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Agro-climate and Extreme Weather Analysis for Successful Crop Production in Orissa

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FOREWORD

It is generally recognized that second green revolution in India could be realized through small farm development and diversification, particularly in rainfed areas, which have been bypassed by the first revolution. Emphasis on crop diversification and integrated development of both on farm and non-farm sectors is crucial from the point of view of alleviation of rural poverty particularly in rainfed areas. The existing productivity of food grains in Orissa is very low (1.4 t ha^{-1}) which is much lower than that of national average (1.7t ha^{-1}). The main technological constraints of low productivity particularly in rainfed areas of Orissa are vagaries of south-west monsoon, occurrence of dry spells and natural calamities like drought, flood and cyclone etc. In almost every year, significant crop losses in rainfed areas of Orissa occur due to aberrant weather conditions and natural calamities. Therefore, proper understanding of agroclimates and extreme weather events (drought, flood, cyclone), their frequency, probability, extent of damage etc. are very much necessary to develop strategies in the affected areas. In this regard, the NATP (Rainfed Rice Production System) gave enough scope to analyse agroclimates and extreme weather events for improving productivity of rainfed rice areas through alternative agriculture.

I am happy to note that the Water Technology Centre for Eastern Region, Bhubaneswar analysed agroclimate of Orissa and suggested mitigation options to improve productivity of rainfed rice areas through NATP (RRPS-3) where they compared a NATP study district (Dhenkanal) with other agroclimatic zones of Orissa. I strongly believe that this research bulletin "Agro-climate and extreme weather analysis for successful crop production in Orissa" will be a unique source of agroclimates of Orissa and Dr. Gouranga Kar, Scientist (S.S), Agrometeorology and Principal Investigator of the Project, deserve much appreciation for writing this valuable research bulletin. It will be a very good reference book for researchers, policy makers, NGOs, and farmers who are engaged in improving productivity of rainfed rice areas of Orissa.

(I.C. Mahapatra)

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PREFACE

In Orissa ($17^0 22' - 22^0 45'$ N Latitude and $81^0 45' - 87^0 50'$ E Longitude), agriculture provides direct or indirect employment to 64% of the total workforce but climate induced natural disasters like drought, flood, cyclones occurring alone or in combination cause untold misery to the farmers by creating instability in agricultural production. For more than a decade now, it has experienced contrasting extreme weather conditions, from heat waves to cyclones, from droughts to floods. In the last four years, calamities have claimed more than 30,000 lives. They have not only become more frequents, but have hit areas that were never considered vulnerable. The existing productivity of food grains in Orissa was 1405 kg per hectare, which is much lower, compared to some of the more developed states like Andhra Pradesh, Punjab, Haryana, Karnataka, West Bengal and Uttar Pradesh and also below the national average of 1,739 kg per hectare. Hence, there is substantial scope for enhancing agricultural productivity, particularly that of food grains by adopting a multi pronged strategy including improving the productivity of rainfed area, adoption of improved crop and water management strategies. The varied agro-climatic conditions of the state provide excellent scope for horticulture and agricultural diversification, even in rainfed area.

Any pragmatic rainfed crop planning needs a thorough understanding of the climate and in particular, the rainfall (its variability in the amount, distribution and probability of occurrence), evaporative demand and air temperature. The rainfall and evapotranspiration ultimately determine water balance, crop water and irrigation requirements of different crops of the region. Studies of such climatic parameters are thus helpful in defining risk levels in arable agriculture, characterizing length of growing period and cropping system. The main objective of NATP (RRPS) is to refinement of rainfed farming technologies in the farmers' field based on socio-economic and agro-climatic situations of the rainfed region. In this regards, the NATP (RRPS-3) gave enough opportunity to apprraise the agroclimatic situation and extreme weather events of a rainfed district of Orissa i.e. Dhenkanal. In this bulletin we have made an attempt to provide overview of weather and cropping pattern of a NATP (Rainfed Rice Production System) district (Dhenkanal) and compared with other agro-climatic zones of Orissa (based of undivided districts). The different extreme weather events like drought, flood, cyclone etc. were also studied and mitigation options of those were suggested in very simple and farmers' understandable language. We hope this bulletin will be useful for researchers, policy makers, farmers', NGOs for crops and cropping system characterization. It will also be helpful to cope up with the extreme weather events based on their frequency and probability of incidence.

We take opportunity to extend our deep sense of gratitude and indebtdness to the Director General, Deputy Director General (Natural Resource Management) and Assistant Director General (IWM), ICAR for their encouragement and guidance for preparing this research bulletin. The authors are extremly helpful to World Bank authority for providing fund for publishing this bulletin.

(AUTHORS)

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Studies of agroclimate, especially rainfall (it's variability in the amount, distribution and probability of occurrence), evaporative demand and air temperature are helpful in defining risk levels in rainfed aerable agriculture, characterizing length of the growing period and cropping system. The extreme weather or climate induced natural disasters like drought, flood, cyclone, dry spells, heat waves occurring alone or in combination create agricultural instability in Orissa. In this bulletin we have made an attempt to characterize different parameters of agro-climate of Orissa viz., rainfall departure, climatic water balance, probability distribution of monthly rainfall, thermal environments etc. and to study the frequency and probability of existing extreme weather events like drought, flood, cyclone etc. Softwares have been developed to compute reference evapotranspiration, net radiation and climate risks assessment to identify vulnerable zones. Detailed analysis of drought, floods, cyclones, heat waves (frequency, probability and mitigations) were carried out and possible mitigation options have been discussed for each dominant climate induced natural disaster in the region.

1. INTRODUCTION

Any pragmatic crop planning needs a thorough understanding of the climate and in particular, the rainfall (its variability in the amount, distribution and probability of occurrence), evaporative demand and air temperature. The rainfall and evapotranspiration ultimately determine water balance, crop water and irrigation requirements of different crops of the region. Studies of such climatic parameters are thus helpful in defining risk levels in arable agriculture, characterizing length of growing period and cropping system and command area planning.

In Orissa (17° 22′– 22°45′ N Latitude and 81° 45′ - 87°50′ E Longitude), agriculture provides direct or indirect employment to 64% of the total workforce but climate induced natural disasters like drought, flood, cyclone,dry spells, heat wave occurring alone or in combination cause untold misery to the farmers by creating instability in agricultural production. Orissa is one of the most vulnerable states in India to elevated climate induced natural disaster or extreme weather events because it is placed at the head of the Bay of Bengal and even a slight change in the seas behaviour can have an immediate impact on the coast. The Bay becomes the center of low pressures causing heavy rains and cyclones in the state. For more than a decade now, it has experienced contrasting extreme weather conditions, from heat waves to cyclones, from droughts to floods. In the last four years, calamities have claimed more than 30,000 lives. They have not only become more frequents, but have hit areas that were never considered vulnerable. Floods have become an annual affair with the monsoon of 2001 leading to the worst ever flood recorded in Orissa in the past century as 25 out of the 30 districts were inundated and affected one-third of the states 30 million residents. Areas with no history of floods such as districts in western Orissa were submerged. Ironically, Orissa suffered one of its worst droughts in the same year, which affected the lives of 11 million people in more than two-thirds of the states districts, engulfing earlier drought free districts. The dry spells and drought in 2000 and 2002 caused huge crop loss. A heat wave in 1998 killed around 1500 people, mostly in coastal Orissa, a region otherwise known for its moderate temperature. In 1999 two cyclones hit the state in quick succession. The second one (super cyclone) lasted three days and ravaged 14 coastal districts, around 15 million people were affected and 17,000 square kilometer of agricultural land was devastated. The frequency of extreme weather events has increased in the state in the last decade (Table 1). The fluctuating weather conditions of Orissa suggest that it is reeling under climatic chaos.It is therefore urgently needed to develop suitable coping mechanisms to mitigate the effects of climate induced natural disasters in the state. In this bulletin an attempt has been made to analyse agro-climates and climate induced natural disasters in Orissa for development of sustainable agriculture.

2. AGRO-CLIMATIC ZONES IN ORISSA

Based on ecological land classification, recognizing various components like soils, climate, topography, vegetation, crops etc., the NARP (National Agricultural Research Project) delineated Orissa into 10 major agro-climatic zones (Table-2) under four physiographic divisions or geo-climatic zones *viz.*, (i) Northern Plateau (Mayurbhanj, Keonjhar, Sundergarh and part of Dhenkanal, Jajpur, Balasore) (ii) The Central Table Land (part of Bolangir, Dhenkanal, Sambalpur, Phulbani) (iii) Eastern Ghat Zone (Koraput, Kalahandi, Phulbani) (iv) Coastal zone (Balasore, Cuttack, Puri, Eastern Ganjam). The district wise key indicators (1998-99) are given in Annexure–1, which clearly indicates that the four coastal districts namely Cuttack, Puri, Balasore and Ganjam and the districts from the high land region namely Sundargarh and Sambalpur are advanced in the state economy. Broadly eight soil groups viz., red sandy and red loamy, lateritic, red yellow, are coastal alluvial, deltaic alluvial, black soil, mixed red and black soils, brown forest soils were distributed in different physiographic zones. The soils, climate and major cropping patterns of different agro-climatic zones are given in Table-2, while the spatial location of different agro-climatic zones of Orissa are given in Fig.1.

Table-1: The rainfall and production of food grains in Orissa from 1964-65 till date

Year	Area, of food grains ('000 ha)	Yield (kg ha^{-1}) of food grains	Production ('000mt.) of food grains	Climatic events in general	Rainfall (mm)	% deviation from normal (1461 mm)*
1964-65	NA	NA	NA	Normal	1414.1	-3.21
1965-66	NA	NA	NA	Drought	997.1	-31.75
1966-67	NA	NA	NA	Drought	1134.9	-22.32
1967-68	NA	NA	NA	Cyclone and flood	1326.7	-9.19
1968-69	NA	NA	NA	Cyclone and flood	1296.1	-11.29
1969-70	NA	NA	NA	Flood	1802.1	23.35
1970-71	5781	883	5104	Flood	1660.2	13.63
1971-72	5950	732	4354	Cyclone and flood	1791.5	22.62
1972-73	5915	822	4860	Flood and drought	1177.1	-19.43
1973-74	6218	881	5480	Normal	1360.1	-6.91
1974-75	5992	663	3971	Drought (severe)	951.2	-34.89
1975-76	6484	848	5500	Normal	1325.6	-9.27
1976-77	6038	675	4075	Drought	1012.5	-30.70
1977-78	6519	853	5561	Normal	1326.9	-9.18
1978-79	6680	863	5765	Hailstorm, Tornado	1261.3	-13.6
1979-80	6455	600	3872	Drought	950.7	-34.93
1980-81	6909	865	5977	Normal	1321.7	-9.53
1981-82	6738	822	5538	Normal	1187.4	-18.73
1982-83	6417	731	4688	Drought and flood	1179.9	-19.24
1983-84	7323	956	7001	Normal	1374.1	-5.95
1984-85	6652	843	5609	Flood	1302.8	-10.83
1985-86	7043	989	6963	Normal	1606.8	9.98
1986-87	7010	910	6378	Normal	1566.1	7.19
1987-88	6728	752	5058	Drought	1040.8	-28.76
1988-89	6856	1021	7002	Normal	1270.5	-13.04
1989-90	6972	1144	7974	Normal	1283.9	-12.12
1990-91	7089	992	7031	Flood	1865.8	27.71
1991-92	7252	1141	8273	Normal	1465.7	0.32
1992-93	6946	993	6898	Flood and drought	1344.1	-8.00
1993-94	7208	1140	8216	Drought	1421.6	-2.70
1994-95	7120	1122	7986	Flood	1700.0	16.36
1995-96	7194	1101	7923	Flood	1588.0	8.69
1996-97	6360	841	5347	Drought	988.0	-32.38
1997-98	6616	1105	7311	Normal	1502.8	2.86
1998-99	6516	965	6288	Heat wave, drought	1277.5	-12.56
1999-00	NA	NA	5602	Super-cyclone	1435.7	-1.73
2000-01	NA	NA	4975	Drought	1035.9	-29.26
2001-02	NA	NA	7540	Flood	1617.5	10.71
2002-03	NA	NA	NA	Drought	1165.0	-20.26
2003-04	NA	NA	NA	Flood	1646.9	12.72

Actual rainfall data source: Board of revenue, Cuttack and office of Special Relief Commission, Govt. of Orissa.
** Normal data source: Meteorological Centre, (IMD), Bhubaneswar. (2002) NA = Not available*
Source of area, yield and production of food grains :Orissa State Development Report (2002), Planning Commission New Delhi.

Table-2: The agro-climatic zones in Orissa (based on NARP classification)

Zones and districts covered	Climate	Soils	Suitable cropping system
1. North-western plateau zone (Whole Sundergarh, Kuchinda sub-division of Sambalpur district)	Hot and moist sub-humid with mean summer maximum temperature of 38° C and mean winter minimum temperature of 15° C and mean rainfall of 1600 mm.	The plateau is highly prone to erosion as slopes accentuate it. This is mostly a drought prone area having available moisture holding capacity of less than 9 cm within a soil depth of 75 cm. Soils are highly acidic and of low fertility. Some parts of zone having yellow soils have better soil moisture regime because of the heavier sub soil and closer to ground water table.	**Upland:** **Single cropping** – Groundnut / Arhar/ Blackgram/Greengram/Cotton/Jowar/Maize/ Castor/ Niger/Mesta. **Mixed cropping-** Arhar+Rice, Arhar+Groundnut, Cotton+Greengram, Castor+Greengram **Sequence cropping-** Rice-Horsegram/ Mustard, Mung-Niger, Maize-Mustard, Rice-Castor **Medium land:** Sequence cropping : Rice-Mustard/Linseed/ Blackgram **Lowland:** Sequence cropping : Rice-Blackgram/Lentil/ Linseed
2. North Central Plateau Zone (Mayurbhanj and Keonjhar districts except Anandapur and Joda blocks)	Hot and moist sub-humid with mean maximum temperature of 36.6° C and mean winter minimum temperature is 11.1°C. Annual rainfall of 1534.6 mm is mostly spreading from June to September.	Soils are red loam type, acidic in nature, light textured in the surface but heavier in sub-soils. Low fertility level of soil but rich in Ca and Mg as secondary major nutrients.	**Upland:** **Mono cropping** - Groundnut / arhar /maize / greengram /blackgram /castor **Sequential cropping** -Groundnut, Maize-Horsegram, Groundnut-Castor **Mixed cropping** - Arhar+Rice, Arhar+Ragi, Arhar+Groundnut, Arhar+Maize **Medium land:** **Sequential cropping** - Rice-Mustard, Rice-Greengram/Blackgram, Rice-Chickpea, Rice-Safflower **Low land:** **Relay cropping**-Rice-Field pea (Pyra crop) Rice-blackgram

Zones and districts covered	Climate	Soils	Suitable cropping system
3. North Eastern Coastal Plain Zone (Balasore, Anandapur block of Keonjhar district)	The climate of the zone is hot and moist, humid to subhumid, characterized by hot summer, early kharif season with heavy rains. Cyclones occur during September-October almost every year. The mean maximum and minimum temperature of the zone varies between 33.6°C and 14.3°C respectively. The highest mean monthly relative humidity is 83% and minimum of 63%. Balaipal, Balasore, Nilgiri and Basudevpur have highest rainfall of 1600 mm, whereas Remuna and Soro receive the lowest mean annual rainfall of 1200 mm. The zone is a flood and cyclone prone and the rivers Subarnarekha, Jalaka, Budhabalanga, Kanasabhansa, Baitarani and Brahmani carry high flood intermittently.	The soils of this zone are grouped in to 3 broad categories viz. red laterite (Alfisols and Oxisols), alluvial (Entisols) and saline coastal sandy soils (Naplaquents and Ustipramnuts). This zone has diversified and extensive problems of soil erosion. The coastal belt adjacent to long sea coast, wind erosion and shifting of sand dunes are some of the typical problems. Soil salinity is the problem due to frequent inundation of agricultural land by sea water during high tidal periods.	The following are the principal cropping system in rainfed upland, mediumland, lowlands:- **Rainfed upland**-Mung/Pulses/Cowpea, Ragi-Mustard/Mung, Maize/Jowar-Horsegram, Groundnut+Arhar, Mung+Arhar, Rice+Arhar, Rice. **Rainfed medium land-** Rice -Mustard, Jute- Rice -Mustard, Jute-Rice -Mung/Blackgram, Rice -Groundnut/ Castor/Mustard, Rice -Blackgram/Field pea, Rice -wheat. **Low land** – Jute- Rice -Pulses, Rice -Blackgram/ Mung
4. East and South Eastern Coastal Zone (Cuttack, Puri, Ganjam)	The climate is sub-topical, hot and humid with mean summer maximum temperature of 39°C and mean winter minimum temperature of 11.5°C. The average rainfall in the zone is 1,340 mm. The rainfall in the zone generally decreases from North East to South West. Cyclone and hail stroms are common features in the zone.	This zone has saline soil in the lateral tract, a few km along the sea coast in the East. A vast area of alluvial soils behind the saline strip in the Eastern part, lateritic soil in the Western part and a small patch of black soils in the South Western part of the zone were found. The soils of this zone belong to five categories: (i)Coastal saline and sandy soils (ii)Alluvial soils (iii) Lateritic soils (iv) Black soils (v) Red lateritic soils.	Cropping intensity of the zone is 168%. The cropping pattern of the zone is as follows-Rice-Rice, Rice-Pulse, Rice-Pulse/ Groundnut, Rice-Potato-Til, Olitorious Jute-Wheat-Early Wheat-Greengram, Capsularis Jute-Greengram, Early rice-Cauliflower, Cabbage, Okra, Sugarcane.

Zones and districts covered	Climate	Soils	Suitable cropping system
5. North Eastern Ghat Zone (Phulbani, Rayagada)	Climate is mostly hot, moist, sub-humid. The mean annual rainfall is 1597 mm.	Soils of this zone are grouped under brown forest soils which are medium structured, sandy loam to sandy clay loam, moderately to slightly acidic and medium in soil fertility. There are 7 farming situations in the zone based on soils and climate. They are: (a)Blacksoils, moderate rainfall, high irrigation (b)Alluvial soils, low rainfall, high irrigation (c)Laterite soils, moderate irrigation (e)Red loam soils, moderate rainfall, high elevation, rainfed (f)Red and yellow soils, moderate rainfall, moderate irrigation, moderate elevation (g)Brown forest soils, high rainfall, high elevation, rainfed.	**Unirrigated upland:** **Double Crop :** **Rice**-Greengram/Blackgram/Horsegram, Finger Millet-Niger, **Single Crop**-Groundnut/Maize /Cotton/Tobacco, **Irrigated upland:** Rice-Potato-Summer Vegetable, Rice-Greengram/Vegetable-Summer Vegetable **Unirrigated medium land:** Pre-rice finger millet, Mesta-rice, Til-rice, Single crop Cotton **Irrigated medium land:** Rice-Winter vegetable, Rice-groundnut **Unirrigated lowland:** Single crop-Rice, Rice-Pulses **Irrigated lowland:** Rice (HYV)-Rice(HYV), Rice-Field pea
6. Eastern Ghat Highland Zone (10 blocks of Koraput, 8 blocks of Nabarangpur)	The climate is warm and humid with mean summer maximum temperature of 34.1^{0}C and mean winter temperature of 27.5^{0}C. During winter in high altitude areas of Semiliguda, Pattangi the temperature goes down below 2^0 to 3^{0}C.	In high altitude area of the zone, the red noncalcareous type soil is prevalent. In Narayan Patna block, calcareous mixed red and black forest clay loams are found. In Nabarangpur, Umerkote belt, noncalcareous alluvial soil with various combinations of sandy clay and loam are found. The pH range of high altitude soils varies from 4.9 to 5.5 whereas in Nabrangpur and Umerkote area the pH varies from 5.6 to 6.5. The soils of Indrabati river basin of Nabarangpur belongs to Entisols and Inceptisols and the remaining areas of Nabarangpur are mostly Alfisols.	**Upland:** Ragi, Rice, Niger, Horsegram, Pearl millet, Maize **Medium land:** Vegetables, Rice-Maize, Rice-Ragi, Maize-Vegetables, Rice-Lentil, Rice-Wheat-Blackgram. **Low Jhola Land:** Rice (Monocrop), Rice-Rice

Zones and districts covered	Climate	Soils	Suitable cropping system
7. South Eastern Ghat Zone (Koraput, Malkangiri, Similiguda)	The climate is warm and humid, with mean summer maximum temperature of 34.1° C. The mean annual rainfall is 1714 mm of which 85% is received during the monsoon period.	The zone consists mostly of Alifisols and Inceptisols. In areas where forest vegetation exists, the humus content of soils is found to be rich.	Rice is the principal crop occupying 63% of the gross cropped area of the zone. Other important crops that are widely cultivated are millets (20%), mesta (1.3%) and sesamum (37.08%). A number of fruit crops, particularly mango, lime and guava are successfully grown in the zone. There is large scope for introduction of spices (Cardamom and Pepper) and beverages namely Coffee.
8. Western Undulating Zone (Entire district of Kalahandi, Dabagaon block of Koraput)	The climate of the zone is hot, moist and subhumid characterized by a hot dry summer, uneven rainfall in monsoon and extreme cold in winter. Average annual rainfall of the zone varies from 960 to 1617 mm. The hilly regions of Rampur receives a rainfall of 2615 mm.	The major soil types found in the zone can be grouped under red soil, red and yellow soil, red and black soil, alluvial soil covering 44.5%, 27.4%, 9%, 12.8% and 6.3% area of the zone, respectively.	**Rainfed monocropped :** Rice, Maize, Groundnut, Blackgram, Ragi, Sesamum, Horsegram, Pigeonpea **Rainfed double cropped :** Rice-horsegram, Groundnut-horsegram/mustrad Maize-mustrad/niger/sesamum **Irrigated :** Rice-wheat, Rice-rice,Rice-vegetables, Vegetables-sugarcane.
9. West Central Table Land Zone (23 blocks of Sambalpur and 26 blocks of Bolangir)	Climate of the zone is hot to sub-humid with mean maximum summer temperature of 40° C and mean winter temperature of 12.4° C. In January, temperature drops up to 8° C. Generally South West monsoon sets in by 2nd week of June and continues upto September. The mean annual rainfall is 1180 mm.	The soils of this zone can be classified into 7 groups (i)Red soils(Alfisols)(ii)Laterite & Lateritic soil (Ultisols and Oxisols), (iii)Black soil (Vertisols)(iv)Mixed red and black soils (Association of Ultisols and Vertisols)(v)Mixed red and yellow soils (Ultisols),(vi)Forest soil and alluvial soils (Entisols). The red and yellow soils cover more than 50% area of the zone.	Cropping intensity is 154.0% in the zone. There are 7 farming situations in the zone and the cropping system of each farming situation is different depending on rainfall and socio economic condition. **Major cropping system :** **Monocrop** : Rice, Groundnut, Black gram, Sesamum, Vegetables **Double/triple crop** : Rice-vegetables, Rice-blackgram, Groundnut-vegetables, Rice-groundnut, Rice-mustard, Rice-greengram.
10. Mid Central Table Land Zone (Dhenkanal, Angul and sukinda block of Jajpur)	The climate of the zone is hot and dry-sub humid. The mean maximum summer temperature is 38.7 °C and the mean minimum winter temperature is 14.0 °C. The mean annual rainfall is 1421mm.	Soils of Sukinda, Bhuban, Kamakhyanagar, Gondia, Dhenkanal, Hindol are light textured lateritic- Rhodustalfs, Paleustalfs, Haplustalfs and Ultisols. The area of Angul, parts of Chandipara, Talcher etc. consists of mixed red and black soils, alluvial soils and river valleys.	Rice is the principal crop in the area, comprising of 53% of the gross cultivated area, Pulses comprising of horsegarm, greengram, blackgram constitute 15% of gross cropped area. Oilseeds comprising of sesamum constitute 7% of the gross cropped area. Cotton and vegetables are widespread under lift irrigation project area, utilizing subsoils ground water.

***Source :** Agro-climatic zone specific research (editor : S.P. Ghosh, 1991), Indian Council of Agricultural Research, New Delhi.*

3. AGRO-CLIMATIC CHARACTERIZATION

3.1 Long term rainfall analysis

3.1.1 Deviation of annual rainfall from normal

Based on percentage of departure of actual seasonal rainfall from normal, IMD (Indian Meteorological Department) has classified four categories of rainfall situation viz., normal (+19 to –19%), deficit (-19 to -59%), scanty (<-59%) and excess (>+19%). Accordingly, annual rainfall of past 44 years (1960-2003) for 13 undivided districts of Orissa were categorized and decade wise results are presented in Table-3.

Table-3: Decade wise distribution of excess, normal and deficit southwest monsoon rainfall

Districts	1960-69			1970-79			1980-89			1990-2004		
	Excess	Normal	Deficit	Excess	Normal	Deficit	Excess	Normal	Deficit	Excess	Normal	Deficit
Dhenkanal	0	4	6	1	6	3	0	9	1	1	9	4
Cutack	1	7	2	1	4	5	0	8	2	2	8	4
Puri	0	4	1	0	5	5	0	5	5	2	9	3
Balasore	1	5	4	1	6	3	1	4	5	5	8	1
Koraput	0	6	4	2	5	3	0	8	2	1	10	1
Ganjam	1	6	3	0	7	3	0	9	1	3	10	1
Phulbani	0	3	7	0	2	8	0	7	3	3	5	6
Sambalpur	0	4	6	0	4	6	0	5	5	1	9	4
Sundergarh	0	3	7	0	3	7	0	3	7	0	2	11
Mayurbhanj	0	8	2	1	6	3	0	6	4	0	6	6
Bolangir	0	5	5	0	3	7	1	1	8	2	7	4
Keonjhar	1	7	2	2	6	2	1	5	4	3	8	1
Kalahandi	0	8	2	2	5	3	3	7	0	2	8	4

3.1.2 Seasonal distribution of rainfall

From the normal monthly rainfall (Table-4) distribution in different seasons *viz.* southwest monsoon (June-September), post monsoon (October-November), winter (December-February) and pre-monsoon (March-May) were computed (Table-5). Study revealed that about 62-173 mm rainfall occurs during pre-monsoon period which would be useful for summer ploughing to make the land ready for final land preparation in rainfed upland and direct sowing of rainfed lowland rice in medium deep and deep water rice ecologies.

The average rainfall during southwest monsoon months (June-September) were 863-1413 mm (62-88 %) but major part of this rain is generally lost through runoff which can be utilized for providing supplementary irrigation to second crops. It can be utilized as life saving irrigation particularly in the years when rain during post monsoon season is low or also for growing short duration pulses like green gram, blackgram and oilseeds like mustard, linseed and groundnut in rainfed lowlands after rice during winter/summer season. A very good amount of rainfall (92-248 mm) is also received during post-monsoon season of October-November, which will helpful for rainfed lowland rice because most of the long duration photo-sensitive rice varieties in the region *viz.*, Gayatri, Savitri, Durga and Sarala etc, are at flowering stage during late October or early November. Any deficit of rainfall during this period adversely affects the final yield of rainfed low-land rice. The winter rain is meager (1.7-4.3 %) and crops like pea, linseed, lathyrus, blackgram and safflower can be grown by utilizing the residual soil moisture in rainfed shallow lowlands. Growing of high value, high duty crops without supplimentary irrigation during winter or dry season (December-April) would be risky.

