

Growing Season Characterisation of Khordha District of Odisha

A

*Thesis submitted to the Orissa University of Agriculture and
Technology in partial fulfillment of the requirement for the
Degree of Master of Sciences in Agriculture
(Agricultural Meteorology)*

By

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CERTIFICATE-I

This is to certify that the thesis entitled "**Growing Season Characterisation of Khordha District of Odisha**" submitted in partial fulfillment of the requirements for the award of the degree of **Masters of Sciences in Agriculture (Agricultural Meteorology)** to the Orissa University of Agriculture and Technology is a faithful record of bonafide and original research work carried out by **Tapas Panigrahi, Adm. No. 03AM/14** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged.

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This is to certify that the thesis entitled "Growing Season Characterisation of Khordha District of Odisha" submitted by Tapas Panigrahi, Adm. No. 03AM/14 to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of **Masters of Sciences in Agriculture (Agricultural Meteorology)** has been approved by the students' advisory committee and external examiner.

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ABBREVIATIONS USED

AWHC	:	Available Water Holding Capacity
CRIDA	:	Central Research Institute for Dryland Agriculture
CV	:	Co-efficient of Variance
EVP	:	Evaporation
EWS	:	Earliest Week of Start
GSL	:	Growing Season Length
IMD	:	India Meteorological Department
ISM	:	Initial Soil Moisture
LGP	:	Length of Growing Period
LWS	:	Latest Week of Start
MW	:	Meteorological Week
PET	:	Potential Evapotranspiration
PPT	:	Precipitation
RF	:	Rainfall
RH	:	Relative Humidity
SAS	:	Statistical Analysis Software
SMW	:	Standard Meteorological Week
SRC	:	Special Relief Commissioner
SS	:	Bright Sun Shine
STDEV	:	Standard Deviation
SW	:	South-west
SWC	:	Soil Water holding Capacity
Tmax	:	Maximum Temperature
Tmin	:	Minimum Temperature
WC	:	Weather Cock

ABSTRACT

Khordha is an important coastal district of Odisha, comprising of ten blocks. It comes under East & South-Eastern coastal plain agro-climatic zone. Agriculture plays a vital role in the economic development of the district. Agriculture in Khordha district is mostly rainfed. Hence, rainfall plays an important role for crop production in the district. Rainfall characterisation is thus an essential part of agriculture to identify the climatic risks and for a pragmatic crop planning. The determination of start, end and duration of growing season, and the pattern of dry spell during the season are useful information for the planning of land preparation and planting activities. The timing and distribution of rainfall determine the length of growing season.

In the present investigation the growing season was determined based on rainfall, temperature and available soil moisture. Length of growing period (LGP) was calculated through a simple water balance model of FAO by taking weekly precipitation (PPT), potential evapotranspiration (PET) and available water holding capacity (AWHC) of soil. Soil moisture plays a big role in determining LGP in rainfed equal as break monsoon/dry period. From the past 20 years climate data, results indicated that, the number of occurrence of warm days increased, while the number of occurrence of cold days were decreased. But in 2009 it showed drastically and gradually decreased thereafter. Number of extreme hot days ($\geq 40^{\circ}\text{C}$) was lowest (7 days) in 1995 and highest (42 days) in 2014. In case of occurrence of cold days ($\leq 15^{\circ}\text{C}$), it was highest (43 days) in 1995, while lowest (14 days) in 2009. Rainfall is not a limiting factor for Khordha district because it receives 1463 mm of annual average rainfall and at 75% of probability the district receives 1210 mm of rainfall. The probability of consecutive wet for two weeks varied from 60% to 90% during SW monsoon, while the probability of consecutive dry week was zero. No significant changes in start, end and subsequent length of growing season occurred over the past 20 years. The average growing season length in Khordha was 26 weeks at 50 mm soil water storage. Hence it was concluded that more than one number of long duration crop (150 days) can't be grown without supplementary irrigation. So there is a need of reorientation of cropping pattern by taking a cereal crop of 120 days duration followed by a pulse crop of 60 days duration to exploit limited cropping season.

CHAPTER 1

INTRODUCTION

INTRODUCTION

Agriculture in Odisha is the mainstay of majority of the populace and thus, holds the key to socio-economic development of the state. The state has cultivated area of 61.80 lakh hectares out of which 29.14 lakh hectares is high land, 17.55 lakh hectares medium land and 15.11 lakh hectares low land. Flood, drought and cyclone visit regularly with varying intensity. The frequent occurrence of these natural calamities badly affects the production of Kharif rice, the major crop of the state. Similarly, in drought years, there is considerable loss in production of pulses and oilseeds both during Kharif and Rabi. These, stand as stumbling blocks in the way of enhancing crop production and productivity (Disaster Management Plan for Odisha, Dept. of Agriculture, 2013). The extreme weather or climate induced natural disasters like drought, flood, cyclone, dry spells, and heat waves occurring alone or in combination create agricultural instability in Odisha. Thus 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), evapotranspiration, air temperature and relative humidity. The rainfall and evapotranspiration ultimately determine Length of Growing Period (LGP), crop water irrigation requirements of different crops of the region. Studies of such climatic parameters are thus helpful in defining risk level arable agriculture, characterising crop growing season and cropping system (Kar *et al.* 2004).

