3rd Aug (15 days), 7th Aug (18 days) respectively. Life saving irrigation should be provided for meeting the crop water requirements in the above periods.

7. Forest area of the said district and the annual rainfall were examined for the correlation. The area under forests being almost constant for good length of period variations in rainfall were noticed leading to conclusion that the area under forests bear no direct relationship with rainfall. However , the forest cover is necessary for conservation of soil moisture and for improving the sustained spring flows round the year. The conserved soil moisture and the flow in the springs will help the farmer to fight the drought and crop failure.

8. The ground water potential study of Bhawanipatna block revealed that the present level of utilisation of its ground water resource has been very meagre and there is enough scope for further development of this for both main and life saving irrigation. It was observed that of the annual net

utilisable ground water resource for irrigation of 4726.53 Ha.m, only 13.13 % (620.83 Ha.m) have been utilised so far and rest 4105.7 Ha.m of ground water is available for further exploitation.

9. The seasonal consumptive use of water or water requirement of the crops upland rice, maize, greengram, blackgram, seasmum, and minor millet (all kharif) and greengram (pre-rabi) were estimated to be 557.855 mm, 524.406 mm, 279.786 mm, 348.776 mm, 396.087 mm , 296.085 mm and 255.720 mm respectively.

10. The maximum irrigation requirement for the principal crop upland rice in the blocks Bhawanipatna, Kesinga, Nawapara, Khariar, Boden, Golamunda, Dharamgarh and Narla were found to be 98.43 mm, 64.06 mm, 69.05 mm, 78.55 mm, 96.40 mm, 70.40 mm and 102.23mm, 65.00 respectively all during the first effective CDS except in Bhawanipatna and Narla where it was during the 3rd CDS. Table 4.2 giving the irrigation requirements for different crops under consideration for the first three effective critical dry spells in each block can be used for approximately fixing in the water requirement of a farm under single or multicrop planning in regards to both main and life saving irrigation.

CHAPTER VI

SUGGESTIONS FOR FUTURE WORK

SUGGESTIONS FOR FUTURE WORK

1. In determination of critical dry spells it has been assumed that for paddy, the principal crop in the district of Kalahandi, the dry spell becomes critical if it exceeds 7 days. This assumption has been made on the basis of local information. However , it is suggested that in future more studies be carried out in respect of soil moisture and crop relationship for more accurate value of the duration of the critical dry spell.

2. During the study no correlation was established between the yearly rainfall and forest area. It is expected that areal coverage under forests has a direct bearing on streamflows and moisture status of the soil. Thus it is suggested that in future such relationship of the forest coverage be studied.

3. In course of the study critical dry spells have been identified and the farmers have been advised to make provision of supplemental irrigation from ground water and surface flows to check crop failure during these spells. Since the ground water potential in the district is much underutilised, it is suggested that attempts be taken for utilisation of ground water to its fullest extent. For this purpose detailed studies should be carried out for identifying location specific feasibility of dug wells, bore wells etc.

4. In the present study drought phenomenon have been analysed for 8 blocks of the district. Since it is observed by experience that the whole district is drought prone, it is suggested that similar analysis be carried out for the entire district.

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APPENDICES

APPENDIX A

Table A-1 Blockwise rainfall distribution in Kalahandi district.

	Name of the Blocks	No.of years	Mean annual rainfall(cm)	C.V. (%)	S.D	CK/S.E
1.	Bhawanipatna	21	141.32	27.89	39.42	2.40
2.	Kesinga	21	130.51	34.28	45.30	(-)0.05
3.	Langigarh	21	115.02	42.31	48.67	0.13
4.	Karlamunda	21	114.42	25.76	29.47	2.13
5.	Narla	21	122.20	24.28	29.67	3.15
6.	M.Rampur	21	148.78	24.51	36.47	1.84
7.	Th. Rampur	21	270.06	31.56	85.24	2.59
8.	Dharamgarh	21	124.30	22.20	27.62	0.24
9.	Junagarh	21	132.00	25.57	33.75	0.09
10.	Jayapatna	21	124.48	36.38	45.28	0.23
11.	Golamunda	21	112.90	32.24	36.40	2.06
12.	Kalampur	21	157.27	19.01	29.90	3.59
13.	Koksara	21	150.40	23.42	35.22	3.47
14.	Nawapara	21	128.75	25.15	32.38	2.24
15.	Komna	19	123.49	24.74	30.55	2.23
16.	Khariar	21	109.54	21.49	23.54	2.25
17.	Boden	21	99.33	26.61	26.43	1.99
18.	Sinapali	21	96.40	24.07	23.20	2.23

Table A-2 Decadal variation in population and growth rate of population in Kalahandi district.

Decade	Variation in 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.

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

Soil type	Blocks	General texture	% to Total
Red Soil	M.Rampur, Th.Rampur, Lanjigarh, Lanjigarh, Parts of Nawapara, Komna, Dharamgarh, Boden and Sinapalli	Loamy sand to sandy loam	44.5
Red & Yellow soil	Parts of Narla, M.Rampur, Koksara, Jaipatna, Kalampur and Junagarh	Sandy loam to loam	27.4
Red & Black soil	Parts of Boden, Kesinga & Karlamunda,	Loam to clay	9.0
Black soil	Bhawanipatna, Khariar, Dharamgarh, Parts of Golamunda, Koksara & Kesinga	Heavy clay	12.8
Alluvial soil	Parts of Dharamgarh, Karlamunda & Nawapara	Loam to silt loam	6.3

Table A-4 Land utilisation pattern in Kalahandi district, 1989-90

Sl. No.	Items	Area (1000 Ha.)	% of total area
1.	Total Geographical area	1158	1
2.	Forest area	505	43.6
3.	Barren and uncultivatable land	3	0.26
4.	Land put to non-agriculture use	32	2.76
5.	Cultivatable waste	6	0.52
6.	Permanent pasture and grazing land	24	2.07
7.	Miscellaneous tree crops not included in net area sown	10	0.86
8.	Current fallows	9	0.78
9.	Other follows	5	0.73
10.	Net area sown	564	48.71
11.	Grass cropped area incluiding fruits	838	72.37
12.	Area sown more then once excluiding fruits	274	23.66
13.	Cropping intensity	149	-
14.	Net area irrigated	74	13.12

Source : District statistical hand book, Kalahandi, 1991

Table A-5 Distribution of land holdings to major groups in Kalahandi district as compared to Orissa, 1985-86.

Category of holding and size group	No. of operational holdings		Area operated(ha)		Av. size per ha. of holdings	
	Kalahandi	Orissa	Kalahandi	Orissa	Kalahandi	Orissa
Marginal (less than 1 ha.)	76895 (35.70)	1867603 (52.09)	43749 (9.93)	919489 (17.48)	0.57	0.49
Small (1 to 2 ha)	60840 (28.25)	910089 (25.38)	83033 (18.84)	1273057 (24.20)	1.36	1.40
Semi-medium (2 to 4 ha)	51057 (23.70)	583313 (16.27)	133955 (30.40)	1567452 (29.80)	2.62	2.69
Medium (4 to 10 ha)	23542 (10.93)	203943 (5.69)	132582 (30.08)	1167042 (22.18)	5.63	5.72
Large (greater than 10 ha.)	3065 (1.42)	20580 (0.57)	47386 (10.75)	333778 (6.34)	15.46	16.29
All holdings	215399	3585528	440705	5260818	2.05	1.47

Source : Agiricultural Census of Orissa, 1985-86.
Note : Figures within parantheses denote percentage to totals.

Table A-6 Area production and yield rate of principal crop of Kalahandi district as compared to Orissa, 1990 - 91.
A=Area in '000 hectors
P=Production in '000 tons
Y=Yield rate in kgs/ha.

Crop	Kalahandi			Orissa		
	A	P	Y	A	P	Y
Rice	317.93	300.42	945			
Mize	13.89	13.76	991	167.13	176.09	1054
ragi	28.03	20.52	732	242.84	261.53	892
Small millets	6.80	4.07	598	63.80	33.56	526
Gram(mung)	74.16	43.11	581	735.24	377.74	514
Gram(biri)	50.51	29.98	593	570.09	302.93	531
Horsegram (kulthi)	47.85	30.78	643	406.30	231.07	569
Arhar	10.26	6.34	618	164.00	124.40	758
Sesamum	40.61	18.22	449	337.00	176.89	528
Niger	18.78	9.98	531	180.38	83.69	464
Rapseed	16.13	8.67	509	162.14	81.72	449
Mustard	16.13	8.67	509	162.14	81.72	449
Groundnut	19.14	20.63	1078	397.85	521.00	309
Cotton	3.12	3.92	0.96	6.50	8.21	0.98
Sugarcane	3.60	24.20	6337	49.00	354.90	72.42
Onion	3.75	21.80	5813	43.93	292.00	6647

Table A-7 Net area Irrigated by different irrigation sources in Kalahandi district (potential created)

Sl. No.	Source	Net Area Irrigated (in'000 Ha.)		
		Kharif	Rabi	Total
1.	Major and Medium irrigation projects	18.06	4.35	22.41
2.	Minor irrigation project (flow)	26.14	6.03	32.17
3.	Lift irrigation projects	12.91	8.44	21.35
4.	C.D. & private sources	16.65	7.79	24.44
	Total from all sources	73.76	26.61	100.37

Source : Orissa Agricultural Statistics 1989-90

Table A-8 Block wise ground water resource of Kahalandi district

Sl. No.	A	B	C	D	E	F
1	Bhawanipatna	5241.83	4455.55	620.83	3834.72	13.93
2	Boden	3164.80	2690.08	380.59	2309.49	14.14
3	Dhramagarh	4111.56	3494.53	265.37	3229.46	7.59
4	Golamunda	4864.34	4134.69	385.49	3749.20	9.32
5	Jaipatna	4722.53	4014.15	168.07	3846.08	4.18
6	Junagarh	5577.16	4740.59	547.96	4165.63	11.55
7	Kalampur	1666.34	1416.39	158.76	1257.63	11.20
8	Karlamunda	4058.46	3449.69	237.65	3212.04	6.88
9	Kesinga	5360.71	4556.60	513.80	4042.80	11.27
10	khariar	3518.10	2990.38	618.72	2371.66	20.69
11	Koksara	5120.09	4352.08	318.36	4333.74	7.37
12	Komma	7672.55	6521.66	585.13	5936.53	8.97
13	Lanjigarh	3898.11	3313.39	132.37	3181.02	3.99
14	M.Rampur	4663.89	3964.31	375.76	3588.55	9.47
15	Narla	5096.68	4332.18	536.76	3795.42	12.39
16	Nuapara	7453.07	6335.11	739.55	5595.56	11.67
17	Sinapalli	3645.94	3099.05	482.02	2617.03	15.55
18	Thumal Rampur	3867.59	3287.45	63.35	3224.10	1.92
	T O T A L	83703.75	71147.88	7130.54	64290.66	182.08

A - Name of the Block
B - Total annual recharge in Ha.m/year
C - Utilisable ground water resource for irrigation in Ha.m/year
D - Net annual draft in Ha.m/year
E - Ground water balance for irrigation in Ha.m/year
F - Level of ground water development in Ha.m/year

APPENDIX-B

Table B-1 Onset and withdrawal of effective monsoon and occurrence of critical dry spells in Bhawanipatna

Year	Effective Monsoon Onsets on	Effective Monsoon Ends on	Critical Dry Spells (CDS*) Date & length, 1st CDS		Date & length, 2nd CDS		Date & length, 3rd CDS		Total no.of CDS
1967	12 Jun	24 Sep	02 Jly	18	25 Aug	7		0	2
1968	17 Jly	12 Sep	24 Jly	13	13 Aug	23		0	2
1969	09 Jun	18 Sep	16 Jun	14	25 Aug	27		0	2
1970	23 Jun	11 Sep	06 Jly	9	30 Jly	12	25 Aug	10	3
1971	11 Jun	16 Oct	18 Jun	28	05 Aug	42	17 Sep	23	3
1972	19 Jun	31 Oct	03 Jly	28	25 Aug	9	11 Sep	8	4
1973	02 Jun	25 Oct	09 Jun	22	12 Jly	27	23 Aug	57	3
1974	01 Aug	22 Aug	08 Aug	13		0		0	1
1975	01 Aug	07 Sep	16 Aug	7		0		0	1
1976	01 Jly	06 Nov	10 Sep	57		0		0	1
1977	20 Jun	17 Nov	12 Jly	7	09 Sep	11	27 Sep	51	3
1978	26 Jun	14 Sep	29 Aug	9		0		0	1
1979	17 Jun	08 Aug	26 Jun	7	16 Jly	8		0	2
1980	13 Jun	15 Sep	02 Aug	13		0		0	1
1981	15 Jun	27 Sep	22 Jun	12	10 Jly	16	31 Aug	20	3
1982	13 Jun	06 Sep	20 Jun	21	09 Aug	12		0	2
1983	18 Jun	06 Sep	03 Aug	9		0		0	1
1984	09 Jun	09 Sep	16 Jun	9	19 Jly	7	02 Aug	15	3
1985	03 Jun	01 Oct	08 Jly	12	22 Aug	8	08 Sep	17	3
1986	16 Jun	21 Aug	18 Jly	7		0		0	1
1987	30 Jun	10 Sep	06 Jly	7	20 Jly	20		0	2
1988	14 Jun	24 Sep	30 Jun	13	12 Aug	29		0	2
1989	07 Jun	12 Sep	14 Jun	8	29 Jun	18	23 Jly	8	4
1990	07 May	31 Oct	14 May	17	19 Jly	21	13 Sep	11	4
1991	02 Jly	04 Oct	28 Aug	11	23 Sep	11		0	2
1992	10 Jun	07 Sep	25 Jun	18	23 Aug	8		0	2
Mean	19 Jun	23 Sep	10 Jly	14	06 Aug	16	30 Aug	22	2