Table- 4: Normal rainfall (mm) of different undivided districts of Orissa

Districts	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Dhenkanal	15.5	30.8	18.7	28.8	59.5	208.9	382.0	333.0	220.6	93.6	25.2	4.5	**1421.1**
Cuttack	13.7	27.5	20.8	34.2	86.5	222.3	351.8	315.8	229.2	147.4	46.7	5.4	**1501.3**
Puri	14.2	26.2	19.7	26.8	67.2	207.0	310.8	300.3	244.7	167.0	57.9	7.3	**1449.1**
Balasore	17.1	30.6	34.3	53.1	105.1	218.2	332.6	313.8	243.1	171.0	42.3	7.2	**1568.4**
Koraput	6.7	11.3	16.2	53.4	75.0	205.8	351.1	380.3	262.1	116.5	35.8	7.6	**1521.8**
Ganjam	10.8	22.2	21.3	42.3	76.8	169.2	221.6	242.4	229.6	179.8	68.6	11.0	**1395.6**
Phulbani	13.0	27.6	25.1	35.5	66.0	239.1	390.8	373.8	260.3	127.2	31.8	6.9	**1597.1**
Sambalpur	14.3	24.4	16.4	17.6	30.9	218.7	469.6	430.9	224.3	61.6	14.7	3.6	**1527.0**
Sundergarh	19.9	36.7	19.3	20.1	41.1	250.9	480.2	458.2	223.9	75.9	16.1	5.3	**1647.6**
Mayurbhanj	21.9	35.5	29.8	47.3	96.7	235.2	426.4	375.5	232.5	113.5	27.4	6.6	**1648.2**
Bolangir	13.9	18.2	13.9	18.7	29.1	233.7	391.7	407.1	232.0	65.6	15.9	3.7	**1443.5**
Kalahandi	11.5	15.4	13.6	23.7	33.7	228.3	343.5	384.6	220.9	81.9	17.9	3.2	**1378.2**
Keonjhar	22.2	38.0	23.0	43.3	88.9	209.5	391.8	335.3	233.0	112.7	31.7	5.1	**1534.5**

Source: Board of revenue, Govt. of Orissa, Cuttack

Table-5: Season wise distribution of rainfall in different undivided districts of Orissa

Districts	Monsoon		Post monsoon		Winter		Premonsoon	
Dhenkanal	1144.5	(80.5)	118.8	(8.4)	50.8	(3.6)	107.0	(7.5)
Puri	1062.8	(73.3)	224.9	(15.5)	47.7	(3.3)	113.7	(7.8)
Balasore	1107.7	(70.6)	213.3	(13.6)	54.9	(3.5)	192.5	(12.3)
Koraput	1199.3	(78.8)	152.3	(10.0)	25.6	(1.7)	144.6	(9.5)
Ganjam	862.8	(61.8)	248.4	(17.8)	44.0	(3.2)	140.4	(10.1)
Phulbani	1264.0	(79.1)	159.0	(10.0)	47.5	(3.0)	126.6	(7.9)
Sambalpur	1343.5	(88.0)	76.3	(5.0)	42.3	(2.8)	64.9	(4.3)
Sundergarh	1413.2	(85.8)	92.0	(5.6)	61.9	(3.8)	80.5	(4.9)
Mayurbhanj	1269.6	(77.0)	140.9	(8.5)	64.0	(3.9)	173.8	(10.5)
Bolangir	1264.5	(87.6)	81.5	(5.6)	35.8	(2.5)	61.7	(4.3)
Kalahandi	1177.3	(85.4)	99.8	(7.2)	30.1	(2.2)	71.0	(5.2)
Keonjhar	1169.6	(76.2)	144.4	(9.4)	65.3	(4.3)	155.2	(10.1)

** The figure in parenthesis indicates percentage of total annual rainfall.*

Source: Board of revenue, Govt. of Orissa, Cuttack

3.1.3 Coefficient of variation of monthly rainfall

The coefficient of variation of monthly rainfall was computed and results are presented in Table-6. Study reveals that among different months rainfall variability is less during monsoon months for all the districts. Among different months, rainfall was less variable in July and August The summer and winter rainfall are meagre and highly variable. So growing of second crop during winter season after rainy season upland and medium land rice without supplementary irrigation would be risky. In lowland rainfed rice ecologies, second crops like pulses (greengram, blackgram, pea), oilseeds (linseed, safflower, niger) can be grown utilizing residual soil moisture.

Table-6 : Coefficient of variation (%) of monthly rainfall in different undivided districts of Orissa.

Districts	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Dhenkanal	188.55	148.76	132.44	81.57	89.42	45.84	8.75	35.01	29.57	93.88	172.72	325.01
Phulbani	160.50	160.43	127.93	81.81	101.27	51.82	40.00	41.40	45.01	91.11	192.29	321.20
Kalahandi	27.99	156.86	188.88	88.02	97.92	51.34	35.78	38.56	51.65	105.31	170.93	342.84
Koraput	221.08	133.67	99.93	65.78	83.24	44.03	22.69	29.88	34.38	71.44	156.14	254.94
Mayurbhanj	209.16	143.31	102.43	71.64	63.15	28.07	31.25	45.12	45.12	101.39	202.95	233.92
Sambalpur	170.36	135.15	142.62	104.35	78.79	55.78	32.32	31.47	43.38	86.13	193.50	305.99
Sundergarh	179.13	142.48	166.30	91.84	78.57	46.36	33.41	30.71	41.53	87.33	193.83	303.68
Bolangir	233.26	210.23	266.23	275.99	162.71	56.71	37.15	46.03	56.97	131.35	201.46	274.71
Cuttack	193.79	126.40	135.18	92.66	99.85	41.69	38.98	29.74	36.88	85.26	164.47	258.77
Balasore	144.69	120.54	114.61	81.11	78.84	44.73	31.35	33.85	41.29	78.62	163.85	282.92
Ganjam	152.70	129.13	102.17	65.21	117.09	49.36	36.64	37.25	40.93	70.03	137.91	331.50
Puri	193.36	144.09	125.60	102.60	167.30	52.00	39.60	35.78	38.24	99.32	144.38	261.72
Keonjhar	161.73	145.56	124.69	85.29	55.06	44.96	27.75	27.10	35.65	87.91	178.00	341.14

3.1.4 Climatic water balance and length of growing period

The climatic water balance parameters *viz.*, actual evapotranspiration (AET), moisture surplus and length of growing period (LGP) were computed using Thronthwaite and Mather's (1957) book keeping procedure, considering the average available water capacity of soils as 125 mm/m. Study reveals that AET of the region ranged between 750 mm to 1150 mm in different districts. Large to moderate water surplus (300-630 mm) was available in different districts (Fig. 2). Since winter rainfall (dry season) is meager and erratic, this amount of rainfall may be harvested and utilized for providing supplementary irrigation for growing short duration crops like greengram, blackgram, linseed, mustard, sunflower, safflower, pea etc. during dry season. The length of the growing period (LGP) in different districts ranged between 180-240 days starting from 23rd standard weeks (4th to 10th June) and ending in December-January and occurred mainly in 4 humid months (July to October) and three moderate dry months (November and December-January) (Fig. 3).

3.1.5 Mean monthly southwest monsoon rainfall at different probability levels and its utility for crop planning

The probable date of onset of southwest monsoon in the region is 23rd standard meteorological weeks (10th June) in different districts and thus length of growing period (LGP) also

Fig. 1 : Agro Climatic zones of Orissa

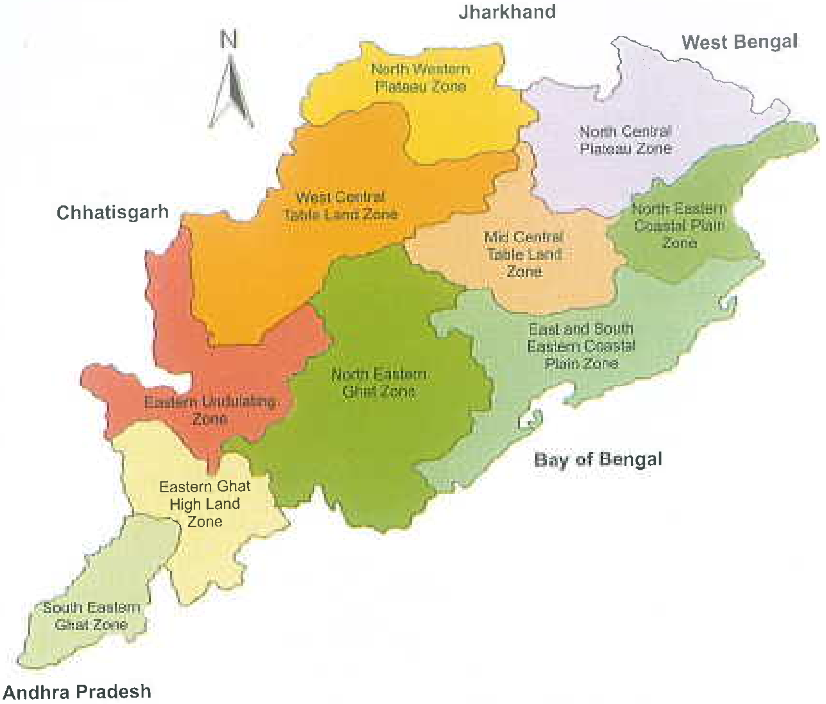


Fig. 2 : Surplus water (mm) as per climatic water balance

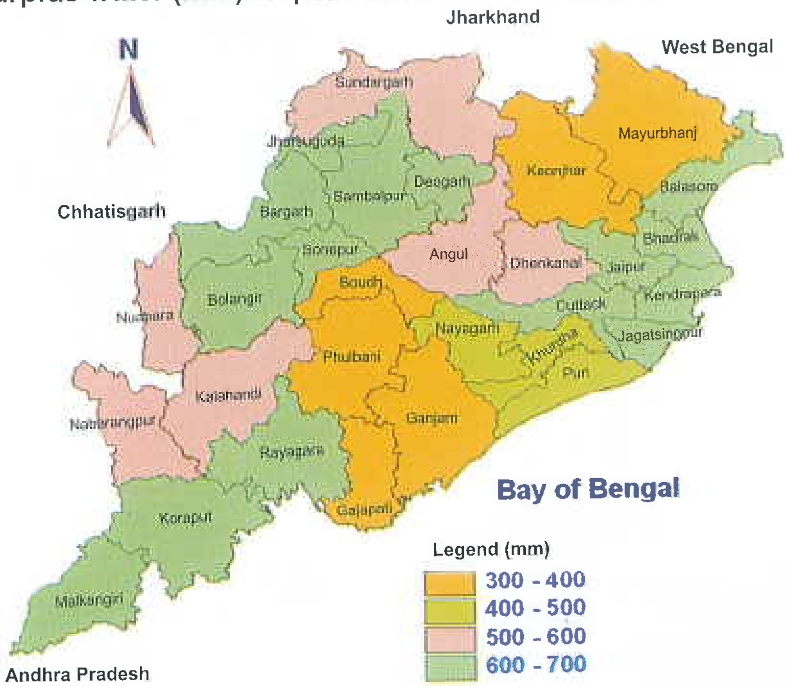


Fig. 3 : Length of the growing period (days) in Orissa

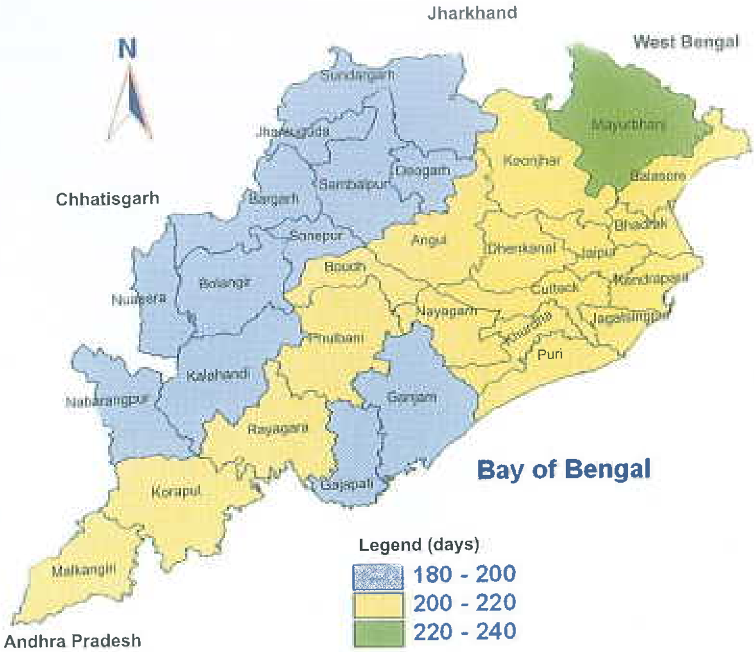
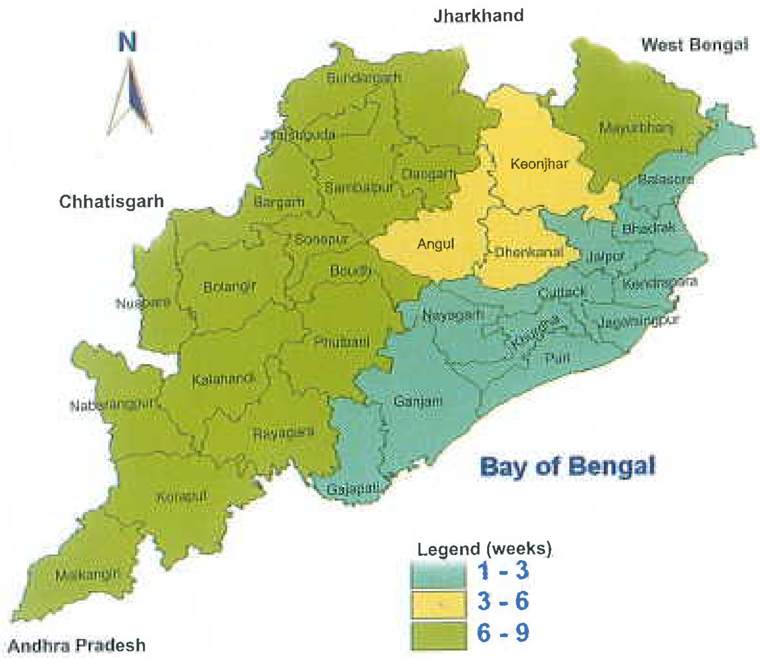


Fig. 4 : Favourable temperature weeks for growing winter crops



starts from 23[rd] standard weeks. Hence sowing operation can be initiated from that week but prediction of southwest monsoon in different seasons is of paramount importance for assessing rainfall at highly assured level for raising crops successfully with high and stable yield because agriculture in Orissa is southwest monsoon dependent. In this study monthly southwest monsoon (June- September) rainfall were predicted at 30 %, 50 % and 70 % probability levels using different probability distribution (Table-7). In the first southwest monsoon month i.e., in June, 132 to 227 mm rainfall was observed at 70 % (most dependable limit) probability level in different districts. Therefore in the rainy season direct seeded crops namely groundnut (*Arachis hypogea* L.), pigeonpea [*Cajanas cajan* (L.) *Millsp.*], cowpea [*Vigna unguiculata* (L.) *Walp*], maize (*Zea mays* L.) and blackgram (*Phaseolus mungo* L.) can be sown and rice nurseries can be prepared in 23[rd] to 24[th] standard week with the commencement of southwest monsoon in different districts of Orissa. The rainfall at dependable level during June can be utilized for upland direct seeded crop planning. In the month of July at 70 % probability level, 225-302 mm rainfall was projected, which could be utilized for rice transplanting starting from first fortnight of July in medium and low land rice ecosystems. The transplanting of rainy season rice in the first week of July will have additional advantage of assured rain during August and September.

To increase the rainwater use efficiency and productivity of light textured rainfed upland, rice can be substituted with other low water requiring crops through sole or intercropping. In case maize, groundnut, pigeonpea and direct seeded rice based intercrops could not be sown by the end of June or fail to establish in June due to dry spell or aberrant weather, then sowing of these crops should not be done afterwards because of delayed sowing of maize, groundnut or upland rice may cause crop failure or very low productivity. The crops like blackgram, cowpea, and sesamum can be sown successfully up to last week of July. Since the rainfall after October is uncertain and erratic, sowing of high value winter crops without supplementary irrigation is not possible in the region. In this study monthly rainfall was predicted at 30%, 50% and 70% probability levels using different probability distribution viz., Normal, Lognormal, Log pearson and Extreme Value Type-1, and was compared with that of observed values (Weibull's method).

Table-7: Predicted and observed monthly rainfall (mm) at different districts of Orissa.

DHENKANAL															
Months	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	16.0	8.1	0.0	-	-	-	-	-	-	13.5	5.6	-	8.5	1.0	0.0
Feb	27.8	15.7	3.3	-	-	-	-	-	-	23.9	11.8	1.8	21.3	6.4	0.3
Mar	41.1	24.4	7.5	-	-	-	-	-	-	35.8	19.2	5.4	30.2	7.0	0.9
Apr	40.2	28.2	16.1	32.4	19.2	11.2	35.1	22.0	12.6	36.4	24.5	14.6	30.9	19.9	13.9
May	86.6	59.1	31.1	66.4	46.8	32.8	66.3	46.7	32.7	77.8	50.5	27.7	59.5	47.1	33.8
Jun	244.9	197.8	149.7	232.0	175.0	131.3	144.0	191.7	142.5	229.8	182.9	143.9	221.8	182.8	140.0
Jul	362.8	302.0	239.9	352.4	276.8	216.4	371.4	311.4	243.7	343.4	282.7	232.4	355.8	291.5	232.4
Aug	405.2	339.8	273.1	393.4	313.9	249.6	410.5	340.8	269.3	384.3	319.1	265.0	413.4	316.8	247.3
Sep	238.1	206.3	174.0	231.5	197.4	167.8	234.0	200.5	169.9	227.9	196.3	170.0	240.7	206.0	161.2
Oct	120.9	81.3	40.8	-	-	-	-	-	-	108.2	68.7	35.9	97.1	54.8	33.1
Nov	37.8	19.9	1.7	-	-	-	-	-	-	32.1	14.3	-	20.0	2.8	0.0
Dec	10.6	3.9	-	-	-	-	-	-	-	8.5	1.8	-	0.0	0.0	0.0

PURI															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	25.8	12.9	-	-	-	-	-	-	-	21.7	8.8	-	9.8	2.6	0.0
Feb	29.0	16.6	3.9	-	-	-	-	-	-	25.1	12.7	2.4	20.1	8.0	0.7
Mar	34.6	20.9	7.0	-	-	-	-	-	-	30.2	16.6	5.4	30.3	8.1	0.8
Apr	36.7	23.9	10.9	-	-	-	-	-	-	32.6	19.9	9.3	31.7	16.6	7.5
May	105.9	56.7	6.6	-	-	-	-	-	-	90.2	41.2	0.5	60.7	32.0	22.4
Jun	204.7	161.1	116.7	185.2	142.0	108.4	184.8	141.6	108.1	190.7	147.3	111.3	186.5	150.8	105.2
Jul	342.3	283.9	224.5	321.4	265.3	218.2	317.7	261.3	216.0	323.6	265.5	217.3	334.9	261.2	216.0
Aug	375.2	318.7	261.0	362.8	299.6	246.4	370.8	309.9	253.3	357.1	300.8	254.0	366.8	328.8	274.5
Sep	261.4	217.7	173.2	255.3	198.9	154.3	269.5	226.1	176.0	247.4	203.9	167.8	255.7	222.3	174.0
Oct	201.7	133.0	63.0	146.3	84.2	48.0	156.3	93.6	52.3	179.7	111.3	54.4	134.6	106.3	62.0
Nov	73.4	41.9	9.8	-	-	-	-	-	-	63.3	32.0	5.9	43.5	15.8	2.0
Dec	10.0	4.3	-	-	-	-	-	-	-	8.2	2.5	-	0.8	0.0	0.0

BALASORE															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	17.2	9.8	2.3	-	-	-	-	-	-	14.8	7.5	1.4	10.4	2.6	0.0
Feb	31.6	19.4	7.0	-	-	-	-	-	-	27.7	15.6	5.5	29.3	6.9	0.1
Mar	49.8	31.0	12.0	-	-	-	-	-	-	43.8	25.5	9.7	38.8	22.2	3.5
Apr	72.2	50.7	28.9	-	-	-	-	-	-	65.3	44.0	26.2	60.2	41.2	19.8
May	138.6	98.3	57.2	113.8	71.3	44.3	122.0	80.2	49.0	125.9	85.6	52.2	104.7	81.5	54.1
Jun	294.0	238.6	182.0	276.5	214.9	166.2	286.1	227.2	174.2	276.3	221.0	175.1	284.0	230.3	164.1
Jul	317.6	273.2	227.9	308.5	259.6	217.7	313.7	266.4	222.3	303.4	259.2	222.4	222.9	270.1	302.9
Aug	378.9	322.6	265.1	378.0	298.7	234.9	395.9	345.5	277.0	360.9	304.8	258.1	380.8	325.2	266.2
Sep	302.1	248.4	193.6	289.5	224.3	173.0	302.4	242.3	185.2	284.9	231.4	186.9	295.4	244.7	183.9
Oct	217.1	154.0	89.7	176.2	115.0	74.5	184.3	123.2	78.7	196.9	134.1	81.9	154.4	123.1	72.9
Nov	60.0	32.4	4.3	-	-	-	-	-	-	51.2	23.7	0.8	25.8	8.7	1.0
Dec	9.3	3.8	-	-	-	-	-	-	-	7.5	2.0	-	0.0	0.0	0.0

GANJAM															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	19.7	11.0	2.1	-	-	-	-	-	-	16.9	8.2	1.0	9.7	1.3	0.0
Feb	34.2	20.5	6.5	-	-	-	-	-	-	29.8	16.1	4.7	22.8	8.2	0.0
Mar	42.5	27.7	12.7	-	-	-	-	-	-	37.8	23.1	10.9	31.4	18.9	7.5
Apr	50.4	37.6	24.5	-	-	-	-	-	-	46.3	46.3	22.9	50.5	32.1	21.0
May	124.8	76.9	28.0	85.1	49.1	28.1	94.4	59.6	33.5	109.5	109.5	22.0	77.8	52.2	35.2
Jun	214.5	145.0	123.3	197.7	147.7	109.7	206.5	158.8	116.7	200.0	200.0	117.7	196.4	132.5	120.3
Jul	259.2	217.6	175.2	247.5	203.5	166.8	249.9	206.5	168.6	245.9	204.5	170.0	152.5	201.8	171.6
Aug	291.1	244.4	296.2	282.2	226.0	180.2	293.6	242.7	192.1	276.6	229.5	190.3	279.1	242.4	193.2
Sep	259.1	213.3	166.4	240.5	198.9	163.9	234.0	192.3	160.5	244.9	198.7	160.7	229.5	185.7	155.3
Oct	236.6	173.4	109.1	199.8	133.1	88.0	206.3	139.7	91.4	216.4	153.5	101.2	207.3	144.9	73.4
Nov	93.7	53.9	13.3	-	-	-	-	-	-	81.0	41.3	8.4	60.7	20.0	2.8
Dec	16.4	5.9	-	-	-	-	-	-	-	13.0	2.5	-	1.3	0.0	0.0

PHULBANI															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	21.0	11.4	1.7	-	-	-	-	-	-	17.9	8.4	0.5	12.8	1.3	0.0
Feb	30.3	16.5	2.5	-	-	-	-	-	-	25.9	12.2	0.8	20.1	5.7	1.1
Mar	35.3	21.2	6.8	-	-	-	-	-	-	30.8	30.8	5.1	25.1	11.0	4.0
Apr	45.3	31.8	18.0	-	-	-	-	-	-	41.0	41.0	16.3	37.5	28.5	14.6
May	94.5	62.4	29.6	-	-	-	-	-	-	84.2	84.2	25.6	59.4	44.8	36.6
Jun	239.5	188.6	136.6	216.3	166.7	127.8	214.6	164.9	126.8	223.3	172.5	130.3	227.9	157.5	126.1
Jul	382.2	316.4	249.3	360.4	293.9	238.7	364.3	298.5	241.5	361.1	295.6	241.1	326.5	297.8	246.5
Aug	421.6	246.3	269.6	395.0	319.3	257.0	395.6	320.0	257.4	397.5	322.5	260.2	374.4	302.7	264.0
Sep	256.2	207.6	158.1	248.7	181.9	132.3	265.8	217.3	160.2	240.7	192.3	152.1	255.3	207.2	147.2
Oct	126.4	85.8	44.4	-	-	-	-	-	-	113.4	72.9	39.3	101.5	69.1	32.6
Nov	42.8	21.4	-	-	-	-	-	-	-	35.9	14.6	-	15.5	2.5	0.0
Dec	10.9	4.1	-	-	-	-	-	-	-	8.7	1.9	-	0.0	0.0	0.0

CUTTACK															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	16.3	8.1	-	-	-	-	-	-	-	13.7	5.6	-	7.6	0.5	0.0
Feb	28.3	17.1	5.6	-	-	-	-	-	-	24.7	13.5	4.2	20.3	5.2	0.5
Mar	42.3	24.8	6.9	-	-	-	-	-	-	36.7	19.3	4.7	26.9	14.1	4.2
Apr	42.0	28.4	14.4	30.9	16.0	8.5	33.5	18.5	9.4	37.7	24.1	12.7	35.4	19.5	8.2
May	131.2	86.3	40.6	95.5	56.8	33.5	101.4	62.4	36.1	116.8	72.2	35.0	97.2	62.9	33.9
Jun	233.2	191.6	149.1	219.5	175.6	139.9	221.2	177.6	141.1	219.9	178.4	144.0	224.6	178.0	139.1
Jul	374.5	310.5	245.3	351.8	289.9	238.0	349.9	287.8	236.7	354.0	290.3	237.4	358.6	285.6	225.8
Aug	401.1	347.4	292.7	288.1	333.1	285.1	388.0	333.0	285.0	384.0	330.5	286.0	392.7	322.2	271.5
Sep	269.1	225.8	181.7	268.8	203.9	153.8	284.8	240.7	183.7	255.3	212.1	176.3	266.6	230.8	206.4
Oct	200.6	139.0	76.2	157.4	96.0	58.0	166.7	105.2	62.5	180.9	119.5	68.5	144.1	109.1	72.9
Nov	64.9	35.0	4.5	-	-	-	-	-	-	55.3	25.5	0.8	29.5	8.7	1.4
Dec	6.6	2.8	-	-	-	-	-	-	-	5.4	1.6	-	0.0	0.0	0.0

KORAPUT															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	17.2	8.0	-	-	-	-	-	-	-	14.2	5.1	-	3.9	0.5	0.0
Feb	16.5	9.8	2.8	-	-	-	-	-	-	14.4	7.6	2.0	1.3	4.0	0.5
Mar	25.3	16.6	7.8	-	-	-	-	-	-	22.5	13.9	6.7	19.3	11.5	5.7
Apr	54.6	40.7	26.5	47.6	32.3	21.7	50.5	35.6	23.6	50.2	36.3	24.8	52.8	30.7	25.2
May	101.9	71.1	39.8	-	-	-	-	-	-	92.1	61.4	35.9	68.6	54.0	46.1
Jun	252.1	204.9	156.8	236.3	185.4	144.8	241.0	191.0	148.2	237.0	190.0	150.9	232.2	174.9	154.3
Jul	385.2	344.6	303.2	378.8	335.8	297.1	380.3	337.8	298.4	272.3	331.8	298.1	394.7	327.4	293.3
Aug	382.1	318.8	254.4	380.7	285.2	212.4	405.3	334,9	252.1	361.9	298.9	246.5	384.8	343.0	267.4
Sep	270.4	237.7	187.6	257.5	217.6	183.2	254.2	214.0	181.2	257.3	216.4	182.5	258.5	207.6	174.8
Oct	131.6	95.8	59.3	110.9	73.1	47.7	116.7	79.2	51.0	120.2	84.5	54.9	107.2	83.6	53.7
Nov	39.7	22.0	4.0	-	-	-	-	-	-	34.0	16.4	1.8	22.9	7.1	1.9
Dec	16.7	7.2	-	-	-	-	-	-	-	13.6	4.2	-	2.0	0.1	0.0

MAYURBHANJ															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	28.1	13.4	-	-	-	-	-	-	-	23.4	8.8	-	10.4	1.3	0.0
Feb	36.2	20.7	5.0	-	-	-	-	-	-	31.2	15.9	3.1	28.9	10.1	1.8
Mar	11.1	24.3	11.1	-	-	-	-	-	-	33.0	20.2	9.5	31.2	16.4	5.1
Apr	66.9	48.7	30.2	57.0	33.8	19.8	62.1	39.2	22.5	61.1	43.0	28.0	61.9	45.3	24.4
May	109.0	81.1	54.6	94.8	67.5	47.8	96.9	69.7	96.9	100.4	73.5	51.2	91.4	71.3	49.5
Jun	285.4	275.7	185.0	284.8	209.1	153.5	298.8	257.3	196.5	169.5	220.0	178.8	289.7	227.5	167.5
Jul	332.4	290.1	246.9	322.5	279.6	241.8	322.4	279.5	241.7	213.9	279.7	241.6	310.9	276.9	253.9
Aug	393.7	338.7	282.6	393.8	316.7	253.7	411.6	361.2	293.6	376.1	321.3	275.7	395.1	345.8	302.2
Sep	331.0	268.1	204.0	308.6	243.5	191.3	315.0	351.2	196.0	310.9	248.3	196.2	328.1	258.5	179.8
Oct	159.5	104.4	48.3	113.4	68.7	41.2	42.1	70.7	42.1	141.9	81.0	41.5	134.2	68.6	45.7
Nov	32.7	15.9	-	-	-	-	-	-	-	27.3	10.6	-	10.8	2.8	0.2
Dec	9.0	4.1	-	-	-	-	-	-	-	7.4	2.5	-	3.2	0.0	0.0