In this study an attempt has been made to characterise the crop growing season of Khordha district of Odisha. The geographic location of Khordha district stands at 19⁰.55' to 20⁰.25'N Latitude and 84⁰.55' to 86⁰.5'E Longitude. Its bioclimatology is much influenced for the short radial distance from the Bay of Bengal and presence of a huge water body like the Chilika Lake. It is situated in the East & South-Eastern coastal plain and the agro-climatic zone blessed with sandy-loam, loam, clay-loam and clayey soil in varied agro-eco system. Khordha is divided into two district sub-regions, one is Deltaic Alluvium sub-region which comprises of 3 blocks Baliana, Balipatna and Chilika whereas Banpur, Begunia, Bhubaneswar, Bolagarh, Jatni, Khordha & Tangi belong to Lateritic sub-region. Seasonal climate variability, notably rainfall variability, results in depressed seasonal agricultural production in rainfed conditions which mostly rely on rainfall as the

main source of required moisture (Bannayan *et al.* 2010). The most important questions about rainfall from the farmer's point of view are concerned with the onset, cessation and length of the rainy season including the risk of dry spells within the growing season. These constitute the so-called growing season characteristics. The timing and distribution of rainfall determine both the length and quality of the growing season, and hence have important implications for agricultural production and food security. The quality of a growing season is largely determined by the distribution of rainfall within the season (Nganga *et al.* 2015)

This study presents the findings that was undertaken to analyze the growing season characteristics in Khordha district of Odisha. Software, namely, Weather Cock and PET calculator, developed by CRIDA, Hyderabad were taken for precise analysis.

In the context of above, study entitled “**Growing Season Characterisation of Khordha District of Odisha**” is undertaken consisting of historical weather data analysis by using Weather Cock, PET calculator and SAS with following objectives

- To study growing season thermal characteristics of Khordha district.
- To study spatial and temporal variability of rainfall in Khordha district.
- To determine the length of growing period (LGP) for different soil types of Khordha district.
- To calculate probability of consecutive wet and dry spell during major growing period of Khordha district.

CHAPTER 2

REVIEW OF LITERATURES

REVIEW OF LITERATURE

A literature review can be an informative, critical, and useful synthesis of a particular topic. It can identify what is known (and unknown) in the subject area, identify areas of controversy or debate, and help formulate questions that need further research (Bolderston, 2008).

A good review can extract new ideas from others' work by synthesizing and summarizing previous sources. New theories can be built from the evidence discussed, and new directions for future research can be suggested (Brettle & Gambling, 2003).

The review has been organised objective wise under the following headings:

1. Growing season thermal characteristics of Khordha districts of Odisha.
2. Spatial and temporal variability of rainfall in Khordha district.
3. Length of growing period (LGP) for different soil types of Khordha district.
4. Probability of consecutive dry and wet spell during crop growing period.

2.1 Growing season thermal characteristics of Khordha district of Odisha

Pasupalak (2015) reported that the entire coastal districts of Odisha are warm in SW monsoon season and post monsoon season. Kandhamal and Boudh are two coldest district and minimum less temperature even in summer. During summer, the entire western, southern and two central district namely Angul and Dhenkanal are in the hottest zone exceeding 38°C.

Mean day length during vegetative growing period had a decreasing trend at most of the investigated stations owing to delay of sowing date or/and advancement of heading date, which counterbalanced the roles of temperature in controlling the duration of vegetative growing period. In-depth analyses showed that thermal requirements from sowing to almost each development stage increased, however the thermal requirements to complete each single development stage changed differently, which tended to increase yield and adapt to ongoing climate change (Tao *et al.* 2012).

During the period of 1980–2009, the regional average growing season indices (i.e., the start, end and length of the growing season) showed significant changes due to increasing air temperatures. The variations in the growing season indices throughout the TP during the last 50 years had been strongly correlated with the elevation (Dong *et al.* 2012).

The thermal requirements of crop cultivars to complete each single development stage changed differently. The different changes in cultivar thermal characteristics among development stages tend to increase crop yield (Tao *et al.* 2012).

The seasonal mean maximum temperature of Odisha is 32 °C as reported by Kumar *et al.* (2011). They have predicted an increase of 1 °C in temperature and 10% increase in rainfall at coastal districts of Odisha by 2030.

In the context of global warming, an increasing number of studies based on phenological, meteorological and satellite data have reported a lengthening of the growing season related to air temperature increases for most of the Northern Hemisphere during the twentieth century (Jeong *et al.* 2011).

The strong albedo of the snow/ice cover in spring and autumn on the higher plateau results in a much smaller effect due to solar radiation, and the large thermal capacity of the snow/ice cover functions as a buffer and stabilizes the temperature variation in spring and autumn (Lu *et al.* 2010), which leads to relatively low rates of change in the growing season indices in the higher regions of the TP.

An earlier onset of spring for mid- and higher latitudes and a significant extension of the growing season particularly in the northern hemisphere, due to climate warming (Craufurd and Wheeler, 2009).

Agricultural production and ecosystems throughout the TP are strongly constrained by low temperature due to the high altitude, which causes a short growing season (Piao *et al.* 2006, Paltridge *et al.* 2009).

Lavalle *et al.* (2009) reported that a longer growing season may favour the introduction of new species in areas previously limited by unfavourable thermal conditions.

The majority of events advanced significantly, 78% of mean trends in emergence and flowering dates of annual crops were significant, and more than 80% of the correlation coefficients between crop phenology changes and seasonal temperatures were significant (Estrella *et al.* 2009).

Previous studies found that the growing season length has been extended for the majority of the Northern Hemisphere in association with increasing temperatures (Linderholm, 2006).

The intensity of assimilation, as measured by the agricultural production of dry substance, is fairly well proportional to the daily increment of the effective temperature sum (Solantie, 2004).

Menzel *et al.* (2003) found that the variation in the growing season in Germany was most dependent on the increase in the daily minimum temperature.

Based on phenological data, Abu-Asab *et al.* (2001) demonstrated that the start of the growing season for 89 plants was directly correlated to the local minimum temperatures.

2.2 Spatial and temporal variability of rainfall in Khordha district.

Saha *et al.* (2015) found that the spatial distribution of rainfall in Mizoram is highly variable. The dependency of agricultural production on monsoonal rainfall is high with increasing proneness of Mizo agriculture towards the consequences of rainfall variability. Substantial amount of annual rainfall (~36%) received during pre-monsoon season (March–May) has reduced the sole dependency on monsoonal rainfall during June–September (~58%).