* Critical Dry Spell (CDS) : When length of spell exceeds 7 days

Earliest probable date of OEM (p=0.68) : 01 Jun
Mean Date of OEM : 19 Jun
Latest probable date of OEM (p=0.68) : 07 Jly

Earliest probable date of OEM (p=0.50) : 08 Jun
Median date of OEM : 15 Jun
Latest probable date of OEM (p=0.50) : 23 Jun

Standard deviation (days) : 18
Semi-inter-quartile range (days) : 8

Average date on which effective monsoon ends : 23 Sep
Average number of CDS per year : 2

Average date on which 1st CDS starts : 10 Jly Length (days): 14
Average date on which 2nd CDS starts : 06 Aug Length (days): 16
Average date on which 3rd CDS starts : 30 Aug Length (days): 22

Table B-2 Onset and withdrawal of effective monsoon and occurrence of critical dry spells in Kesinga

Year	Effective Monsoon		Critical Dry Spells (CDS*)						
	Onsets on	Ends on	Date & length, 1st CDS		Date & length, 2nd CDS		Date & length, 3rd CDS		Total no.of CDS
1967	13 Jun	12 Sep	26 Jun	23	28 Jly	7	24 Aug	12	3
1968	19 Jly	03 Oct	26 Jly	10	12 Aug	27	09 Sep	18	3
1969	07 Jun	05 Aug	17 Jun	7		0		0	1
1970	31 May	23 Sep	07 Jun	15	05 Jly	11	24 Jly	18	4
1971	30 May	04 Sep	18 Jun	10	03 Aug	7		0	2
1972	16 Jun	19 Sep	15 Jly	15	23 Aug	8	07 Sep	11	3
1973	23 Jun	25 Oct	13 Jly	9	22 Aug	58		0	2
1974	29 Jun	09 Aug	05 Jly	28		0		0	1
1975	18 Jun	26 Oct	25 Jun	38	08 Aug	23	07 Sep	43	3
1976	22 Jun	06 Sep	29 Jun	7		0		0	1
1977	10 Jun	09 Sep	26 Jly	8		0		0	1
1978	03 Jly	24 Aug	10 Jly	16		0		0	1
1979	15 Jun	09 Aug	22 Jun	11	09 Jly	17		0	2
1980	13 Jun	15 Sep	10 Jly	7		0		0	1
1981	15 Jun	27 Sep	22 Jun	30	07 Sep	14		0	2
1982	06 Jun	12 Sep	13 Jun	28	13 Aug	10		0	2
1983	04 Jly	11 Sep	02 Aug	10	19 Aug	9		0	2
1984	10 Jun	03 Sep	17 Jun	8	03 Jly	10	05 Aug	22	3
1985	10 Jly	11 Oct	27 Jly	13	08 Sep	8	17 Sep	10	4
1986	16 Jun	02 Oct	19 Jly	14	16 Aug	16	08 Sep	17	3
1987	30 Aug	02 Oct		0		0		0	0
1988	25 Jly	20 Sep	10 Aug	20	31 Aug	10		0	2
1989	08 Jun	11 Sep	29 Jun	39	07 Aug	12	20 Aug	15	3
1990	04 May	05 Nov	11 May	26	25 Jun	9	19 Jly	28	5
1991	11 Jly	29 Oct	10 Aug	7	25 Aug	18	13 Sep	17	4
1992	09 Jun	05 Sep	17 Jun	21	18 Aug	11		0	2
Mean	21 Jun	18 Sep	03 Jly	16	08 Aug	15	25 Aug	19	2

* Critical Dry Spell (CDS) : When length of spell exceeds 7 days

Earliest probable date of OEM (p=0.68) : 30 May
Mean Date of OEM : 21 Jun
Latest probable date of OEM (p=0.68) : 13 Jly

Earliest probable date of OEM (p=0.50) : 04 Jun
Median date of OEM : 15 Jun
Latest probable date of OEM (p=0.50) : 27 Jun

Standrd deviation (days) : 23
Semi-inter-quartile range (days) : 12

Average date on which effective monsoon ends : 18 Sep
Average number of CDS per year : 2

Average date on which 1st CDS starts : 03 Jly Length (days): 16
Average date on which 2nd CDS starts : 08 Aug Length (days): 15
Average date on which 3rd CDS starts : 25 Aug Length (days): 19

Table B-3 Onset and withdrawal of effective monsoon and occurrence of critical dry spells in Nawapara

Year	Effective Monsoon		Critical Dry Spells (CDS*)						
	Onsets on	Ends on	Date & length 1st CDS		Date & length 2nd CDS		Date & length 3rd CDS		Total no.of CDS
1967	18 Jun	17 Sep	27 Jun	12	18 Aug	16		0	2
1968	19 Jun	31 Sep	26 Jun	13	29 Jly	41	17 Sep	7	3
1969	18 Jun	16 Sep	12 Jly	8	05 Aug	27		0	2
1970	28 May	27 Sep	13 Jun	7	05 Jly	10	22 Jly	11	5
1971	29 May	23 Aug	19 Jun	9	01 Aug	15		0	2
1972	24 Jun	21 Sep	15 Jly	16	25 Aug	8	10 Sep	10	3
1973	29 Jun	25 Oct	17 Jly	12	19 Aug	27	22 Sep	27	3
1974	03 Jly	18 Sep	10 Jly	9	26 Jly	17	13 Aug	29	3
1975	03 Jly	17 Oct	10 Jly	22	07 Sep	34		0	2
1976	22 Jun	31 Aug	29 Jun	8		0		0	1
1977	13 Jun	17 Nov	12 Jly	7	03 Aug	13	30 Aug	8	5
1978	11 Jun	18 Sep	18 Jun	27	21 Jly	15	26 Aug	16	3
1979	19 Jun	28 Sep	14 Jly	8	07 Aug	27	10 Sep	10	3
1980	07 Jun	16 Sep	24 Jly	18	18 Aug	17		0	2
1981	29 Jly	23 Sep	23 Aug	30		0		0	1
1982	06 May	11 Sep	13 May	53	20 Jly	8	11 Aug	10	3
1983	20 Jun	02 Oct	08 Aug	15		0		0	1
1984	10 Jun	03 Oct	17 Jun	7	31 Jun	9	20 Aug	7	4
1985	30 May	07 Sep	06 Jun	23	27 Aug	10		0	2
1986	13 Jun	05 Oct	19 Jly	11	21 Aug	39		0	2
1987	01 Jly	03 Oct	18 Jly	21	15 Aug	7	05 Sep	28	3
1988	22 Jun	03 Oct	06 Jly	47	29 Aug	8		0	2
1989	06 Jun	11 Sep	10 Jly	39	25 Aug	10		0	2
1990	09 Jun	29 Sep	23 Jun	13	21 Jly	19	31 Aug	7	4
1991	11 Jly	12 Aug	24 Jly	12		0		0	1
1992	16 Jly	07 Sep	01 Aug	9	17 Aug	14		0	2
Mean	18 Jun	23 Sep	06 Jly	17	07 Aug	17	28 Aug	14	2

* Critical Dry Spell (CDS) : When length of spell exceeds 7 days

Earliest probable date of OEM (p=0.68) : 01 Jun
Mean Date of OEM : 18 Jun
Latest probable date of OEM (p=0.68) : 05 Jly

Earliest probable date of OEM (p=0.50) : 09 Jun
Median date of OEM : 18 Jun
Latest probable date of OEM (p=0.50) : 28 Jun

Standrd deviation (days) : 17
Semi-inter-quartile range (days) : 9

Average date on which effective monsoon ends : 23 Sep
Average number of CDS per year : 2

Average date on which 1st CDS starts : 06 Jly Length (days): 17
Average date on which 2nd CDS starts : 07 Aug Length (days): 17
Average date on which 3rd CDS starts : 28 Aug Length (days): 14

Table B-4 Onset and withdrawal of effective monsoon and occurrence of critical dry spells in Khariar

Year	Effective Monsoon		Critical Dry Spells (CDS*)						
	Onsets on	Ends on	Date & length, 1st CDS		Date & length, 2nd CDS		Date & length, 3rd CDS		Total no.of CDS
1967	20 Jun	24 Sep	27 Jun	20	30 Jly	10	16 Aug	20	3
1968	22 Jly	04 Oct	29 Jly	30	10 Sep	18		0	2
1969	22 Jun	18 Sep	14 Aug	28		0		0	1
1970	27 May	13 Sep	13 Jun	9		0		0	1
1971	29 May	26 Aug	19 Jun	62		0		0	1
1972	22 Jun	04 Oct	07 Jly	28	21 Aug	14	11 Sep	9	4
1973	06 Jun	25 Oct	13 Jun	11	11 Jly	21	08 Aug	49	4
1974	02 Jly	16 Sep	09 Jly	24	09 Aug	12	22 Aug	24	3
1975	20 Jun	10 Sep	14 Aug	20		0		0	1
1976	18 Jun	30 Aug	26 Jun	7	12 Aug	11		0	2
1977	13 Jun	16 Nov	12 Jly	8	19 Aug	17	12 Sep	8	4
1978	16 Jun	15 Sep	23 Jun	11	24 Aug	15		0	2
1979	19 Jun	04 Aug	26 Jun	7	09 Jly	15		0	2
1980	13 Jun	15 Sep	10 Jly	7	24 Jly	16	23 Aug	9	3
1981	28 Jly	23 Sep	10 Aug	14	31 Aug	22		0	2
1982	20 Jun	26 Aug	27 Jun	10	30 Jly	8	14 Aug	11	3
1983	20 Jun	01 Oct	05 Jly	16	05 Aug	19	07 Sep	18	3
1984	25 Jun	07 Aug	01 Jly	12	27 Jly	10		0	2
1985	17 Jun	01 Oct	16 Aug	8	09 Sep	16		0	2
1986	10 Jun	02 Oct	26 Jun	22	18 Jly	13	14 Aug	22	4
1987	14 Jly	07 Sep	21 Jly	34		0		0	1
1988	15 Jun	03 Oct	30 Jun	36	11 Aug	19	06 Sep	9	3
1989	10 Jun	11 Sep	28 Jun	10	14 Jly	34	24 Aug	11	3
1990	06 Jun	01 Nov	17 Jly	23	31 Aug	7	08 Sep	14	4
1991	31 Jun	31 Sep	15 Jly	7	19 Aug	42		0	2
1992	10 Jun	10 Sep	17 Jun	27	30 Jly	9	22 Aug	12	3
Mean	19 Jun	20 Sep	07 Jly	18	08 Aug	16	26 Aug	16	2

* Critical Dry Spell (CDS) : When length of spell exceeds 7 days

Earliest probable date of OEM (p=0.68) : 05 Jun
Mean Date of OEM : 19 Jun
Latest probable date of OEM (p=0.68) : 04 Jly

Earliest probable date of OEM (p=0.50) : 13 Jun
Median date of OEM : 18 Jun
Latest probable date of OEM (p=0.50) : 24 Jun

Standard deviation (days) : 15
Semi-inter-quartile range (days) : 6

Average date on which effective monsoon ends : 20 Sep
Average number of CDS per year : 2

Average date on which 1st CDS starts : 07 Jly Length (days): 18
Average date on which 2nd CDS starts : 08 Aug Length (days): 16
Average date on which 3rd CDS starts : 26 Aug Length (days): 16

Table B-5 Onset and withdrawal of effective monsoon and occurrence of critical dry spells in Boden