SAMBALPUR															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	31.3	16.2	0.9	-	-	-	-	-	-	26.5	11.5	-	10.4	1.3	0.0
Feb	21.3	12.5	3.5	-	-	-	-	-	-	18.5	9.7	2.5	28.9	10.1	1.8
Mar	25.0	14.4	3.5	-	-	-	-	-	-	21.6	11.0	2.2	31.2	16.4	5.1
Apr	21.7	16.1	6.3	-	-	-	-	-	-	19.3	11.7	5.3	61.9	45.3	24.4
May	43.2	30.7	17.9	35.0	22.4	14.2	36.6	23.9	15.0	39.2	26.7	16.3	91.4	71.3	49.5
Jun	247.4	191.8	135.1	222.0	164.3	121.0	225.7	168.3	123.2	329.7	174.2	128.2	289.7	227.5	167.5
Jul	400.6	343.0	284.2	402.1	320.1	253.5	409.3	376.2	314.5	382.2	324.8	277.0	310.9	276.9	253.9
Aug	432.4	371.6	309.6	420.1	352.7	295.2	428.0	363.1	302.2	413.0	352.4	302.1	395.1	345.8	302.2
Sep	249.9	203.9	157.0	235.5	184.6	144.7	141.2	191.7	148.5	235.2	189.4	151.3	328.1	258.5	179.8
Oct	63.2	43.7	23.7	-	-	-	-	-	-	57.0	37.5	21.3	134.2	68.6	45.7
Nov	23.3	11.6	-	-	-	-	-	-	-	19.6	7.9	-	10.8	2.8	0.2
Dec	11.7	4.5	-	-	-	-	-	-	-	9.4	2.2	-	3.2	0.0	0.0

KALAHANDI															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	16.3	7.6	-	-	-	-	-	-	-	13.5	4.9	-	4.7	0.0	0.0
Feb	18.8	10.3	1.7	-	-	-	-	-	-	16.1	7.7	0.7	11.5	1.5	0.0
Mar	29.2	14.7	-	-	-	-	-	-	-	24.5	10.1	-	11.8	7.5	2.1
Apr	32.5	22.4	12.1	-	-	-	-	-	-	29.2	19.2	10.8	28.9	18.0	8.5
May	58.0	37.8	17.3	-	-	-	-	-	-	51.5	31.5	14.8	38.5	30.4	18.0
Jun	267.9	211.5	153.9	247.1	182.9	134.6	257.2	165.8	142.1	249.9	193.6	146.9	242.2	204.2	141.1
Jul	419.8	353.9	286.7	419.2	324.0	249.2	437.9	384.0	305.1	398.7	333.1	278.5	399.9	370.7	285.0
Aug	431.5	354.6	276.3	420.9	317.6	238.3	447.0	372.6	283.0	406.9	330.4	266.7	447.7	337.2	265.2
Sep	270.5	213.5	155.4	251.8	186.2	136.9	268.4	212.9	156.0	152.3	195.5	148.3	230.3	188.2	148.8
Oct	101.9	65.9	29.1	72.0	45.1	27.9	73.6	46.5	28.6	90.4	54.5	24.6	74.4	50.5	28.1
Nov	21.9	11.5	0.9	-	-	-	-	-	-	18.6	8.2	-	8.0	1.2	0.0
Dec	9.2	3.3	-	-	-	-	-	-	-	7.3	1.4	-	0.0	0.0	0.0

SUNDERGARH															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	28.1	14.5	0.7	-	-	-	-	-	-	23.8	10.3	-	18.9	3.0	0.1
Feb	22.2	12.9	3.1	-	-	-	-	-	-	19.2	9.8	2.0	13.3	6.8	3.0
Mar	23.1	12.4	1.5	-	-	-	-	-	-	19.7	9.0	0.1	12.2	4.9	0.6
Apr	26.4	14.9	7.6	-	-	-	-	-	-	19.7	12.6	6.8	20.1	15.5	5.6
May	51.6	36.7	21.4	45.1	22.2	10.8	52.6	33.0	16.4	46.8	31.9	19.5	47.9	36.1	16.2
Jun	251.0	202.3	152.6	234.7	180.2	137.7	141.5	188.3	142.7	235.5	186.9	146.5	241.0	178.3	137.5
Jul	389.4	333.3	275.9	372.0	318.6	272.0	368.6	214.8	269.8	371.5	315.4	268.9	357.7	315.0	287.5
Aug	391.8	336.7	280.6	382.2	318.9	265.1	392.6	332.8	274.9	374.2	213.4	273.8	398.3	325.8	279.5
Sep	245.5	201.9	157.5	233.1	183.8	144.3	239.1	191.2	148.9	231.6	188.2	152.1	230.8	198.1	146.4
Oct	82.9	56.9	30.4	-	-	-	-	-	-	74.6	48.7	27.1	71.4	38.2	20.8
Nov	16.4	8.2	-	-	-	-	-	-	-	13.8	5.6	-	7.2	0.3	0.0
Dec	10.9	0.6	-	-	-	-	-	-	-	8.7	2.1	-	1.7	0.0	0.0

BOLANGIR															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	33.3	15.1	-	-	-	-	-	-	-	27.5	9.3	-	10.1	0.9	0.0
Feb	33.3	15.9	-	-	-	-	-	-	-	28.8	3.1	-	17.4	5.2	0.1
Mar	57.1	23.9	-	-	-	-	-	-	-	48.5	13.5	-	19.2	4.7	0.4
Apr	91.6	37.6	-	-	-	-	-	-	-	74.3	20.6	-	23.7	11.9	7.2
May	87.4	47.3	6.5	42.5	21.3	10.6	44.0	22.5	11.0	74.6	34.7	1.5	38.7	25.2	12.2
Jun	237.1	183.4	128.7	208.5	161.8	125.0	200.3	154.2	121.3	219.9	166.5	122.0	192.6	160.4	115.5
Jul	376.8	315.8	253.6	-	-	-	-	-	-	357.3	296.5	246.0	372.0	331.6	248.8
Aug	405.0	326.8	247.1	-	-	-	-	-	-	380.0	302.1	237.4	368.2	316.9	266.0
Sep	231.8	178.8	124.8	217.2	144.1	94.8	237.6	178.2	118.1	214.9	162.1	118.2	221.8	165.9	120.7
Oct	81.3	48.3	14.7	-	-	-	-	-	-	70.8	37.9	10.6	49.7	28.0	15.0
Nov	23.2	11.3	-	-	-	-	-	-	-	19.4	7.6	-	13.0	0.2	0.0
Dec	8.5	3.5	-	-	-	-	-	-	-	6.9	1.9	-	0.3	0.0	0.0

KEONJHAR															
	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
Months	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	21.5	11.7	1.7	-	-	-	-	-	-	18.4	8.6	0.4	12.2	3.1	0.0
Feb	31.9	18.1	4.1	-	-	-	-	-	-	27.5	13.8	2.4	17.5	8.2	2.2
Mar	41.0	24.9	8.4	-	-	-	-	-	-	35.8	19.8	6.4	29.7	11.2	0.7
Apr	56.1	38.5	20.6	-	-	-	-	-	-	50.5	33.0	18.4	56.6	32.4	10.5
May	103.6	80.8	57.6	94.0	69.3	50.8	96.7	72.4	52.6	96.3	73.6	54.7	100.5	70.8	48.3
Jun	251.4	203.8	155.2	248.0	175.4	123.2	266.0	216.6	156.0	236.2	188.7	149.3	251.6	200.1	139.6
Jul	326.4	285.6	243.6	331.8	270.1	319.1	334.5	312.3	267.8	313.6	272.6	238.4	316.4	284.2	252.1
Aug	326.8	334.6	286.6	373.6	322.2	277.0	379.2	329.6	282.1	366.7	319.7	280.7	371.0	342.7	274.4
Sep	381.8	235.6	191.1	266.5	221.7	183.8	267.0	222.3	184.2	265.3	221.8	185.6	109.6	224.5	173.2
Oct	279.3	98.6	52.6	108.9	69.5	44.0	108.7	69.4	43.9	129.2	84.3	47.0	6.2	62.4	38.3
Nov	143.6	12.7	0.8	-	-	-	-	-	-	20.7	9.0	-	0.2	2.0	0.0
Dec	8.6	3.1	-	-	-	-	-	-	-	6.9	1.4	-	0.0	0.0	0.0

Primary data Source: *Board of revenue, Govt. of Orissa, Cuttack*

3.1.6 Determination of best-fit probability distribution for predicting monthly rainfall.

The rainfall predicted during southwest months (June–September) at 50 % and 70 % probability levels by different distribution viz. Normal, Log-Normal, Log-Pearson and Extreme Values Type-I was compared with that of the observed values (Weibulls' formula). The best-fit probability distribution was computed by performing chi-square(χ^2) test. The lowest chi-square value was observed when rainfall was predicted using Log Pearson Probability distribution almost for all the districts except Dhenkanal, Mayurbhanj, Kalahandi and Keonjhar where Extreme Value Type-1 distribution was found the best fit. (Table-8).

$$\chi^2=\sum\frac{(O_i-E_i)^2}{E_i}$$

Where, O_i = observed rainfall (mm) based on Weibulls' formula, E_i = estimated rainfall (mm) from different probability models

Table-8: χ^2 test of observed and predicted monthly rainfall of different districts of Orissa during Southwest Monsoon period.

Cuttack

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.2
Jul	2.0	1.6	0.1	0.6	0.0	0.5	0.1	0.6
Aug	1.8	1.5	0.4	0.6	0.4	0.6	0.2	0.7
Sep	0.1	3.4	3.5	18.0	0.4	2.8	1.6	5.1
	4.9	**7.2**	**4.0**	**19.2**	**0.8**	**3.2**	**1.9**	**6.6**

Puri

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	0.7	1.1	0.5	0.1	0.6	0.1	0.1	0.3
Jul	1.8	0.3	0.1	0.0	0.0	0.0	0.1	0.0
Aug	0.3	0.7	2.8	3.2	1.2	1.8	2.6	1.7
Sep	0.1	0.0	2.8	2.5	0.1	0.0	1.7	0.2
	62.3	**55.4**	**12.0**	**9.9**	**3.5**	**3.7**	**28.4**	**970.6**

Balasore

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	0.3	1.8	1.1	0.0	0.0	0.6	0.4	0.7
Jul	0.0	24.7	0.4	33.3	0.1	29.2	0.5	29.1
Aug	0.0	0.0	2.4	4.2	1.2	0.4	1.4	0.3
Sep	0.1	0.5	1.9	0.7	0.0	0.0	0.8	0.0
	0.4	**26.9**	**5.7**	**38.2**	**1.3**	**30.2**	**3.0**	**30.1**

Ganjam

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	1.1	0.1	1.6	1.0	4.4	0.1	22.8	0.1
Jul	1.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0
Aug	0.0	35.8	1.2	0.9	0.0	0.0	0.7	0.0
Sep	3.6	0.7	0.9	0.5	0.2	0.2	0.9	0.2
	5.8	**36.7**	**3.6**	**2.6**	**4.7**	**0.3**	**24.4**	**0.3**

Dhenkanal

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	1.1	0.6	0.3	0.6	0.4	0.0	0.0	0.1
Jul	0.4	0.2	0.8	1.2	1.3	0.5	0.3	0.0
Aug	1.6	2.4	0.0	0.0	1.7	1.8	0.0	1.2
Sep	0.0	0.9	0.4	0.3	0.2	0.4	0.5	0.5
	3.1	**4.2**	**1.5**	**2.0**	**3.5**	**2.8**	**0.8**	**1.7**

Phulbani

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	5.1	0.8	0.5	0.0	0.3	0.0	1.3	0.1
Jul	1.1	0.0	0.1	0.3	0.0	0.1	0.0	0.1
Aug	12.9	0.1	0.9	0.2	0.9	0.2	1.2	0.1
Sep	0.0	0.8	3.5	1.7	0.5	1.1	1.2	0.2
	19.1	**1.7**	**4.9**	**2.1**	**1.7**	**1.3**	**3.7**	**0.5**

Koraput

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	4.4	0.0	0.6	0.6	1.4	0.3	1.2	0.1
Jul	0.9	0.3	0.2	0.0	0.3	0.1	0.1	0.1
Aug	1.8	0.7	11.7	14.2	0.2	0.9	6.5	1.8
Sep	3.8	0.9	0.5	0.4	0.2	0.2	0.4	0.3
	10.9	**1.9**	**13.0**	**15.3**	**2.1**	**1.5**	**8.1**	**2.3**

Mayurbhanj

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	8.4	1.7	1.6	1.3	3.5	4.3	0.3	0.7
Jul	0.6	0.2	0.0	0.6	0.0	0.6	0.0	0.6
Aug	0.1	1.4	2.7	9.3	0.7	0.3	1.9	2.5
Sep	0.3	2.9	0.9	0.7	24.5	1.3	0.4	1.4
	9.5	**6.1**	**5.2**	**11.8**	**28.6**	**6.5**	**2.6**	**5.3**

Sambalpur

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	6.6	7.8	24.3	17.9	20.8	15.9	16.3	12.0
Jul	12.7	3.2	5.8	0.0	26.2	11.7	7.1	1.9
Aug	1.8	0.2	0.1	0.2	0.8	0.0	0.1	0.0
Sep	14.6	3.3	29.6	8.5	23.3	6.6	25.2	5.4
	35.8	**14.5**	**59.9**	**26.6**	**71.1**	**34.2**	**48.7**	**19.3**

Kalahandi

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	0.3	1.1	2.5	0.3	8.9	0.0	0.6	0.2
Jul	0.8	0.0	6.7	5.1	0.5	1.3	4.2	0.2
Aug	0.9	0.4	1.2	3.0	3.4	1.1	0.1	0.0
Sep	3.0	0.3	0.0	1.0	2.9	0.3	0.3	0.0
	4.9	**1.8**	**10.4**	**9.5**	**15.6**	**2.8**	**5.2**	**0.4**

Sundergarh

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	2.8	1.5	0.0	0.0	0.5	0.2	0.4	0.6
Jul	1.0	0.5	0.0	0.9	46.7	1.2	0.0	1.3
Aug	0.4	0.0	0.1	0.8	0.1	0.1	59.2	0.1
Sep	0.1	0.8	1.1	0.0	0.2	0.0	0.5	0.2
	4.3	**2.8**	**1.3**	**1.7**	**47.7**	**1.5**	**60.1**	**2.2**

Bolangir

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	2.9	1.4	0.0	0.7	0.2	0.3	0.2	0.3
Jul	0.8	0.1					4.2	0.0
Aug	0.3	1.4					0.7	3.4
Sep	0.9	0.1	3.3	7.1	0.8	0.1	0.1	0.1
	4.9	**3.0**	**3.3**	**7.8**	**1.1**	**0.3**	**5.2**	**3.9**

Keonjhar

Months	Normal		Lognormal		Log Pearson		Extreme Value Type-1	
	50%	70%	50%	70%	50%	70%	50%	70%
Jun	0.1	1.6	3.5	2.2	1.3	1.7	0.7	0.6
Jul	0.0	0.3	0.7	14.1	2.5	0.9	0.5	0.8
Aug	0.2	0.5	1.3	0.0	0.5	0.2	1.7	0.1
Sep	0.5	1.7	0.0	0.6	0.0	0.7	0.0	0.8
	0.8	**4.1**	**5.6**	**16.9**	**4.3**	**3.5**	**2.9**	**2.4**

3.1.7 Number of drought, normal and surplus months in a year

Drought, normal and surplus months in a year were categorized based on the criteria of Sharma *et al.*, 1979 and results of past 44 years are presented in Annexure-2 .

If the mean rainfall is denoted by 'm', then the months receiving rainfall less than m/2 are defined as 'drought months', the months receiving rainfall more than 2m are defined as 'surplus months' and the months receiving rainfall in between these are defined as 'normal months'. The probability of occurrence of number of drought months in a year at different probability levels was also computed using Weibulls' formula and are presented in Table-9.

3.1.8 Wet-dry spell analysis : The wet-dry weeks based on probability of weekly 10, 20, 30 mm. rainfall were computed and are given in Fig.5(a-i) to determine approximate sowing period of direct seeded upland crops.

Initial probabilities (probabilities of week considering being wet or dry) of occurrence of weekly rainfall were determined using the follwong relationship;

(i) Probability of week considering being wet, P(W) = F(W)/N, Where F(W) is the frequency of wet weeks and N, the number of years of data used.

(ii) Probability of week considered being dry, P(D) = F(D) /N, F(D) is the frequency of dry weeks and N is the number of years of data used.

The conditional probabilities (probabilities of wet week followed by wet weeks) were determined using the following relationships :

$$P\left(\frac{W}{W}\right)=\frac{F(W/W)}{F(W/W)+F(D/W)}$$

F(W/W) is the frequency of wet week given that previous week was wet and F(D/W) is the frequency of dry week given that the previous week was wet. In general, from weekly rainfall probability analysis it can be said that (i) pre-monsoon shower may occur between 16th to 19th standard weeks, making off season tillage and preparation of seedbeds for rainy season upland crops feasible then (ii) rainfed, low water requiring, direct seeded upland crops can successfully be grown in upland rice soils during 24th -38th weeks and earliest sowing can be completed in 24th standard weeks (11th to 17th June) at 70% (dependable) probability level.

3.1.9 Mapping cold periods for growing winter crops

The key ecological characteristics of cold requiring crops like wheat, *Brassica*, potato, chickpea etc. are general adaptation of its photosynthetic and growth process to daily mean temperatures in the range of 15-19 ^{0}C and minimum temperature of 10-14 ^{0}C. In India both the

Table-9: Number of drought months (DM) in a year at different probability levels.

No. of DM in a year	Probability (%) of years												
	Cuttack	Puri	Balasore	Dhenkanal	Phulbani	Koraput	Kalahandi	Keonjhar	Ganjam	Mayurbhanj	Sambalpur	Sundergarh	Bolangir
8	2.22	6.25	2.22	2.22	-	-	3.36	-	-	2.32	3.33	4.51	6.81
7	6.66	12.5	6.66	4.44	7.77	2.32	9.09	7.77	-	4.65	10	10.23	29.89
6	17.77	22.5	14.44	15.55	17.77	8.14	22.72	7.13	7.77	12.79	20	18.18	30.68
5	31.11	37.5	29.99	33.33	35.55	18.6	39.77	32.22	26.88	29.06	37.77	31.81	45.74
4	46.66	58.75	54.44	52.22	54.44	40.69	60.23	55.55	52.22	46.51	58.88	54.54	71.59
3	69.99	80	73.33	73.33	71.11	76.77	81.81	73.33	75.55	67.44	77.77	78.14	88.63
2	88.88	92.5	87.77	87.77	87.77	88.37	94.32	86.66	93.33	84.88	92.22	4.51	97.72

start and end of the potential cold requiring crop season is limited by the onset and end of favorable weather mainly temperature, within the season itself warmer temperatures shorten the vegetative crop duration of these crops. This accounts for the decrease in the life duration and productivity of the cold requiring winter crops as one proceeds from North to South in the wheat, *Brassica* or potato belt of India. In Orissa, farmers cultivate cold requiring crops irrespective of their suitability of growing or getting net return from these crops. Hence an attempt has been made to analyze thermal regime to study feasibility of growing cold requiring crops commercially with good net economic return. In this study number of weeks of existence of favourable mean temperature of 15 – 19 °C and minimum temperature of 10 – 14 °C were identified and mapped into 3 zones (Fig. 4) using ARCVIEW GIS software. Study reveals that optimum mean favourable temperature of 15-19 °C and minimum temperature of 10-14 °C prevailed for 7-10 weeks in districts belong to agro-ecological subregions (AESR 12.1) where as in Costal belt of Orissa (AESR 12.2), these favourable temperature weeks prevailed only for 1-3 weeks. In Keonjhar, Dhenkanal the favourable temperature persisted for 5 – 7 weeks. It was also found that in coastal districts, mean and minimum temperatures for growing cold requiring crops existed upto 04 standard meteorological weeks (last week of January), which coincided with flowering stage of wheat, *Brassica*, chickpea etc. and tuber initiation stage of potato. But during pod formation stage of pulses and oilseeds, grain filling stage of wheat and tuber bulking stage of potato (05-08 standard meteorological weeks, first week of February onwards), minimum temperature increased abruptly, which might restrict accumulation of photosynthates towards economic part of these cold requiring crops because of higher respiration. As a result these crops record low productivity in the region. Therefore, based on availability of favourable thermal regimes, the cold requiring crops may be grown in districts of AESR 12.1 particularly in Mayurbhanj, Sambalpur, Bolangir, Phulbani, etc., but before initiating commercial cultivation of these crops economic feasibility should be studied.

3.2 Computation of reference evapotranspiration using climatological models through a developed software.

The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ET_o. The crop evapotranspiration under standard conditions, denoted as ET_c, is the evapotranspiration from disease free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions. Crop evapotranspiration can be calculated from climatic data and by integrating directly the crop resistance, albdeo and air resistance factors using empirical equations. Several researches have analyzed evapotranspiration at different locations based on availability of data. In this study, a software has been developed for computing reference evapotranspiration where users will have options for applying different formulae based on availability of data. (Table 10). The potential or reference evapotransipiration, computed with twenty climatological models is given Table 11. The major forms of software for computing daily, weekly and monthly reference evapotranspiration using different climatological models are given in page 57.

3.3 Computation of crop water requirements

The crop water requirement (ET_c) of major crops in the region was computed by multiplying the crop coefficients (K_c) with ETo at different growth stages (Doorenbos and Pruitt, 1977; Doorenbos and Kassam, 1979). The ET_o was computed by using CROPWAT 4.0 model (Table 12).

Table-10: Empirical formulae for determining reference or potential evapotranspiration

Sl. No.	Methods	Data Required	Formulae
1.	**Hargreaves**	Temperature	$ET_o = \frac{1}{\lambda} 0.0023 R_a \sqrt{TD} (T_c+17.8)$
2.	**Blaney Criddle**	Temperature	$ET_0 = (0.0173 \times TA - 0.314) \times K_c \times TA (DL/445.6) \times 25.4$
3.	**Behnkey and Maxey**	Temperature	$ET_o = \frac{T_c}{1.9} \times W_e$
4.	**Papadakis**	Temperature	$PET = \frac{0.5625 (e_{max} - e_{min-2}) \times 10}{ND}$
5.	**Thornthwaite**	Temperature	For daily $PET = \frac{K_a \times e \times 10}{ND}$
6.	**Hamon**	Temperature, Humidity	$PET = 0.0055 \times (DL/12)^2 \times (AH \times 2.88) \times 25.4$

7.	**Priestley Taylor**	Temperature, Humidity, Bright sunshine hour	$E_p = \propto \frac{1}{\lambda} \frac{\Delta}{(\Delta + v)} (R_n\text{-}G)$
8.	**Turc (1961)**	Temperature, Bright sunshine hour	$ET_o = 0.0.13 \frac{T_c}{(T_c+15)} (R'_s+50)$
9.	**Turc**	Temperature, Bright sunshine hour	$PET = 0.40 \frac{T_c}{(T_c+15)} \frac{(R'_s+50)}{ND}$
10.	**Jensen Haise**	Temperature, Bright sunshine hour	$ET_o = \frac{(0.025T_c + 0.08) R_s X11.6}{28.6}$
11.	**Modified Jensen Haise**	Temperature, Bright sunshine hour	$PET = 0.012 (TA - 15.4) R'_s \ X\ 0.408$
12.	**Makkink's**	Temperature, Bright sunshine hour	$PET = 0.61 \times 0.0171 \times R'_s \times \frac{\Delta}{\Delta + v} - 0.12$
13.	**Stephen and Stewart**	Temperature, Bright sunshine hour	$PET = (0.0082\ TA - 0.19) \times (R'_s/1500) \times 25.4$
14.	**Grassi**	Temperature, Bright sunshine hour	$PET = k \times C_{RS}.\ CT.\ C_{crc}.\ F \times (25.4)$ $= 0.537 \times 0.000675 \times R'_s (0.62 + 0.00559\ TA) \times 1.09 \times 25.4$
15.	**Corrected Penman**	Temperature, Humidity, Bright sunshine hour, Wind speed	$ET_o = c [\frac{\Delta}{\Delta + v} R_n + \frac{v}{\Delta + v} 2.7\ W_f (E_s - E_a)]$
16.	**FAO Penman**	Temperature, Humidity, Bright sunshine hour, Wind speed	$ET_o = [\frac{\Delta}{\Delta + v} R_n + \frac{v}{\Delta + v} 2.7\ W_f (E_s - E_a)]$
17.	**Kimberly Penman**	Temperature, Humidity, Bright sunshine hour, Wind speed	$ET_o = \frac{1}{\lambda} \frac{\Delta}{(\Delta + v)} (R_n\text{-}G) + \frac{1}{\lambda} \frac{v}{(\Delta + v)} 6.43\ W_f\ (E_s - E_a)$
18.	**Penman Monteith**	do	$ET_o = \frac{0.408\ \Delta\ (R_n - G) + v\ [900/(T_c+273)]\ u_2\ (E_s - E_a)}{\Delta + v^*}$

19.	Penman (1948)	do	$PET = KE_0$ $E_0 = \left(\frac{\Delta}{\Delta+\nu} Qn + \frac{\nu}{\Delta+\nu} E_a\right)$
20.	FAO-24 Radiation	do	$ET_o = x\left[\frac{\Delta}{\Delta+\nu} + \frac{R_n}{\lambda}\right] - 0.3$ $X = 1.066 - 0.13 \times 10^{-2} RH_{mean} + 0.045 U_d - 0.20 \times 10^{-3} RH_{mean} \times U_d - 0.315 \times 10^{-4} \times RH^2_{mean} - 0.11 \times 10^{-2} \times Ud^2$ $RH_{mean} = \frac{RH_{mean} + RH_{min}}{2}$ (%), U_d = daytime wind speed (m/s)

Notations:

T_c: Average of maximum and minimum temperature (^{0}C) , TD : Difference between maximum and minimum temperature (^{0}C), TA : Mean temperature (^{0}F), R_a: Extraterrestrial Solar Radiation ($MJm^{-2}day^{-1}$), λ : Latent heat of vapourisation ($MJ\ Kg^{-1}$), Δ= slope of SVP curve ($kPa\ ^0C^{-1}$), K_c: Crop coefficient (from table of Alfaalfa), DL: Day length (hour), W_e: Water requirement const = 0.3263, e_{max}: saturated vapour pressure at mean monthly max temperature. (mb), e_{min-2}: saturated vapour pressure corresponding to dew point temperature. (mb), ($T_{dew} = T_{min}$ -2), ND : No of days in the month, I= Annual seasonal heat Index, a: An empirical exponent, Ka : Adjustment factor (Michael 1978), AH : Absolute humidity in gm^{-3} , e_d: Actual Vapour Pressure (mb), e_s: Saturated Vapour Pressure (mb), TK : Mean air temp (^{0}K).