The variability of annual rainfall in Odisha is 21% CV. Eight districts have high variability (>23%), while 10 districts have low variability (<20%), variability is maximum (25%) in Sonepur district and minimum (16%) in Sundargarh district. In general districts of low rainfall have high variability and few rainy days. (Pasupalak, 2015).

The area-averaged precipitation shows an increasing trend in the Southeast Tibetan Plateau (STP) with strong temporal and spatial variations. The seasonal and annual precipitation increased, except in the summer; the annual precipitation

increased by about one millimetre per year over the last 52 years. The spring precipitation significantly increased at the 99% confidence level, while the mean summer precipitation insignificantly decreased at the 95% confidence 10 level (Zhang *et al.* 2015).

Hossain *et al.* (2014) observed that rainfall increased during the period 1948–2007, while the trends intensified during post-1990s. Post-monsoon and winter rainfall was observed to follow significant positive trends at most weather stations during the time period 1948–2007. The rate of change was found in exposed zone and interior zone are +12.51 and +4.86 mm/year, respectively, over post monsoon and +0.9 and +1.86 mm/year, respectively, over winter.

Temporal and spatial distributions of precipitation changes were extremely uneven and variable between regions (Manish, 2014).

Jain *et al.* (2013) reported significant increase in August rainfall (as well as monsoon rainfall), with no significant trend in annual rainfall for NMMT (Nagaland, Manipur, Mizoram and Tripura ~ 70,495 sq. km) hydro-meteorological subdivision.

Summer (July–September) seasonal and annual rainfall data exhibit significant decreasing trends in northern, north-western and western parts of the Ethiopia, whereas a few grid points in eastern areas show increasing annual rainfall trends. Most other parts of the country exhibit statistically insignificant trends. Regions with high annual and seasonal rainfall distribution exhibit high temporal and spatial correlation indices (Wagesho *et al.* 2013).

Spatial variability of rainfall over Jordan indicated high rainfall patterns in the western and north western sub-regions the western and the north western sub-regions depict relatively higher rainfall patterns. According to temporal variability, monthly average is least for the month of June, July, August and September for all these 28 years (~0 mm) while maximum rainfall occurs in the month of January (98.1mm) followed by February (83.7 mm) and December (78.1mm). Figure 5 and 6 show the monthly average rainfall distribution of 28 years of individual months (Al-Mashagbah and Mohammad, 2013).

The summer monsoon rainfall over northeast India shows characteristic spatial and temporal variability due to the interaction of basic monsoon flow with orography and the synoptic scale systems developing over Indian region (Mohapatra *et al.* 2011).

Das *et al.* (2009) reported the role of significant erratic annual rainfall received for imposing serious threats of agricultural drought in the different states of NE India.

Jhajharia *et al.* (2009) observed no significant trends in monsoonal rainfall for the plains of Assam, Arunachal Pradesh and Meghalaya, but increasing trend for Tripura, mostly during winter season. Significant decrease in summer monsoon rainfall over the 'South Assam Meteorological Subdivision' (including Mizoram) was observed @ 11 mm/decade¹.

Bewket and Conway (2007) found that high levels of spatial variability exist at sub regional scales in Ethiopia that are unlikely to be fully explained by large-scale climate influences. Choice of study period strongly influences the results of trend analysis in this region due to the effects of decadal variability (particularly because the 1980s was the driest decade and the 1990s the wettest decade on record). Annual rainfall in the region recovered during the 1990s, although 2001–2003 were average or slightly lower. There are no consistent emergent patterns or trends in daily rainfall characteristics in this part of Ethiopia.

The summer rainfall that accounts for the major part (approx. 65–95%) of total annual rainfall over Ethiopia is governed by the El Niño-Southern Oscillation (ENSO) and further enhanced by local climatic forcing (Korecha and Barnston, 2007).

From 1900 to 2005 the precipitation increased significantly in eastern parts of northern and southern America, northern Europe and northern and central Asia, whereas precipitation decreased in the Sahel, the Mediterranean, southern Africa and 10 parts of southern Asia (IPCC, 2007).

Previous results have shown that precipitation generally increases with the elevation in the Asian monsoon region and generally decreases with elevation in the Indian 25 monsoon region (Lu *et al.* 2007).

Seleshi and Camberlin (2006) reported absence of trends in many indices of extreme rainfall events for the kiremt and belg rainfall seasons in much of Ethiopia and absence of trend in the length of maximum dry spells (days with <1 mm rainfall) in both seasons.

Seleshi and Zanke (2004) who found no significant trend in the annual and seasonal rainfall totals in the central, northern and north-western parts of the country over the period 1965–2002.

The first winter and summer patterns indicated that the large-scale atmospheric circulation could be responsible for the winter and summer precipitation variability (Tosic, 2004).

The response of spatial variability is more pronounced when runoff is simulated from poorly networked station rainfall data in large catchments (Smith *et al.* 2004).

Estimating the spatial distribution of climatic data has become an important part of studies helping to understand climate change and its effects throughout the world (Price *et al.* 2000).

Von (1991) reported that a 10% decrease in seasonal rainfall from the long-term average generally translates into a 4.4% decrease in the country's food production.

2.3 Length of growing period (LGP) for different soil types of Khordha district.

Total length of LGP which was calculated over the period between start and end of LGP for each individual year revealed that the lowest LGP of 154 days was recorded in 1988-89 as against the highest LGP of 350 days in 1977-78. When averaged over 1968-2012, it was observed that mean LGP accounts for 217 ± 46 days with CV of 21% (Sattar and Khan, 2016).

Pasupalak (2015) found that the average duration of growing season for Odisha is 27, 28, 31 and 37 weeks in soils having water holding capacity of 50, 100, 150 and 200mm of soil WHC. In some districts of eastern Odisha like Kendrapara,

Ganjam, Khordha and Puri, the duration of growing season is below 25 weeks with 50mm of soil WHC.