Year	Effective Monsoon: Onsets on	Effective Monsoon: Ends on	Critical Dry Spells (CDS*): Date & length, 1st CDS		Date & length, 2nd CDS		Date & length, 3rd CDS		Total no.of CDS
1967	18 Jun	23 Sep	25 Jun	24	01 Aug	9	17 Aug	36	3
1968	20 Jly	03 Oct	27 Jly	42	09 Sep	18		0	2
1969	07 Jun	18 Sep	23 Jun	11	10 Jly	7	24 Jly	9	4
1970	27 May	21 Sep	11 Jun	10	05 Jly	10		0	2
1971	11 Jun	28 Aug	18 Jun	13	07 Jly	20		0	2
1972	15 Jun	21 Sep	08 Jly	52	13 Sep	7		0	2
1973	02 Jly	22 Oct	09 Jly	36	21 Aug	56		0	2
1974	-------- No effective monsoon this year ----------------								
1975	07 Jly	10 Sep	23 Jly	9	08 Aug	26		0	2
1976	22 Jun	01 Sep	28 Jly	11	15 Aug	10		0	2
1977	28 Apr	28 Sep	04 May	40	20 Jun	17	04 Aug	12	5
1978	12 Jun	23 Sep	19 Jun	11	13 Jly	23	21 Aug	19	3
1979	20 Jun	28 Sep	27 Jun	27	06 Aug	46		0	2
1980	13 Jun	17 Sep	29 Jly	15	20 Aug	15		0	2
1981	30 Jly	27 Sep	10 Aug	14	31 Aug	20		0	2
1982	04 Jly	09 Sep	18 Jly	9	15 Aug	18		0	2
1983	22 Jun	23 Sep	29 Jun	16		0		0	1
1984	11 Jun	18 Aug	18 Jun	7	15 Jly	11		0	2
1985	16 Jun	23 Sep	23 Jun	7	16 Jly	12	19 Aug	17	3
1986	16 Jun	07 sep	24 Jun	19	19 Jly	17	12 Aug	25	3
1987	03 Jun	30 Aug	10 Jun	37	17 Jly	12	30 Jly	9	4
1988	12 Jun	21 Sep	19 Jly	9	04 Aug	7	06 Sep	8	3
1989	09 Jun	23 Sep	24 Jun	23	23 Jly	13	23 Aug	11	3
1990	06 May	07 Oct	13 May	23	25 Jun	9	18 Jly	13	5
1991	02 Jun	05 Oct	09 Jun	24	14 Jly	7	24 Aug	36	3
1992	09 Jly	21 Aug		0		0		0	0
Mean	16 Jun	18 Sep	29 Jun	20	29 Jly	16	12 Aug	17	2

* Critical Dry Spell (CDS) : When length of spell exceeds 7 days

Earliest probable date of OEM (p=0.68) : 27 May
Mean Date of OEM : 16 Jun
Latest probable date of OEM (p=0.68) : 06 Jly

Earliest probable date of OEM (p=0.50) : 08 Jun
Median date of OEM : 16 Jun
Latest probable date of OEM (p=0.50) : 24 Jun

Standrd deviation (days) : 21
Semi-inter-quartile range (days) : 8

Average date on which effective monsoon ends : 18 Sep
Average number of CDS per year : 2

Average date on which 1st CDS starts : 29 Jun Length (days): 20
Average date on which 2nd CDS starts : 29 Jly Length (days): 16
Average date on which 3rd CDS starts : 12 Aug Length (days): 17

Table B-6 Onset and withdrawal of effective monsoon and occurrence of critical dry spells in Golamunda

Year	Effective Monsoon		Critical Dry Spells (CDS*)						
	Onsets on	Ends on	Date & length, 1st CDS		Date & length, 2nd CDS		Date & length, 3rd CDS		Total no.of CDS
1967	12 Jun	13 Sep	26 Jun	15	29 Jly	13	18 Aug	7	4
1968	19 Jun	29 Sep	26 Jun	15	24 Jly	7	07 Aug	32	4
1969	02 Jun	02 Sep	07 Jly	8	08 Aug	24		0	2
1970	06 Jun	25 Aug	13 Jun	8		0		0	1
1971	05 May	19 Jun	12 May	16	04 Jun	8		0	2
1972	22 Jun	21 Sep	05 Jly	44	25 Aug	10	11 Sep	9	3
1973	31 Jun	24 Oct	14 Jly	9	30 Jly	14	27 Aug	52	3
1974	03 Jly	24 Oct		0		0		0	0
1975	22 Jun	22 Aug	11 Jly	10		0		0	1
1976	22 Jun	02 Sep		0		0		0	0
1977	24 Jun	25 Sep	01 Jly	16	08 Sep	10		0	2
1978	02 Jly	13 Oct	24 Aug	50		0		0	1
1979	20 Jun	29 Jly	03 Jly	19		0		0	1
1980	08 Jun	03 Oct	05 Jly	8	20 Jly	46	19 Sep	14	3
1981	01 Jly	23 Sep	08 Jly	13	16 Aug	7	07 Sep	15	3
1982	09 Jun	11 Sep	25 Jun	16	17 Jly	11	14 Aug	11	4
1983	20 Jun	06 Sep	27 Jun	18	03 Aug	20		0	2
1984	11 Jun	19 Aug	18 Jun	7	02 Aug	10		0	2
1985	03 Jun	17 Sep	23 Jun	7	13 Jly	9	16 Aug	8	4
1986	16 Jun	12 Sep	23 Jun	12	18 Jly	8	12 Aug	24	3
1987	15 Jly	22 Sep	22 Jly	18	16 Aug	9	01 Sep	14	3
1988	18 Jun	22 Sep	14 Jly	8	05 Aug	41		0	2
1989	08 Jun	22 Sep	22 Jun	10	08 Jly	10	24 Aug	11	3
1990	06 Jun	08 Oct	24 Jly	15	30 Aug	23		0	2
1991	31 Jun	06 Oct	20 Aug	41		0		0	1
1992	10 Jun	04 Sep	17 Jun	22	19 Aug	9		0	2
Mean	16 Jun	13 Sep	03 Jly	16	31 Jly	15	25 Aug	17	2

* Critical Dry Spell (CDS) : When length of spell exceeds 7 days

Earliest probable date of OEM (p=0.68) : 03 Jun
Mean Date of OEM : 16 Jun
Latest probable date of OEM (p=0.68) : 31 Jun

Earliest probable date of OEM (p=0.50) : 11 Jun
Median date of OEM : 18 Jun
Latest probable date of OEM (p=0.50) : 26 Jun

Standard deviation (days) : 14
Semi-inter-quartile range (days) : 8

Average date on which effective monsoon ends : 13 Sep
Average number of CDS per year : 2

Average date on which 1st CDS starts : 03 Jly Length (days): 16
Average date on which 2nd CDS starts : 31 Jly Length (days): 15
Average date on which 3rd CDS starts : 25 Aug Length (days): 17

Table B-7 Onset and withdrawal of effective monsoon and occurrence of critical dry spells in Dharamgarh

Year	Effective Monsoon: Onsets on	Effective Monsoon: Ends on	Critical Dry Spells (CDS*): Date & length, 1st CDS		Date & length, 2nd CDS		Date & length, 3rd CDS		Total no.of CDS
1967	17 Jun	20 Sep	30 Jun	16	30 Jly	7	27 Aug	10	3
1968	16 Jly	04 Oct	23 Jly	14	13 Aug	17	10 Sep	18	3
1969	26 Jun	17 Sep	09 Aug	32		0		0	1
1970	30 May	19 Sep	06 Jun	13	31 Jly	7	23 Aug	7	3
1971	30 May	31 Aug	19 Jun	8	12 Jly	8	10 Aug	14	3
1972	17 Jun	21 Sep	07 Jly	26	21 Aug	9	08 Sep	11	3
1973	06 Jun	25 Oct	13 Jun	13	12 Jly	10	29 Jly	16	5
1974	04 Jly	01 Sep	11 Jly	45		0		0	1
1975	19 Jun	01 Oct	16 Aug	15	07 Sep	18		0	2
1976	15 Jun	06 Sep		0		0		0	0
1977	31 Apr	21 Nov	07 May	43	05 Aug	7	09 Sep	67	3
1978	10 Jun	14 Sep	17 Jun	13	24 Aug	14		0	2
1979	15 Jun	31 Sep	22 Jun	11	05 Aug	50		0	2
1980	08 Jun	15 Sep	27 Jly	36		0		0	1
1981	26 Jly	27 Sep	16 Aug	15	01 Sep	19		0	2
1982	09 Jun	29 Aug	25 Jun	13	15 Jly	23		0	2
1983	18 Jun	04 Aug	02 Jly	12		0		0	1
1984	09 Jun	09 Sep	16 Jun	8	01 Aug	24		0	2
1985	16 Jun	12 Sep	12 Jly	9	21 Aug	7		0	2
1986	15 Jun	20 Aug	24 Jun	9	17 Jly	7		0	2
1987	31 Jun	06 Oct	17 Jly	31	08 Sep	22		0	2
1988	25 Jun	10 Aug		0		0		0	0
1989	14 Jun	10 Sep	21 Jun	10	07 Jly	29	23 Aug	11	3
1990	06 May	11 Oct	13 May	24	13 Jun	8	28 Jun	9	5
1991	11 Jly	29 Oct	21 Aug	69		0		0	1
1992	10 Jun	07 Sep	17 Jun	20		0		0	1
Mean	15 Jun	18 Sep	02 Jly	21	03 Aug	15	18 Aug	18	2

* Critical Dry Spell (CDS) : When length of spell exceeds 7 days

Earliest probable date of OEM (p=0.68) : 28 May
Mean Date of OEM : 15 Jun
Latest probable date of OEM (p=0.68) : 03 Jly

Earliest probable date of OEM (p=0.50) : 08 Jun
Median date of OEM : 15 Jun
Latest probable date of OEM (p=0.50) : 22 Jun

Standard deviation (days) : 19
Semi-inter-quartile range (days) : 7

Average date on which effective monsoon ends : 18 Sep
Average number of CDS per year : 2

Average date on which 1st CDS starts : 02 Jly Length (days): 21
Average date on which 2nd CDS starts : 03 Aug Length (days): 15
Average date on which 3rd CDS starts : 18 Aug Length (days): 18

Table B-8 Onset and withdrawal of effective monsoon and occurrence of critical dry spells in Narla

Year	Effective Monsoon: Onsets on	Effective Monsoon: Ends on	Critical Dry Spells (CDS*): Date & length, 1st CDS		Date & length, 2nd CDS		Date & length, 3rd CDS		Total no.of CDS
1967	16 Jun	18 Dec	30 Jun	20	28 Jly	8	20 Aug	16	4
1968	18 Jly	01 Oct	25 Jly	11	12 Aug	26	09 Sep	16	3
1969	11 Jun	04 Sep	18 Jun	7	01 Jly	18	04 Aug	12	4
1970	31 Jun	27 Sep	07 Jly	32	23 Aug	28		0	2
1971	11 Jun	29 Sep	18 Jun	32	27 Jly	63		0	2
1972	23 Jun	20 Sep	06 Jly	26	10 Aug	8	25 Aug	9	4
1973	30 Jun	24 Oct	13 Jly	8	28 Jly	13	17 Aug	62	3
1974	02 Jly	24 Aug	09 Jly	22	07 Aug	10		0	2
1975	12 Jun	09 Sep	26 Jun	7	16 Jly	14	13 Aug	20	3
1976	21 Jun	10 Sep	27 Aug	7		0		0	1
1977	25 Jun	20 Nov	05 Aug	10	22 Aug	10	08 Sep	67	3
1978	11 Jun	13 Sep	08 Jly	15	23 Aug	14		0	2
1979	18 Jun	01 Oct	25 Jun	7	08 Jly	14	05 Aug	28	4
1980	12 Jun	17 Sep	03 Jly	15	02 Aug	32		0	2
1981	28 Jly	25 Sep	23 Aug	26		0		0	1
1982	27 Jly	26 Aug	10 Aug	14		0		0	1
1983	18 Jun	25 Sep	04 Aug	24	04 Sep	14		0	2
1984	25 Jun	04 Sep	15 Jly	10	05 Aug	13		0	2
1985	20 Jun	11 Oct	12 Jly	9	17 Sep	24		0	2
1986	16 Jun	06 Sep	19 Jly	10	19 Aug	17		0	2
1987	15 Jly	31 Aug	22 Jly	17	15 Aug	15		0	2
1988	19 Jun	23 Sep	19 Aug	28		0		0	1
1989	07 Jun	08 Sep	30 Jun	17	23 Jly	14	07 Aug	8	4
1990	19 Jun	04 Nov	26 Jun	9	31 Aug	22	07 Oct	21	3
1991	05 Jun	06 Oct	14 Jun	19	14 Jly	8	29 Aug	14	4
1992	10 Jun	10 Sep	17 Jun	24	17 Aug	17		0	2
Mean	23 Jun	25 Sep	13 Jly	16	07 Aug	18	24 Aug	24	2

* Critical Dry Spell (CDS) : When length of spell exceeds 7 days

Earliest probable date of OEM (p=0.68) : 08 Jun
Mean Date of OEM : 23 Jun
Latest probable date of OEM (p=0.68) : 07 Jly

Earliest probable date of OEM (p=0.50) : 11 Jun
Median date of OEM : 19 Jun
Latest probable date of OEM (p=0.50) : 27 Jun

Standard deviation (days) : 15
Semi-inter-quartile range (days) : 8

Average date on which effective monsoon ends : 25 Sep
Average number of CDS per year : 2

Average date on which 1st CDS starts : 13 Jly Length (days): 16
Average date on which 2nd CDS starts : 07 Aug Length (days): 18
Average date on which 3rd CDS starts : 24 Aug Length (days): 24

Table B-9 Onset and withdrawal of effective monsoon based on mean in different blocks under study

Block	Earliest Probable date (p=0.68)	Mean date	Latest probable date (p=0.68)	standard daviation (days)	mean date of withdrawal of monsoon
Bhawanipatna	01 Jan	19 Jun	07 Jly	18	23 Sep
Kesinga	30 May	21 Jun	13 Jly	23	18 Sep
Nawapara	01 Jun	18 Jun	05 Jly	17	23 Sep
Khariar	05 Jun	19 Jun	04 Jly	15	20 Sep
Boden	27 May	16 Jun	06 Jly	21	18 Sep
Golamunda	03 Jun	16 Jun	31 Jun	14	13 Sep
Dharamgarh	28 May	15 Jun	03 Jly	19	18 Sep
Narla	08 Jun	15 Jun	07 Jly	15	25 Sep

Table B-10 Onset of effective monsoon based on median in different blocks under study

Block	Earliest Probable date (p=0.50)	Median date	Latest probable date (p=0.50)	Semi-inter quartile range days
Bhawanipatna	08 Jun	15 Jun	23 Jun	8
Kesinga	04 Jun	15 Jun	27 Jun	12
Nawapara	09 Jun	18 Jun	28 Jun	9
Khariar	13 Jun	18 Jun	24 Jun	6
Boden	08 Jun	16 Jun	24 Jun	8
Golamunda	11 Jun	18 Jun	26 Jun	8
Dharamgarh	08 May	15 Jun	22 Jun	7
Narla	11 Jun	19 Jun	27 Jun	8

Table B-11 Occurrence of critical dry spells (CDS) in different blocks under study.