R_s = Solar radiation (mm/day), $\nu* = \nu(1+0.34\nu_2)$

ν= Psychometric Constant, R_n: Net Radiation ($MJm^{-2}day^{-1}$), G: Soil heat flux density ($MJm^{-2}day^{-1}$), Rs': Solar radiation ($cal\ cm^{-2}\ day^{-1}$), k: constant, C_{RS}: Co-efficient of radiation, C_{crc}: Co-efficient representing plant cover at 1.0 for medow, c: Penman correction factor, W_f: wind function, RH_{max}: Maximum Relative Humidity (%), RH_{min}: Minimum Relative Humidity (%)

U_2: wind speed at 2m height (m/s), E_a : Actual vapour Pressure (kPa), Es : Saturated vapour Pressure (kPa), ν^* : Modified Psychometric constant, K = Constant, $\propto$: Albedo = 0.23,

f : Blaney Criddle factor, n : Bright Sunshine hour (hrs), N : Maximum Daylight Hour, p : Percentage of annual daytime hour, RH_{mean} : Mean Humidity (%),

ET_o : Reference evapotranspiration (mm/day), PET : Potential evapotranspiration (mm/day)

E_0 = Potential evaporation (mm/day)

Table-11: Computed PET or ET_o for Dhenkanal with different climatological models

Methods	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hargreaves	4.36	6.02	7.2	8.91	9.6	8.16	5.95	6.72	4.99	5.08	4.6	3.94
Blaney Criddle	2.77	3.67	4.66	6.87	7.99	8.22	7.59	7.54	6.14	4.92	3.48	2.55
Behnkey Maxey	3.49	3.99	4.41	5.6	5.81	5.63	5.18	5.27	4.89	4.5	3.75	3.3
Papadakis	4.36	8.12	8.74	13.73	14.74	11.5	6.86	8.28	5.88	5.8	5.15	3.69
Thornthwaite	2.45	3.39	3.95	12.29	15.64	12.83	7.44	8.22	5.88	4.19	2.83	2.29
Hamon	3.67	4.17	4.61	7.36	9.43	12.28	12.15	12.29	9.43	7.02	4.41	3.35
Pristley Taylor	3.01	3.41	4.88	6.35	6.79	6.11	5.46	5.19	4.41	4.76	3.37	2.75
Turc (1961)	3.51	3.67	5.01	5.86	5.98	5.06	4.51	4.27	3.79	4.54	3.77	3.37
Turc	3.48	4.03	4.97	6.01	5.93	5.19	4.47	4.24	3.89	4.5	3.86	3.35
Jensen Haise	4.18	4.65	6.87	9.23	9.65	7.89	6.64	6.31	5.32	6.22	4.66	3.91
ModJen Haise	4.56	4.96	7.21	9.37	9.75	8.01	6.81	6.46	5.5	6.51	5.02	4.32
Makkink	2.86	2.94	4.21	4.95	5.04	4.19	3.7	3.46	3.04	3.73	3.06	2.74
Stephen SteWart	2.64	2.92	4.29	5.7	5.94	4.87	4.11	3.91	3.3	3.88	2.93	2.48
Grassi	4.22	4.3	5.95	6.87	7.02	5.85	5.19	4.88	4.31	5.32	4.48	4.1
Correct Penman	4.44	5.22	6.44	7.69	7.8	6.99	6.2	6.14	5.52	5.9	4.84	4.12
FAO Penman	3.7	3.51	6.06	8.58	9.48	9.63	9.47	8.95	7.49	7.81	4.55	3.31
Kimberly Penman	3.52	4.34	5.05	6.96	7.28	5.97	4.89	4.67	4.03	4.55	3.73	3.25
Penman Monteith	3.63	4.87	6.54	8.46	9.21	6.73	4.93	4.58	3.98	4.42	3.71	3.44
Penman(1948)	4.83	4.64	8.24	9.62	11.09	8.67	7.4	6.77	5.15	7.35	5.2	4.69
FAO Radiation	4.14	4.51	6.74	8.11	8.25	6.2	4.88	4.48	3.93	5.02	4.39	4

Table-12: Computed reference (ET_0) crop evapotranspiration (mm) with CROPWAT 4.0 model

Districts	Months											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Dhenkanal	112	137	195	240	279	207	136	146	120	133	108	105
Phulbani	78	87	136	168	174	147	105	108	99	105	78	68
Kalahandi	84	95	149	180	198	156	112	115	108	112	84	74
Koraput	77	87	136	156	170	132	93	99	93	103	78	71
Mayurbhanj	77	87	152	171	192	141	108	112	102	108	81	71
Sambalpur	90	109	158	198	236	108	112	118	111	118	90	81
Sundergarh	108	125	192	225	254	191	118	119	115	129	111	100
Bolangir	96	109	149	207	242	174	115	118	111	121	96	84
Cuttack	93	104	176	198	220	159	115	118	111	124	96	84
Balasore	96	109	180	201	217	156	118	121	111	118	96	87
Ganjam	124	123	170	162	177	150	121	130	123	136	126	118
Puri	124	129	167	159	174	150	127	136	132	146	126	121
Keonjhar	87	104	164	192	211	159	112	112	105	124	90	84

Climatic data source: Climatological Table, IMD, New Delhi

Table-13 (a) : Computed crop water requirements (mm) of major crops using CROPWAT 4.0 model

Crop	Dhenkanal	Bolangir	Sambalpur	Mayurbhanj	Koraput	Sundergarh
Blackgram (K)	416	324	357	315	282	374
Blackgram (R)	339	279	272	237	232	330
Cowpea	407	351	349	308	275	366
Greengram (K)	416	359	357	315	282	374
Greengram (R)	339	279	272	237	232	330
Groundnut (K)	494	427	424	378	339	447
Groundnut (R)	469	386	378	329	282	455
Maize (K)	382	330	327	290	259	343
Maize (R)	322	264	258	224	220	313
Pigeonpea (K)	552	479	474	426	385	504
Sesamum	238	207	201	186	178	231
Sugarcane	2090	1760	1745	1517	1391	1939
SummerRice	915	754	750	641	595	863
WinterRice	717	623	614	555	508	662
SpringWheat	484	397	390	338	326	468

K=Kharif, R= Rabi

Table 13 (b) : Computed crop water requirements (mm) of major crops using CROPWAT 4.0 model.

Crop	Cuttack	Balasore	Ganjam	Phulbani	Puri	Keonjhar	Kalahandi
Blackgram (K)	347	345	347	309	359	335	330
Blackgram (R)	283	291	342	230	347	275	248
Cowpea	340	337	339	302	351	328	323
Greengram (K)	347	345	347	309	359	335	330
Greengram(R)	283	291	342	230	347	275	248
Groundnut (K)	417	414	431	371	448	402	396
Groundnut (R)	390	401	448	317	451	379	343
Maize(K)	319	317	322	285	334	308	304
Maize(R)	267	276	322	217	325	260	235
Pigeonpea	471	468	507	418	529	455	445
Sesamum	214	215	280	183	293	206	194
Sugarcane	1726	1740	1733	1471	1753	1672	1585
SummerRice	744	759	721	614	714	723	667
WinterRice	619	616	695	702	725	596	580
SpringWheat	400	412	451	326	453	389	353

K=Kharif, R= Rabi

3.4 Computation of net radiation

The net radiation (R_n) is the difference between the incoming net shortwave radiation (R_{ns}) and the out going net long wave radiation (R_{nl}). It is the energy available for different physiological and biophysical processes in plants life. The net radiation can be equated to all the separate forms of energy that contribute to the energy flow away from the sites of absorption of radiation; thus R_n = H+ LE+G+Q+F

H = Sensible heat flux, LE= Latent heat flux, G = Conduction of heat into the ground, F = Photosynthetic rate, Q = Conduction of heat into biomass. Most of the time instrumental measurement of net radiation by net radiometer is not cost effective, also time consuming and tedious.It is therefore, urgently felt to develop an alternative way for computing net radiation using routinely measured weather parameters. A software (ENERBAL) using "Visual Basic" has been developed for computing net radiation at any location. Using that software, mean monthly net radiation (MJ M^{-2} day^{-1}) for different undivided districts of Orissa were derived and results are presented in the Table 14.

Net radiation (R_n)= R_{ns} - R_{nl} ; R_{ns} = Net shortwave radiation (MJm^{-2} day^{-1}), R_{nl} = Net outgoing longwave radiation (MJm^{-2} day^{-1}).

where, $R_{nl} = \sigma \left[\frac{T^4_{max,K} + T^4_{min,K}}{2} \right] (0.34 - 0.14\sqrt{e_a})(1.35 \frac{R_s}{R_{so}} - 0.35)$

$R_{ns} = (1-\alpha) R_s$, $R_{so} = (a_s + b_s) R_a$, $R_s = (a_s + b_s n/N) R_a$. $N = \frac{24}{\pi} \omega_s$

ω_s = arc Cos [- tan(φ) tan(δ)], $Ra = \frac{24(60)}{\pi} G_{sc} d_r [\omega_s \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\sin(\omega_s)]$

φ (Radians)= $\frac{\pi}{180}$ (Latitude in decimal degrees)

$d_r = 1+0.0033 \text{ Cos}(\frac{2\pi}{365} J)$, $\delta = 0.409 \text{ Sin } (\frac{2\pi}{365} J - 1.39)$.

$$e_a = \frac{e^0(T_{min}) \frac{RH_{max}}{100} + e^0(T_{max}) \frac{RH_{min}}{100}}{2}, \quad e^0(T) = 0.6108 \exp\left[\frac{17.27\, T}{T + 237.3}\right]$$

Where,

T : Air temperature (^{0}c)

RH_{max} : Maximum relative humidity (%), RH_{min} : Minimum relative humidity (%)

R_a : Extraterrestrial radiation (MJm^{-2} day^{-1}), G_{sc} : Solar Constant = 0.082 MJm^{-2} day^{-1}

d_r : Inverse relative distance earth from sun, ω_s : Sunset hour angle (Radian)

φ: Latitude (Radian), δ : Solar declination (Radian)

R_s: Incoming solar or shortwave radiation (MJm^{-2} day^{-1})

n : actual duration of sunshine (hours)

N : maximum possible duration of sunshine or daylight hours (hour)

a_s : regression constant, expressing the fraction of extraterrestrial radiation reaching the earth (n=o)

a_s+b_s : fraction of extraterrestrial radiation reaching the earth on clear sky (n=N)

R_{so} : clear-sky solar radiation ($MJm^{-2}\ day^{-1}$), α : albedo

σ: Stefan-Boltzman constant ($4.903 \times 10^{-9}\ MJm^{-2}\ day^{-1}$)

T_{max}, κ = Maximum absolute temperature (k =^{0}c+273.16)

T_{min}, κ = Minimum absolute temperature (k=^{0}c $\pm$273.16)

e_a : actual vapour pressure. (κP_a)

Software for computing reference evapo-transpiration with different climatological models

Table-14: Computation of net radiation ($MJ\ m^{-2}\ day^{-1}$) in different undivided districts of Orissa

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Balasore	8.82	9.74	14.04	16.43	17.12	14.67	13.34	12.5	11.18	12.81	9.79	8.16
Sambalpur	8.25	9.04	12.23	14.11	15.11	14.27	13.29	12.41	11.02	12.33	9.26	7.7
Cuttack	8.76	9.56	13.54	15.98	16.85	14.55	13.29	12.43	11.15	12.77	9.75	8.12
Puri	9.33	10.31	14.71	16.76	17.31	14.73	13.33	12.48	11.18	12.95	10.04	8.47
Ganjam	9.52	10.4	14.66	16.65	17.24	14.64	13.31	12.47	11.22	13.09	10.19	8.73
Mayurbhanja	8.23	9.14	13.37	15.76	16.76	14.76	13.2	12.54	11.11	12.58	9.44	7.99
Kalahandi	8.07	9.08	12.18	14.13	14.96	14.08	13.04	12.2	10.9	12.37	9.43	7.74
Bhubaneswar	8.75	9.81	13.96	16.29	16.78	14.52	13.3	12.45	11.2	12.93	9.87	8.05
Bolangir	8.48	9.27	12.44	14.65	15.58	14.18	13.16	12.31	11.0	12.45	9.57	7.88
Keonjhar	8.13	9.01	12.76	14.95	16.07	14.36	13.13	12.27	10.89	12.19	9.07	7.5
Koraput	8.71	9.44	12.95	14.86	15.38	13.69	12.62	11.89	10.75	12.29	9.71	8.26
Phulbani	8.57	9.31	12.6	14.42	14.95	13.93	12.95	12.12	10.83	12.3	9.65	8
Dhenkanal	8.59	9.35	12.75	15.24	16.19	14.67	13.48	12.8	14.39	9.33	9.47	8.04

4. DROUGHT ANALYSIS

Drought is a protracted period of deficient precipitation resulting in extensive damage to crops and hydrological imbalance. It is a period of abnormally dry weather sufficiently prolonged for the lack of precipitation to cause a moisture deficiency with respect to man's usage of water. During drought, actual moisture supply at a given place rather consistently falls short of the climatically expected and shortage in the appearance of natural waters with respect to normal is expected. Drought in India generally results from anomalies in large-scale circulation of the atmosphere and oceans as well as due to occurance of regional dry spells. The El Nino phenomenon in the Pacific Ocean may provide fairly short-term prediction of drought in India.

4.1. Types of drought

Based on impacts of deficit precipitation on different components of hydrological cycle and biosphere, drought may be classified into four categories.

4.1.1. Meteorological drought: Meteorological drought is simply the departure of precipitation from normal over some period of time. Meteorological measurements are the earliest indications of drought.

4.1.2. Agricultural drought: Agricultural drought occurs when there is not enough soil moisture to meet the needs of water requirements of a particular crop at a particular time. Depending on the time of occurrence of drought and general climatic conditions of the region, agricultural drought may be classified into 5 categories *viz.*, (a) early season drought, (b) Mid-season drought, (c) Late season or terminal drought, (d) Apparent drought and (e) Permanent drought.

Agricultural drought can be assessed by

(i) assessment of transpiration index, which is the ratio of actual amount of watter transpired (AT) to PT (potential transpiration) may be termed as Transpiration coefficient (K), the rational measure of crop water spread.

(ii) Moisture defict index (MDI)

$$MDI = \frac{(AET - PET)}{PET} \times 100$$

Then, PET =Potential evapotranspiration, AET= Actual evapotranspiration.

4.1.3. Hydrological drought

Hydrological drought refers to deficiencies in surface and subsurface water supplies. When precipitation is reduced or deficient over an extended period of time, this shortage will be reflected in declining surface and subsurface water levels.

4.1.4. Socio-economic drought

Socio-economic drought occurs when physical water shortage starts to affect economic condition of the people, individually or collectively.

Therefore, different types of drought occurs in the following sequence.

Meteorological drought > Agricultural drought > Hydrological drought > Socio-economic drought.

4.2 Measurement of drought

There are several drought indices that measure how much precipitation for a given period of time has deviated from historically established normals. Drought indices are normally continuous functions of rainfall and/or temperature, river discharge or other measurable variable. But rainfall data are widely used to calculate drought indices for drought measurements because long-term rainfall records are often available. Some of the well-known indices for drought measurements are Palmer drought severity index, Crop moisture index, Standardized precipitation index, Surface water supply index, Reclaimation drought index, Bhalme and Mooley index, Deciles, National rainfall index, Percentage of normal rainfall etc (Table-15,a). In this study, using percentage departure from normal and standardized precipitation index (SPI) were used for drought analysis.

Table-15 (a): The characteristics of some drought indices

Index and its developer	Input data*	Time scale	Brief description
PDSI (Palmer drought severity index):Palmer (1965)	P,T,CPI	Weekly, biweekly, monthly	The PDSI is a soil moisture algorithm calibrated for relatively homogenous regions. It is based on moisture inflow, outflow and storage. Many US government agencies and states still rely on the PDSI to trigger drought relief programs.
Crop moisture index: Palmer (1968)	P,T,ET, L, RO	Weekly	A PDSI derivative, which reflects moisture supply in the short term across major supply in the short term across major crop-producing regions.
SPI (Standardized precipitation index) : McKee *et al.*, (1993)	P	Multiple of months	An index based on the probability of precipitation for any time scale.
Surface water supply index (SWSI): Shafer and Dexman (1982): Garen (1993)	P,sn,RO, reservoir storage	Monthly	The SWSI is based on probability, similar to the SPI, but it also considers the snow pack, runoff, and reservoir storage.
Reclamation drought index (RDI): Bureau of Reclamation(USA)	P	Monthly	RDI is calculated on the river basin scale, since the index is unique to each river
BMI: Bhalme and Mooley (1979)	P	Monthly	The BMI models the percentage departure of P from the long-term average using an algorithm similar to that of the PDSI
Deciles: first promoted by the Australian drought authorities who currently use it	P	Monthly	The deciles method groups monthly precipitation occurrences into deciles. By definition 'much lower than' normal precipitation cannot occur more often than 20 % of the time.
Precipitation anomaly classification (PAC): Janowiak *et al.*, (1986)	P	Monthly	The PAC is an improvement of the Australian 'decile' method of drought classification
National rainfall index (NRI) : Gommes and Petrassi(1994)	P	Monthly	The NRI patterns abnormalities of precipitation on a continental scale.
Percentage of normal (PN)	P	Monthly	PN is obtained by dividing P with the normal value. It is a simple calculation well suited to the needs to TV weather people and general audiences.

**P= precipitation, T=temperature, ET = evapotranspiration, L=soil moisture, RO= runoff , sn = snowpack*
Source ; Ntale and Gan (2003).

Remote Sensing technology in drought assessment

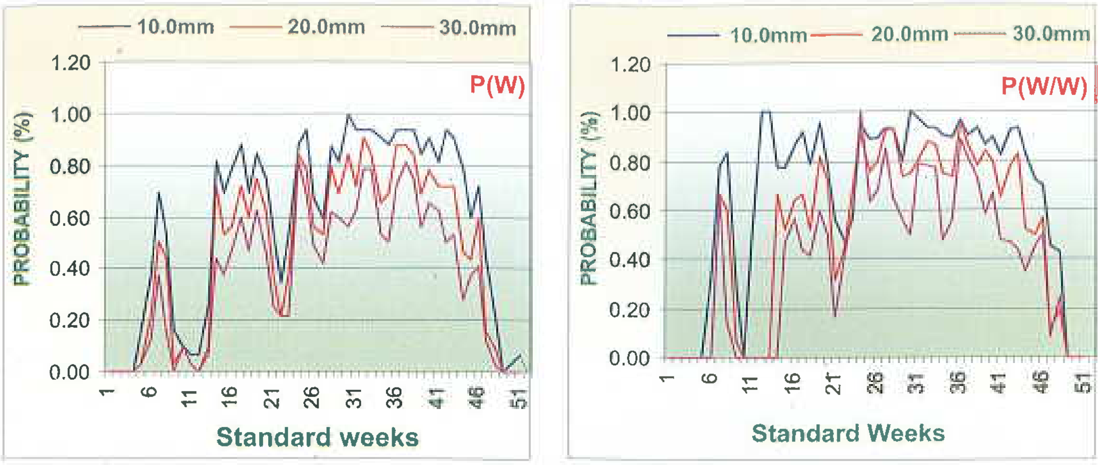
Traditional methods of drought assessment and monitoring rely on rainfall data, which are limited in the region, often inaccurate and most importantly difficult to obtain in near-real time. On the other hand, the satellite-sensor data are consistently available and can be used to detect onset of drought, its duration and magnitude. The crop yield can be predicted 5 to 13 weeks prior to harvest using remote sensing techniques. Vegetative conditions over the world are reported occasionally by NOAA using the Advanced Very High Resolution Radio meter (AVHRR) data. The spatial resolution of AVHRR data is 10 km, which is likely to be coarse for effective drought monitoring at smaller scales. Recently with Moderate-Resolution Imaging Spectro-meter (MODIS) composited reflectance data are made available at no cost every 8 days by NASA and USGS, through the Earth Resources Observation Systems (EROS) data centre. The different drought-related indices derived from remote sensing data are given in Table 15 (b).

Table-15(b): Drought-related indices derived from remote sensing data

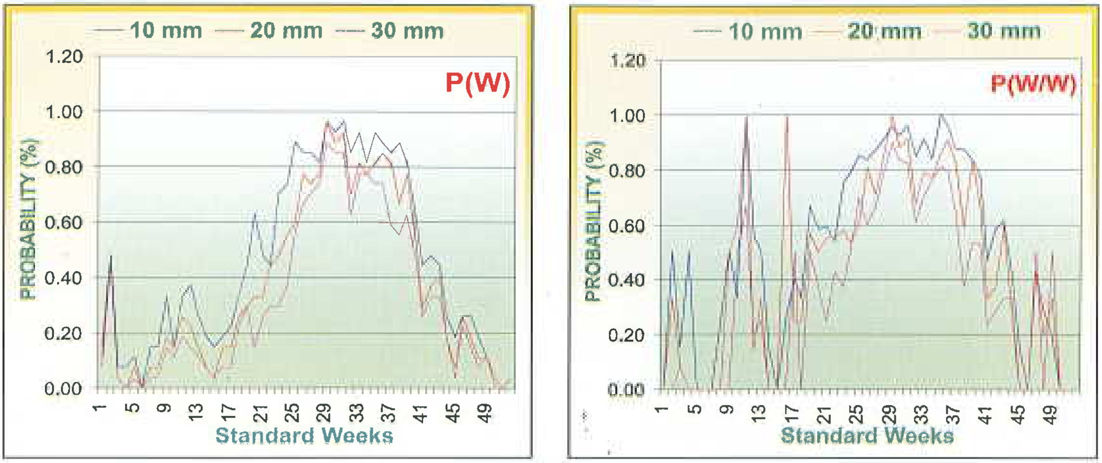
Normalized difference vegetation Index (NDVI)	NDVI = $(\gamma_{NIR} - \gamma_{red}) / (\gamma_{NIR} + \gamma_{red})$ Where γ_{NIR} & γ_{RED} are the reflectance in the near infra-red & red bands respectively. NDVI ranges from -1 to 1.	Drought severity = $NDVI_i - NDVI_{mean,m}$ Where $NDVI_i$ is the current NDVI for month i and $NDVI_{mean,m}$ is the long-term mean NDVI for a calendar month m (m= 1,2,....,12).
Enhanced vegetation index (EVI)	Unlike NDVI, enhanced vegetation index (EVI) takes the advantage of multiple bands. The EVI is calculated as: $$EVI = G^* \frac{P_{NIR} - P_{Red}}{P_{NIR} + C_1{}^* P_{Red} - C_2{}^* P_{Blue} + L}$$ Where, G = Gain Factor P_{NIR} = NIR Reflectance, P_{Red} = Red Reflectance, P_{Blue} = Blue Reflectance C_1 = Atmosphere Resistance Red Correction Coefficient C_2 = Atmosphere Resistance Blue Correction Coefficient L = Canopy Background Brightness correction Factor	The coefficients adopted in the EVI algorithm are, L= 1, C1= 6, C2=7.5, and G (gain factor) =2.5. EVI is more sensitive in high biomass regions and ensures the improved monitoring through a reduction in atmosphere influences.
Vegetation condition index (VCI)	The VCI shows, effectively, how close is the current months NDVI to the minimum NDVI calculated from the long-term record of remote sensing images. $$VCI_J = \frac{(NDVI_i - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} X\ 100$$	Where, $NDVI_{max}$ and $NDVI_{min}$ are calculated from the long-term record (e.g. 20 years) for that month (or week), and j is the index of the current month (week). In dry month when the vegetation condition is poor and the VCI is close or equal to zero. On the other hand, with optimal condition of vegetation, the VCI is close to 100%. The VCI of 50% reflects a fair vegetation condition.
Temperature condition index (TCI)	Unlike VCI, the TCI includes the deviation of the current months (weeks) value from the recorded maximum. $$TCI_J = \frac{(BT_{max} - BT_j)}{(BT_{max} - BT_{min})} X\ 100$$	Where BT is the brightness temperature (e.g. AVHRR band 4). Under the atmospheric conditions, objects emit heat in this thermal band. The max and min values of BT are calculated from the long-term (e.g. 20 years) record of remote sensing images for each calendar week or month j. The low TCI value (close to 0%) indicates the very high temperature in that month or week.

Fig. 5 : Initial (P.W.) and conditional probabilities (P, W/W) in different standard weeks.