Ngetich *et al.* (2013) found that for the higher altitude regions, average LR onset, representative of the normal/conventional growing period, ranged from 22nd to 26th March to end of April in the region. For the lower altitude region, it ranged from 16th to 30th March. For SR, onset was generally earlier in the high altitude areas with Kiamaogo having the earliest on 13th October. In the low altitude region, onset was comparatively late compared to the higher potential region, but unlike the LR season, spatial and temporal variation was narrower.

The length of growing period (LGP) of four micro-land forms in Bankura district, West Bengal, was determined after estimating the per cent moisture content as well as the stored moisture of soils. The duration of growing period was 150-160 days (Tanr), 160-170 days (Baid) as compared to Kanali (180- 190 days) and Bahal (200-210 days) found by (Dutta *et al.* 2012).

Growing season ended considerably earlier at low elevations than at high elevations, possibly because of the earlier start and more severe dry period in low-elevation areas, such that the length of the growing season was longer in the forests than in the unirrigated fields, paddy fields and urban areas(Chang *et al.* 2011).

Mupangwa *et al.* (2011) concluded that growing seasons have not changed significantly over the past 50 to 74 years in southern Zimbabwe. The relationship between start and end of growing season is stronger as aridity increases.

The results showed that, when temperature was the only limiting factor, Bojnourd station with 197 days showed the longest growing season, however, when precipitation was used along with temperature, longest growing season (124 days) was obtained for Sabzevar station (Bannayan *et al.* 2011).

The simulation results showed that LGP varied greatly from year to year, particularly in locations with sandy soils, due mostly to variation in monthly rainfall occurring at the early part of the growing season (April), but also to some extent by variation at the end of growing season (October). Soil texture on the other hand is

shown to have a large influence on the end of the rice growing period and hence LGP, and also water stress development during growth (Inthavong *et al.* 2010).

The results confirmed that greater growing season stress is likely to occur in areas with a short LGP, as the short LGP was strongly associated with low clay content soils (Inthavong *et al.* 2010).

Liu *et al.* (2010) reported that the national average start of the growing season has shifted 4.6–5.5 days earlier while the average ending date of the growing season has moved 1.8–3.7 days later, increasing the length of the growing season by 6.9–8.7 days depending on the base temperature.

Lavalle *et al.* (2009) reported that a longer growing season may favour the introduction of new species in areas previously limited by unfavourable thermal conditions.

Differences in LGP between the two locations (i.e. south and northwest where soils had similar clay content) are attributed to variation in rainfall. Less water being stored in the fields during the growing season and shorter LGP, reflects a decline in rainfall from south to northwest of the province (Inthavong, 2009).

The existence of relationships between start, end and length of growing season, and number of wet days per growing season is critical for planning farming activities before the start and during the season (Mugalavai *et al.* 2008).

Numerous studies have reported that changes in the growing season length have strong effects on crop production and ecosystems (Piao *et al.* 2007).

Tadross *et al.* (2007) reported that a growing season of 90-120 days can be experienced in southern African countries such as Malawi and Zambia.

An extended growing season length may provide optimal conditions for earlier planting, thereby ensuring maturation and increasing productivity (Linderholm, 2006).

Liu *et al.* (2006) observed an increase in GSL of approximately 17 days over the eastern and central Tibetan Plateau in 1961–2003.

The lack of significant long-term changes suggests that the characteristics of the growing season are influenced by other factors such as rainfall distribution in addition to total rainfall and date of start of the rains (Twomlow *et al.* 2006).

In some years the rains start early while in others they arrive late. Abrupt end of the growing season has been reported in some semi-arid parts of sub-Saharan Africa (Usman and Reason, 2004).

Feng and Hu (2004) found that GSL exhibited an increasing trend in the north and west of the USA, but a decline in the south and southeast USA.

The length of growing season decreases as aridity increases (Aviad *et al.* 2004).

Based on different temperature threshold, many researchers found increasing trends of the growing season length (GSL). For example, an increasing trend in GSL in Italy was found by (Moonen *et al.* 2002).

The condition of having no dry spell of more than 10 days after start of growing season eliminates the possibility of a false start of the season. A period of 30 days is the average length for the initial growth stage of most crops (Allen *et al.* 1998).

Jones and Briffa (1995) analysed daily mean temperatures during the growing season (defined as days with temperature warmer than 5°C) from ca. 200 stations in the former Soviet Union, and found little change in a number of growing season-related variables in the last 110 years, so they found no change in growing season length in their study area.

Oladipo and Kyari (1993) reported that the LGP is more sensitive to the rainfall at beginning of the growing season than to the cessation of rainfall at the end of the season, for investigations in the onset, cessation and LGP in North- ern Nigeria.

2.4 Probability of consecutive dry and wet spell during crop growing period.

The analysis showed that the more chance of occurrence of dry spell at MW 44 to 45 in all talukas of Jalna district. The data studied in the project revealed that the probability of occurrence of 2 weeks dry spell was highest in 44th MW while the

probability of occurrence of 4 weeks dry spell was highest in 42th MW (Gaikwad and Maniyar, 2015).

The results indicated that probability of occurrence of dry week is higher from week 1st to 14th and also from week 41st to 52nd. The range of probability of occurrence of dry week in these weeks varies from 41.67% to 100%. Probability of occurrence of wet week is higher from week 17th to 40th. The range of probability of wet week in these weeks varies from 66.67% to 100%. Week 1st to 4th and 43rd to 52nd of the year remains under stress on an average, as there are 50% to 95.83% chances of occurrence of two consecutive dry weeks. The analysis showed that monsoon starts effectively from week 23rd (4th June to 10th June) in North Lakhimpur (Dabral *et al.* 2014).