Block	First CDS		Second CDS		Third CDS		Average Number of CDS/ Year
	Date	Length (days)	Date	Length (days)	Date	Length (days)	
Bhawanipatna	10 Jly	14	06 Aug	16	30 Aug	22	2
Kesinga	03 Jly	16	08 Aug	15	25 Aug	19	2
Nawapara	06 Jly	17	07 Aug	17	28 Aug	14	2
Khariar	07 Jly	18	08 Aug	16	26 Aug	16	2
Boden	29 Jly	20	29 Jly	16	12 Aug	17	2
Golamunda	03 Jun	16	31 Jly	15	25 Aug	17	2
Dharamgarh	02 Jly	21	03 Aug	15	18 Aug	18	2
Narla	13 Jly	16	07 Aug	18	24 Aug	24	2

APPENDIX-C

Table C-1 Weekly observed minimum, maximum & normal rainfall and the probality of the weekly normal rainfall equalling or exceeding the normal in any year in Bhawanipatna block.

Week	Minimum (mm)	Maximum (mm)	Normal (mm)	Probability (%)
1	0	32.0	1.5	11.54
2	0	29.6	2.4	11.54
3	0	23.0	1.2	7.69
4	0	22.2	2.0	19.23
5	0	22.4	1.5	11.54
6	0	49.4	6.2	19.23
7	0	40.2	4.3	23.08
8	0	15.0	1.6	19.23
9	0	23.9	2.6	19.23
10	0	43.3	4.3	23.08
11	0	53.6	6.5	26.92
12	0	59.4	5.8	19.23
13	0	23.0	2.6	26.92
14	0	34.4	5.6	26.92
15	0	30.0	4.5	30.77
16	0	52.0	9.3	26.92
17	0	88.0	7.7	23.08
18	0	138.5	13.4	19.23
19	0	55.0	10.5	34.62
20	0	93.0	10.3	30.77
21	0	33.2	4.4	23.08
22	0	62.0	16.8	34.62
23	0	134.0	22.6	38.46
24	0	334.8	55.3	38.46
25	0	303.1	77.5	42.31
26	0	383.8	95.9	34.62
27	0	295.0	84.0	38.46
28	0	227.5	68.4	46.15
29	11.6	433.0	85.0	38.46
30	0	332.0	77.6	38.46
31	0	470.7	109.9	38.46
32	11.0	323.0	92.2	34.62
33	0	526.1	96.2	34.62
34	0	225.0	76.8	42.31
35	0	289.6	64.3	38.46
36	0	240.0	68.1	46.15
37	6.9	506.5	97.5	38.46
38	0	98.0	30.2	46.15
39	0	208.6	34.5	38.46
40	0	524.0	38.6	26.92
41	0	72.0	12.8	34.62
42	0	65.0	13.3	34.62
43	0	120.0	7.8	26.92
44	0	29.0	4.0	26.92
45	0	78.2	9.5	29.92
46	0	6.0	0.4	7.69
47	0	87.5	4.0	7.69
48	0	3.8	0.2	7.69
49	0	0	0	100.00
50	0	20.4	1.1	7.69
51	0	22.6	1.1	7.69
52	0	18.0	1.2	7.69

Table C-2 Weekly observed minimum, maximum & normal rainfall and the probality of the weekly normal rainfall equalling or exceeding the normal in any year in Kesinga block.

Week	Minimum (mm)	Maximum (mm)	Normal (mm)	Probability (%)
1	0	26.0	2.0	7.69
2	0	50.0	3.1	11.54
3	0	13.0	0.5	3.85
4	0	22.0	1.8	11.54
5	0	0	0	100.00
6	0	21.0	1.6	19.23
7	0	53.0	5.6	23.08
8	0	18.0	2.7	19.23
9	0	58.0	4.7	23.08
10	0	14.0	1.2	19.23
11	0	49.0	6.7	26.92
12	0	51.0	5.7	19.23
13	0	22.0	1.9	19.23
14	0	8.0	0.5	11.54
15	0	38.0	5.2	19.23
16	0	93.0	7.4	19.23
17	0	31.5	2.6	19.23
18	0	58.0	5.3	19.23
19	0	73.0	8.2	23.08
20	0	73.0	8.2	19.23
21	0	27.0	2.4	50.38
22	0	54.0	10.6	38.46
23	0	110.0	20.6	34.62
24	0	276.0	44.8	34.62
25	0	246.0	71.1	38.46
26	0	253.6	88.8	46.15
27	0	310.5	75.2	34.62
28	0	179.0	65.4	42.31
29	0	385.0	56.6	30.77
30	0	225.0	81.5	42.31
31	2.5	293.0	99.7	30.77
32	0	285.0	91.4	23.08
33	6.0	292.0	90.7	34.62
34	0	238.0	80.7	42.31
35	0	331.0	59.2	34.62
36	0	200.0	58.6	38.46
37	0	466.0	76.4	34.62
38	0	144.0	29.6	30.77
39	0	136.0	25.7	30.77
40	0	272.0	32.8	26.92
41	0	75.0	8.4	26.92
42	0	90.0	11.0	34.62
43	0	67.5	5.0	19.23
44	0	84.0	6.9	19.23
45	0	129.0	5.9	7.69
46	0	18.0	0.7	3.85
47	0	28.0	2.2	7.69
48	0	0	0	100.00
49	0	0	0	100.00
50	0	13.6	0.6	7.69
51	0	0	0	100.00
52	0	17.0	1.1	7.69

Table C-3 Weekly observed minimum, maximum & normal rainfall and the probality of the weekly normal rainfall equalling or exceeding the normal in any year in Nawapara block.

Week	Minimum (mm)	Maximum (mm)	Normal (mm)	Probability (%)
1	0	18.5	1.7	15.38
2	0	30.0	2.7	15.38
3	0	52.4	2.5	11.54
4	0	21.4	1.9	11.54
5	0	21.8	1.3	11.54
6	0	71.3	4.8	11.54
7	0	32.0	4.9	26.92
8	0	92.5	4.7	15.38
9	0	35.0	4.6	23.08
10	0	25.0	3.4	23.08
11	0	41.7	6.3	26.92
12	0	102.2	6.7	15.38
13	0	13.0	0.8	11.54
14	0	24.0	3.2	23.08
15	0	10.0	0.9	15.38
16	0	42.0	5.9	26.92
17	0	25.7	2.3	19.23
18	0	61.0	5.6	19.23
19	0	39.6	7.1	26.92
20	0	59.0	8.6	26.92
21	0	39.1	3.6	23.08
22	0	72.0	12.0	26.92
23	0	126.4	18.8	38.46
24	0	157.4	40.2	42.31
25	0	221.2	49.8	34.62
26	0	281.4	74.2	34.62
27	1.5	446.2	91.8	19.23
28	1.0	282.1	79.5	42.31
29	1.5	306.0	76.4	38.46
30	0	255.0	71.5	42.31
31	0	307.0	80.8	34.62
32	9.2	331.8	81.4	46.15
33	0.8	208.2	84.1	38.46
34	0	150.0	65.1	38.46
35	0	238.8	59.0	38.46
36	0	191.0	48.3	34.62
37	0	244.6	67.5	42.31
38	0	173.8	31.0	38.46
39	0	108.4	30.5	34.62
40	0	146.8	30.1	26.92
41	0	115.6	10.9	30.77
42	0	59.8	4.8	23.08
43	0	151.0	9.0	23.08
44	0	20.7	2.4	19.23
45	0	69.0	3.3	7.69
46	0	20.4	0.9	7.69
47	0	59.0	5.5	19.23
48	0	6.2	0.3	7.69
49	0	4.3	0.2	3.85
50	0	21.7	1.2	11.54
51	0	7.0	0.3	3.85
52	0	16.0	1.0	11.54

Table C-4 Weekly observed minimum, maximum & normal rainfall and the probality of the weekly normal rainfall equalling or exceeding the normal in any year in Khariar block

Week	Minimum (mm)	Maximum (mm)	Normal (mm)	Probability (%)
1	0	46.0	2.2	7.69
2	0	30.8	2.3	15.38
3	0	32.5	1.5	7.69
4	0	29.5	1.8	15.38
5	0	14.3	1.5	15.38
6	0	108.6	5.8	15.38
7	0	27.3	4.2	26.92
8	0	32.1	2.1	19.23
9	0	64.5	4.6	23.08
10	0	50.5	2.9	11.54
11	0	32.5	2.7	26.92
12	0	78.5	5.0	15.38
13	0	13.0	1.4	19.23
14	0	57.8	7.4	26.92
15	0	23.8	3.6	26.92
16	0	49.3	10.5	34.62
17	0	32.5	4.9	30.77
18	0	42.5	5.0	19.23
19	0	42.5	4.2	19.23
20	0	87.8	9.0	30.77
21	0	28.8	3.0	26.92
22	0	69.5	14.3	34.62
23	0	102.3	22.9	38.46
24	0	137.8	35.1	38.46
25	0	234.0	62.2	34.62
26	0	237.8	80.0	42.31
27	0	400.8	72.6	42.31
28	11.5	205.0	64.8	46.15
29	7.0	250.5	67.6	34.62
30	3.0	222.5	62.7	30.77
31	5.8	259.0	63.0	34.62
32	3.3	179.0	62.9	46.15
33	0	178.3	64.3	42.31
34	0	168.8	56.8	42.31
35	0	146.8	41.7	42.31
36	0	132.9	45.2	38.46
37	4.8	231.8	55.4	38.46
38	0	102.0	22.9	38.46
39	0	174.0	32.5	30.77
40	0	300.9	36.2	34.62
41	0	93.3	13.9	34.62
42	0	28.5	5.2	26.92
43	0	141.0	8.2	23.08
44	0	54.8	8.4	26.92
45	0	128.9	6.0	15.38
46	0	36.0	1.4	3.85
47	0	62.0	3.2	11.54
48	0	4.0	0.2	3.85
49	0	0	0	100.00
50	0	12.0	1.0	11.54
51	0	0	0	100.00
52	0	15.5	1.2	11.54

Table C-5 Weekly observed minimum, maximum & normal rainfall and the probality of the weekly normal rainfall equalling or exceeding the normal in any year in Boden block.

Week	Minimum (mm)	Maximum (mm)	Normal (mm)	Probability (%)
1	0	33.0	1.5	7.69
2	0	31.2	2.0	7.69
3	0	10.0	0.4	3.85
4	0	14.6	1.0	7.69
5	0	15.0	1.0	7.69
6	0	36.8	1.9	11.54
7	0	55.0	4.1	15.38
8	0	58.0	2.2	3.85
9	0	25.0	4.9	26.92
10	0	36.0	2.4	11.54
11	0	46.0	4.4	19.23
12	0	46.4	4.2	11.54
13	0	11.2	1.7	23.08
14	0	31.2	3.4	19.23
15	0	23.2	3.1	23.08
16	0	48.2	5.8	23.08
17	0	52.0	6.1	23.08
18	0	87.6	13.2	26.92
19	0	75.4	7.9	19.23
20	0	31.0	4.8	26.92
21	0	79.0	8.4	23.08
22	0	141.0	19.5	38.46
23	0	59.0	20.3	38.46
24	0	127.1	41.4	46.15
25	0	210.0	62.3	34.62
26	0	167.0	56.0	50.00
27	0	168.5	52.8	42.31
28	0	254.4	61.3	34.62
29	0	153.6	70.8	42.31
30	0	359.0	77.5	30.77
31	0	317.3	55.8	38.46
32	0.2	207.0	68.6	42.31
33	0	226.0	71.0	42.31
34	0	243.6	57.3	34.62
35	0	115.6	38.5	38.46
36	0	150.2	41.3	42.31
37	0	311.0	71.0	30.77
38	0	190.6	34.8	46.15
39	0	140.0	31.9	38.46
40	0	236.4	29.9	26.92
41	0	123.0	14.5	23.08
42	0	34.0	6.7	34.62
43	0	125.0	7.7	19.23
44	0	29.1	2.4	15.38
45	0	13.0	1.4	15.38
46	0	43.0	1.8	7.69
47	0	39.4	1.5	3.85
48	0	0	0	100.00
49	0	0	0	100.00
50	0	7.0	0.3	3.85
51	0	0	0	100.00
52	0	15.0	0.6	3.85

Table C-6 Weekly observed minimum, maximum & normal rainfall and the probality of the weekly normal rainfall equalling or exceeding the normal in any year in Golamunda block.