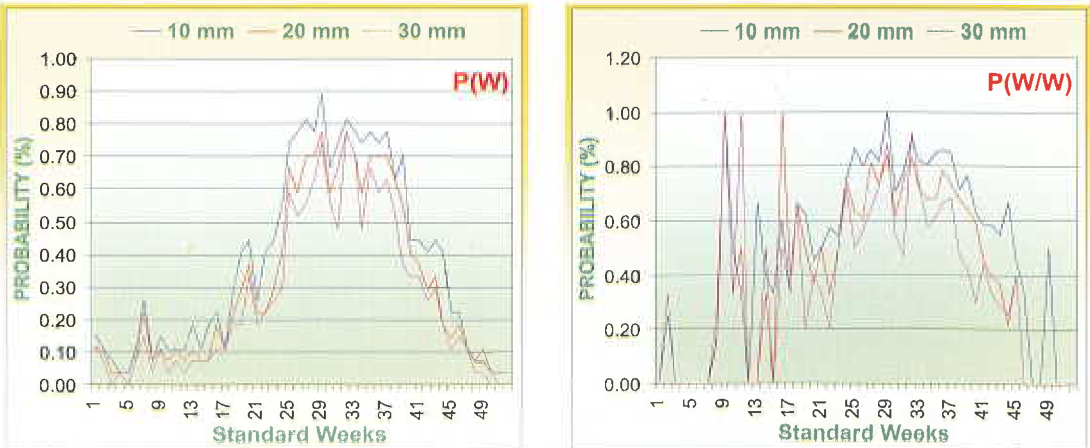
(a) Dhenkanal



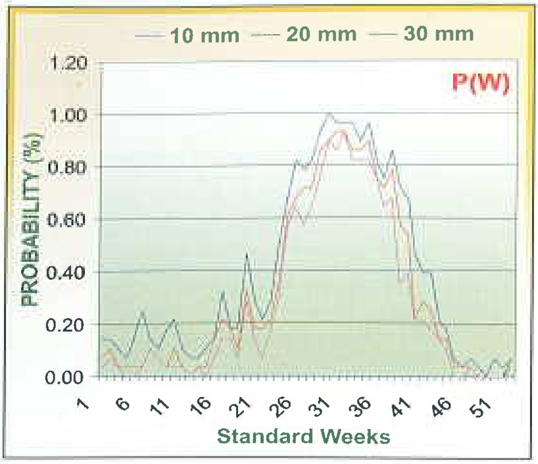
(b) Cuttack

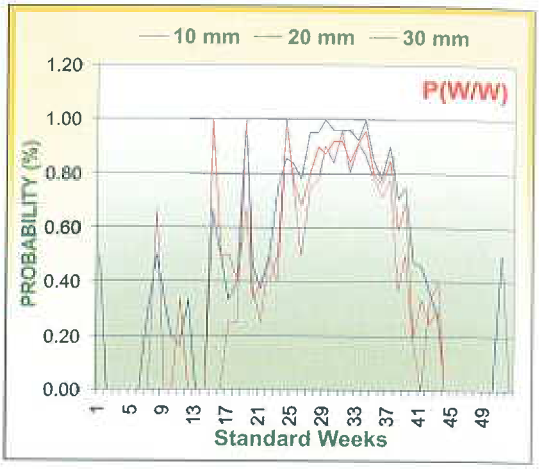


(c) Puri

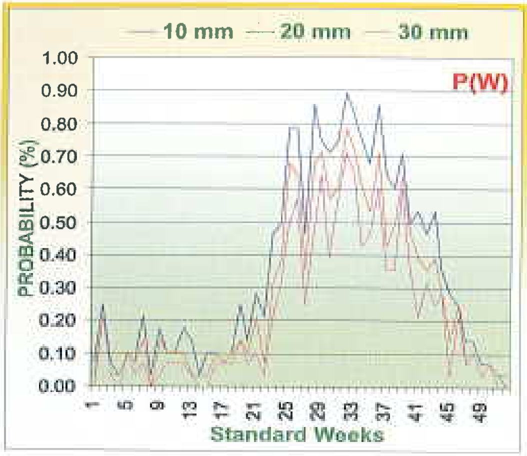


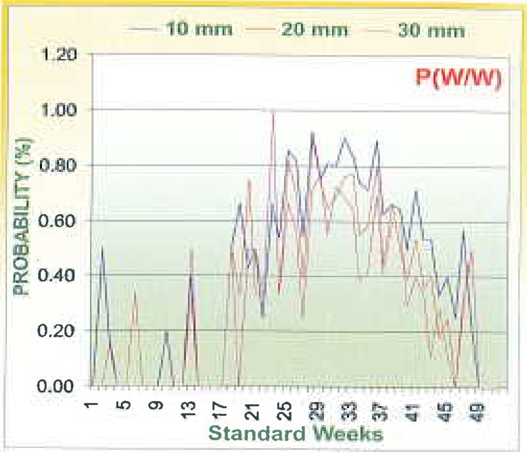
(d) Sambalpur



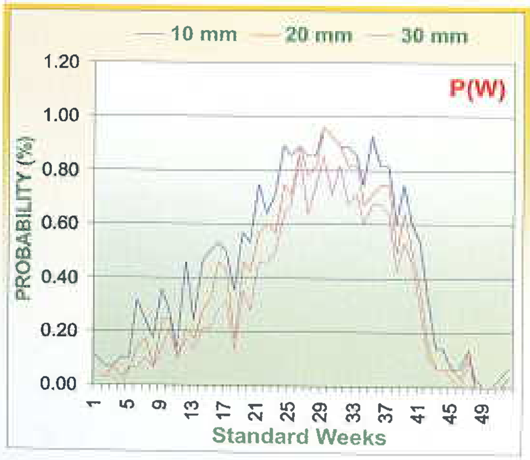


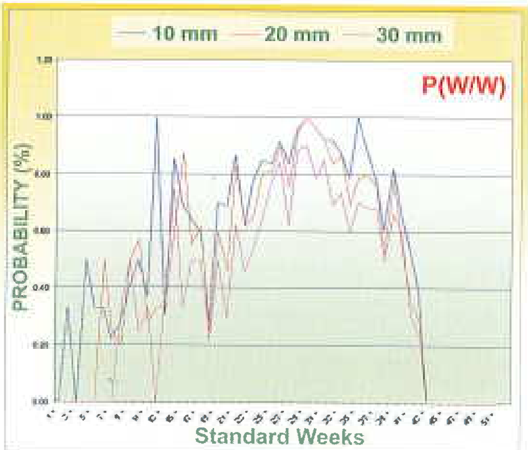
(e) Ganjam



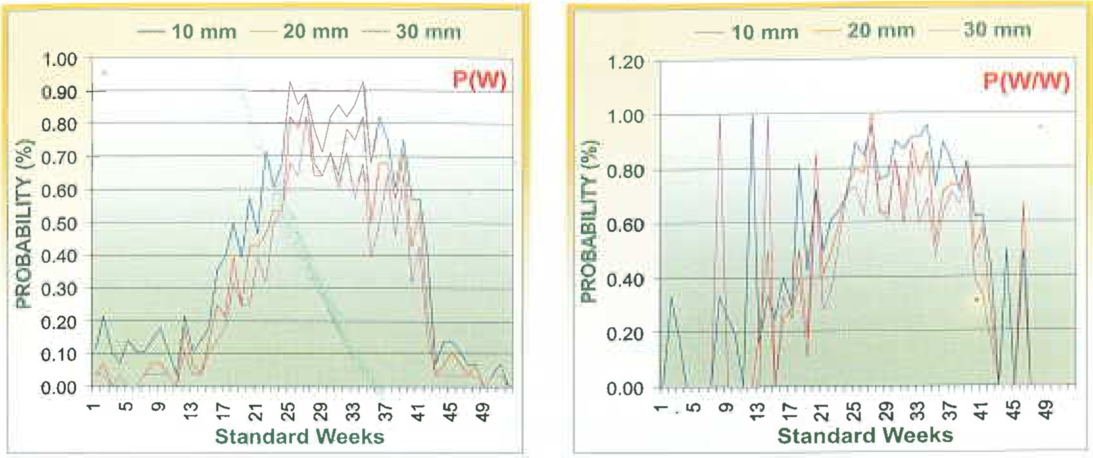


(f) Kalahandi

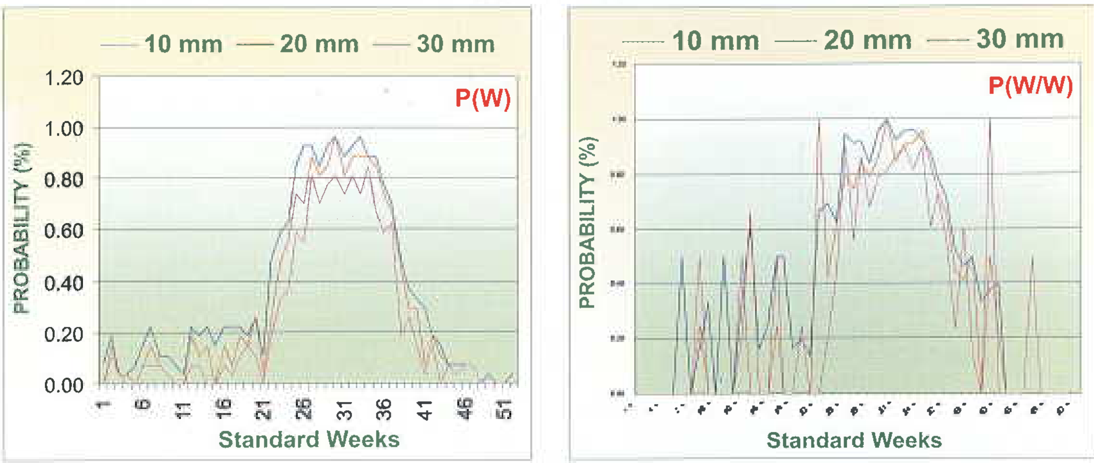




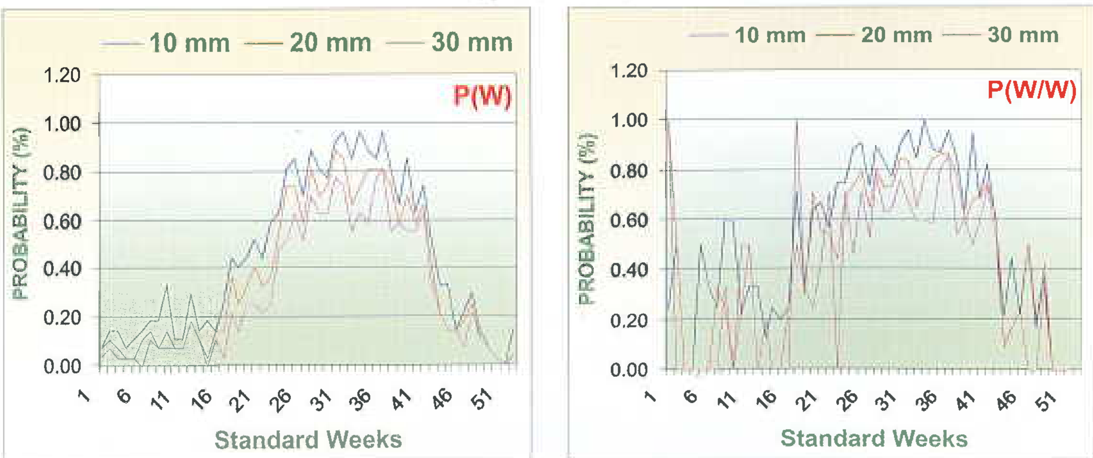
(g) Koraput

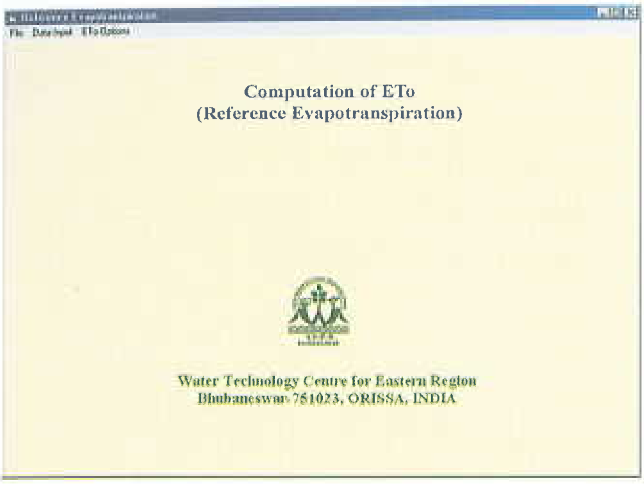


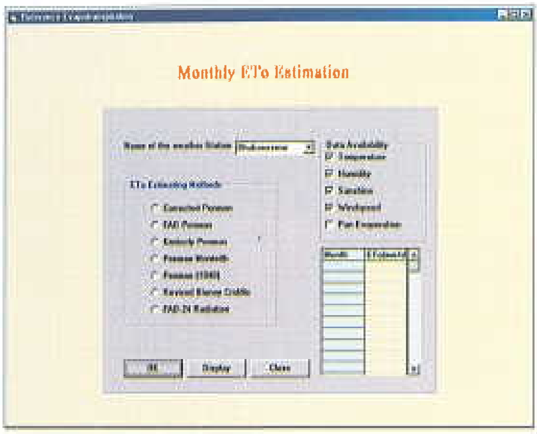
(h) Bolangir

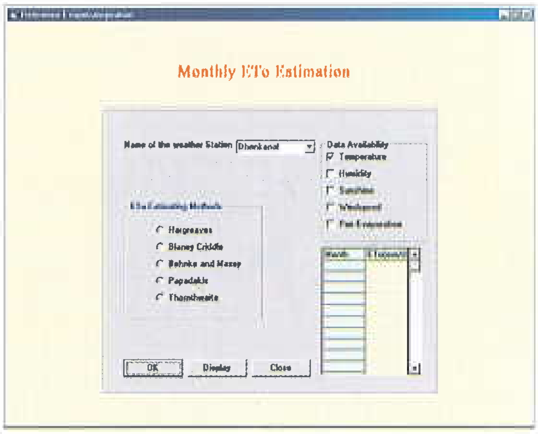


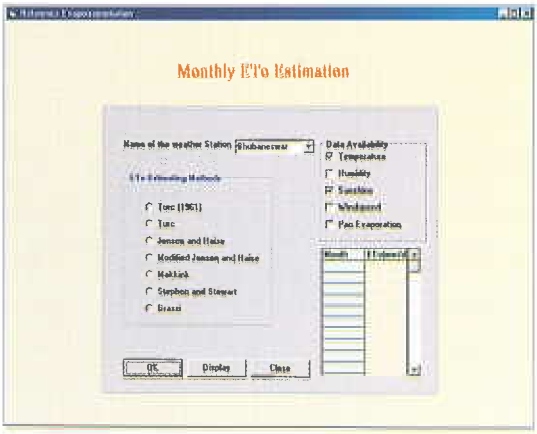
(i) Balasore

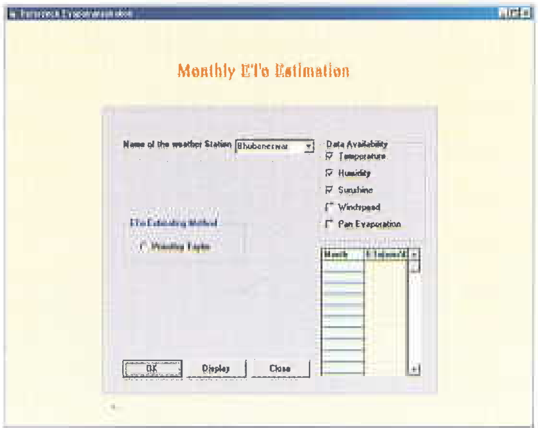












Sample forms of computing reference evapotranspiration withdifferent climatological models

4.2.1. Drought analysis using percentage departure from normal:

Based on the available rainfall data, the percentage departure from normal (P.D.) has been calculated using the following formula,

$$P.D. = [(R_i - \bar{R}) / \bar{R}] \times 100$$

where, R_i = actual rainfall for the year (mm).

$\bar{R}$ = Long Period Average (LPA) rainfall for 1960-2003 (mm).

Table-16: Frequency of meteorological drought between 1960-2003 based on departure of actual annual rainfall.

Drought Frequency between 1960-2003			Decade-wise drought frequency (Moderate / severe)			
DISTRICTS	MOD	SEVERE	1960-69	1970-79	1980-89	1990-2003
Dhenkanal	9	1	4	2	1	3
Cuttack	9	0	2	3	1	3
Puri	7	1	1	3	2	2
Balasore	11	0	3	3	5	0
Phulbani	14	1	2	6	3	3
Koraput	3	0	1	2	0	0
Kalahandi	4	2	2	1	1	2
Keonjhar	11	0	3	4	0	4
Ganjam	5	0	3	0	1	1
Mayurbhanj	7	0	2	2	1	2
Sambalpur	10	1	3	4	4	3
Sundergarh	18	2	5	4	5	5
Bolangir	16	2	2	6	6	4

MOD= Moderate drought, SEVERE= Severe drought.

Table-17: Frequency of meteorological drought between 1960-2003 based on departure of one, two and three month's actual rainfall.

Districts	June		July		August		September		Jul-Aug		Aug-Sept		Jul-Sept	
	MOD	SEVERE	MOD	SEVERE	MOD	SEVERE	MOD	SEVERE	MOD	SEVERE	MOD	SEVERE	MOD	SEVERE
Dhenkanal	6	6	15	5	11	2	12	2	10	3	7	0	7	1
Cuttack	12	7	12	3	2	1	6	5	9	0	4	0	6	0
Balasore	7	2	8	5	6	2	9	3	6	2	6	1	5	1
Puri	10	11	8	2	5	2	12	3	10	0	4	1	6	2
Sambalpur	14	10	23	3	8	5	11	6	14	2	12	2	16	1
Ganjam	8	7	6	3	8	3	16	1	9	0	6	1	5	1
Koraput	9	4	8	0	12	3	16	1	5	1	11	0	1	0
Kalahandi	10	9	6	3	7	4	11	6	9	2	11	2	8	1
Phulbani	15	12	15	5	11	4	14	7	11	4	12	3	10	3
Keonjhar	9	5	22	5	5	1	11	2	11	2	5	0	7	1
Bolangir	13	14	10	5	9	8	12	12	15	2	14	6	14	4
Sundergarh	14	9	23	8	16	7	7	7	18	4	7	0	21	3
Mayurbhanj	11	2	26	5	8	3	10	1	14	1	5	2	11	1

MOD= Moderate drought, SEVERE= Severe drought.

Table-18: Quantification of meteorological droughts with SPI based on two and three months' rainfall departure. (Data base ; 1960-2003)

Districts	Jul-Aug			Aug-Sept			Jul-Sept		
	MD	SD	ED	MD	SD	ED	MD	SD	ED
Dhenakanal	8	2	2	6	1	0	6	1	0
Cuttack	7	1	1	5	1	0	5	0	0
Puri	9	1	0	3	1	0	6	2	0
Sambalpur	10	2	1	9	4	0	12	2	1
Ganjam	7	2	0	5	2	0	4	1	0
Koraput	5	2	1	9	1	1	9	1	0
Kalahandi	8	2	1	10	2	1	7	2	0
Phulbani	11	3	1	10	2	1	9	2	1
Keonjhar	9	2	2	4	1	0	5	1	0
Bolangir	12	4	1	11	3	1	11	2	1
Sundargah	14	3	2	5	1	0	14	3	2
Mayurbhanj	10	4	1	5	1	0	9	1	1
Balasore	5	3	1	5	2	1	5	1	0

MD= Moderately dry, SD = Severely dry, ED = Extremely dry

According to Indian Meteorological Department (IMD), meteorological drought is defined as occurring when the seasonal rainfall received over an area is less than 75% of its long period average value. It is further classified as 'Moderate Drought' if the rainfall deficit is within a range of 25% to 50% and 'Severe Drought' if departure exceeds >50%.

The area, whose drought frequency is >20% of the years, is classified as 'Drought area' and the area, whose drought frequency is >40% of the years, is classified as 'Chronically Drought affected area'.

Based on the criteria, the frequency of drought years was computed between 1960-2003 for different undivided districts of Orissa and are presented in Table 16.

Frequency of drought months between 1960-2003 based on departure of one, two and three month's actual rainfall was also computed and are presented in Table 17.

4.2.2. Drought analysis through standardized precipitation index (SPI)

Standardized precipitation Index (SPI) is based on the probability distribution of precipitation and requires less input data and calculation. A long-term precipitation record at the desired station is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI may be computed with different time steps (e.g. 1 month, 3 month, ...48 months). Positive SPI values indicate greater than median precipitation and negative value indicate less than median precipitation. The "drought" part of the SPI range is arbitrary split into "near normal" conditions (0.99<SPI<-0.99), moderately dry (-1.0 <SPI<-1.49), severely dry (-1.5<SPI<-1.99) and extremely dry (SPI<-2.0). A drought event starts when SPI value reaches –

1.0 and ends when SPI becomes positive again. The positive sum of the SPI for all the months within a drought event is referred to as "drought magnitude".

In contrast to all drought indices, which are based on water balance accounting scheme that involves precipitation, evapo-transpiration, runoff and soil moisture, the Standardized Precipitation Index (SPI) has been developed to quantify a precipitation deficit for different time scales.

- **Identification, quantification and classification of drought**

SPI1, SPI2 and SPI3 values were computed using monthly rainfall values for the period of 44 years (1960-2003) for undivided districts of Orissa. According to SPI1 values out of four rain receiving months of Southwest monsoon in India, July was most affected followed by June and September, while August was near normal.(Table.17). The results are in agreement with Indian Meteorological Department (IMD) definition of meteorological drought

- **Effect on production of *kharif* rice – a case study in Orissa drought 2000 in Orissa.**

Linear correlation coefficients were computed between productivity of major *kharif* crop in Orissa i.e. rice and SPI values, (SPI1, SPI2, and SPI3) to see the overall impact of drought on the production of rice in the state (Table 18). It is observed from the table that September is crucial month from rice production of view. The *kharif* rice is at reproductive stage in the month of September so drought at this stage is very critical for affecting productivity of rice adversely.

Table-19: Correlation coefficients of production of rice with SPI values (based on data of 2000).

Districts	Correlation coefficient (r) of rice with SPI of						
	June	July	August	September	Jun-jul	Jul-Aug	Aug-Sept
Cuttack	0.11	0.59**	0.37	0.57**	0.31	0.32	0.36
PURI	0.17	0.51*	0.39	0.53**	0.32	0.29	0.36
BALASORE	0.03	0.60**	0.32	0.59**	0.29	0.39	0.40
DHENKANAL	0.07	0.51*	0.29	0.57**	0.33	0.31	0.38
PHULBANI	0.19	0.45	0.34	0.56**	0.23	0.43	0.39
KORAPUT	0.18	0.57	0.34	0.67**	0.30	0.42	0.32
KALAHANDI	0.23	0.67	0.23	0.59**	0.31	0.34	0.36
KEONJHAR	0.23	0.56	0.45	0.64**	0.32	0.33	0.37
GANJAM	0.13	0.67	0.35	0.62**	0.33	0.38	0.38
MAYURBHANJ	0.16	0.49	0.35	0.67**	0.30	0.36	0.35
SAMBALPUR	0.17	0.56	0.34	0.61**	0.34	0.37	0.30
SUNDERGARH	0.0	0.67	0.50	0.62**	0.19	0.37	0.28
BOLANGIR	0.23	0.62	0.2	0.67**	0.30	0.41	0.27

**Significant at 1% level of probability, *Significant at 5% level of probability.

4.3 Predicted drought based on probability of annual rainfall

The probability of moderate and severe drought years are predicted by using the Weibull's and Log pearson methods and are presented in Table-20.

Table-20: Probability (%) of moderate and severe droughts in different undivided districts of Orissa

	Weibulls method		Log Pearson distribution	
Districts	Mod Drought	Severe Drought	Mod Drought	Severe Drought
Cuttack	22.23	2.23	20.00	1.00
Puri	25.00	5.00	28.00	8.00
Balasore	26.67	2.23	22.00	1.00
Dhenkanal	26.67	4.45	30.00	8.00
Koraput	29.31	2.33	31.00	1.00
Ganjam	20.00	2.23	25.00	1.00
Phulbani	35.56	4.45	40.00	8.00
Sambalpur	33.34	4.45	38.00	7.00
Sundergarh	50.00	9.10	46.00	13.00
Mayurbhanj	20.94	2.33	23.00	1.00
Bolangir	43.20	9.10	40.00	14.00
Kalahandi	28.19	6.72	32.00	9.00
Keonjhar	28.89	4.45	30.00	7.00

4.4 Impact of drought on ecosystem and livelihoods

4.4.1 Crop, human and livestock losses

In Orissa, agriculture during *kharif* season depends on performance of southwest monsoon. Due to occurrence of agricultural drought, rainfall and soil moisture are not sufficient to meet the water requirements of crops, as a result crop growth and development suffer. At early season 'sprouting drought' occurs in rice in Orissa. Dry spells or breaks in southwest monsoon at mid season affect tillering stage of rice. Sometimes crop also encounters moisture stress during the reproductive stage because of early withdrawal of southwest monsoon.

As a case study, drought in Orissa during 2000 was analysed and some of the impacts of drought 2000 in Orissa were (i) rice coverage shortfall - 1 lakh ha (ii) total loss of paddy - 3.9 lakh ha (iii) total loss of paddy in money value - Rs. 664 crore (iv) farm households affected - 7.6 lakh (v) loss of man days - 3.6 crore (Due to less employment opportunities, starvation death and migration of families to other parts of the country) (vi) increase in school dropouts/ child labour/ bonded labour (vii) 11% of children were acutely malnourished. The crop loss during drought year 2000 in Orissa is given in Table-21. The average income per household in Orissa during drought year and nature of consumption adjustment in drought year are given in Table-24 and 25, respectively.

With the failure of southwest monsoon again in 2002, Orissa government declared all the 30 districts and 283 blocks, with anticipated crop loss of 50 % and above during the *Kharif* season as drought affected. During drought 2002, more than 90 % crop loss was reported from Kendrapara (94.2 %, worst hit district), Balasore (94.1 %), Gajapati (92.6 %), Jajpur (91.1 %). More than 50 percent crop loss was reported from Kandhamal, Rayagada, Nayagarh, Deogarh, Bolangir, Bhadrak, Nabarangpur, Jharsuguda and Nuapada.

Table-21: Crop loss during the drought year in Orissa- a case study of 2000 drought.

Sl. No	Type of land	Extent of land affected (In Lakh Hectare)	Average yield Per hectare (Quintal)		Total yield of the state		Estimated loss of crop yield (in Lakh ton)	Amount of loss in Rupees (Crore)
			Normal year	2000	Normal Year (in Lakh ton)	2000 (in Lakh ton)		
1.	High Land	3.48	15.16	4.72	5.28	1.64	3.64	192.92
2.	Middle Type of land	5.16	2.80	10.84	12.28	5.59	6.69	354.57
3.	Low Land	2.05	24.78	16.02	5.08	3.28	1.80	95.40
TOTAL		10.69	20.70	9.62 (46.47%)	22.64	10.51 (46.42%)	12.13 (53.58%)	642.89

Source : Revenue Department, Govt. of Orissa

4.4.2 Ground water deficiency

Ground water is recharged during southwest monsoon season due to rainfall. As such ground water level is directly related to rainfall. Due to low and erratic behaviour of the monsoon, recharge is reduced and as a result ground water level is declined.

The Orissa State experienced drought in the year 2000 because of low and erratic behaviour of southwest monsoon. This has directly affected the ground water status in the State. Water levels measured with different hydrograph stations during April/May month are considered as pre-monsoon water level and measurements during November are considered as post-monsoon water level. Difference between pre-monsoon and post monsoon water level gives recharge due to rainfall. Depletion in post monsoon water level and deficiency in drought for the year 2000 was analyzed. The intensity of drought based on percentage departures of post monsoon water level is given in Table 22.

Table-22: Classification of drought based on ground water depletion level

Classification	Percentage departures of post monsoon W.L. or Recharge from the Normal W.L/Recharge	Intensity of Drought
MO	0 or above	No Drought
M1	< 0 to-25%	Mild Drought
M2	<-25 % to-50 %	Moderate Drought
M3	< -50%	Severe Drought

W.L. = Water Level

The percentage departure of ground water level and change in water level in April and November 2000 i.e. recharge during the monsoon from their normal values for 30 hydrograph stations in Orissa was calculated and analyzed for drought.(Jha *et al.*, 2001).

Table-23: Percentage departure of ground water level and recharge for 2000

*bgl = below ground level

Sl. No	District	Ground Water Level (Nov)			Water level fluctuation of monsoon period			Mean of column 5 & 8 i.e.	Intensity of drought
		Normal departure, value (m) bgl	Post monsoon Nov.2000, (m) bgl	%	Normal value, (m) bgl	Recharge for 2000, (m) bgl	Departure (%)	Mean departure (%)	
1	2	3	4	5	6	7	8	9	10
1.	Angul	2.89	4.03	-39	3.28	2.17	-33	-36	M2
2.	Balasore	2.59	3.18	-23	2.74	2.03	-26	-24	M1
3.	Bargarh	2.70	3.67	-36	1.98	1.27	-36	-36	M2
4.	Bhadrak	1.80	2.19	-22	2.23	1.41	-37	-30	M2
5.	Bolangir	2.98	4.20	-42	2.49	1.52	-39	-41	M2
6.	Boudh	2.38	4.09	-72	3.43	1.84	-46	-59	M3
7.	Cuttack	1.69	2.30	-36	1.92	0.68	-65	-51	M3
8.	Deogarh	3.12	3.49	-12	2.08	1.63	-22	-17	M1
9.	Dhenkanal	3.05	4.30	-41	3.23	1.63	-50	-45.5	M2
10.	Gajapati	3.42	4.58	-34	3.24	2.54	-22	-28	M2
11.	Ganjam	1.61	2.33	-45	3.33	2.00	-40	-42.5	M2
12.	Jagatsinghpur	1.50	1.96	-31	1.54	0.38	-75	-53	M3
13.	Jajpur	2.05	2.86	-40	2.17	0.72	-67	-53.5	M3
14.	Jharsuguda	3.43	4.37	-27	2.37	1.88	-21	-24	M1
15.	Kalahandi	2.86	3.60	-26	2.95	2.10	-29	-27.5	M2
16.	Kendrapara	1.86	2.53	-37	1.76	0.34	-81	-59	M3
17.	Keonjhar	3.19	4.24	-33	3.29	1.81	-45	-39	M2
18.	Khurda	3.45	4.96	-44	2.42	0.38	-84	-64	M3
19.	Koraput	3.77	4.14	-10	2.95	1.94	-35	-22.5	M1
20.	Malkangiri	2.60	3.09	-14	3.46	2.72	-21	-17.5	M1
21.	Mayurbhanj	3.37	4.10	-22	3.86	3.21	-17	-19.5	M1
22.	Nuapada	2.97	4.83	-63	2.86	0.85	-70	-66.5	M3
23.	Nabarangpur	3.00	3.97	-32	3.42	3.05	-11	-21.5	M1
24.	Nayagarh	2.77	3.49	-26	2.11	1.60	-24	-25	M1
25.	Phulbani	5.55	7.14	-29	3.10	1.49	-52	-40.5	M2
26.	Puri	1.62	1.96	-21	1.53	0.54	-65	-43	M2
27.	Rayagada	4.07	4.55	-12	2.18	1.44	-34	-23	M1
28.	Sambalpur	2.96	3.79	-27	2.72	1.75	-36	31.5	M2
29.	Sundergarh	3.48	4.0	-15	3.41	2.69	-21	-18	M1
30	Sonepur	2.18	2.44	-12	2.09	2.06	-2	-7	M1

Source : Jha etal., 2001

Analysis of ground water level and water level fluctuation reveals (Table.23) that severe drought occurred in 7 districts of Boudh, Cuttack, Jagatisinghpur, Jajpur, Kendrapara, Khurda and Nuapada. Moderate drought occurred in 12 districts of Angul, Bargarh, Bhadrak, Bolangir, Dhenkanal, Gajapati, Ganjam, Kalahandi, Keonjhar, Phulbani, Puri and Sambalpur and mild drought occurred in remaining 11 districts.

4. 4.3 Lowering of water levels of major reservoirs, short fall of surface and subsurface water supply

Longer precipitation deficiency ultimately affects the water levels of major reservoirs and results hydrological drought. Although climate is a primary contributor to hydrological drought, other factors such as changes in land use, deforestation, land degradation etc. also affects hydrological characteristic of the basin. Water deficiency in major reservoirs ultimately affects irrigation, hydroelectric power production etc. During drought 2002 in Orissa, water levels at mid southwest monsoon season for major reservoirs of Orissa were collected and are given in Table.24. Deficit rainfall reduced release of water in canals. Of the total 1.5 million hectares in the command area, irrigation to only 0.5 lakh hectares could be available during drought year 2002. Major Irrigation projects could not service the command areas. Minor irrigation projects were also with inadequate water reserve during that drought affected year.

Table-24: Reservoir status of major projects as on 13.08.2002

Sl No	Reservoir	Full Reservoir level	Date & Time	Reservoir Level on 13.8.2002	Inflow	Outflow
1	Hirakud	630.00ft.	13.08.2002/12.00 hrs.	604.08 ft.	106000 cusec	21928 cusec
2.	Rengali	123.50 m.	13.08.2002/09.00 hrs.	114.65 m.	4307.66 cumec	724.04 cumec
3.	Balimela	1516.00ft.	13.08.2002/08.00 hrs.	1442.30 ft.	12905 cusec	1548 cusec
4.	Machhkund	2750.00ft.	13.08.2002/08.00 hrs.	2694.80 ft.	-	-
5.	Upper kolab	858.00 m.	13.08.2002/08.00 hrs.	847.00 m.	117.00 cumec	23.72 cumec
6.	Indravati	642.00 m.	13.08.2002/08.00 hrs.	627.68 m.	152.078 cumec	12.611 cumec
7.	Salandi	82.30 m.	13.08.2002/08.00 hrs.	62.04 m.	11.81 cumec	2.50 cumec

Source: Water resources department, Govt. of Orissa.

4.5 Drought mitigation options

Study revealed that even in drought affected year, Orissa received not less than 900 mm annual rainfall. Through scientific and improved crop and water management strategies and site–specific land use system, agricultural droughts can be mitigated to some extent.Some of the drought mitigation options are given in this section :

4.5.1. Crop diversification and improved crop and water management practices

Crop diversification that involves crop rotation and cropping system of cereals, legumes, oilseeds, fruits and vegetables results in availability of wide variety of foods for ensuring food, nutrition and environmental security of the country. The low water requiring crops can overcome drought than that of traditional crops. Legume also improves sustainability by enhancing soil fertility and reducing build up of pest and diseases. So site specific sustainable crop diversification plan based on potential and prospects of existing natural resources may serve as an effective tool to the hands of farmer to improve productivity, profitability and sustainability of agricultural system and to combat drought in rural Orissa. Some of the crop diversification options to combat drought in Orissa are given in Table.27.

Table-25: Average income per household in Orissa during the normal and drought years

Source of income	Normal years (Rs.)	Drought yrs. (Rs.)	Difference (%)
1.Crop	12018	4210	-65
(a) Rice	9290	2367	-74
(b) Other crops	2728	1890	-31
2.Farm-labour	2474	1182	-52
3.Non-farm activities	4291	6661	55
4.Other sources	1317	1192	-9
5.Total income	32117	17502	-46
6.Sale of livestock	72	1774	-
7.Sale of land	0	4768	-
8.Sale of other assets	0	2329	-
9.Mortgaging/Borrowing	0	3130	-
10.Total(asset sale +borrowing)	72	12001	-

Source: http://www.knowledgebank.irri.org /theme /

Table-26: Nature of consumption adjustments in selected districts of Orissa

Item	All district
% of household who reduced the quantity of food consumed	87.5
Average number of meals during normal year	3.08
Average number of meals during drought years	2.26
% of household who reduced the number of meals	67
Average number of meals during drought year (those with reduction in the no. of meals)	1.28
% of household who ate food not normally eaten	44

Source : http:/www.knowledgebank.irri.org/theme/

Table-27: Drought mitigation options through alternative crop and water management strategies

Situation	Crop and water management options
(i) Normal onset of southwest monsoon (10th June)	• To increase the productivity and water use efficiency of upland, rice can be substituted with low water requiring crops like maize, blackgram, groundnut, greengram, cowpea, pigeonpea etc. Double cropping in upland can be done through maize-horsegram/sesamum rotation. The legume based intercropping system like groundnut + pigeonpea, groundnut + blackgram, groundnut+greengram, groundnut+cowpea in the ratio of 4:1 was proved as successful. • For very traditional rice farmers those who cannot afford to leave rice even in upland, partial substitution of rice through rice based intercropping like rice+pigeonpea, rice+blackgram, rice+groundnut (4:1) is recommended. • Based on rainfall analysis, 24th standard weeks (14th 20th June) was found feasible for sowing of direct seeded upland crops.