Markov chain model indicated that equal to or greater than 50% initial probability of wet weeks were found during 27th to 35th SMW (Standard Meteorological Week) except 28th SMW at Durg block, during 27th to 35th SMWs except 33rd and 34th SMW at Dhamdha block and during 27th to 36th SMWs except 32nd SMW at Patan block, indicating good enough rainfall during seedling and vegetative growth period of rice crop at the three study blocks. Conditional probability of wet weeks also, by and large, indicated good rainfall during this period. Initial and conditional probabilities of dry weeks equal to or greater than 50% were found during nursery (23rd – 26th SMW) and reproductive (37th – 40th SMW) stages of rice crop. This result was found by Pali *et al.* (2014) for Durg district of Chhattisgarh.

The occurrence of dry spells longer than 15 days in a season was more rampant in the lower altitude parts (semi-arid regions) of central high lands of Kenya as reflected by the Kiambere, Kiritiri, Machang'a and Kamburu sites in both seasons (Ngetich *et al.* 2013).

The analysis of consecutive dry and wet spells for Varanasi region revealed that there are less than 20% chances that two consecutive dry weeks will occur during rainy season except 35th and 39th SMW. Similarly, the probability of occurrence of 3 consecutive dry weeks is also very less (less than 10% except 38-39th SMW). The probability of 2 consecutive wet weeks are more than 50% during 26th to 36th SMW and more than 35% during 26-35th SMW (Nema *et al.* 2013).

The results show that in the Makanya catchment the length of dry spell occurrence is highly variable in space, even over relatively short distances. In certain areas the probability of crop failure reaches levels that make rainfed agricultural unsustainable, even close to areas where currently rainfed agriculture is successfully being practised (Fischer *et al.* 2013).

The study reveals that, in south Odisha, the probability of two consecutive dry weeks < 10% during 24th to 39th weeks. The probability occurrence of three consecutive dry weeks is high from 43rd week onwards (55.0 %) and probability of three consecutive dry weeks is less than 10% between 23rd to 39th weeks. The analysis also reveals that the probability of three consecutive wet weeks is very low up to 23rd week and it increased as high as up to 100 per cent in 29th week and it start reducing from 38th week. It reduces to 0% by 43rd week (Dash *et al.* 2013).

There was no significant change in the number of wet days per season over the period reviewed. There is a high probability of 14 and 21 day dry spells during the peak rainfall months in semi-arid southern Zimbabwe (Mupangwa *et al.* 2011).

The result indicated that among the different agroclimatic zones of Bihar state, the initial probability of occurrence of dry week is high (more than 60 %) up to 23rd standard meteorological week for zones-I, IIIA and IIIB while it is up to 18th week for zone-II. The probability occurrence of two consecutive wet weeks is high (more than 60 %) from 28th to 34th weeks, but it is fluctuating and in the case of probability of occurrence of three consecutive weeks, it is never above 60 % even in the peak monsoon months of July and August for zone-I. However, the probability occurrence of three consecutive wet weeks is high (more than 50 %) during the 29th week only and all other weeks between 26th to 39th weeks are below 50 per cent for zone-IIIA (Subash *et al.* 2009).

Semi-arid southern Zimbabwe experiences frequent droughts and dry spells during the growing season, making rainfed cropping risky (Cooper *et al.* 2008).

Increases in dry spell lengths and reductions in wet day frequencies have been reported in Malawi, Zambia and Zimbabwe (Tadross *et al.* 2007).

For Tanzania, Tilya and Mhita (2007) analysed the spatial and temporal frequency of wet and dry spells with 22 rain gauges spread over the country. This study shows the spatial structure of dry spells of Tanzania: long wet spells in the north-eastern highlands and long dry spells in the centre part of the country.

Dry spell analysis of weather data from a site in Machakos district with similar characteristics as low potential areas of the central highlands of Kenya reveals that, maize on a sandy soil is exposed to a dry spell exceeding 15 days in more than three out of five seasons (Barron *et al.* 2003).

During 24th to 39th week probability of two and three consecutive wet weeks is varies from 52.8 to 100% and 28.81 to 100% respectively. This indicates that during this period sufficient rain will be available for plant growth (Panigrahi and Panda, 2002).

CHAPTER 3

MATERIALS AND METHODS

MATERIALS AND METHODS

Research methodology is a way to systematically solve the research problem. It is the structural configuration of the study for conducting research within the framework of the objectives. It includes methods, tools, techniques and approaches for any research work. Methodology furnishes the building block, back bone of the process of enquiry and reasoning, data generation as well as processing. As a whole, research methodology is concerned with the objective verification of generalisation which requires logical analysis of problems and devising appropriate procedure to obtain evidence.

3.1 The study area

Khordha district is located between $19^{\circ}.55'$ to $20^{\circ}.25'$ N Latitude and $84^{\circ}.55'$ to $86^{\circ}.5'$ E Longitude. It comes under East & South-Eastern coastal plain agroclimatic zone and the zone blessed with sandy-loam, loam, clay-loam and clayey soil in varied agro-eco system. The district has 10 blocks, namely, Baliana, Balipatna, Banapur, Begunia, Bhubaneswar, Bolagarh, Jatani, Chilika, Khordha and Jatani (Fig.3.1).



Fig.3.1 Block boundary of Khordha district

(Source: mapsofindia.com)

The climate of area can be described as tropical and paddy is the most dominant crop in this area. Beside paddy other major crops grown in this area are groundnut, black gram, green gram, horse gram, sugarcane and *Rabi* vegetables. Khordha is having 202874 ha. of gross cropped area out of which net sown area is 132108 ha. with cropping intensity 153%. The agricultural activities in the study locations are mainly rainfed, however rainfall is very variable and uncertain. When the farmers cultivate same crop or same variety of any given crop in this locations with variable annual precipitation, final crop yield output would be also quite different across different year.