Week	Minimum (mm)	Maximum (mm)	Normal (mm)	Probability (%)
1	0	35.0	1.3	3.85
2	0	23.0	1.5	11.54
3	0	31.0	1.2	3.85
4	0	5.0	0.3	7.69
5	0	1.1	0.1	7.69
6	0	26.0	2.5	23.08
7	0	39.0	5.1	19.23
8	0	32.0	2.1	15.38
9	0	98.0	6.1	19.23
10	0	73.0	7.0	26.92
11	0	48.7	4.1	23.08
12	0	53.4	4.9	15.38
13	0	54.5	3.9	19.23
14	0	33.0	3.6	26.92
15	0	30.0	3.9	30.77
16	0	98.0	8.1	23.08
17	0	30.0	4.6	23.08
18	0	60.0	5.9	15.38
19	0	375.0	24.0	11.54
20	0	28.0	2.6	23.08
21	0	39.0	3.8	19.23
22	0	87.0	10.8	26.92
23	0	80.0	19.2	30.77
24	0	156.0	45.7	34.62
25	0	176.0	54.5	34.62
26	0	197.0	70.8	38.46
27	0	350.0	83.0	42.31
28	0	185.5	62.6	42.31
29	0	355.0	90.2	34.62
30	0	334.0	75.1	34.62
31	0	380.0	86.4	38.46
32	2.0	195.0	59.8	42.31
33	0	255.0	75.6	34.62
34	2.0	335.0	90.6	30.77
35	0	121.0	42.5	46.15
36	0	160.0	47.6	34.62
37	0	177.5	51.8	34.62
38	0	108.8	26.8	46.15
39	0	149.0	27.3	38.46
40	0	358.0	30.1	23.08
41	0	112.0	18.1	26.92
42	0	113.0	10.0	23.08
43	0	112.0	5.8	11.54
44	0	42.0	3.3	11.54
45	0	50.0	2.0	3.85
46	0	9.0	0.7	7.69
47	0	45.0	2.1	7.69
48	0	0.8	0	3.85
49	0	0	0	100.00
50	0	45.5	2.3	7.69
51	0	0	0	100.00
52	0	17.0	0.7	3.85

Table C-7 Weekly observed minimum, maximum & normal rainfall and the probality of the weekly normal rainfall equalling or exceeding the normal in any year in Dharamgarh block.

Week	Minimum (mm)	Maximum (mm)	Normal (mm)	Probability (%)
1	0	0	0	100.0
2	0	25.0	1.6	7.69
3	0	5.0	0.3	7.69
4	0	10.2	0.6	11.54
5	0	11.4	0.9	15.38
6	0	37.0	3.4	15.38
7	0	34.0	2.7	11.54
8	0	25.0	1.6	11.54
9	0	19.0	3.3	23.08
10	0	23.0	2.6	15.38
11	0	45.0	3.1	19.23
12	0	47.2	3.0	11.54
13	0	25.0	2.3	19.23
14	0	38.0	5.4	26.92
15	0	22.0	2.5	15.38
16	0	52.0	9.3	34.62
17	0	25.0	3.4	23.08
18	0	90.0	7.0	23.08
19	0	104.2	11.9	26.92
20	0	114.0	12.6	23.08
21	0	26.0	4.4	38.46
22	0	73.8	10.7	34.62
23	0	177.8	25.6	30.77
24	2.0	160.0	43.0	38.46
25	0	244.0	62.6	38.46
26	2.0	313.7	87.4	38.46
27	0	283.1	68.1	26.15
28	3.0	214.6	75.9	38.46
29	10.2	288.5	85.8	38.46
30	7.0	346.0	81.5	38.46
31	3.0	355.0	90.9	42.31
32	0	175.0	66.1	34.62
33	0	473.2	93.3	30.77
34	0	208.6	70.4	38.46
35	0	139.5	49.3	38.46
36	0	148.0	65.1	50.00
37	1.0	337.1	60.5	38.46
38	0	198.0	26.5	30.77
39	0	201.0	28.9	34.62
40	0	356.0	30.1	23.08
41	0	86.6	14.7	30.77
42	0	37.4	7.3	34.62
43	0	116.8	7.2	19.23
44	0	67.5	5.9	23.08
45	0	62.0	3.5	11.54
46	0	12.0	0.5	3.85
47	0	69.1	3.9	7.69
48	0	0	0	100.00
49	0	0	0	100.00
50	0	16.8	0.8	7.69
51	0	0	0	100.00
52	0	0	0	100.00

Table C-8 Weekly observed minimum, maximum & normal rainfall and the probality of the weekly normal rainfall equalling or exceeding the normal in any year in Narla block.

Week	Minimum (mm)	Maximum (mm)	Normal (mm)	Probability (%)
1	0	27.0	1.9	15.38
2	0	28.0	1.5	7.69
3	0	25.0	1.0	7.69
4	0	62.0	3.2	15.38
5	0	75.0	2.9	3.85
6	0	41.3	2.9	11.54
7	0	52.6	5.9	19.23
8	0	26.0	2.6	15.38
9	0	25.8	3.5	15.38
10	0	61.4	5.4	15.38
11	0	41.0	3.1	11.54
12	0	64.0	4.2	11.54
13	0	15.9	1.5	19.23
14	0	17.2	2.7	23.08
15	0	58.0	5.6	26.92
16	0	62.0	5.7	26.92
17	0	72.0	6.8	15.38
18	0	91.0	10.0	23.08
19	0	54.6	10.3	34.62
20	0	62.0	9.2	23.08
21	0	35.0	1.8	11.54
22	0	85.0	14.1	38.46
23	0	67.6	11.8	26.92
24	0	186.8	59.5	50.00
25	0	257.0	74.7	26.92
26	13.6	251.4	88.1	42.31
27	0.7	288.0	73.3	26.92
28	0	231.0	63.9	30.77
29	0	715.0	76.9	26.92
30	12.0	359.8	96.9	30.77
31	7.0	241.4	84.59	42.31
32	6.1	286.0	87.9	42.31
33	0	304.4	89.4	34.62
34	0	477.8	84.1	38.46
35	0	359.0	57.6	23.08
36	0	307.4	49.8	34.62
37	0	364.0	64.0	30.77
38	0	560.0	43.6	23.08
39	0	173.0	38.1	30.77
40	0	793.6	51.5	11.54
41	0	142.8	12.1	19.23
42	0	71.0	9.3	19.23
43	0	97.0	7.1	23.08
44	0	68.8	7.1	19.23
45	0	69.8	3.8	7.69
46	0	24.0	1.7	11.54
47	0	56.0	3.2	7.69
48	0	4.0	0.2	7.69
49	0	7.0	0.3	3.85
50	0	21.4	1.5	7.69
51	0	0	0	100.00
52	0	58.0	3.0	7.69

APPENDIX D

Table D-1 Probability of different dry and wet spells in Bhawanipatna block

Week No.	F (d)	F (dd)	P (d) %	P (dd) %	2d %	3d %	F (w)	F (ww)	P (w) %	P (ww) %	2w %	3w %
1	24	21	92	88	85	81	2	0	8	0	0	0
2	25	23	96	92	92	85	1	0	4	0	0	0
3	26	25	100	96	92	88	0	0	0	0	0	0
4	25	23	96	92	92	85	1	0	4	0	0	0
5	26	25	100	96	92	81	0	0	0	0	0	0
6	25	23	96	92	84	81	1	0	4	0	0	0
7	24	21	92	88	88	78	2	0	8	0	0	0
8	26	25	100	96	88	84	0	0	0	0	0	0
9	24	21	92	88	88	76	2	0	8	0	0	0
10	26	25	100	96	86	78	0	0	0	0	0	0
11	22	19	85	86	77	71	4	1	15	25	5	0
12	23	21	88	91	81	78	3	1	12	33	0	0
13	25	23	96	92	92	79	1	0	4	0	0	0
14	26	25	100	96	86	75	0	0	0	0	0	0
15	22	19	85	86	74	65	4	2	15	50	5	0
16	23	20	88	87	77	64	3	1	12	33	0	0
17	24	21	92	88	76	63	2	0	8	0	0	0
18	23	19	88	83	62	57	3	0	12	0	0	0
19	23	19	88	83	62	57	3	0	12	0	0	0
20	21	15	81	71	75	48	5	0	19	0	0	0
21	25	23	96	92	62	33	1	0	4	0	0	0
22	20	13	77	65	41	13	6	0	23	0	5	2
23	17	9	65	53	20	3	9	2	35	22	11	7
24	13	4	50	31	7	2	13	4	50	31	34	27
25	8	1	31	13	10	2	18	12	69	67	55	42
26	6	2	23	33	5	0	20	16	77	80	59	49
27	5	1	19	20	0	0	21	16	81	76	67	61
28	3	0	12	0	4	2	23	19	88	83	80	65
29	3	1	12	33	5	2	23	21	88	91	71	62
30	5	2	19	40	6	0	21	17	81	81	70	58
31	3	1	12	33	0	0	23	20	88	87	73	64
32	3	0	12	0	0	0	23	19	88	83	77	55
33	2	0	8	0	0	0	24	21	92	88	65	49
34	5	0	19	0	3	0	21	15	81	71	61	41
35	6	1	23	17	6	2	20	15	77	75	52	39
36	8	2	31	25	10	6	18	12	69	67	52	21
37	6	2	23	33	14	7	20	15	77	75	31	14
38	16	10	62	63	29	15	10	4	38	40	17	8
39	13	6	50	46	27	22	13	6	50	46	23	6
40	15	8	58	53	48	34	11	5	42	45	11	0
41	22	18	85	82	60	53	4	1	15	25	0	0
42	21	15	81	71	71	62	5	0	19	0	0	0
43	24	21	92	88	80	74	2	0	8	0	3	0
44	23	20	88	87	81	78	3	1	12	33	0	0
45	25	23	96	92	92	81	1	0	4	0	0	0
46	26	25	100	96	88	84	0	0	0	0	0	0
47	24	21	92	88	88	85	2	0	8	0	0	0
48	26	25	100	96	96	92	0	0	0	0	0	0
49	26	25	100	96	96	92	0	0	0	0	0	0
50	26	25	100	96	96	92	0	0	0	0	0	0
51	26	25	100	96	96	--	0	0	0	0	0	-
52	26	25	100	96	--	--	0	0	0	0	-	-

Table D-2 Probability of different dry and wet spells in Kesinga block

Week No.	F (d)	F (dd)	P (d) %	P (dd) %	2d %	3d %	F (w)	F (ww)	P (w) %	P (ww) %	2w %	3w %
1	25	23	96	92	88	78	1	0	4	0	0	0
2	24	21	92	88	85	78	2	0	8	0	0	0
3	25	23	96	92	88	81	1	0	4	0	0	0
4	25	23	96	92	88	76	1	0	4	0	0	0
5	25	23	96	92	83	69	1	0	4	0	2	0
6	22	19	85	86	71	68	4	2	15	50	0	0
7	23	19	88	83	73	78	3	0	12	0	0	0
8	26	25	100	96	92	81	0	0	0	0	0	0
9	25	23	96	92	84	78	1	0	4	0	0	0
10	24	21	92	88	85	85	2	0	8	0	0	0
11	24	22	92	92	85	85	2	0	8	0	0	0
12	24	22	92	92	85	65	2	0	8	0	0	0
13	25	23	96	92	74	68	1	0	4	0	0	0
14	22	17	85	77	78	63	4	0	15	0	0	0
15	25	23	96	92	77	67	1	0	4	0	1	0
16	20	16	77	80	67	52	6	2	23	33	0	0
17	23	20	88	87	68	48	3	0	12	0	0	0
18	22	17	85	77	60	46	4	0	15	0	0	0
19	21	15	81	71	62	57	5	0	19	0	0	0
20	22	17	85	77	78	46	4	0	15	0	0	0
21	25	23	96	92	57	27	1	0	4	0	1	0
22	17	10	65	59	31	4	9	2	35	22	9	6
23	15	7	58	47	8	2	11	3	42	27	26	17
24	8	1	31	13	9	0	18	11	69	61	47	35
25	7	2	27	29	0	0	19	13	73	68	55	36
26	6	0	23	0	4	1	20	15	77	75	50	43
27	6	1	23	17	8	2	20	13	77	65	65	54
28	6	2	23	33	6	2	20	17	77	85	63	43
29	4	1	15	25	4	1	22	18	85	82	58	50
30	7	2	27	29	9	0	19	13	73	68	64	45
31	3	1	12	33	0	0	23	20	88	87	62	54
32	5	0	19	0	5	0	21	15	81	71	66	51
33	4	1	15	25	0	0	22	18	85	82	65	44
34	4	0	15	0	4	0	22	17	85	77	57	30
35	8	2	31	25	3	1	18	12	69	67	37	27
36	9	1	35	11	12	3	17	9	65	53	34	17
37	6	2	23	33	6	2	20	15	77	75	28	10
38	12	3	46	25	18	12	14	5	54	36	19	12
39	15	6	58	40	39	31	11	4	42	36	26	9
40	18	12	69	67	55	26	8	5	31	63	10	1
41	20	16	77	80	36	32	6	2	23	33	3	0
42	17	8	65	47	57	53	9	1	35	11	0	0
43	24	21	92	88	85	70	2	0	8	0	0	0
44	25	23	96	92	80	76	1	0	4	0	0	0
45	23	19	88	83	84	78	3	0	12	0	0	0
46	26	25	100	96	92	88	0	0	0	0	0	0
47	25	23	96	92	92	88	1	0	4	0	0	0
48	26	25	100	96	96	88	0	0	0	0	0	0
49	26	25	100	96	92	88	0	0	0	0	0	0
50	25	23	96	92	92	88	1	0	4	0	0	0
51	25	24	96	96	92	--	1	0	4	0	0	-
52	26	25	100	96	--	--	0	0	0	0	-	-