	• For medium and lowland, off-season tillage with pre-monsoon shower can be done in 19th –20th standard weeks for raising rice nurseries. Off-season tillage will recharge the soil profile and rice can be sown immediately on that land after onset of monsoon. • Since during four south-west monsoon months (June-September) 80% of rainfall occurs under normal condition, which may be harvested and recycled for raising second crops after rice specially medium and lowland rice ecologies. • Under normal monsoon condition, some of the suitable rice varieties for up medium and lowlands are: **Upland:** Kalinga-II, Kalinga-III, Heera, Vandana, Anjali, Pathara **Medium land:** Lalat, Swarna, Masoori. **Low land:** Savitri, Gayatri, Padmini, Moti, Mahalaxmi, Rajashree. Some of the suitable varieties of non rice crop in upland of Orissa are: Maize-hybrids: Ganga-5, Daccan-103, KH 510, KH 101; Composites: Shakti-1, Novjyot. Groundnut- TMV-2, Smruti, AK-12-24. Pigeonpea- UPAS-120, ICPL 151, T21, KPH-8. Blackgram- T-9, PU30, Sarada. Greengram- K-851, Dhauli. Horsegram- Urmi, Madhu. Sesame- Kanak, Konika, Gurat-1,Uma
(ii) Dry spell after sowing but normal onset (Drought at early stage)	• When sowing is completed after normal onset of monsoon but dry spell occurs after 1-2 weeks of sowing consequently for 2-3 weeks, raising community nurseries of rice is recommended for transplanted rice. Direct seeded rice is also damaged because of incidence of 'sprouting drought'. Resowing of direct seeded rice should be avoided till sufficient rains have been received. • If sufficient good quality seed is not available, locally available seeds from adjoining areas should be used after proper germination check. • In upland non-rice low water requiring crops may be gap filled and re-sowed with subsequent rain rather than allowing sub-optimal poor plant stand to persist. • Ridge and furrow land configuration technology may be adopted at 20 days after sowing as in-situ soil moisture practices for non-rice upland crops.
(iii) Timely onset but early withdrawal (late season drought)	In this scenario, farmers will sow crops as per local recommended practices in different land ecologies, because of normal onset of southwest monsoon. But early withdrawal of monsoon will affect the crop at reproductive stage. The possible mitigation options are : • Development of ridge and furrow across the slope will be effective for soil moisture and rainwater conservation for direct seeded crops like maize, groundnut, pigeonpea, upland rice, blackgram, greengram etc. to overcome late season drought. • Use of locally available organic mulch materials to conserve soil moisture is recommended. The practices of intercropping and multiple cropping during *kharif* minimize the risks of aberrant weather in upland. If fertilizers are to be applied, foliar application is recommended. • Harvesting of crops like cowpea, maize, greengram, etc. for fodder purpose and harvesting of upland rice at physiological maturity when late season drought is anticipating.

	• Fields should be leveled for uniform water distribution within the sub-plot. Cover cropping like greengram, cowpea can be adopted to restrict the soil moisture loss from the field. • Repeated intercultural operations and integrated weed management practices should be adopted to make the field weed free. Lowland rice will be at tillering to dough stage, so harvested excess runoff water during early monsoon period should be utilized for protective irrigation.
(iv) Delay in onset of monsoon (maximum 3-4 weeks form normal date)	• Shifting from traditional crops/varieties to short duration low water requiring crops in upland, by substituting rice totally. • The recommended dose of nitrogen application should be reduced by 40 % in rainfed situation and should be applied, as basal and full-recommended dose of P and K should be placed as basal. • The field should be free of weeds for utilization of water and nutrients by the late sown crops. Furrow sowing of *kharif* crops at closer plant-to-plant distance with wider inter-row spacing. • Frequent intercultural operation to facilitate effect of loose soil as dust mulch. • Use of bulky organic manures and summer ploughing to recharge the soil profile are recommended. • Major emphasis should be given on in-situ rainwater conservation, harvesting excess runoff for its recycling to make provision for protective irrigation at later stage/crops. • Seed treatment and proper plant protection measures should be taken to avoid any germination failure. • In the event of late arrival of southwest monsoon the pulses like cowpea, blackgram, greengram can be grown upto last week of July in Orissa but pigeonpea, groundnut, maize are not recommended to be sown after 20th July. Castor ban be successfully planted upto last week of August. Planting of maize, cowpea, greengram, blackgram after first week of August can be done only for the purpose of fodder.

4.5.2. Alternative land use system through dry land horticulture or agro-forestry for drought mitigation

- **Dry land horticulture**

Low water requiring dry land fruit crops can play a unique role in mitigating drought in rainfed areas of eastern India. Besides, drought mitigation these will meet the nutritional needs of our country because these fruits provide vitamins, minerals and carbohydrates. Presently India produces 44.13 million tones fruits but their production is not adequate to meet the minimum daily requirement of population of the country. Therefore emphasis should be laid on fruit crops which can be grown with less water even on marginal and sub marginal lands. Increase their production to provide a balanced diet to the people. Dry land fruits provide vitamin A and C whose deficiencies are very common in Indian masses, resulting in blindness and anaemia. Several fruits contain carotene (a precursor of vitamin A), which is converted to vitamin A in the human body.

Non-traditional fruits which are neither grown commercially on large scale nor are traded widely such as bael, custard apple, jackfruit, jamun, tamarind, aonla, karonda, wild ber etc. are very rich sources of vitamins, minerals and having high nutritive value. Besides these are easier to grow, hardy in nature, producing fruits even under adverse soil and climatic conditions and on marginal, sub marginal lands. The non-traditional fruits like jackfruits, phalsa, pummelo, and wild apricot are rich sources of carotene. Aonla, custard apple and jamun are rich sources of vitamin C. Tamarind, phalsa, bael and wood apple are rich sources of calcium and phosphorus while iron content is high in tamarind, wild ber, custard apple and karonda fruits. Apart from nutritive value, non-traditional low water requiring fruits are particularly more important for medical properties. Aonla is main ingredient for 'chyavanpras'. Unripe bael fruit cures diarrhoea and dysentery. Jamun fruits help in curing diabetes. Besides, non-traditional fruits also impart diversity and palatability of our food. Tamarind is an important ingredient of receipe of many Indian dishes. Aonla and guava are rich sources of pectin. Therefore these non traditional fruit crops have tremendus potential to grow in eastern India for mitigating drought as well as to provide nutritional security.

- **Agro-forestry in drought prone areas**

Agroforestry is a land management system that optimizes the overall land productivity and reduces resources depletion through the utilization of positive interactions between crops – trees- animal in its temporal and spatial dimensions for meeting the demand of food, fodder, firewood, fiber, timber, pulpwood etc. Conjunction of horticulture and agro-forestry with crops would ensure the seasonal access to fruits, fuel, fodder and fiber. To overcome the problem of malnutrition, non-traditional fruits can easily be incorporated into various agro-forestry systems. Some of the non-traditional fruit trees like bael, aonla, and ber have already been proved successful in agro forestry system for augmenting income of farmers and generating more employment. Some of the well established agro forestry management systems for drought prone areas are (i) Agri-horticultural system (ii) Horti-pastoral system (iii) Hort-silvicultural system (iv) Hort-silvi-pastoral and horti-agri-silvicultural systems etc.

4.5.3 Rainwater harvesting and farm-enterprise diversification through farming system approach for drought mitigation

Rainwater harvesting and its multiple uses through farm enterprise diversification is another best option for increasing production, productivity and sustainability of agricultural system. Farming systems represent an appropriate combination of farm enterprises viz. cropping system, livestock, poultry, fisheries, forestry and the means available to the farmer to raise them for increasing productivity and profitability. The farming system as a whole provides opportunity to make use of produce/waste materials of one component as input for another component, either at minimum cost or free of cost. For example, the crop by-product is utilized as fodder for animals, and animal byproduct i.e. milk and dung may be utilized for increasing income and soil fertility, respectively. Some of the proven enterprise diversification through farming system approach is discussed below.

- **Aquaculture and rice-fish integration in food security and employment generation**

Aquaculture has tremendous capacity to achieve food security and generate employment in rainfed areas. Fisheries can be easily integrated with lowland rice to form rice-fish integrated system. The seasonal water logging in rainfed areas can overcome by adopting integrated farming like lowland rice with fish during *kharif* season. The same area can be brought under cultivation of *rabi* crops during winter season when water logging will be over. The rice-fish integrated system in rainfed lowland rice ecosystem of eastern India has already been proved successful for augmenting income of farmers and generating employment.

- **Fish-duck farming**

The productivity of water can be increased through fish-duck farming. Duckery and fishery are two separate systems (avian and aquatic) but can maintain symbiotic relationship when integrated together. The raising of ducks with fish in the same pond is more rational as compared to any other system of integrated farming. The pond provides both living and foraging area for duck and fish. The droppings of ducks are rich in non-protein nitrogenous substances which serve as ready made feed for the fishes thus minimizing the expenditure of artificial feeding which is about 70 % of total input. Fish and duck together ensure higher profit in drought prone area due to higher production of fish yield, duck eggs and duck-meat within unit time and limited water area through minimum investment.

- **Livestock enterprises**

To improve the productivity in rainfed area of eastern India, livestock enterprises can be introduced in addition with cropping system. Demand for animal products has increased because of rise in the income and purchasing power of middle class with greater emphasis on nutrition and environmental security. It is now emphasized that food (food and fodder) production should always linked with judicious and balanced use of natural resources. Dairy, piggery, goatery and poultry based farming system though production of milk, meat, egg can provide all basic nutrients to masses as well as it will minimize the impact of drought from season specific crop based agriculture.

4.5.4 Indigenous rainwater management practices for drought mitigation

Indigenous rainwater management practices refer to proven farmer practices developed over long periods from the experiences of farmers themselves. With indigenous practices, rainwater is stored according to local needs and geographical situations and used for irrigation, domestic use and drinking purpose of cattle. In these systems, groundwater recharging is also taken care of.

Methods of rainwater management may be divided into two categories.

- **Agronomic measures**

  i) Facilitate a better intake of rainwater into the soil by improving organic matter content and soil structure.

  ii) Reduce surface runoff.

Some of the indigenous agronomic measures for rainwater management are (i) contour farming (ii) cover cropping (iii) intercropping (iv) mixed cropping (v) addition of organic and green manures (vi) conservation tillage (vii) mulch tillage (viii) off-season ploughing (ix) dead furrowing/shallow trenching.

- **Mechanical measures**

Mechanical measures consist of constructing mechanical barriers across the direction of water flow to retard or retain the runoff and help to conserve soil and water. These measures include:

(i) field bunding (ii) bench terracing (iii) level bench terrace (iv) outward-sloping bench terrace (v) inward-sloping bench terrace (vi) farm ponds (vii) embankment-type ponds (viii) dugout-type ponds (ix) community ponds (x) small rock-check dams etc.

5. FLOOD ANALYSIS

Flood is another important climate induced natural disaster, which have become an annual affair now in Orissa. The monsoon of 2001 and 2003 plunged Orissa into a fresh crisis. As many as 7032 villages in 1254 Gram Panchayats in 118 blocks in 17 districts with 3.54 million people were cut off or submerged in flood waters. The damage caused to agriculture was stupendous. About 360 thousand hectares of rice crop were rotting under water. The total loss, as per government's early estimates was about Rs. 17.13 Crores.

5.1 Drainage system and major river basins in Orissa

The Mahanadi, the Brahmani, the Baitarani, the Budhabalang, the Subarnarekha, the Rushikulya, the Nagavalli, the Vamsadhara, the Indravati, the Kolab and their tributaries form the major drainage system in the state of Orissa. The catchment area and water resources of different rivers are given in Table 28 and major rivers of Orissa with frequent flood zone are presented in Fig.6.

5.1.1. The Mahanadi Basin

Mahanadi Basin is an inter-state basin comprising of four States, State of Orissa, Chhattisgarh, Jharkhand and Maharashtra and total basin area constitute 141589 sq km. The major part of the basin lies mostly in Chhattisgarh and Orissa. The Mahanadi catchments upstream of Hirakud is 83,409 sq km out of which 75,136 sq km lies in Chhattisgarh, 635 sq km lies in Jharkhand, 238 sq km lies in Maharashtra and 7, 400 sq km in Orissa. The total catchments area in Orissa inclusive of both upper and lower catchments are 65627 sq km.

The Mahanadi is the largest river of the state with a catchment area of about 1.41 lakh sqkm. of which about 65 thousand sqkm lie in Orissa. The total length of the river is about 851 km and the total length of the river in Orissa is 494 km. Jeera, Ong, Tel, Hariharjore, Surubalijore, Manjore, Bagh, Salki, Brutang, Kusumi and Kuanria are the major tributaries down stream of Hirakund. The main branches of the river are Kathjodi, Devi, Kuakhai, Kushabhadra, Daya, Bhargavi, Birupa, Chitrotpala and Paika. Some of the branches of the Mahanadi meet the branches of the Brahmani, making it a complex stystem. The major floods due to the Mahanadi with discharge in different years are given in Table-28.

Table – 28: Major floods with discharge in the Mahanadi, Brahmni and Subarnarekha

MAHANADI BASIN					BRAHMANI BASIN				SUBERNAREKHA BASIN			
Year	Date	Gauge in Mt.	Discharge in cusecs	Remarks	Year	Date	Gauge in Mt.	Discharge in cusecs	Year	Date	Gauge in Mt.	Discharge in cusecs
1	2	3	4	5	1	2	3	4	1	2	3	4
1964	08.07.1964	29.41	700501		1964	23.08.64	21.98	440617				
1965	31.07.1965	27.13	313076		1965	31.07.65	20.91	231311				
1966	31.07.1966	28.74	584969		1966	26.06.66	20.94	203938				
1967	07.08.67	27.08	782161		1967	05.09.67	21.49	335717				
1968	16.08.68	26.15	753799		1968	15.08.68	21.52	297041	1968	04.08.68	6.04	241596
1969	01.08.69	27.02	977092	Flood	1969	15.08.69	23.85	417942	1969	15.09.69	5.18	157331
1970	28.08.70	26.49	654126		1970	01.07.70	21.18	310322	1970	05.09.70	11.92	194834
1971	10.08.71	26.37	749737		1971	09.08.71	24.15	557738	1971	28.07.71	11.4	271077
1972	15.09.72	26.09	713817		1972	15.07.72	23.07	338154	1972	14.08.72	11.31	250071
1973	28.09.73	26.87	926973	Flood	1973	21.07.73	24.26	656917	1973	03.09.73	11.98	311574
1974	19.08.74	26.37	762099		1974	19.08.74	23.47	437721	1974	18.08.74	11.83	345709
1975	24.08.75	26.46	817516		1975	20.08.75	24.78	856369	1975	20.08.75	11.83	253578
1976	15.08.76	26.73	933401	Flood	1976	14.08.76	23.13	365244	1976	19.09.76	11.77	241987
1977	14.09.77	26.75	934708	Flood	1977	08.08.77	23.29	377924	1977	07.08.77	11.89	256138
1978	29.08.78	26.98	984191		1978	03.09.78	23.44	418330	1978	03.09.78	12.13	266461
1979	10.08.79	25.66	625729		1979	08.08.79	22.65	233077	1979	10.08.79	9.72	70083
1980	22.09.80	27.8	1227299	Flood	1980	25.06.80	21.51	144989	1980	07.09.80	9.39	82940
1981	11.08.81	25.66	619230		1981	14.07.81	21.43	138607	1981	26.07.81	9.99	77012
1982	31.08.82	28.52	1580570	Flood	1982	22.08.82	22.49	201746	1982	13.09.82	9.69	69934
1983	09.09.83	26.61	886108		1983	07.09.83	23.15	284997	1983	07.09.83	9.9	78876
1984	17.08.84	26.45	825887		1984	18.08.84	23.68	347013	1984	09.08.84	11.61	282316
1985	07.08.85	26.62	890523		1985	29.08.85	22.86	303306	1985	17.10.85	12.1	218265
1986	22.07.86	26.63	900412	Flood	1986	22.07.86	22.61	287065	1986	06.06.86	9.81	57416
1987	24.07.87	24.52	346595		1987	31.08.87	21.49	161608	1987	29.08.87	11.28	149971
1988	09.08.88	24.35	316150		1988	04.08.88	22.62	255535	1988	29.06.88	11.95	199271
1989	19.08.89	23.8	231805		1989	28.07.89	21.65	161850	1989	06.08.89	11.59	175690
1990	06.09.90	26.19	728398		1990	15.10.90	21.97	193855	1990	04.08.90	11.05	128595
1991	14.08.91	27.13	1166548		1991	13.08.91	23.46	417110	1991	24.08.91	10.52	105408
1992	21.08.92	27.37	1208608		1992	29.07.92	22.18	195131	1992	28.09.92	10	92217
1993	28.08.93	25.99	814538		1993	16.07.93	21.1	128730	1993	16.09.93	9.91	81463
1994	06.09.94	27.22	1115264	Flood	1994	19.09.94	23.21	302001	1994	06.08.94	20	170736
1995	25.07.95	26.72	945731	Flood	1995	21.09.95	21.69	182428	1995	05.09.95	10.87	110984
1996	23.08.96	24.88	466685		1996	23.06.96	22.06	213196	1996	27.07.96	11.21	152025
1997	06.08.97	26.52	852168		1997	06.08.97	22.77	260315	1997	07.08.97	12.2	250731
1998	13.09.98	26.26	809087		1998	14.09.98	22.33	226833	1998	12.09.98	10.51	108380
1999	11.08.99	25.64	634775		1999	30.10.99	23.29	350008	1999	09.08.99	11.62	149501
2000	28.07.00	23.45	178349		2000	19.08.00	18.44	67885	2000	28.07.00	9.83	59392
2001	20.07.01	27.21	1408797	Flood	2001	25.07.01	23.56	479328	2001	13.07.01	11.2	164974
2002	14.09.02	25.46	587380		2002	09.09.02	20.33	75339	2002	13.09.02	9.91	85127
2003	30.08.03	27.74	1349844	Flood	2003	11.10.03	22.46	247044				

5.1.2. The Brahmani Basin

Brahmani Basin is situated in between the Mahanadi Basin and the Baitarani Basin. The river Brahmani rises near village Nagari in Ranchi district of Jharkhand at an elevation of about 600 mt. After flowing for about 258 km inside Jharkhand and Bihar it enters into Orissa territory. In Jharkhand it is called South Koel and after the tributary Sankha falls into it near Rourkela. It flows down in Orissa as Brahmani and falls into Bay of Bengal near Dhamara.The major tributaries of the Brahmani are Koel, Kuradhi, Mankada, Samakoi and Raniala on the left and Karo, Sankh, Kukura, Gohira, Tikra, Singdajor, Nigra, Barjor on the right. The prominent flood prone area under the basin are Bari, Badachana, Binjharpur, Rajkanika, Aul, Damanpur, Ghagara, Srirampur, Alapua, Andharua and Rajnagar. All thses areas are situated in the last down streams of the Brahamni river mouth in the district of Kendrapara, Jajpur and Dhenkanal.

5.1.3. The Baitarani Basin

Baitarani originates from the Gonasika hills of Keonjhar at an elevation of about 900 mt. at latitude $21^0\ 31'$ North and longitude $85^0 33'$ East. Baitarani Basin is one of the three major basins in the state of Orissa. Although comparatively it is smaller than that of Mahanadi and Brahmani, it brings heavy flow and creates havoc in lower reaches during monsoon. The Keonjhar district of Orissa covers the major portion of the basin area where as Mayurbhanj, Sundergarh, Bhadrak, Jajpur, Dhenkanal, Cuttack and Balasore districts cover the rest. The river after traversing in hilly regions enters the plains at Anandapur. Further below it meets the deltaic region at Akhuapada where it branches off and bifurcates. Further below it meets the river Brahmani and assumes the name Dhamara and joins the Bay of Bengal. The flood prone area in the Baitarani river basin are Dhamnagar, Basudevpur, Bhadrak,Chandbali, Tihid, Bhandari Pokhari, Bonth block of Bhadrak district, Hatadihi, Anandpur, Ghasipura blocks of Keonjhar district and Dasarathpur, Jajpur blocks of Jajpur district. The Chandbali is situated at the mouth of the Baitarani river and is the most flood prone zone of the basin.

5.1.4. The Subarnarekha Basin

Subarnarekha Basin covers the border area of Northern Orissa. It spreads over the states i.e Jharkhand, West Bengal and Orissa in an area of 13222 sq km, 3002 sq km and 3022 sq km respectively. The basin area in Orissa is divided in three parts *viz.*, Upper basin (1929 sq km) in Mayurbhanj district, middle basin (266 sq km) in Mayurbhanj district and lower basin (788 sq km) in Balasore district. The river Subarnarekha originates from Nagi village on flat surface of Ranchi plateau in Chhotanagpur highland in Jharkhand at an elevation of 740 mt. It forms a boundary of Orissa and West Bengal for a small stretch and thereafter naturally goes through Orissa at Rajnagar. The river has got flat slope and has many bends before it falls into Bay of Bengal covering a length of 60 km in Orissa. The peak gaudge height and discharge of the basin are given in Table-28.

5.1.5. The Budhabalanga Basin

The Budhabalanga basin is situated below Subarnarekha basin in the district of Mayurbhanja, Balasore and partly of Bhadrak The river Budhabalanga rises from the Similipal hills of Mayurbhanj district at an elevation of about 300 m and falls into the Bay of Bengal at Chandipur of Balasore district after flowing about 164 km. Prominent flood prone areas under the basin are Balasore, Nilagiri, Sora and Basudevpur. Chandipur is situated at the mouth of Budhabalanga river and this area is the most flood prone area under the basin.

5.1.6. The Rushikulya Basin

River Rushikulya originates near village Digi in Phulabani district at an elevation of about 1000 m and after flowing for 165 Km in Ganjam district falls in Bay of Bengal. This basin comprises mainly in the district of undivided Ganjam and some portion in Nayagarh and Phulbani district.Total submerged prone area of this basin is about 0.4 lakh hectare and flood zone area is Aska area, because Aska is situated in the deltaic area of Baghua and Badanadi in left and Rushikulya in right. Hence, Aska is heavily affected by frequent flood.

5.1.7. The Vamsadhara Basin

River Vamsadhara rises form the hills of Kalahandi district near village Langigarh at an elevation of 1150 m. After flowing for a length of 160 km in Rayagada and Gajapati district in Orissa, it forms the boundary between Orissa and Andhra Pradesh for nearly 25 Km and then traveling for about 36 Km in Andhara Pradesh falls in to the Bay of Bengal. The total catchment is 11, 500 Sq km of which 9,400 Sq km lies in Orissa. Vamsadhara Basin mainly covers the districts Gajapati, Rayagada and parts of Phulbani in Orissa and some portion is in Andhra Pradesh.

5.1.8. The Upper Kolab Basin

The river Kolab originates from Baster district, which is under chhotanagapur platue of Madhya Pradesh. The reservoir has maximum level of 858 meter. The reservoir had achieved the peak reservoir level of 857.57 meter in 2003.

5.1.9. The Indravati Basin

Indravati reservoir envisages 4 dams and 8 dykes. It spreads over 110 Sq. km. area. The river Indravati originates from Tuamul Sampur and near Kusumpodar link channel it has been linked with Muran river and Podagarha nalla. The FRL of the reservoir is 642.00 mtr. The power house release flows in power channel at Mukhiguda and impounds at Hati Barrage at Mangalpur.

Table-29 : Catchments and water resources of different river basins

River basin	Catchment Area (sq. Km.)	Water Resources in Mcum		Live Storage Capacity in Mcum		
		Average	75% Dependable	Completed Projects	Ongoing Projects	Future Projects
Mohanadi	65628	61949	36313	6299.40	2270.36	5351.03
Brahmani	22516	16253	14348	5031.70	38.00	799.30
Baitarani	13482	7380	5686	606.70	313.80	1691.80
Kolab	10300	11734	9699	2198.00	-	764.90
Rushikulya	8963	3121	2278	96.98	27.40	206.41
Vamsadhara	8960	5148	3821	155.23	-	735.70
Indravati	7400	6243	4834	1485.50	-	95.90
Budhabalanga	4838	3057	2521	576.10	-	174.20
Nagabali	4500	2626	1519	0.32	-	365.07
Subernarekha	2983	2308	1270	92.38	843.50	1417.28
Bahuda	890	440	294	0.87	-	34.45

Table-30. Discharge (cusecs) at different probability levels from the Mahanadi

Weibulls			Log Pearson Type-III		
Value	Return Period (Year)	Probability (%)	Value	Return Period (Year)	Probability (%)
178349	1	99	165464	1.01	99
587680	1.16	80	525717	1.25	80
654126	1.6	70	626759	1.42	70
749738	1.7	60	711837	1.66	60
809088	1.98	50	809066	2	50
825888	2.3	43	871720	2.32	43
926973	3.18	30	988129	2.33	30
984192	5.11	20	1092690	5	20
1166549	6.82	15	1148333	6.66	15
122799	10.24	10	1223661	10	10
1349844	13.65	7	1282093	14.28	7
1408798	20.48	5	1317708	20	5

Table- 31. Discharge (cusecs) at different probability levels from the Brahmani

Weibulls			Log Pearson Type-III		
Value	Return Period (Year	Probability (%)	Value	Return Period(Year	Probability (%)
67885	1	99	66751	1.01	99
182428	1.24	80	175056	1.25	80
203938	1.41	70	208973	1.42	70
233077	1.64	60	239682	1.66	60
287065	2.03	50	277807	2	50
302001	2.28	43	304469	2.32	43

350008	3.4	30	359552	3.33	30
417942	5.11	20	417132	5	20
437721	6.82	15	451983	6.66	15
479328	10.25	10	505435	10	10
557738	13.68	7	553495	14.28	7
656917	20.5	5	586562	20	5

Table-32. Discharge (cusecs) at different probability levels from the Baitarani

Weibulls			Log Pearson Type-III		
Value	**Return Period (Year)**	**Probability (%)**	**Value**	**Return Period (Year)**	**Probability (%)**
68386	1.02	99	40891	1.01	99
103310	1.2	80	147384	1.25	80
206942	1.41	70	179670	1.42	70
228933	1.68	60	207553	1.66	60
232441	2	50	240181	2	50
249935	2.4	43	261639	2.32	43
300629	3.4	30	302425	3.33	30
324555	4.6	20	340135	5	20
370271	5.99	15	360655	6.66	15
374081	8.8	10	388990	10	10
396021	13.98	7	411468	14.28	7
408942	17	5	425412	20	5

Table-33. Discharge (cusecs) at different probability levels from the Subarnarekha

Weibulls			Log Pearson Type-III		
Value	**Return Period (Year)**	**Probability (%)**	**Value**	**Return Period (Year)**	**Probability (%)**
57416	1	99	39178	1.01	99
81463	1.24	80	95734	1.25	80
105408	1.44	70	113889	1.42	70
128595	1.64	60	130605	1.66	60
157331	2	50	151765	2	50
175690	2.38	43	166846	2.32	43
241596	3.27	30	198789	3.33	30
253578	5.14	20	233378	5	20
266461	7.1	15	254936	6.66	15
282216	11	10	288955	10	10
310589	12.5	7	320571	14.28	7
311574	18	5	342909	20	5

5.2 Flood probability analysis

Flood probability was analysed based on oocurrance of flood point discharge level using Weibull's and Log Pearson Type-III probability distribution model (Table 30-33). In the year, when discharge exceeds 9,00,000 cusec in the Mahanadi is considered as flood year. Based on the hydro-meteorological synoptic situations of the Mahanadi, Brahmani, Baitarani and Subarnarekha river basins of past 30 years data probability of flood year was predicted using Log Pearson probabilistic distribution and Weibulls' method. Study (Table 30) revealed that probability of occurrence of discharge exceed 900000 cusec from the Mahanadi river is 32.7 %. So probability of occurrence of flood is 33 in the Mahanadi river basin.

5.3 Flood control measures

The following flood control measures were suggested for mitigating effects of flood.

5.3.1. Early warning and precautions

Necessary warning should be given before release of water from different reservoir through wireless network to blocks and vulnerable, inaccessible Grampanchyats.

5.3.2. Rising to the occasion and emergency relief

During the time of occurrence of flood, proper measures should be taken for rescue and evaluation. Emergency equipment such as jackets, buoys, inflated rubber boats should be kept ready in sufficient number. The free kitchen service, dry food service, kerosene, match boxes and polythene sheet should be provided on emergency basis to the marooned people.