Daily weather data (1995-2010) of Bhubaneswar, obtained from Department of Agricultural Meteorology, OUAT, Bhubaneswar were used for calculation. Daily weather data included the maximum and minimum temperature, relative humidity, sunshine hours, wind speed and evaporation. Moreover daily rainfall data (1995-2014) at block level were collected from SRC, Odisha and used for growing season assessment.

3.2 Assessment of growing season characteristics

‘Growing season’ can be defined as the period of the year during which rainfall distribution characteristics are suitable for germination, establishment, and full development of the crop. It is the period of the year categorised as the rainy or wet season, the length of which varies spatially, temporally and with crop type.

Twenty years of climatic data were used to characterise the growing season of the study area. The definition of start and end of growing season given by Stern *et al.* (1982) was adopted in this study. The length of the growing season was taken as the duration between the onset and cessation dates of the growing season. Seasonal rainfall was computed from the daily records between the start and end dates of the season for each year. The numbers of consecutive wet and dry weeks within the growing season were determined for each year of record. This was done for the each block of Khordha district. In this study the software, namely, ‘Weather Cock’, ‘PET calculator’ were used for weather data analysis which were developed by CRIDA, Hyderabad. Weather Cock contains 26 numbers of modules, which are related to agroclimatic parameters. Out of total modules 8 to 10 modules were used in this study

for weather data analysis. Some attention to be made before going for weather data analysis by using Weather Cock software are as follows

1. NEVER rename the Weather Cock folder.
2. All Data files are should be either created in Notepad or as csv file (comma separated values) of excel.
3. Kindly examine the data file structure in the SAMPLE DATA folder for any analysis before creating the new data file.
4. While analysing data with .csv file if any error occurs then open the .csv file in Notepad and delete all the last commas in every data line.
5. Data for every day Date structure- mm/dd/yyyy.
6. The possible errors in data are like 12.8.0 or 12..8 or 12.8.instead of 12.8. Data may be typed as a non-numeric symbols (space, _, +).

Correct Data File

Bhubaneswar

Year, Week, RF (MM)

2016, 1, 0

2016, 2, 0

In Correct Data File

Bhubaneswar

Year, Week, RF (MM) ,,

1971, 1, 0 ,,

The outline deals with research method and procedures are as follows.

3.2.1 Collection of historical weather data

Daily rainfall data at block level was collected from Special Relief Commissioner (SRC), Government of Odisha over the period of 1995 to 2014 and processed by using Statistical Analysis Software (SAS, 2014). Daily weather parameters like maximum temperature (Tmax), minimum temperature (Tmin), relative humidity (RH), bright sunshine (SS) and evaporation (EVP) of Bhubaneswar were collected from Department of Agricultural Meteorology, OUAT, Bhubaneswar for the period over 16yrs (1995 - 2010).

3.2.2 Analysis of air temperature

3.2.2.1 Normal temperature

Annual, seasonal and monthly normal temperatures (Tmax and Tmin) were calculated by using the software “Weather Cock” (WC) (Rao et al. 2015). The input data file comprised of daily Tmax and Tmin over the period of 1995 to 2014 (20years). The module of WC named as “Normal.exe” was used to derive seasonal and monthly normal temperature. Daily weather data of Bhubaneswar except rainfall data were taken as the secondary data source for Khordha district. It was because of unavailability of daily weather data at block level. Daily, weekly, monthly and seasonal normal values were obtained by the help of “Normal.exe” module. The output file was like in the following (fig.3.2)

3.2.2.2 Extreme temperature frequency

Extreme temperature frequency was calculated by using daily Tmax and Tmin data separately. Extreme temperatures were taken as ≥ 40 and ≤ 15 for Tmax and Tmin respectively. It is because the annual normal Tmax and Tmin of Khordha district are 33 and 22.4 respectively. Temperature frequency was computed to identify the trend of temperature over the past 20yrs (1995-2014). The modules, namely, “Maximum Temperature.exe” and “Minimum Temperature.exe” were used to compute the extreme temperature frequency. The output file was like in the following (fig.3.3).

3.2.3 Spatial and temporal variability of rainfall

Spatial and temporal variability of rainfall were calculated by using block wise daily rainfall data. Rainfall analysis were done over the period of 20yrs to find out the mean annual, seasonal and monthly rainfall variability with respect to each block. Block wise daily rainfall data were collected from Special Relief Commissioner (SRC), Odisha and the data were processed by using SAS. “Rainy Day.exe” module was used to analyse the rainfall data.