Table D-3 Probability of different dry and wet spells in Nawapara block

Week No.	F (d)	F (dd)	P (d) %	P (dd) %	2d %	3d %	F (w)	F (ww)	P (w) %	P (ww) %	2w %	3w %
1	26	25	100	96	88	81	0	0	0	0	0	0
2	24	21	92	88	85	78	2	0	8	0	0	0
3	25	23	96	92	88	81	1	0	4	0	0	0
4	25	23	96	92	88	78	1	0	4	0	0	0
5	25	23	96	92	84	73	1	0	4	0	0	0
6	24	21	92	88	80	74	2	0	8	0	0	0
7	23	20	88	87	81	71	3	1	12	33	3	0
8	25	23	96	92	84	74	1	0	4	0	0	0
9	24	21	92	88	81	66	2	0	8	0	0	0
10	24	21	92	88	75	66	2	0	8	0	0	0
11	22	18	85	82	74	71	4	0	15	0	0	0
12	23	20	88	87	84	78	3	0	12	0	0	0
13	26	25	100	96	92	88	0	0	0	0	0	0
14	25	23	96	92	92	76	1	0	4	0	0	0
15	26	25	100	96	83	76	0	0	0	0	0	0
16	23	19	88	83	81	71	3	0	12	0	0	0
17	25	23	96	92	84	73	1	0	4	0	0	0
18	24	21	92	88	79	64	2	0	8	0	4	1
19	22	19	85	86	69	61	4	2	15	50	3	0
20	21	17	81	81	71	83	5	1	19	20	0	0
21	24	21	92	88	69	45	2	0	8	0	3	1
22	20	15	77	75	50	13	4	2	23	33	10	4
23	17	11	65	65	16	2	9	4	35	44	15	9
24	12	3	46	45	6	1	14	6	54	43	34	26
25	7	1	27	14	5	1	19	12	73	63	55	48
26	5	1	19	20	5	1	21	16	81	76	70	53
27	4	1	15	25	3	1	22	19	85	86	64	47
28	6	1	23	17	10	2	20	15	77	75	57	43
29	7	3	27	43	5	1	19	14	73	74	55	35
30	5	1	19	20	3	0	21	16	81	76	51	38
31	7	1	27	14	0	0	19	12	73	63	54	44
32	3	0	12	0	3	0	23	17	88	74	72	60
33	4	1	15	25	0	0	22	18	85	82	71	53
34	3	0	12	0	2	0	23	19	88	83	66	31
35	6	1	23	17	3	0	20	15	77	75	36	21
36	9	1	35	11	0	0	17	8	65	47	38	20
37	7	0	27	0	15	6	19	11	73	58	39	0
38	13	7	50	54	19	10	13	7	50	54	0	0
39	16	6	62	38	33	27	10	0	38	0	8	2
40	17	9	65	53	53	47	9	2	35	22	9	0
41	22	18	85	82	75	66	4	1	15	25	0	0
42	24	21	92	88	81	74	2	0	8	0	0	0
43	24	21	92	88	85	78	2	0	8	0	0	0
44	25	23	96	92	88	81	1	0	4	0	0	0
45	25	23	96	92	88	81	1	0	4	0	0	0
46	25	23	96	92	88	85	1	0	4	0	0	0
47	25	23	96	92	92	88	1	0	4	0	0	0
48	26	25	100	96	96	92	0	0	0	0	0	0
49	26	25	100	96	96	92	0	0	0	0	0	0
50	25	24	96	96	92	88	1	0	4	0	0	0
51	26	25	100	96	96	--	0	0	0	0	0	-
52	26	25	100	96	--	--	0	0	0	0	-	-

Table D-4 Probability of different dry and wet spells in Khariar block

Week No.	F (d)	F (dd)	P (d) %	P (dd) %	2d %	3d %	F (w)	F (ww)	P (w) %	P (ww) %	2w %	3w %
1	25	23	96	92	88	81	1	0	4	0	0	0
2	25	23	96	92	88	81	1	0	4	0	0	0
3	25	23	96	92	88	85	1	0	4	0	0	0
4	25	23	96	92	92	85	1	0	4	0	0	0
5	26	25	100	96	92	81	0	0	0	-	0	0
6	25	23	96	92	84	78	1	0	4	0	0	0
7	24	21	92	88	85	74	2	0	8	0	0	0
8	25	23	96	92	84	78	1	0	4	0	0	0
9	24	21	92	88	85	81	2	0	8	0	0	0
10	25	23	96	92	92	85	1	0	4	0	0	0
11	25	24	96	96	87	85	1	0	4	0	0	0
12	24	22	92	92	88	68	2	0	8	0	0	0
13	26	25	100	96	77	68	0	0	0	0	0	0
14	22	17	85	77	75	53	4	0	15	0	0	0
15	24	21	92	88	65	63	2	0	8	0	0	0
16	21	15	81	71	78	64	5	0	19	0	0	0
17	25	24	96	96	79	69	1	0	4	0	1	0
18	22	18	85	82	75	58	4	1	15	25	0	0
19	24	21	92	88	71	65	2	0	8	0	0	0
20	22	17	85	77	78	56	4	0	15	0	0	0
21	25	23	96	92	78	32	1	0	4	0	2	1
22	18	13	38	72	69	4	8	3	31	38	14	7
23	15	7	81	47	18	3	11	5	42	45	21	16
24	10	2	19	20	16	1	16	8	62	50	47	32
25	5	1	19	20	3	0	21	16	81	76	55	35
26	7	1	27	14	4	1	19	13	73	68	46	37
27	7	1	27	14	5	0	19	12	73	63	59	46
28	5	1	19	20	0	0	21	17	81	81	62	46
29	4	0	15	0	6	4	22	17	85	77	63	53
30	7	3	27	43	18	0	19	14	73	74	62	50
31	6	4	23	67	0	0	20	17	77	85	62	44
32	5	0	19	0	0	0	21	17	81	81	58	41
33	5	0	19	0	10	0	21	15	81	71	58	33
34	8	4	31	50	0	0	18	13	69	72	39	26
35	8	0	31	0	8	0	18	10	69	56	46	29
36	8	2	31	25	0	0	18	12	69	67	43	17
37	7	0	27	0	17	10	19	12	73	63	29	9
38	16	10	62	63	35	19	10	4	38	40	11	5
39	16	9	62	56	35	26	10	3	38	30	15	7
40	16	9	62	56	46	38	10	4	38	40	16	0
41	19	14	73	74	61	56	7	3	27	43	0	0
42	23	19	88	83	81	57	3	0	12	0	0	0
43	25	23	96	92	68	63	1	0	4	0	0	0
44	21	15	81	71	75	69	5	0	19	0	0	0
45	25	23	96	92	88	81	1	0	4	0	0	0
46	25	23	96	92	88	85	1	0	4	0	0	0
47	25	23	96	92	92	88	1	0	4	0	0	0
48	26	25	100	96	96	92	0	0	0	-	0	0
49	26	25	100	96	96	92	0	0	0	-	0	0
50	26	25	100	96	96	92	0	0	0	-	0	0
51	26	25	100	96	96	--	0	0	0	-	0	-
52	26	25	100	96	--	--	0	0	0	-	-	-

Table D-5 Probability of different dry and wet spells in Boden block

Week No.	F (d)	F (dd)	P (d) %	P (dd) %	2d %	3d %	F (w)	F (ww)	P (w) %	P (ww) %	2w %	3w %
1	25	23	96	92	84	81	1	0	4	0	0	0
2	24	21	92	88	88	85	2	0	8	0	0	0
3	26	25	100	96	96	92	0	0	0	0	0	0
4	26	25	100	96	96	88	0	0	0	0	0	0
5	26	25	100	96	92	81	0	0	0	0	0	0
6	25	23	96	92	84	78	1	0	4	0	0	0
7	24	21	92	88	85	74	2	0	8	0	0	0
8	25	23	96	92	84	73	1	0	4	0	0	0
9	23	20	88	87	77	74	3	0	12	0	0	0
10	24	21	92	88	88	77	2	0	8	0	0	0
11	25	24	96	96	84	80	1	0	4	0	0	0
12	23	20	88	87	84	74	3	0	12	0	0	0
13	26	25	100	96	88	81	0	0	0	0	0	0
14	24	21	92	88	85	74	2	0	8	0	0	0
15	25	23	96	92	84	73	1	0	4	0	0	0
16	23	20	88	87	77	57	3	1	12	33	1	0
17	23	20	88	87	66	51	3	0	12	0	0	0
18	20	15	77	75	62	57	6	1	23	17	2	0
19	22	17	85	77	78	65	4	0	15	0	0	0
20	24	22	92	92	76	48	2	0	8	0	0	0
21	23	19	88	83	55	35	3	0	12	0	0	3
22	16	10	62	63	39	18	10	5	38	50	6	11
23	16	10	62	63	28	11	10	5	38	50	19	18
24	11	5	42	55	17	6	15	9	58	60	23	38
25	5	2	19	40	6	3	1	17	81	81	65	56
26	6	2	23	33	12	0	20	16	77	80	66	55
27	4	2	15	50	0	0	22	19	85	86	71	61
28	3	0	12	0	3	1	23	19	88	83	76	69
29	4	1	15	25	5	2	22	19	85	86	71	52
30	3	1	12	33	5	0	23	20	88	87	65	54
31	7	3	27	43	0	0	19	14	73	74	61	47
32	3	0	12	0	0	0	23	19	88	83	68	50
33	4	0	15	0	6	2	22	17	85	77	63	33
34	7	3	27	43	10	1	19	14	73	74	39	29
35	11	4	42	36	6	1	15	8	58	53	43	33
36	7	1	27	14	5	2	19	14	73	74	55	26
37	5	1	19	20	7	4	21	16	81	76	37	16
38	13	5	50	38	25	7	13	6	50	46	21	13
39	14	7	92	50	25	20	12	5	46	42	29	7
40	15	4	81	27	66	55	11	7	42	64	11	0
41	22	18	85	82	71	66	4	1	15	25	0	0
42	23	19	88	83	73	67	3	0	12	0	0	0
43	23	19	88	83	81	78	3	0	12	0	0	0
44	25	23	96	92	92	85	1	0	4	0	0	0
45	26	25	100	96	92	85	0	0	0	0	0	0
46	25	23	96	92	88	85	1	0	4	0	0	0
47	25	23	96	92	92	88	1	0	4	0	0	0
48	26	25	100	96	96	92	0	0	0	0	0	0
49	26	26	100	96	96	92	0	0	0	0	0	0
50	26	25	100	96	96	92	0	0	0	0	0	0
51	26	25	100	96	96	-	0	0	0	0	0	-
52	26	25	100	96	-	-	0	0	0	0	-	-