5.3.3. Health care and sanitation

During flood, sources of water are generally affected and to prevent any outbreak of water borne diseases necessary measures should be taken in the form of supply of chlorine tablets, digging bore wells, raising the platform of tube wells etc. Proper care should be taken for snake and scorpion bite.

5.3.4. Employment generation during flood year

The farmers of flood prone areas are heavily affected due to extensive damage of agricultural land and *kharif* crops. Sometimes due to late receedence of floodwater, growing of *rabi* crops in the marooned area is also affected. As a result, entire agricultural work force throughout the year in the flood affected areas is affected. It is therefore necessary to provide them at least 100-120 days working days to assure their food security and for restricting large scale migration.

5.3.5. Restoration work

Necessary steps should be taken for restoration work of different breaches, repairing of damaged infrastructure including roads, bridges, and community development work. It is necessary to provide shelter to homeless people specially those are in below poverty level (BPL) and to construct flood resistant school building.

6. CYCLONE

A cyclone is a small low pressure system with winds spiraling anticlock wise in the northern hemisphere and clockwise in southern hemisphere around a central area of low pressure. Cyclones are roughly circular or oval in form, hence the isobars on weather maps are also shown circular or oval. But the outermost isobars get deformed to form troughs. Cyclones originate as a wave along a front separating two masses of air differing in temperature, densities and directions mainly between latitudes 5^0 and 15^0 N during the periods April to June and October to December. Sever cyclones are rare from July to September in our country. The Bay of Bengal cyclones generally move west or northwest and strike the east coast but some recurve and strike the West Bengal, Bangladesh or Burma coast. The Arabian Sea storms also move generally west or northwest across the Arabian sea towards the Arabian coast, but some of them recurve and affect the west coast of India. More storms form in the Bay of Bengal than in the Arabian sea. The major cyclones in the Bay of Bengal which affected Orissa are presented in the Table-34. The wind and cyclone hazard map of Orissa are presented in Fig-7.

6.1 Formation of cyclones

The life span of tropical cyclone averages a week. The larger the sea area, the more intense the storm grows. A tropical cyclone has a definite life cycle, which comprises of following four phases.

6.1.1. Formative stage

In this stage a tropical disturbance is noticed in a large oceanic area where winds become variable with thunder squalls. Pressure falls slowly and the central pressure deficit is the order of 10 mb. Steep convective activities take place where there is a low pressure system at the sea level. The temperature of the upper atmospheric region above the low rises because of release of latent heat by cumulonimbus clouds in this area. The isobaric surfaces are also elevated. This stage lasts for 2-3 days.

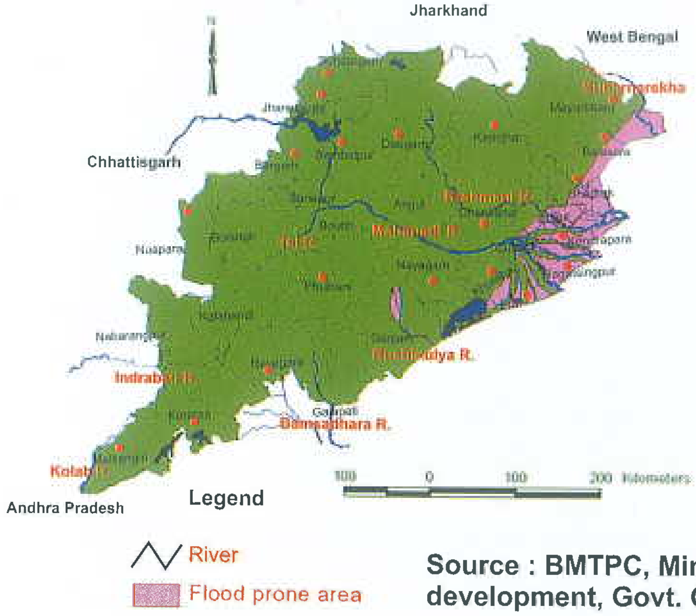
6.1.2. Immature stage

There is rapid fall in the central pressure, reaching the lower limit. Clouds and rain get organized into narrow inward spiral bands. Area of strong winds remains small but winds attain maximum speed within very less period.

6.1.3. Mature stage

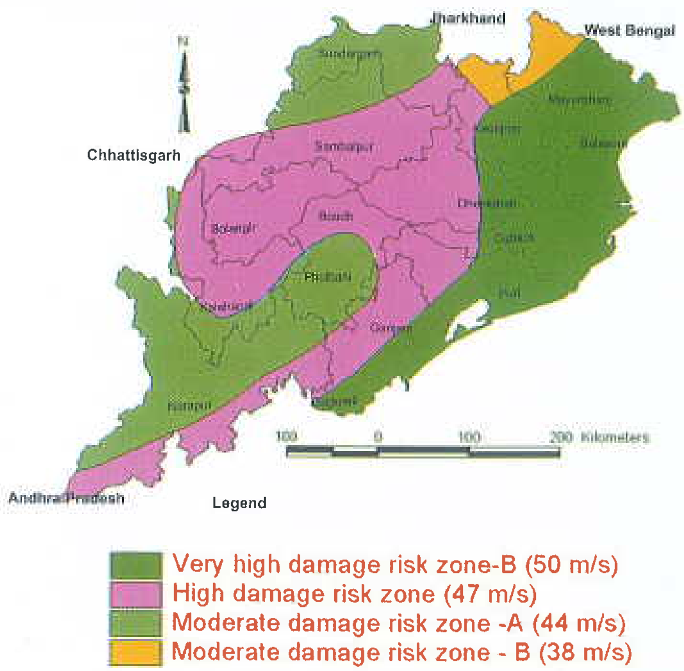
The pressure and wind speed does not change much during this stage. There is no further deepening of pressure occurs and the areas covered by the strong wind are largest in this stage. The circulation expands outwards and asymmetry sets in as the area of rain and gales extends much more to the right in the direction of the system. This process lasts a few days.

Fig. 6 : Frequent flood zone with major rivers in Orissa

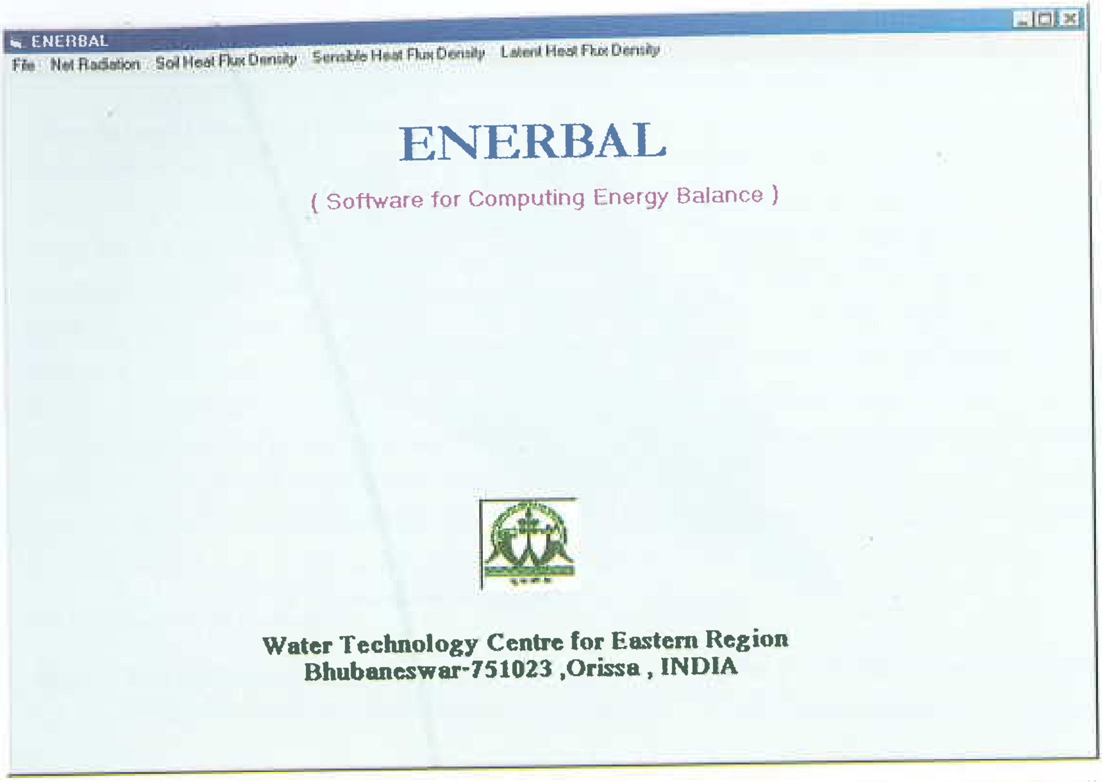


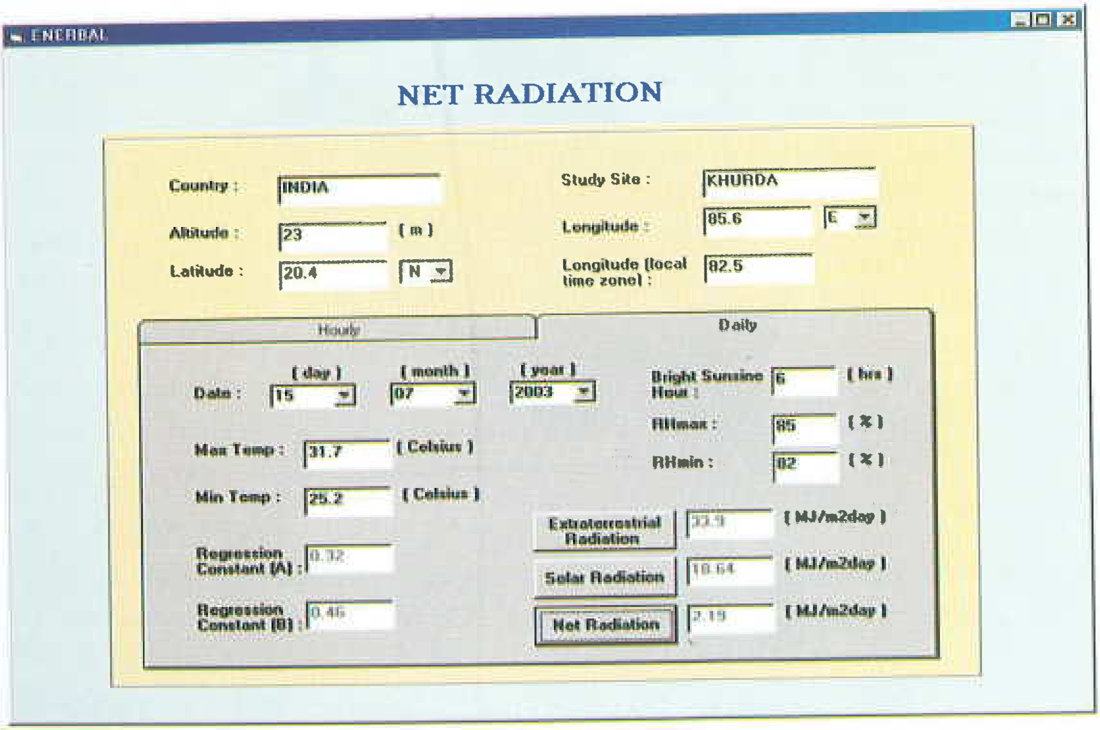
Source : BMTPC, Ministry of Urban development, Govt. Of India

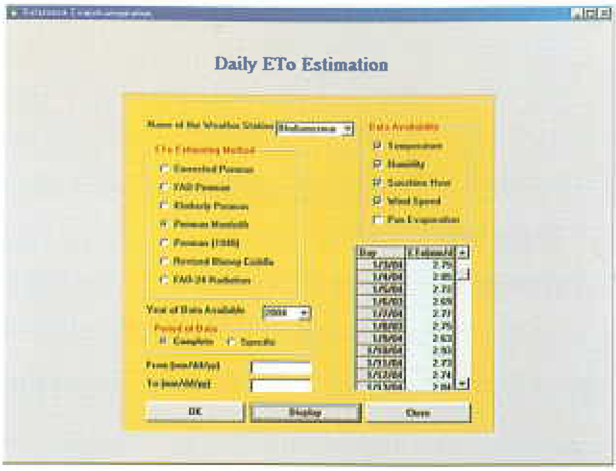
Fig. 6 : Cyclone and wind hazard map of Orissa

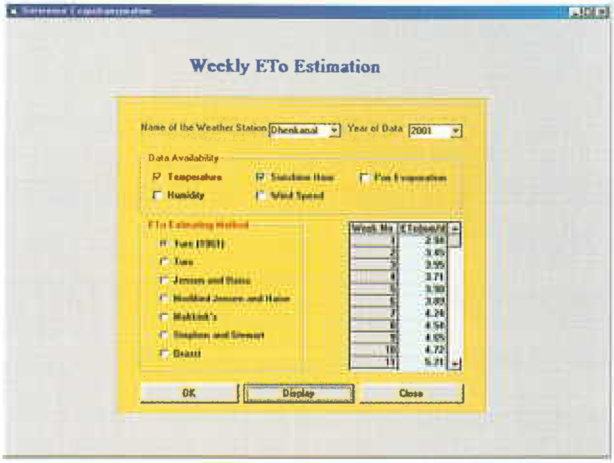


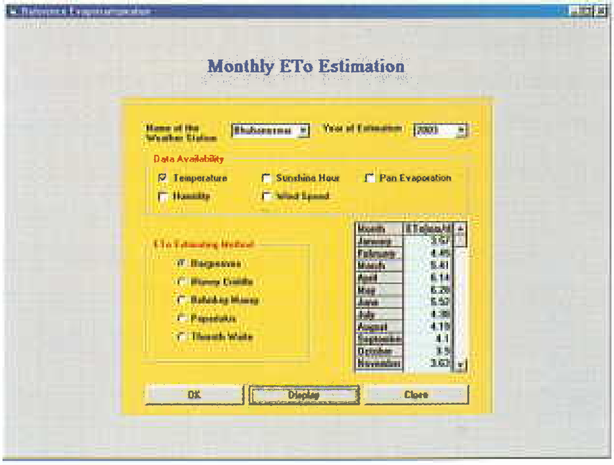
Source : BMTPC, Ministry of Urban development, Govt. Of India


ENERBAL
File
Net Radiation
Soil Heat Flux Density
Sensible Heat Flux Density
Latent Heat Flux Density
ENERBAL
(Software for Computing Energy Balance)
Water Technology Centre for Eastern Region
Bhubaneswar-751023 ,Orissa , INDIA


ENERBAL
NET RADIATION
Country :
INDIA
Study Site :
KHURDA
Altitude :
23
(m)
Longitude :
85.6
E
Latitude :
20.4
N
Longitude (local time zone) :
82.5
Hourly
Daily
(day)
(month)
(year)
Date :
15
07
2003
Bright Sunshine Hour :
6
(hrs)
RHmax :
85
(%)
RHmin :
82
(%)
Max Temp :
31.7
(Celsius)
Min Temp :
25.2
(Celsius)
Extraterrestrial Radiation
(MJ/m2day)
Solar Radiation
(MJ/m2day)
Regression Constant (A) :
Regression Constant (B) :
Net Radiation
(MJ/m2day)







Sample forms of software for computing daily, weekly & monthly reference evapotranspiration (ET_0) with different climatological models.

6.1.4. Dissipating stage

The decay starts where the system enters land or an oceanic region where the sea surface temperature is lower than 26 °C or moving out of the tropics to the belt of westerly. Over land, the moisture supply is drastically curtailed, cutting of the energy input and also there is dissipation of energy due to increased frictional drag. The wind speed decreases, the cyclone weakens though rainfall may persist for a day or two.

6.2 Type of tropical disturbances

Some of the following nomenclatures are used to classify the tropical vertical disturbances.

	Nomenclature	*Wind speed*
6.2.1.	Low pressure area	Upto 16 knot*
6.2.2.	Depression	17-26 knot
6.2.3.	Deep depression	27-33 knot
6.2.4.	Cyclone storm (CS)	34-47 knot
6.2.5.	Severe cyclonic storm (SCS)	48-64 knot
6.2.6.	Severe cyclonic storm with core of hurricane winds	> 64 knot

*1 Knot (Nautical miles) = 1.853 Km hr^{-1}

6.3 Effects of cyclone on ecosystem services and livelihoods

The ecosystem services and livelihoods are affected during cyclone are mainly due to hurricane force wind, storm surge or tidal wave, torrential rains and floods. The pressure gradient around the eye of the cyclone frequently produces sustained gusty winds in excess of 150 Km hr^{-1}. The oscillations created by pressure difference between upwind and downwind causes collapse of buildings, uprooting of plants etc. In a cyclone storm in the open sea there is rise in the water level due to the low pressure, which hits the coast as a solid wall of water with the speed of the hurricane winds. This is known as storm surge or tidal wave, which causes devastation in the coastal region. The sea level at times, rises as high as 15 to 20 meter as the storm approaches coast and the sea water penetrating inland causes widespread inundation and submersion of low lying areas. The torrential rains create flood and devastate the cyclone affected areas. The rainfall pattern varies from storm to storm. In some cases the rainfall extends a few hundreds of kilometers away form the storm center. Rainfall is heavier with slow moving system because of the longer duration. Deaths occur from drowning in the tidal waves and floods, collapse of structures and trees, electrocution, rail/road/air accidents, drowning of fishing boats and also from epidemics in the aftermath due to contamination of water, food etc. The exact damage depends on the maximum sustained wind speed and peak gusts. During last 100 years, the most severe cyclone occurred recently on 29-30th Oct, 1999 in coastal Orissa, which was regarded as SUPER CYCLONE.

6.4 Cyclone combat plan

To reduce the vulnerability from cyclones, the planning can be done in different phases.

Phase 1: (Long term measures or preparedness)

In the cyclone prone areas to mitigate the effects of cyclone, following long-term measures may be initiated.

- Construction of permanent cyclone proof structure along the coastal belt to provide shelter to evacuated people during the cyclone. Introducing afforestation of coastal belt, construction of dykes, dams, embankments, wind breaks for reducing the speed of storm and minimizing the extent of damages.
- Setting up of sufficient health center and storage of sufficient food, medicines, baby milk and drinking water facilities should be made so that here is no shortage during crisis. The sufficient deep tube wells should be dug in each of the residential units of the coastal states to get fresh drinking water even after epidemics.
- Widening public highways for quick evacuation and to carry out easy relief operations. There should be provision of trained manpower to guide and prepare proper evacuating plans, relief operations without difficulty.
- Creation of awareness among the common people is the most important aspect of cyclone preparedness. It can be done by organizing public meetings, awareness campaigns, and educating the students regarding cyclones and its management. The state government of coastal states should include cyclone management as a topic in the course curriculum of schools and colleges and different training institutes to make them ready to face any future eventualities.
- Provision of generator with higher capacity should be made for smooth running of the major governments offices, internet, phones etc. in the important towns and cities of the affected states in absence of electricity for continuous period. It will facilitate emergency search and relief operations in the affected rural and remote areas.
- Emergency cyclone broadcasting radio station should be established along the coastal areas for issuing cyclone warnings or some emergency announcement in case the regular broadcasting station fails to do so.

- There should be provision of satellite phone which will help in establishing the communication links between the isolated areas and relief centers located elsewhere at short notices during the time of cyclone when ground communication net working system will collapse due to cyclone.

Phase II: Prevention (Just and immediate before the cyclone)

- Continuous broadcasting of cyclone warnings should be made to make the people alert to meet the aftermath of the cyclone.
- Assembling all trained manpower and government's crisis management personnel to chalk out the evacuation plan to evacuate the cyclone affected people.
- Storing and packing of emergency supplies like food, drinking water, medicines, blankets, polythene sheets etc. to supply to the victims.
- Organizing emergency shelters and evacuating the people of likely affected area.

Phase III: Resource (emergency relief)

- Identification of affected areas and estimation of nature and extent of loss due to cyclone immediately with the help of satellite data.
- Providing emergency relief like supply of food, drinking water, medicines, baby milk, blanket, polythene sheet etc. on war footing basis to reduce the causalities.
- First aid center and temporary mobile health center should be established for treatment of injured and epidemics affected people.
- Quick disposal and burning of dead bodies of human beings and carcasses to avoid any epidemics.
- Establishment of communication link through satellite in case the ground communication network fails.

Phase IV: Recovery or rehabilitation (After the cyclone)

- Rehabilitation of the affected people by reconstructing their houses, ameliorating agricultural land should be taken on priority basis
- Supply of agricultural inputs like seeds, fertilizers, pesticides and small farm implements at concessional rate in order to restore the agricultural production and productivity of vast affected coastal areas.
- Proper scientific investigation is also required to study the salinity level of the soil for suitability of crop production after intrusion of saline seawater.
- Provision of soft loan, tax relief and implementation of crop insurance scheme should be made by the government to the cyclone victims.

Table-34: Major cyclones in Orissa between 1970-2003

Sl. No.	Date	Area affected	Damage losses
1.	September 7-14,1971	South Orissa coast and adjoining North Andhra coast.	This system caused considerable damage to crops, houses, telecommunications and other property in the coastal districts of Orissa. viz, Ganjam, Puri and Cuttack. 90 people died and 8000 cattleheads perished.
2.	September 20-25.1971	South Orissa coast near Gopalpur.	Considerable damage to crops and houses due to flood and heavy rain at Vamsadhara village in Srikakulum and Koraput districts.
3.	October 26-30,1971	Crossed Orissa coast near Paradip early in the morning of October 30. Maximum wind speed recorded was 150 – 170 KMPH (81-92 Kt.). Lowest pressure recorded 966 hPa near the storm.	10,000 People died and more than one million people rendered homeless. 50,000 Cattle heads perished, 8,00,000 houses damaged.
4.	September 7-14, 1972	Crossed the extreme North Andhra Coast on the afternoon of Sept. 10th. Maximum wind speed recorded at Puri was 175 KMPH (94kt)	100 people died and 8000 cattle heads lost. Near about 2 lakhs people were affected due to this system. Heavy damage to crops and other property was reported from Ganjam, Puri and Cuttack districts, the worst affected being Ganjam district.
5.	September 20-25, 1972	Crossed extreme South Orissa coast near Gopalpur on the afternoon of 22nd September and weakened into a depression by the morning of the 23rd. September. Maximum wind recorded in gust was 136 KMPH (73 Kt.) at Gopalpur about 0740 UTC 0n 22nd.	Caused damage to crops and houses. No loss of life was reported.
6.	November 3-9,1973	Crossed Orissa coast close to and north of Paradip on the early morning of 9th November. I t weakened rapidly and maximum wind speed was recorded 100 KMPH (54 Knot) at Paradip and Chandbali experienced surface2 wind of 100 KMPH (54 Knot).	Caused damage to standing crops in the coastal districts of Orissa between Paradip and Chandbali.
7.	September,14-28, 1981	Crossed Orissa coast near Puri on the early morning of September 26 and weakened into a depression on that evening over interior Orissa and adjoining East Madhya Pradesh.	5 launches were lost in the Bay and many houses were damaged in Midnapur districts of West Bengal and Cuttack districts of Orissa.
8.	May 31 to June 5th, 1982	Crossed on 3rd June near Paradip, Orissa	This cyclone caused heavy damage in the coastal district of Puri, Cuttack and Balasore.
9.	October 9-14,1984	Crossed North Orissa coast near Chandbali in the forenoon of 14th October.	The system caused damage in Cuttack and Balasore district of Orissa and Midnapore district of West Bengal.
10.	17-21 September 1985	Crossed on 20 Sept. closed to Puri, Orissa.	Krishnaprasad, Chilika, Tangi submerged for 3 days due to inundation of sea water. 1.5 mt sea wave of Puri coast was recorded.
11.	13-17 October 1985	Crossed Balasore on 16th October.	High tidal wave of about 16 to 18 feet was observed
12	29-30th Oct., 1999	Crossed Orissa coast near Paradip. (SUPER CYCLONE)	The super cyclone lasted three days and ravaged 14 coastal districts around 15 million people were affected and 17,000 square kilometer of agricultural land was devastated.

1 Knot (Kt) = 1.853 $kmhr^{-1}$

7. Heat wave

The Orissa is prone to another climate induced natural disaster i.e. Heat Waves, which occasionally occurs in some parts of the state during May-June and found to move from one region to another. Hence this phenomenon is termed as a heat wave. Some of the favourable factors responsible for severe heat waves are (i) absence of little or no moisture present in the upper air over the region (ii) cloudless skies which allow maximum insolation (iii) large anticyclonic flow (iv) approaching of dry adiabatic lapse rate (v) presence of warm dry air and appropriate flow pattern for transporting hot air over the region. Study revealed that (Table-35) maximum frequency of heat waves over most of the states was found to be in the month of May (Source: IMD, Pune). In some states like Bihar, U.P. and Rajasthan, the heat waves were more prevalent in June.

Indian Meteorological Department has defined heat wave under two categories. In first category the places where normal maximum temperature is more than 40 °C and then day temperature exceeds by 3-4 °C above the normal, it is affected by heat waves. The second category includes the places where normal maximum temperature is 40 °C or less and day temperature is 5-6 °C above the normal, then the place is to be affected by moderate heat waves. When maximum temperature exceeds more than 6 °C than that of normal, severe heat wave conditions occur in that place. The duration of the heat wave is in general 5-6 days but sometimes it may go up to 15 days. However, severe heat wave generally does not last more than 4-5 days. It is more interesting note that deaths or causalities are more in the year succeeding El-Nino year over India, which confirms the finding that the severe heat wave during May and June is preceded by warm ENSO events (Table–36). However, in some years like 1978, 1979, 1985, 1986 1991, 1995

Fig.-8(a): Maximum extreme temperature values during April-June at Cuttack

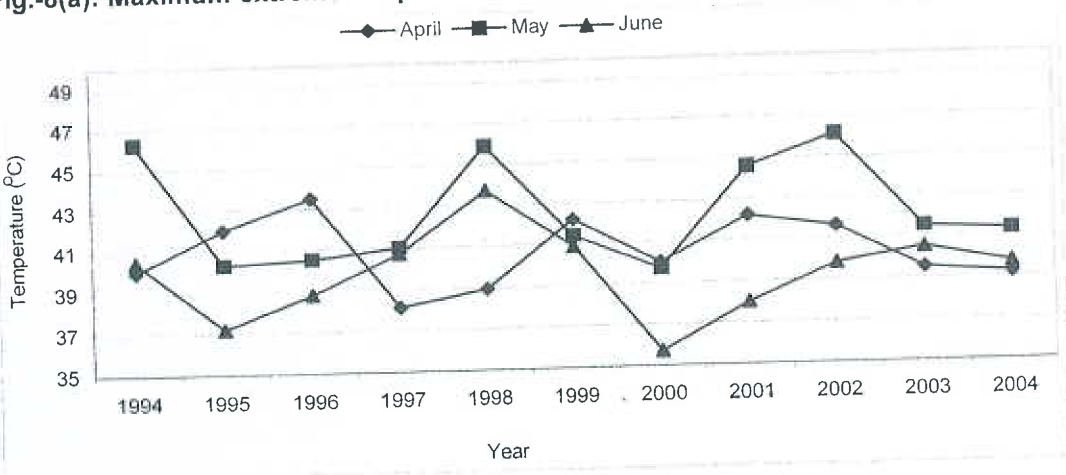
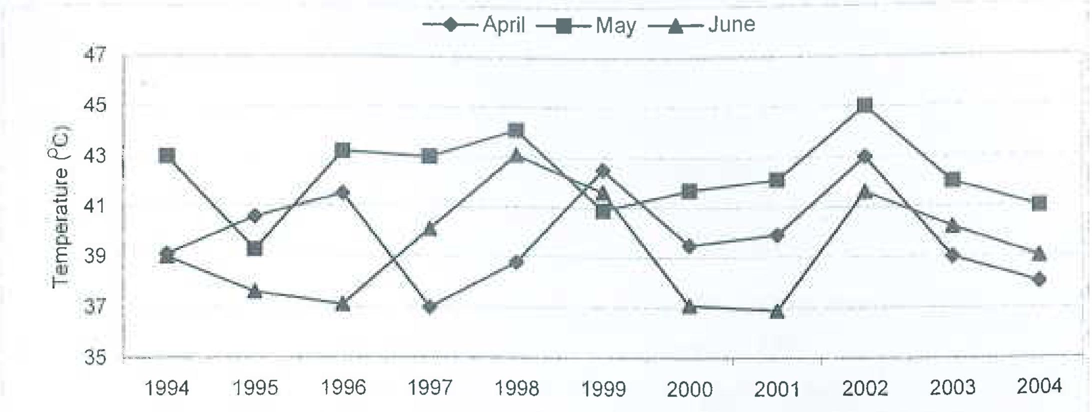


Fig.-8 (b): Maximum extreme temperature values during April-June at Puri.



and 1999 have causalities occur which was not preceded by El-Nino events. A major heat wave in 1998 killed around 1500 people, mostly in coastal Orissa a region otherwise known for its moderate temperature. The extreme maximum temperature during April, May and June in representative coastal districts like Cuttack and Puri are given in Fig. 8 (a) and 8 (b), respectively. Study reveals that in 1998 the highest maximum temperature was 42.6°C when about 1500 people were killed in coastal Orissa. Again in 2002, the peak temperature was 44.5°C in May but the human loss was less because of increasing adaptive capacity and enhancing protective measures.