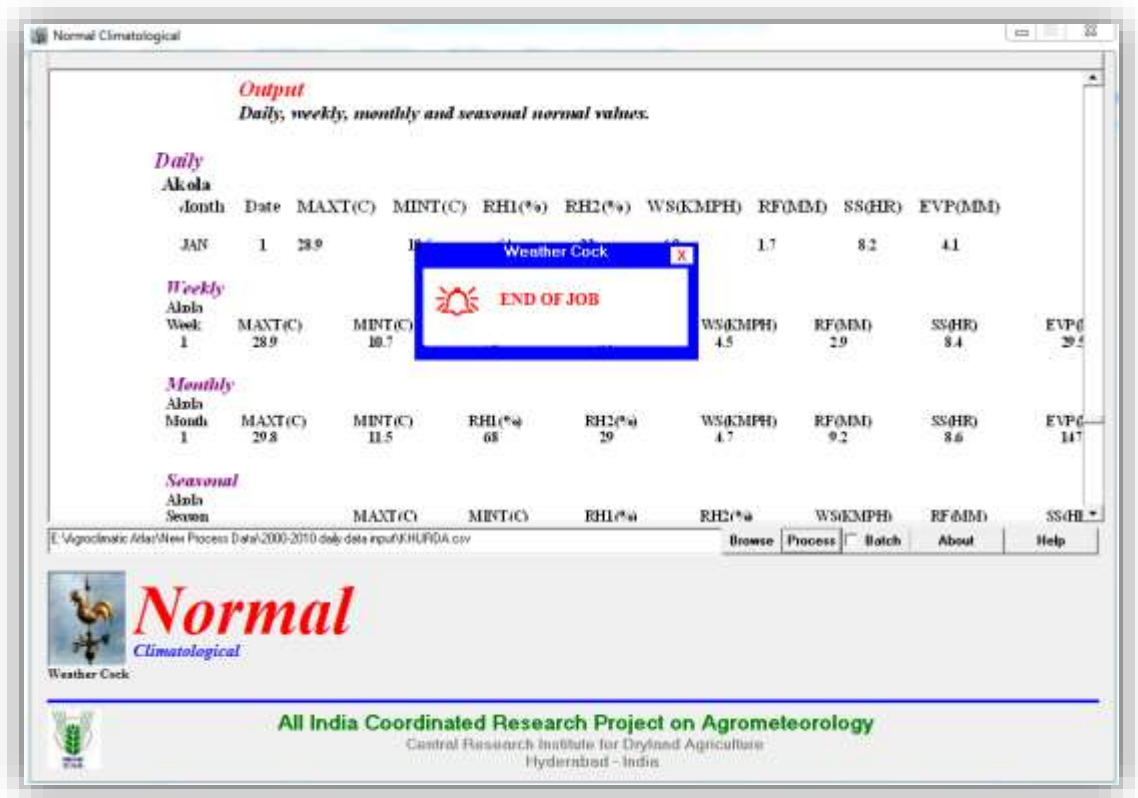


Fig.3.2 Normal temperature output

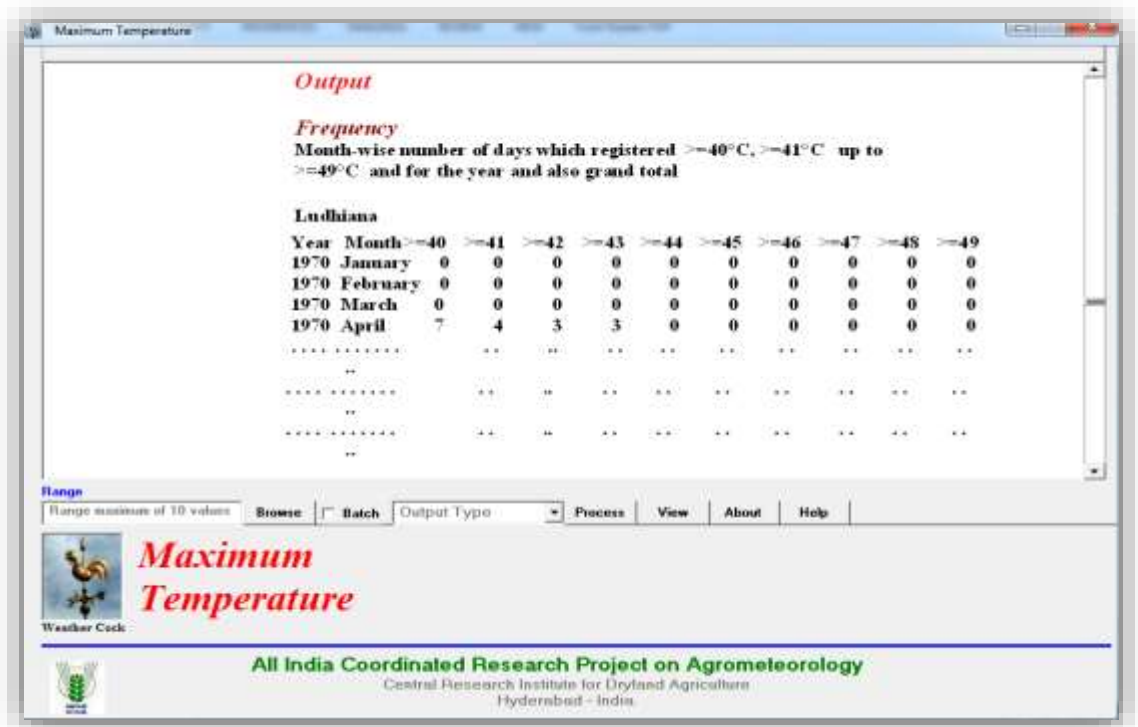


Fig.3.3 Extreme temperature frequency output

3.2.3.1 Annual rainfall and rainy days

Mean annual rainfall and rainy days of each block in Khordha district were computed over the period of 20yrs by the help of “Rainy day.exe” module. Standard deviation (SD) and Co-efficient of variance (CV) were calculated by using statistical equation. Rainy days analysis was done considering that a day with a minimum rainfall of 2.5mm is a rainy day. The output file was like in the following (fig.3.4).

3.2.3.2 Seasonal rainfall and rainy days

Seasonal rainy days and rainfall analysis for each block were also done by the same module which was used for annual rainfall and rainy days analysis. According to the Odisha condition the whole year was categorised into four major season namely SW monsoon, Post-monsoon, summer and winter. Monsoon season consists of four months, namely, June, July, August and September. Post-monsoon consists of two months, namely, October and November. Likewise December, January and February are under winter season and March, April and May are under summer season. SD and CV were also derived for four seasons. The output file was like in the following (fig.3.4).

3.2.3.3 Monthly rainfall and rainy days

Mean monthly rainfall and rainy days for each block were calculated by the same module used in seasonal and annual rainfall analysis. Standard deviation and Co-efficient of variance for every month were calculated by using statistical equations. The output file was like in the following (fig.3.4).

3.2.3.4 Rainfall probability

Annual and weekly rainfall probabilities were calculated through the module “Incomplete Gamma Probabilities.exe”. Block wise weekly rainfall data was used as an input to obtain the annual and weekly probability of rainfall at three levels i.e. 90%, 75% and 50% respectively. The amount of rainfall at three probability level were computed for each standard week by fitting Incomplete Gamma Distribution model. The output file was like in the following (fig.3.5).