Table D-6 Probability of different dry and wet spells in Golamunda bloc

Week No.	F (d)	F (dd)	P (d) %	P (dd) %	2d %	3d %	F (w)	F (ww)	P (w) %	P (ww) %	2w %	3w %
1	25	23	96	92	88	81	1	0	4	0	0	0
2	25	23	96	92	88	85	1	0	4	0	0	0
3	25	23	96	92	92	88	1	0	4	0	0	0
4	26	25	100	96	96	88	1	0	4	0	0	0
5	26	25	100	96	92	76	0	0	0	0	0	0
6	25	23	96	92	80	73	1	0	4	0	0	0
7	23	19	88	83	81	71	3	0	12	0	0	0
8	25	23	96	92	84	73	1	0	4	0	0	0
9	24	21	92	88	80	77	2	0	8	0	3	0
10	23	20	88	87	84	78	3	1	12	33	0	0
11	25	24	96	96	88	78	1	0	4	0	0	0
12	24	22	92	92	81	74	2	0	8	0	0	0
13	24	21	92	88	85	74	2	0	8	0	0	0
14	25	23	96	92	84	74	1	0	4	0	0	0
15	24	21	92	88	81	74	2	0	8	0	0	0
16	24	21	92	88	85	70	2	0	8	0	0	0
17	24	22	92	92	76	59	2	0	8	0	0	0
18	23	19	88	83	68	62	3	0	12	0	0	0
19	22	17	85	77	78	69	4	0	15	0	0	0
20	25	23	96	92	84	69	1	0	4	0	0	0
21	24	21	92	88	75	42	2	0	8	0	2	0
22	22	18	85	82	48	10	4	1	15	25	2	1
23	18	10	69	56	94	3	8	1	31	13	14	10
24	10	2	38	20	8	0	16	7	62	44	47	36
25	5	1	19	20	0	0	21	16	81	76	62	55
26	4	0	15	0	0	0	22	17	85	77	75	55
27	2	0	8	0	2	1	24	21	92	88	68	59
28	7	2	27	29	14	0	19	14	73	74	63	48
29	4	2	15	50	0	0	22	19	85	86	65	54
30	4	0	15	0	4	0	22	17	85	77	70	53
31	4	1	15	25	0	0	22	18	85	82	65	49
32	5	0	19	0	4	2	21	16	81	76	62	50
33	5	1	19	20	8	2	21	16	81	76	66	44
34	5	2	19	40	5	0	21	17	81	81	54	30
35	8	2	31	25	0	0	18	12	67	67	38	26
36	8	0	31	0	4	2	18	10	56	56	38	10
37	7	1	27	14	10	5	19	13	68	68	17	7
38	14	5	54	36	27	10	12	3	35	25	11	2
39	14	7	54	50	24	18	12	5	42	42	8	2
40	16	7	62	44	46	35	10	2	20	20	6	0
41	19	14	73	74	56	52	7	2	29	29	0	0
42	22	17	85	77	78	69	4	0	0	0	0	0
43	25	23	96	92	84	78	1	0	0	0	0	0
44	24	21	92	88	85	81	2	0	0	0	0	0
45	25	23	96	92	92	85	1	0	0	0	0	0
46	26	25	100	96	92	88	0	0	0	0	0	0
47	25	23	96	92	92	88	1	0	0	0	0	0
48	26	25	100	96	96	88	0	0	0	0	0	0
49	26	25	100	96	92	88	0	0	0	0	0	0
50	25	23	96	92	92	88	1	0	0	0	0	0
51	26	25	100	96	96	-	0	0	0	0	0	0
52	46	25	100	96	-	-	0	0	0	0	-	-

Table D-7 Probability of different dry and wet spells in Dhramgarh block

Week No.	F (d)	F (dd)	P (d) %	P (dd) %	2d %	3d %	F (w)	F (ww)	P (w) %	P (ww) %	2w %	3w %
1	26	25	100	96	92	88	0	0	0	0	0	0
2	25	23	96	92	92	88	1	0	4	0	0	0
3	26	25	100	96	96	92	0	0	0	0	0	0
4	26	25	100	96	96	84	0	0	0	0	0	0
5	26	25	100	96	87	77	0	0	0	0	0	0
6	23	20	88	87	77	71	3	1	12	33	0	0
7	24	21	92	88	85	81	2	0	8	0	0	0
8	25	23	96	92	92	81	1	0	4	0	0	0
9	26	25	100	96	88	84	0	0	0	0	0	0
10	24	21	92	88	88	81	2	0	8	0	0	0
11	25	24	96	96	88	85	1	0	4	0	0	0
12	24	22	92	92	88	78	2	0	8	0	0	0
13	25	24	96	96	84	74	1	0	4	0	0	0
14	24	21	92	88	81	61	2	0	8	0	0	0
15	24	21	96	88	72	66	2	0	8	0	3	0
16	20	15	77	75	71	65	6	2	23	33	0	0
17	24	22	92	92	85	64	2	0	8	0	4	1
18	24	22	92	92	70	57	2	1	8	50	2	0
19	21	16	81	76	66	60	5	1	19	20	4	0
20	21	17	81	81	75	64	5	1	19	20	0	0
21	25	23	96	92	83	52	1	0	4	0	1	1
22	22	19	85	86	54	12	4	1	15	25	8	4
23	16	10	62	63	14	3	10	5	38	50	22	15
24	9	2	35	22	9	0	17	10	65	59	45	32
25	8	2	35	22	9	0	17	10	69	69	49	34
26	5	0	19	0	2	0	21	15	81	71	56	46
27	8	1	31	13	0	0	18	11	69	69	49	34
28	4	0	15	0	8	1	22	18	85	82	78	55
29	2	1	8	50	1	0	24	22	92	92	64	56
30	6	1	23	17	8	0	20	14	77	70	67	56
31	3	1	12	33	0	0	23	20	88	87	73	69
33	3	0	12	0	0	0	23	19	88	83	73	56
34	4	0	15	0	4	0	22	17	85	77	49	42
35	7	2	27	29	0	0	19	11	73	58	63	36
36	4	0	15	0	0	0	22	19	73	86	42	24
37	7	0	27	0	21	10	19	11	42	58	24	5
38	17	13	65	76	31	18	9	5	35	56	7	1
39	16	8	62	50	35	24	10	2	38	20	5	1
40	18	10	69	56	48	37	8	1	31	13	5	0
41	20	14	81	70	62	55	6	1	23	17	0	0
42	22	17	85	77	75	66	4	0	15	0	0	0
43	24	21	92	88	81	74	2	0	8	0	0	0
44	24	21	92	88	81	74	2	0	8	0	0	0
45	25	23	96	92	92	81	1	0	4	0	0	0
46	26	25	100	96	88	84	0	0	0	0	0	0
47	24	21	92	88	88	85	2	0	8	0	0	0
48	26	25	100	96	96	92	0	0	0	0	0	0
49	26	25	100	96	96	92	0	0	0	0	0	0
50	26	25	100	96	96	92	0	0	0	0	0	-
51	26	25	100	96	96	-	0	0	0	0	-	-
52	26	25	100	96	-	-	0	0	0	0	-	-

Table D-8 Probability of different dry and wet spells in Narla block

Week No.	F (d)	F (dd)	P (d) %	P (dd) %	2d %	3d %	F (w)	F (ww)	P (w) %	P (ww) %	2w %	3w %
1	25	23	96	92	88	81	1	0	4	0	0	0
2	25	23	96	92	88	81	1	0	4	0	0	0
3	25	23	96	92	88	81	1	0	4	0	0	0
4	25	23	96	92	88	78	1	0	4	0	0	0
5	25	23	96	92	84	70	1	0	4	0	0	0
6	24	21	92	88	76	70	2	0	8	0	0	0
7	23	19	88	83	81	67	3	0	12	0	0	0
8	25	23	96	92	80	70	1	0	4	0	0	0
9	23	19	88	83	77	71	3	0	12	0	0	0
10	24	21	92	88	85	78	2	0	8	0	0	0
11	24	22	92	92	85	81	2	0	8	0	0	0
12	24	22	92	92	88	85	2	0	8	0	0	0
13	26	25	100	96	96	84	0	0	0	0	0	0
14	26	25	100	96	87	77	0	0	0	0	0	0
15	23	20	88	87	77	68	3	1	12	33	0	0
16	24	21	92	88	81	62	2	0	8	0	0	0
17	24	21	92	88	70	57	2	0	8	0	2	0
18	21	16	81	76	66	51	5	1	19	20	4	0
19	21	17	81	81	62	57	5	1	19	20	0	0
20	22	17	85	77	78	52	4	0	15	0	0	0
21	25	23	96	92	64	55	1	0	4	0	1	1
22	18	12	69	67	59	10	8	2	31	25	16	11
23	20	17	77	85	13	4	6	3	23	50	16	8
24	6	1	23	17	7	2	20	14	77	70	39	31
25	10	3	38	30	13	3	16	8	62	50	50	38
26	6	2	23	33	5	0	20	16	77	80	59	50
27	5	1	19	20	0	0	21	16	81	76	70	47
28	4	0	15	0	2	0	22	19	85	86	58	46
29	7	1	27	14	0	0	19	13	73	68	56	47
30	4	0	15	0	0	0	22	17	85	77	71	62
31	3	0	12	0	0	0	23	19	88	83	77	64
32	2	0	8	0	0	0	24	21	92	88	76	58
33	3	0	12	0	2	1	23	19	88	83	67	47
34	5	1	19	20	8	3	21	16	81	76	58	32
35	9	4	35	44	11	0	17	12	65	71	36	15
36	10	3	38	30	0	C	16	9	62	56	25	14
37	9	0	35	0	21	5	17	7	65	41	36	13
38	15	9	58	60	15	8	11	6	42	55	15	5
39	12	3	46	25	26	20	14	5	54	36	16	3
40	16	9	62	56	47	36	10	3	38	30	8	0
41	21	16	81	76	62	52	5	1	19	20	0	0
42	22	17	85	77	71	58	4	0	15	0	0	0
43	23	19	88	83	72	64	3	0	12	0	3	0
44	22	18	85	82	75	69	4	1	15	25	0	0
45	24	21	92	88	85	74	2	0	8	0	0	0
46	25	23	96	92	84	81	1	0	4	0	0	0
47	24	21	92	88	88	85	2	0	8	0	0	0
48	26	25	100	96	96	88	0	0	0	0	0	0
49	26	25	100	96	92	88	0	0	0	0	0	0
50	25	23	96	92	92	85	1	0	4	0	0	0
51	26	25	100	96	92	-	0	0	0	0	0	-
52	24	22	92	92	-	-	2	0	8	0	-	-

APPENDIX E

Table E-1 Reference crop evapotranspiration by modified Penman method in mm/day

Year : 1976

1	5.817	2	5.968	3	5.813	4	5.798	5	6.175	6	6.160
7	7.306	8	7.858	9	8.098	10	8.187	11	8.339	12	10.204
13	9.432	14	7.475	15	7.288	16	9.017	17	6.220	18	10.640
19	8.548	20	6.012	21	8.843	22	7.790	23	6.212	24	5.905
25	6.318	26	3.647	27	4.065	28	2.871	29	2.765	30	3.622
31	3.118	32	4.202	33	3.816	34	3.299	35	3.198	36	3.042
37	3.649	38	6.020	39	7.450	40	6.961	41	7.218	42	3.858
43	6.194	44	7.467	45	5.753	46	5.708	47	5.140	48	4.322
49	6.016	50	5.894	51	5.017	52	6.129				

Year : 1978

1	5.788	2	4.200	3	6.089	4	5.831	5	6.143	6	5.099
7	5.400	8	5.848	9	7.362	10	7.357	11	7.597	12	7.727
13	7.571	14	8.074	15	5.699	16	9.004	17	8.444	18	7.523
19	9.391	20	9.856	21	9.469	22	7.762	23	9.386	24	6.870
25	3.143	26	3.309	27	6.495	28	5.423	29	5.907	30	5.153
31	3.131	32	2.652	33	3.139	34	2.745	35	4.058	36	6.008
37	2.979	38	4.615	39	5.347	40	4.333	41	6.083	42	6.707
43	5.859	44	3.504	45	4.405	46	6.420	47	5.538	48	4.255
49	4.919	50	5.022	51	4.532	52	5.030				

Year : 1981

1	5.942	2	4.575	3	5.386	4	5.743	5	6.165	6	6.515
7	6.662	8	7.172	9	7.545	10	7.286	11	6.925	12	7.201
13	7.439	14	8.528	15	9.025	16	8.637	17	7.994	18	9.119
19	7.970	20	9.926	21	7.647	22	7.787	23	9.294	24	8.198
25	6.904	26	6.648	27	7.662	28	6.151	29	6.103	30	5.592
31	6.348	32	7.162	33	5.862	34	5.848	35	5.749	36	4.966
37	5.697	38	5.284	39	5.964	40	6.289	41	6.875	42	7.295
43	6.842	44	6.822	45	6.174	46	6.008	47	5.960	48	5.921
49	4.926	50	4.182	51	4.644	52	5.203				

Year : 1982

1	5.043	2	5.872	3	5.653	4	6.216	5	5.668	6	6.790
7	6.266	8	7.478	9	7.011	10	7.311	11	7.854	12	7.529
13	8.136	14	9.209	15	8.051	16	8.137	17	8.306	18	8.568
19	8.649	20	8.117	21	9.377	22	9.306	23	10.186	24	7.899
25	7.027	26	7.341	27	9.022	28	6.918	29	5.753	30	6.884
31	6.628	32	6.822	33	6.960	34	7.497	35	6.958	36	5.988
37	5.819	38	7.962	39	8.000	40	7.404	41	7.544	42	5.611
43	6.069	44	6.281	45	5.800	46	5.697	47	5.629	48	5.495
49	5.526	50	5.919	51	5.956	52	5.730				

Year : 1983

1	5.746	2	6.169	3	6.169	4	5.264	5	6.089	6	5.176
7	6.612	8	6.757	9	7.347	10	7.569	11	7.580	12	8.381
13	7.607	14	8.330	15	8.741	16	7.477	17	8.894	18	9.727
19	8.308	20	7.771	21	8.560	22	9.062	23	9.440	24	7.783
25	6.925	26	6.569	27	6.635	28	5.926	29	6.088	30	5.789