7.1 Effects of heat wave on ecosystem services and livelihoods

The intensity of discomfort due to the heat wave varies form place to place. The people of high temperature zone adopts quickly to dry spells or heat waves. For the same intensity of heat waves may create more discomfort to the people of low temperature zone. Prolonged severe heat wave condition may cause serious problems to water supply, dryness, deficit of soil moisture etc. that ultimately affects the agriculture and economy.

Table-35: Total number heat waves associated with loss of human lives 1978-1999

State	Month					
	March	April	May	June	July	Total
Andhrapradesh	-	7(21)	8(447)	3(7)	-	18(475)
Assam	-	1(-)	1(-)	1(26)	-	3(26)
Bihar	-	5(112)	9(182)	14(477)	-	28(771)
Gujarat	2(-)	1(10)	4(24)	-	-	7(34)
Haryana	1(-)	1(-)	1(5)	7(31)	2(1)	12(37)
Himachalpradesh	-	-	1(-)	-	-	1(-)
Karnataka	-	1(2)	1(3)	-	-	2(5)
Madhyapradesh	1(-)	1(-)	5(121)	6(44)4(121)	-	13(165)

Maharastra	2(-)	6(12)	23(110)	4(92)	-	35(243)
Orissa	-	1(7)	10(430)	7(92)	-	15(529)
Punjab	-	1(-)	7(22)	19(882)	2(-)	17(114)
Rajasthan	1(-)	5(8)	16(733)	1(3)	1(2)	42(1625
Tamilnadu	-	-	1(20)	10(496)	-	2(23)
Uttarpradesh	1(-)	3(23)	8(167)	6(83)	1(-)	23(686)
West Bengal	-	10(51)	12(24)	3(25)	-	28(158)
Delhi	-	-	1(24)	1(1)	-	4(49)
Chandigarh	-	-	2(1)		-	3(2)

Source : IMD, Pune

Table-36: Loss of lives and no. of spells of heat waves during 1978-1999

Year	No. of death	No. of spell of heat waves	Remarks
1978	368	9	
1979	365	8	
1980	106	8	
1981	63	4	
1982	11	2	El-Nino year
1983	185	13	
1984	58	9	
1985	141	4	
1986	155	5	
1987	90	7	El-Nino year
1988	924	17	
1989	43	10	
1990	2	2	
1991	250	4	
1992	114	5	
1993	73	6	
1994	274	9	
1995	410	34	
1996	17	9	
1997	8	9	El-Nino year
1998	1550	33	
1999	163	16	

Source : IMD, Pune

8.0 LINKING PESTS AND DISEASES IN RICE WITH WEATHER

Rice is the major crop in Orissa, but depending upon the location and moisture regimes, 5-15 % losses are incurred every year by pests and diseases in rice. The appearance, peak infestation, their selective appetites, reproduction, diapause and dispersion are largely governed by weather elements like rainfall, temperature, photoperiod, light intensity, humidity, wind velocity, drought (moisture deficit) etc. In addition to that, other factors like cultivation of high yielding varieties, high dose of nitrogen and phosphorus, low potassium, high plant density and canopy etc. are some of the favourable conditions for infestation of pests and diseases in rice.

It is therefore, urgently needed to determine critical threshold of weather elements for the incidence and spread of pests and diseases in rice. Effective and timely forecasting can help wipe out of outbreak of pests and diseases in crops as influenced by weather. The interrelationship of weather and pests will provide guidelines for seasonal planning, selection of crops/genotypes, more suited to anticipate climatic conditions. In the present paper, critical weather elements for pest and disease infestation in rice of Orissa were analyzed. The study was carried out based on survey report on weather, pests and diseases of Central Integrated Pest Management Centre (CIPMC), Bhubaneswar.

8.1 Weather and insect pests in rice

The influence of different weather elements on insect pest infestation in rice is given below.

8.1.1 Rainfall

The rainfall has direct influence on insect-pest infestation in rice. In Orissa due to high rainfall and cloudy sky during *kharif* (June-October), problems of rice pests are more than drier areas because many rice insects prefer flooding conditions to no-flooding and dry conditions. Taking the example of gall midge *(Orselia oryzae)*, found in the low-lying paddy and irrigated fields has became a serious major pest after 1970 due to rapid expansion of high yielding varieties. With the onset of southwest monsoon in the region, the insect emerges from the stubbles and other grasses. Standing water in the field favours egg laying and hatching for the insect. The insects like case worm, water weevil and whorl maggot would die without flooded/standing water. Yellow stem borer (*S. incertulus)* possess mechanism to survive under water in the stem of deep-water rice. On the other hand, many insects including yellow stem borer are destroyed due to heavy rainfall. Heavy rainfall is also detrimental to green hoppers *(Nephotettix spp.)*. Occurrence of army worms *(Cirphis compta)*, climbing case worms *(Nimphula depunctalis)* in flooded rice field is frequently observed after the flood recedes.

8.1.2 Relative Humidity

The growth, development and reproduction activities of many rice insects are highly controlled by humidity. During *kharif,* high humidity is caused by cloudy sky and high rainfall. Under high humidity condition, infestation of brown plant hopper (*Nilaparvata lugens)* is more both in *kharif* and summer rice. In summer rice crop, it is a serious pest in high yielding varieties which might be due to their high tillering capacity and due to humid micro-environments (about 85%) caused by frequent irrigations. Rice-rice cropping system and no summer-fallow or no off-season tillage are some other important reasons for expansion of stem borers and plant hoppers in both the seasons.

8.1.3 Drought and moisture stress

The prolonged dry spells favour growth and development of soil inhabiting insect pests including seed and root pests. Longer dry spells followed by good rainfall helps in outbreaks of locusts, armyworms and leaf folders. Thrips, termites, mealy bug infest more during low rainfall periods, especially in upland rice.

8.1.4 Day length and bright sunshine hour

Longer duration of sunshine than the normal helps outbreak of stem borer. Low incident radiation causes 'hopper burn', which might be due to ammonia toxicity, caused by cloudy weather. Increased radiation and opening of stomata of crop allowed the toxic ammonia to escape and reduces intensity of 'hopper burn'.

8.1.5 Wind

Insect pests are dispersed by wind, which is found to be an important factor for migration of white backed plant hopper and stem borer. Migratory insects quickly colonise, multiply rapidly and attack the crop.

After introduction of high yielding rice varieties, responsive to high doses of nitrogen and spread of irrigation, many unknown or minor pest of before 1965 like stem borer, rice hispa, mealy bug, leaf roller etc.have become major now and their incidence has been increased by many folds. The important rice pests with their favourable weather conditions of infestation are given in Table-37.

Table-37: Important rice pests with their favourable weather conditions

Insects	*Suitable ecologies*	*Nature of damage*	*Favourable weather and other external physical factors*
1.Stem borer *(Scirpophaga incertulus)*	All ecosystem	Causes dead heart at tillering stage by puncturing into stem. If it attacks at panicle formation stage, creates chaffy white earheads. After oviposition, the eggs hatch and larvae come out and infest the vegetative tillers. The full-grown larvae pupate at the basal portion or in the parts very near to the soil.	Mean temperature 28-29^0 C and relative humidity 60% are optimum for egg laying on the foliage of host plant. If temperature is high, the moths either do not oviposit or eggs do not hatch. The moths remain suppressed in early crop season till September and in high rainfall areas as the rain increases, the surviving larvae infest the crop. The male and female moths of yellow stem borer *(Scirpophaga incertulus)* cannot survive at temperature range of 44- 48^0 C.

2.Gall midge (*Orseolia oryzae*)	Medium and lowland rice ecosystems	The maggot-like larva attacks developing tillers during active tillering stage of crop and causes their base to swell as gall.	High relative humidity (84-94 %) with cloudy sky, monsoon rainfall following a dry spell are some of the congenial environments for incidence of gall midge in August. If pre-monsoon rain or early monsoon rainfall is less, then onset of pest is delayed. High yielding varieties, continous cropping, heavy dose of nitrogen, closer spacing are some of the physical factors favouring infestation of this insect.
3. Brown plant hoppers (*Nilaparvata lugens*)	Sallow and intermediate systems.	These insects suck the sap by puncturing leaves and sheaths. Plants dry in circular patches called as 'hopper burn'.The insect transmits viral diseases.	Heavy rainfall/flood may be factors of resurgence of *Nilaparvata lugens.*
4. Plant hopper White backed/green leaf etc. . *(Nephotettix* spp.)		Sap sucking small insects. Different species of leaf hoppers are green, white, zig-zag or blue coloured are important in *kharif* rice. They suck sap from leaves resulting in brownish yellow and dry from the tips. Plants become sickly and stunted. Green jassids are carrier of *Tungro* and other viruses. Fields affected by *Tungro* virus may loose 80 % grain yield.	Low sunlight and constant rainfall allow rapid build up of *Nephotettix* spp.. Very heavy rainfall or lack of rainfall is detrimental to population build up. Resurgence of *Nyphotettix* is much less than *N. lugens.*
5.Gundhibug (*Leptocorisa varicornis*)	Upland, shallow, irrigated	Prevalent at reproductive stage of the crop, attacks grains by puncturing and sucking the milk. As a result chaffy white grains are produced in the ear head. Endosperm of affected grains is black and unfit for consumption.	Appears in the early maturing rice in August to September. Low temperature and clear sky are some of the favourable factors for infestation of these insects.
6. Rice Hispa (*Hispa armigera*)	Medium and low land	Leaf scrapping insects. Adults are small black beetles with prominent spines on the dorsal surface of the body and scrap green matter from leaf and white parallel lines appears. Larvae mine inside the leaves.	High rainfall and more rainy days associated with high humidity cause outbreak of this insect. Hispa attacks when the minimum temperature remains at 23-27^{0}C with relative humidity more than 90% during the active vegetative stage of the crop.

6. Leaf-roller (*Cnaphalocrosis medinalis*)	Shallow and irrigated low lands.	The caterpillar remains inside the fold created by them and feed on green matter. Leaves look whitish, after their infestation.	Under low temperature, outbreaks of rice leaf minor are found to be frequent. In the *Kharif* season, the population and incidence of insects are more due to high temperature (31.4^{0}C mean temperature; 36.5^{0}C mean maximum temperature) high humidity (80-95%), high cloud cover, less bright sunshine hours (3-4 hours) in Orissa.
7.Caseworm (*Nymphula depunctalis*)	Intermediate and shallow	Caterpillars cut leaf tops, make tubular cases hanging form leaves, remain inside and feed on green leaves, plants look whitish.	Flood prone areas are more vulnerable to case worm attack. Infests mostly in water stagnated areas.
8.Termites	Drought areas, especially in upland.	Insect attack roots and under ground parts, causing witting and death of plants	Well-drained light soils with dry spells after normal onset of monsoon and early good monsoon rainfall.
9. Mealy bug (*Ripersia oryzae*)			Mealy bug population becomes more abundant in upland rice in years with warmer minimum temperature.

8.2 Weather and rice diseases

Disease is a malfunctioning process that is caused by continues irritation, which results in some suffering producing symptoms. The role of weather in outbreak of plant diseases has been realized from early 20th century. In the last years of the second World War (1943), Bengal had to face a serious famine due to outbreak of *Helminthosporium* in rice (Brown spot). The high yielding, short duration and more fertilizer responsive varieties have been found more susceptible to diseases and have caused great havoc in time to time in many parts of the country. The incidence of wheat rust in Madhya Pradesh in 1947, ergot disease of bajra (pearl millet) in Haryana in 1976, downy mildew in Rajasthan in 1994, Tungro virus of rice in U.P. and Bihar in 1966, virus disease of *rabi* in Karnataka and Andhra Pradesh are worth mentioning. The studies of weather in relationship with disease infestation are necessary to take preventive measures. Early detection of inoculum of infection is very often necessary in determining whether a given or anticipated weather situation will cause an outbreak of a disease in epidemic form. Short and medium range forecasts on disease infestation based on eminent weather will be useful for farmers to take protective measures. In case of air borne diseases where the infective spores get emigrated from distant regions, aeromycological observations are required to issue warning about the arrival of inoculumn. Important rice diseases with their favourable weather conditions and extent of damage are given in Table-38.

Table-38: Important rice diseases with their favourable weather conditions and extent of damage.

Major diseases	Affected plant parts and ecology	Damage	Favourable weather or other external factors
1.Blast (*Pyricularia grisea*)	Infests leaf blade and grain. Hill terrain and rainfed upland rice are mostly affected.	Indefinite spindle shaped water socked spots with grey center and brown margin on the leaf blade. Grain partially chaffy and brittle. Panicle shows white appearance when Infects at the panicle neck.	Higher dose of nitrogenous fertilizer and soils with less silica content and low potassium, nutritional disorder favours infestation of blast. High rainfall and more rainy days associated with high humidity cause outbreak of the disease. The disease incidence is also closely related with temperature and humidity regimes. Blast occurs when the minimum temperature remains at 24-26^{0}C with relative humidity more than 90% during the seedling, tillering and ear emergence stages of the crop. Calm to gentle wind, intermittent rainfall, rainy days followed by rainless days with bright sunshine and again rainy days with high humidity are some of the conditions for spread of the disease.
2.Brown spot (*Helminthos-porium spp.)*	Infests grain in drought and eroded soils. Attacks leaf blade in all ecosystem.	When damages leaf blade, small, oval or oblong spots with brown center and dark reddish brown margins occur on leaf blade. On the whole surface of the grain or on the glumes, dark brown oval or oblong spots appear. An epidemic of the disease in Bengal in 1942 resulted in yield loss of 40-90% and was largely responsible for Bengal famine.	Seed borne, aggravated by poor fertility condition. Higher severity is found in poor soils with low pH, especially with low in potassium. Cloudy weather, intermittent showers and foggy mornings with high relative humidity in the summer are conductive for spread of the diseases. Heavy nitrogen fertilization, close planting, inadequate drainage and iron toxicity are important environmental causes. Heavy rainfall in September accompanied with uniformly favourable temperature variation of 25-30^{0}C followed by continued cloudy weather during October and November and a higher minimum temperature than usual in November are favourable conditions for the continued spore production and development of infection of disease at the heading stage of the crop.

3.Sheath blight *(Rhizoctonia solani)*	Infests leaf blade in upland, semi-deep and water logged low land. Infests stem and sheath in all rainfed ecologies.	Greenish grey irregular lesions with dark line on margins, cobra type lesions are large and develop indefinite in older plants. Greenish grey of dark edged whitish lesions which are oval, oblong or irregular found in sheath. The spots first appear near the water line in fields.	High humidity with cloudy sky, low sunlight, high temperature (28-32^{0}C) during *kharif* are favourable for incidence of this disease.
4.False smut (*Ustilagonoide virens*)	Damages grain almost in all ecosystem	Grains are transformed into large spherical, greenish yellowish or orange velvetty mass, which become powdery later.	(i) Heavy dose of nitrogen. (ii) Excess rainfall during flowering to maturity associated with increased cloudiness, high humidity and lowered maximum temperature are more important for the spread of the disease.
5.Sheath rot (*Sarocladium oryzae*)	Stem and grain.	Rot occurs on the upper most leaf sheaths enclosing the young panicles. These panicles remain in the sheath or emerge only partially .	New disease with the introduction of modern high yielding varieties
6.Bactrial leaf blight *(Xanthomonas oryzae)*	Leaf and entire plants	**Infests in two phases:** (i) On leaf, elongated white lesions. (leaf blight) and (ii) On whole plant: Systemic infection that wilts the entire young plant (Kresek). Plants rot completely, starting from the outer leaves. If plants are cut and immersed in water, bacterial drops appear at cut ends.	Moderate but uniform humidity (86-93%), cloudy weather and less of sunshine (3.3 to 7.8 ha^{-1}) are responsible for the high degree of diseases incidence during monsoon season. Rainfall is important for its secondary spread. High rainfall, more rainy days, high relative humidity and the minimum and maximum temperature range of 24.3 to 34^{0}C favour the disease whereas low rainfall, a negligible number of rainy days, low relative humidity, the minimum and maximum range of 18.2-37.2^{0}C adversely affect the spread of the disease. Water logging and shaded conditions increase the intensity of the disease. Wider spacing and drainage reduces magnitude of infestation.
6. Rice tungro (transmitted by *Nephotettix spp.)*	All ecosystems	Brownish yellow in colour and severe to mild stunting, reduced tillering number.	High tungro incidence has been related to temperature range of 15-20^{0}C. Moderate to low temperature favours dwarf, stripe and black streaked dwarf viral diseases.

From the above study it is revealed that the combined effect of weather is more important than their individual effects for diseases and pests infestation because one factor may be cause or effect of the other. Low radiation, low evaporation, high humidity, high rainfall associated with cloudy sky, in general, are congenial for growth and development of most of the insect pests. Weeds (*Cynodon dactylon, Paspalum scorbiculatum, Echinochloa colonum*), wild rice, ratoon rice, rice-rice rotation serve as perpetuating sources for insect survival, multiplication and infestation from crop to crop.

Annexure- 1: District – wise key indicators of Orissa Agriculture (1998-99).

Sl No.	Zone/District	Food grain Production ('000tones)	Area under food grain ('000ha	Yield rate of food grain (kg/ha)	Cropping intensity (%)	Procuction per hectare of gross cropped area (kg/ha)	(GCA) (in '000ha)	Total gross cropped area (GCA) in '000ha)	% GCA Irrigated
1	2	3	4	5	6	7	9	10	11
I.	**NORTHERN PLATEAU**								
1.	Mayurbhanj	327.0	410.0	798.0	127.0	24.0	166.5	513.0	32.5
2.	Keonjhar	116.9	302.9	623.0	134.0	20.0	123.4	401.0	30.8
3.	Sundargarh	213.1	305.8	697.0	120.0	16.0	94.9	395.0	24.0
II.	**CENTRAL TABLE LAND**								
4.	Dhenkanal (Dhenkanal+Angul)	308.3	394.1	773.0	143.5	18.5	190.2	594.0	32.0
5.	Bolangir (Bolangir+Sonepur)	365.4	455.1	933.5	133.0	24.5	203.3	577.0	35.2
6.	Sambalpur (Sambalpur+Baragarh+Deogarh + Jharsuguda)	844.6	659.2	1109.3	128.0	60.8	382.9	846.0	45.3
III.	**EASTERN GHAT**								
7.	Koraput (Koraput+Malkanagiri+Nabarangpur+ Rayagada)	837.7	753.6	1111.3	131.5	20.5	330.4	1068.0	30.9
8.	Kalahandi (Kalahandi+Nuapada)	326.9	564.4	590.0	138.5	18.5	183.2	725.0	25.3
9.	Phulbani (Phulbani+Boudh)	163.0	189.1	866.0	135.0	11.5	87.1	268.0	32.5
IV.	**COASTAL PLAIN**								
10.	Balasore (Balasore +Bhadrak)	416.2	453.7	1044.5	127.5	89.5	270.8	543.0	49.9
11.	Cuttack (Cuttack+Jajpur+Jagatsinghpur+Kendrapara)	939.0	781.3	1202.0	162.8	44.3	697.3	1009.0	69.1
12.	Ganjam (Ganjam+Gajapati)	710.4	593.2	1278.5	153.0	36.5	352.0	763.0	46.1
13.	Puri (Puri+Khurda +Nayagarh)	674.9	589.9	1156.0	167.3	37.0	425.2	726.0	58.1
V.	ORISSA	6378.3	64.52.2	989	139	36.0	3736.9	8425	40.8

Source : Orissa State Development Report (2002), Planning Commission, New Delhi

Annexure-2: Number of drought, normal and surplus months in a year from 1960-2003

Year	Cuttack			Puri			Balasore			Dhenkanal			Phulbani			Koraput			Kalahandi		
	DM	NM	SM	DM	NM	SM	DM	NM	SM	DM	NM	SM	DM	NM	SM	DM	NM	SM	DM	NM	SM
1960	6	6	0				4	7	1	4	7	1	3	9	0	6	4	2	6	5	1
1961	7	4	1				8	4	0	6	5	1	4	7	1	3	5	4	3	7	2
1962	6	6	0				7	4	1	6	6	0	6	4	2	3	8	1	4	8	0
1963	5	7	0				5	7	0	5	7	0	6	6	0	4	7	1	4	7	1
1964	6	5	1				6	6	0	2	10	0	5	6	1	4	7	1	6	6	0
1965	3	9	0	5	6	1	5	6	1	5	7	0	3	9	0	6	5	1	8	4	0
1966	3	7	2	3	7	2	5	6	1	5	6	1	5	6	1	2	7	3	4	7	1
1967	4	6	2	4	6	2	5	5	2	5	4	3	3	6	3	4	5	3	3	3	6
1968	3	6	3	4	3	5	5	6	1	3	8	1	2	8	2	1	7	4	3	9	0
1969	3	9	0	4	6	2	5	6	1	4	8	0	4	5	3	5	7	0	5	6	1
1970	2	8	2	3	7	2	3	7	2	2	9	1	2	8	2	2	9	1	2	9	1
1971	3	7	2	3	8	1	3	6	3	3	7	2	3	7	2	3	6	3	3	6	3
1972	8	4	0	6	6	0	7	5	0	6	5	1	5	7	0	5	7	0	7	4	1
1973	4	7	1	5	6	1	4	6	2	4	6	2	5	6	1	4	8	0	4	7	1
1974	5	6	1	3	9	0	5	6	1	6	6	0	5	7	0	4	8	0	5	7	0
1975	4	8	0	4	8	0	3	9	0	4	8	0	3	9	0	4	8	0	4	7	1
1976	5	7	0	6	6	0	7	5	0	6	5	1	4	8	0	4	8	0	7	5	0
1977	4	7	1	4	8	0	3	8	1	4	6	2	4	7	1	2	8	2	6	6	0
1978	2	9	1	2	9	1	3	9	0	1	10	1	5	7	0	4	8	0	2	9	1
1979	6	5	1	6	6	0	6	5	1	6	6	0	7	5	0	2	10	0	6	4	2
1980	3	9	0	6	5	1	3	9	0	3	9	0	2	10	0	5	7	0	4	8	0
1981	3	8	1	4	6	2	3	8	1	3	9	0	3	7	2	4	6	2	6	4	2
1982	5	4	3	5	5	2	5	5	2	4	6	2	5	5	2	3	9	0	5	6	1
1983	1	10	1	3	8	1	3	8	1	3	7	2	2	8	2	3	8	1	4	7	1
1984	5	7	0	7	5	0	6	6	0	8	4	0	7	5	0	6	5	1	4	7	1
1985	3	8	1	5	6	1	3	8	1	3	6	3	4	5	3	3	7	2	5	6	1
1986	1	9	2	1	10	1	2	9	1	3	7	2	1	9	2	3	9	0	3	7	2
1987	2	8	2	2	8	2	5	5	2	4	6	2	5	5	2	2	8	2	2	8	2
1988	6	6	0	4	8	0	4	8	0	6	6	0	7	5	0	3	8	1	6	5	1
1989	7	4	1	6	5	1	4	7	1	7	5	0	7	4	1	4	8	0	5	7	0
1990	2	6	4	2	5	5	2	7	3	3	5	4	2	6	4	3	5	4	3	5	4
1991	3	8	1	3	6	3	0	11	1	2	9	1	2	10	0	4	8	0	4	7	1
1992	4	7	1	5	5	2	4	6	2	4	8	0	4	8	0	4	8	0	6	6	0
1993	4	8	0	4	8	0	4	8	0	5	7	0	5	7	0	5	7	0	4	8	0
1994	4	6	2	5	6	1	4	7	1	4	8	0	5	7	0	4	8	0	4	7	1
1995	4	5	3	5	5	2	2	8	2	1	8	3	1	8	3	2	8	2	4	5	3
1996	7	5	0	8	4	0	6	5	1	6	6	0	6	6	0	7	5	0	7	5	0
1997	4	6	2	4	4	4	1	8	3	3	7	2	3	6	3	3	7	2	3	7	2
1998	2	8	2	8	4	0	1	9	2	1	10	1	3	6	3	2	9	1	2	7	3
1999	6	4	2	7	3	2	5	6	1	6	4	2	5	6	1	6	6	0	6	5	1
2000	6	6	0	10	2	0	5	6	1	5	7	0	6	5	1	5	6	1	6	5	1
2001	3	6	3	3	8	1	5	7	0	4	7	1	6	4	2						
2002	3	8	1	4	7	1	4	6	2	5	5	2	9	3	0				8	4	0
2003	3	8	1	7	4	1	2	9	1	2	9	1	3	7	2	4	8	0	5	5	2

Year	Keonjhar			Ganjam			Mayurbhanj			Sambalpur			Sundergarh			Bolangir		
	DM	NM	SM	DM	NM	SM	DM	NM	SM	DM	NM	SM	DM	NM	SM	DM	NM	SM
1960	4	7	1	6	5	1	6	5	1	4	7	1	4	7	1	3	8	1
1961	5	7	0	4	6	2	3	7	2	7	4	1	7	5	0	6	3	3
1962	7	5	0	5	4	3	5	7	0	7	5	0	6	5	1	5	6	1
1963	4	7	1	5	6	1	4	6	2	6	5	1	5	6	1	7	5	0
1964	7	5	0	4	7	1	4	8	0	5	7	0	6	5	1	6	5	1
1965	2	8	2	6	6	0	3	7	2	5	5	2	2	9	1	5	6	1
1966	3	7	2	6	5	1	3	7	2	4	4	4	4	6	2	4	7	1
1967	4	5	3	4	6	2	3	7	2	3	6	3	3	7	2	5	5	2
1968	4	8	0	3	7	2	3	9	0	3	7	2	4	7	1	4	6	2
1969	4	7	1	4	8	0	5	7	0	5	7	0	4	7	1	5	6	1
1970	2	8	2	3	8	1	2	9	1	4	7	1	2	9	1	3	8	1
1971	3	6	3	3	8	1	4	6	2	4	7	1	3	8	1	3	8	1
1972	7	5	0	5	6	1	6	6	0	6	6	0	4	8	0	5	7	0
1973	4	6	2	5	6	1	2	8	2	4	7	1	2	10	0	6	6	0
1974	5	6	1	5	6	1	5	6	1	8	4	0	8	4	0	9	3	0
1975	5	7	0	3	9	0	3	9	0	3	9	0	4	8	0	6	6	0
1976	6	6	0	3	9	0	4	8	0	5	7	0	8	4	0	8	4	0
1977	5	5	2	5	5	2	2	8	2	3	9	0	4	7	1	5	6	1
1978	4	8	0	4	8	0	3	9	0	2	9	1	3	7	2	5	6	1
1979	5	6	1	5	7	0	8	3	1	6	6	0	5	7	0	7	5	0
1980	4	8	0	5	7	0	4	7	1	5	7	0	4	7	1	6	6	0
1981	3	8	1	5	6	1	2	7	3	3	8	1	3	9	0	6	6	0
1982	3	7	2	3	8	1	5	5	2	5	6	1	5	6	1	6	5	1
1983	2	7	3	2	10	0	3	7	2	4	4	4	4	7	1	3	8	1
1984	4	8	0	6	5	1	5	7	0	5	7	0	5	7	0	8	4	0
1985	5	6	1	2	9	1	3	8	1	4	8	0	4	7	1	4	6	2
1986	1	9	2	1	10	1	4	7	1	1	9	2	1	9	2	3	7	2
1987	2	7	3	3	7	2	4	6	2	3	7	2	4	7	1	4	6	2
1988	5	7	0	5	7	0	6	6	0	7	5	0	6	5	1	6	6	0
1989	6	5	1	6	6	0	7	4	1	8	4	0	8	4	0	8	4	0
1990	2	7	3	2	6	4	1	9	2	2	5	5	2	8	2	2	7	3
1991	1	11	0	3	8	1	1	11	0	2	10	0	3	8	1	3	8	1
1992	7	5	0	3	9	0	6	6	0	5	7	0	5	7	0	7	5	0
1993	5	6	1	4	8	0	5	6	1	5	7	0	5	7	0	5	7	0
1994	6	6	0	4	7	1	5	5	2	4	6	2	4	6	2	6	4	2
1995	5	5	2	3	6	3	3	6	3	2	7	3	0	9	3	4	5	3
1996	9	3	0	6	6	0	6	6	0	7	5	0	7	5	0	6	6	0
1997	2	7	3	3	7	2	1	10	1	5	5	2	5	5	2	4	7	1
1998	3	7	2	3	6	3	1	8	3	3	6	3	2	7	3	3	8	1
1999	6	4	2	5	7	0	6	5	1	6	5	1	6	5	1	6	5	1
2000	4	8	0	5	6	1	5	7	0	6	4	2	6	6	0	6	6	0
2001	5	6	1	5	2	5				5	7	0						
2002	4	7	1	3	8	1				3	9	0	4	7	1	4	1	7
2003	2	8	2	4	6	2	3	8	1	3	8	1	3	7	2	4	3	5

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