31	6.165	32	6.305	33	6.905	34	6.216	35	6.339	36	6.478
37	6.394	38	6.226	39	5.810	40	5.583	41	5.897	42	5.169
43	6.556	44	6.282	45	5.453	46	5.975	47	5.898	48	5.928
49	5.593	50	5.383	51	5.452	52	4.890				

Year : 1986

1	4.846	2	4.456	3	4.638	4	6.207	5	6.354	6	5.742
7	4.842	8	6.886	9	6.484	10	7.354	11	7.797	12	8.287
13	8.130	14	9.039	15	8.495	16	8.224	17	7.099	18	8.586
19	8.878	20	8.019	21	8.833	22	7.708	23	9.989	24	7.181
25	4.710	26	5.598	27	6.202	28	5.000	29	5.524	30	6.049
31	6.246	32	5.344	33	5.369	34	5.854	35	6.518	36	6.214
37	5.980	38	6.408	39	5.320	40	4.384	41	6.235	42	7.326
43	7.109	44	5.628	45	4.610	46	6.515	47	6.153	48	5.603
49	4.484	50	4.731	51	5.230	52	4.834				

Year : 1987

1	5.835	2	5.640	3	5.532	4	5.862	5	6.404	6	6.351
7	7.228	8	7.131	9	7.063	10	6.900	11	6.617	12	8.409
13	8.806	14	9.252	15	9.232	16	8.686	17	7.822	18	7.693
19	7.857	20	8.596	21	7.988	22	7.824	23	7.841	24	7.112
25	7.430	26	7.279	27	5.507	28	5.576	29	5.619	30	5.434
31	6.328	32	6.473	33	5.655	34	5.648	35	4.938	36	5.197
37	5.520	38	5.931	39	5.837	40	5.994	41	5.701	42	5.393
43	7.029	44	5.376	45	4.553	46	4.196	47	5.048	48	5.851
49	5.078	50	4.510	51	4.930	52	5.547				

Year : 1988

1	5.544	2	5.694	3	5.527	4	6.155	5	6.562	6	7.160
7	5.746	8	6.107	9	5.123	10	6.351	11	6.781	12	8.282
13	8.402	14	8.856	15	8.478	16	7.687	17	7.619	18	8.340
19	8.739	20	8.636	21	9.259	22	8.865	23	8.750	24	7.023
25	6.790	26	6.247	27	6.339	28	6.184	29	6.390	30	6.004
31	5.523	32	5.696	33	6.108	34	6.032	35	5.833	36	5.794
37	5.663	38	5.382	39	5.484	40	5.254	41	6.926	42	5.851
43	6.176	44	4.876	45	5.376	46	5.168	47	5.110	48	4.975
49	4.907	50	4.610	51	5.193	52	5.473				

Year : 1989

1	4.700	2	5.557	3	5.566	4	5.849	5	6.701	6	6.475
7	7.362	8	7.192	9	8.062	10	7.077	11	6.933	12	8.362
13	7.621	14	9.011	15	9.774	16	8.938	17	8.515	18	9.216
19	9.543	20	9.429	21	8.574	22	8.907	23	8.109	24	6.666
25	6.588	26	5.775	27	6.494	28	6.826	29	6.551	30	5.712
31	6.094	32	6.032	33	5.636	34	5.255	35	5.447	36	5.456
37	5.260	38	5.242	39	5.717	40	5.128	41	5.338	42	5.167
43	4.978	44	4.865	45	4.488	46	4.210	47	4.378	48	4.316
49	4.152	50	3.913	51	3.854	52	3.612				

Table E-2 Weekwise average daily reference crop evapotranspiration (9 years average) in mm/day

Week No.	ETo	Week No.	ETo	Week No.	ETo	Week No.	ETo
1	5.473	14	8.642	27	6.491	40	5.703
2	5.348	15	8.309	28	5.653	41	6.424
3	5.597	16	8.423	29	5.633	42	5.820
4	5.881	17	7.879	30	5.582	43	6.312
5	6.251	18	8.824	31	5.509	44	5.678
6	6.163	19	8.654	32	5.632	45	5.179
7	6.380	20	8.485	33	5.494	46	5.544
8	6.937	21	8.728	34	5.377	47	5.428
9	7.122	22	8.335	35	5.449	48	5.185
10	7.266	23	8.801	36	5.460	49	5.067
11	7.380	24	7.182	37	5.218	50	4.907
12	8.265	25	6.204	38	5.897	51	4.979
13	8.127	26	5.824	39	6.103	52	5.161

Table E-3 Consumptive use of upland rice (ETcrop) during different time intervals

Week No.	Duration	ETo, mm/day	Kc	ETcrop, mm
25	Jun 20--24 (5 days)	5.970	1.10	32.835
26	25-- 1 Jly	5.824	1.10	44.845
27	Jly 2-- 8	6.491	1.10	49.981
28	9--15	5.653	1.10	43.528
29	16--22	5.633	1.10	43.374
30	23--29	5.589	1.05	41.023
31	30--Aug 5	5.509	1.05	40.491
32	Aug 6--12	5.632	1.05	41.395
33	13--19	5.494	1.05	40.381
34	20--26	5.377	1.05	39.521
35	27--Sep 2	5.449	0.95	36.236
36	Sep 3-- 9	5.460	0.95	36.309
37	10--16	5.218	0.95	34.700
38	17--22 (6 days)	5.830	0.95	33.231
Total				557.855

Table E-4 Consumptive use of maize during different time intervals

Week No.	Duration	ETo, mm/day	Kc	ETcrop, mm
26	Jly 1	6.472	0.42	2.718
28	9--15	5.653	0.42	16.619
29	16--22	5.633	0.42	16.561
30	23--29	5.582	0.55	21.490
31	30--Aug 5	5.509	0.63	24.294
32	Aug 6--12	5.632	0.89	35.08
33	13--19	5.494	1.06	40.765
34	20--26	5.377	1.14	42.90
35	27--Sep 2	5.449	1.14	43.483
36	Sep 3-- 9	5.460	1.14	43.57
37	10--16	5.218	1.14	41.639
38	17--23	5.897	1.14	47.05
39	24--30	6.103	1.05	44.85
40	Oct 1-- 7	5.703	0.90	35.928
41	8--14	6.424	0.75	33.726
42	15--18	5.813	0.63	14.650
Total				524.406

Table E-5 Consumptive use of greengram(kharif) during different time intervals

Week No.	Duration	ETo, mm/day	Kc	ETcrop, mm
24	Jun 15--17	6.806	0.27	5.513
25	18--24	6.204	0.27	11.725
26	25--Jly 1	5.824	0.27	11.007
27	Jly 2-- 8	6.491	0.47	21.355
28	9--15	5.653	0.70	27.699
29	16--22	5.633	0.93	36.670
30	23--29	5.582	1.10	42.981
31	30--Aug 5	5.509	1.10	42.419
32	Aug 6--12	5.632	1.10	43.366
33	13--19	5.494	0.79	30.381
34	20--23	5.282	0.32	6.761
Total				279.786

Table E-6 Consumptive use of greengram(pre-rabi) during different time intervals

Week No.	Duration	ETo, mm/day	Kc	ETcrop, mm
34	Aug 20--26	5.377	0.29	10.915
35	27--Sep 2	5.449	0.29	11.061
36	Sep 3-- 9	5.460	0.38	14.523
37	10--16	5.218	0.60	21.915
38	17--23	5.897	0.80	33.023
39	24--30	6.103	1.02	43.575
40	Oct 1-- 7	5.703	1.05	41.917
41	8--14	6.424	1.05	47.216
42	15--21	5.820	0.68	27.703
43	22--23	6.454	0.30	3.872
Total				255.720

Table E-7 Consumptive use of blackgram during different time intervals

Week No.	Duration	ETo, mm/day	Kc	ETcrop, mm
25	Jun 20--24	5.970	0.28	8.358
26	25--Jly 1	5.824	0.28	11.415
27	Jly 2-- 8	6.491	0.30	13.631
28	9--15	5.653	0.47	18.598
29	16--22	5.633	0.63	24.841
30	23--29	5.584	0.79	30.868
31	30--Aug 5	5.509	0.93	35.863
32	Aug 6--12	5.633	1.10	43.366
33	13--19	5.494	1.10	42.303
34	20--26	5.377	1.10	41.402
35	27--Sep 2	5.449	1.10	41.957
36	Sep 3-- 9	5.460	0.80	30.576
37	10--12	5.183	0.36	5.598
Total				348.776

Table E-8 Consumptive use of sesamum during different time intervals

Week No.	Duration	ETo, mm/day	Kc	ETcrop, mm
24	June 15-17	6.806	0.19	3.879
25	18-24	6.204	0.19	8.251
26	25-1 Jly.	5.824	0.19	7.745
27	Jly. 2-8	6.491	0.42	19.083
28	9-15	5.653	0.69	27.304
29	16-22	5.633	0.96	37.875
30	23-29	5.582	1.15	44.935
31	30- 5 Aug.	5.509	1.15	44.347
32	Aug. 6-12	5.632	1.15	41.395
33	13-19	5.494	1.15	44.226
34	20-26	5.377	1.15	43.284
35	27- 2 Sep.	5.449	1.10	41.957
36	Sep. 3- 9	5.460	0.67	25.607
37	10-12	5.183	0.40	6.220
Total				396.087

Table E-9 Consumptive use of minor millet during different time intervals

Week No.	Duration	ETo, mm/day	Kc	ETcrop, mm
25	June 20-24	5.970	0.28	8.358
26	25- 1 Jly.	5.824	0.28	11.415
27	Jly. 2- 8	6.491	0.42	19.083
28	9-15	5.650	0.79	31.261
29	16-22	5.633	1.05	41.402
30	23-29	5.582	1.08	42.199
31	30- 5 Aug.	5.509	1.08	41.648
32	Aug. 6-12	5.632	1.08	42.577
33	13-19	5.494	0.66	25.382
34	20-23	5.282	0.34	7.183
Total				296.085

APPENDIX F

Table F-1 Effective rainfall during first three effective critical dry spells in different blocks under study

Name of Block	Per day av. rainfall at 80 % probability, mm			Effective critical dry spell duration, days			Effective rainfall during CDS, mm		
	1st CDS	2nd CDS	3rd CDS	1st CDS	2nd CDS	3rd CDS	1st CDS	2nd CDS	3rd CDS
Bhawanipatna	4.17	1.44	1.17	14	16	22	35.03	13.82	15.44
Kesinga	4.26	3.77	5.57	16	15	19	40.90	33.93	63.50
Nawapara	3.85	3.66	2.84	17	17	14	39.27	37.33	23.86
Khariar	3.17	5.37	2.21	18	16	16	34.24	51.55	21.22
Boden	2.91	3.12	2.75	20	16	17	34.92	29.95	28.05
Golamunda	3.60	4.25	2.80	16	15	17	34.56	38.25	28.56
Dharamgarh	2.75	2.92	1.60	21	15	18	34.65	26.28	17.28
Narla	4.20	4.70	4.11	16	18	24	40.32	50.76	59.18

Table F-2 Crop Evapotranspiration of different crops during the first three effective critical dry spells in different blocks under study

Block	Effective CDS	Crop Evapotranspiration (ETcrop), mm						
		upland rice	maize	greengram (kharif)	greengram (pre-rabi)	blackgram	sesamum	minor millet
Bhawanipatna	1st	86.82	33.88	65.65	-	45.19	67.65	74.23
	2nd	93.07	88.10	78.82	-	97.50	97.99	71.55
	3rd	113.87	136.95	-	61.63	60.15	55.80	-
Kesinga	1st	104.96	40.07	61.72	-	40.93	59.88	65.36
	2nd	86.89	84.22	66.43	-	91.01	95.16	61.18
	3rd	98.71	117.16	-	52.19	89.76	86.15	-
Nawapara	1st	108.32	41.36	73.52	-	55.12	73.34	80.84
	2nd	98.45	95.36	74.31	-	103.13	107.82	69.06
	3rd	72.33	86.79	-	27.14	68.41	63.64	-
Khariar	1st	112.79	44.77	82.75	-	56.15	83.45	90.17
	2nd	92.53	90.35	68.12	-	96.94	101.34	62.98
	3rd	83.15	99.13		30.27	80.31	75.82	-
Boden	1st	131.32	45.52	69.49	-	47.77	65.93	72.98
	2nd	93.52	68.27	96.27	-	89.68	98.48	93.88
	3rd	90.99	101.20	43.34*	14.08**	101.89	105.97	38.65*
Golamunda	1st	104.96	40.07	61.72	-	40.93	59.88	65.36
	2nd	87.64	67.55	88.41	-	86.19	50.79	85.53
	3rd	88.79	105.42	-	31.84	86.23	82.00	-
Dharamgarh	1st	136.88	52.26	85.72	-	57.07	84.24	91.75
	2nd	87.59	74.61	83.25	-	88.95	91.99	78.56
	3rd	97.67	110.48	-	26.13	99.92	105.20	-
Narla	1st	97.20	42.10	85.38	-	59.27	88.07	23.77
	2nd	104.09	101.49	74.31	-	109.05	114.01	69.06
	3rd	124.18	147.08	-	52.18	95.88	92.34	-

* in 12 days of the CDS ** in 9 days of the CDS