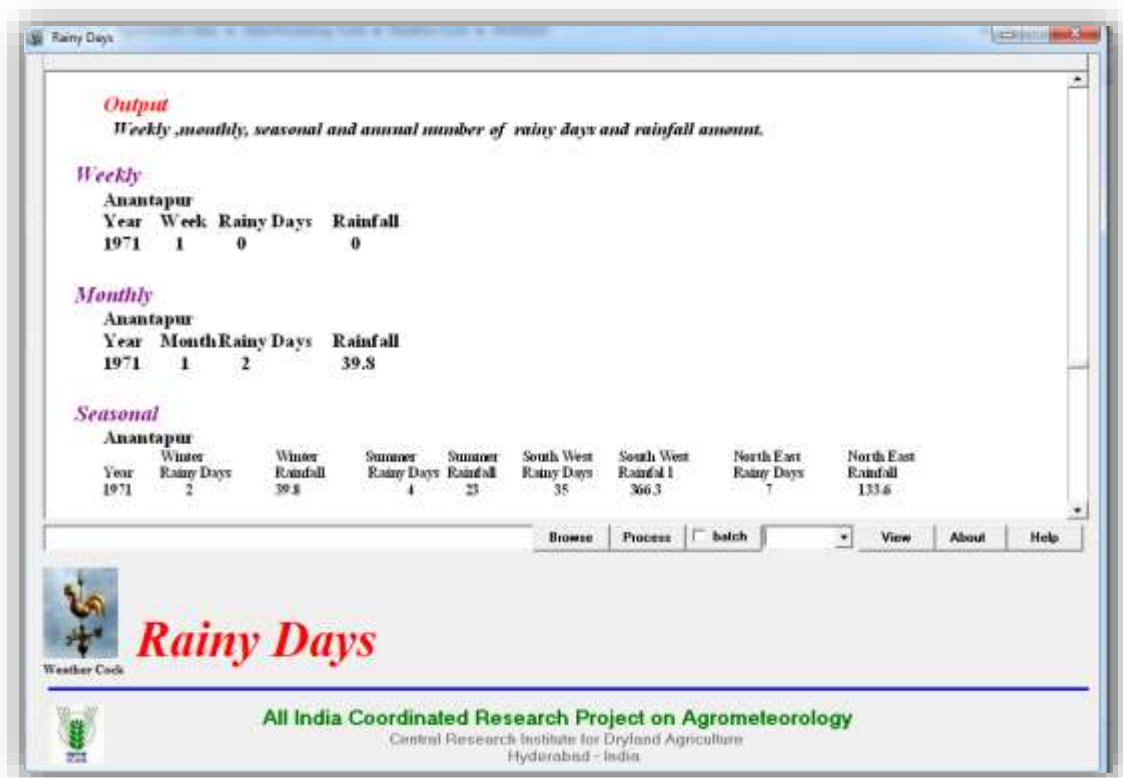


Fig.3.4 Rainfall and rainy days output

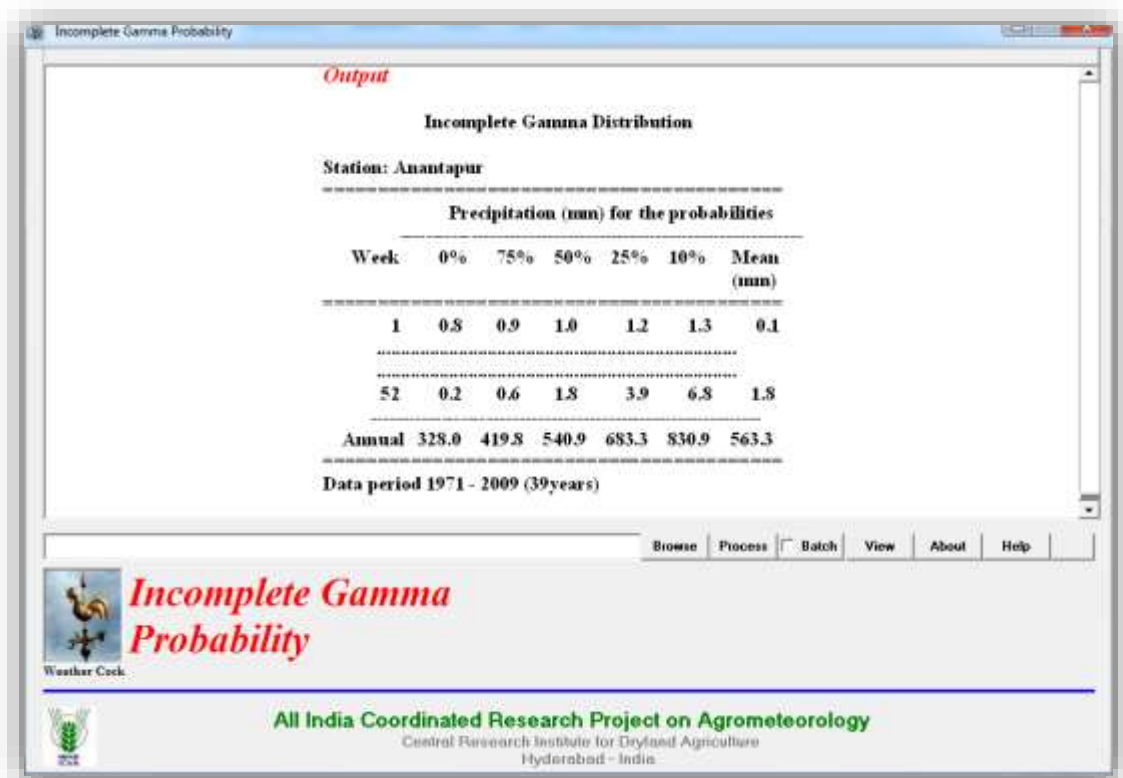


Fig.3.5 Rainfall probability output

3.2.3.5 Meteorological drought frequency

Meteorological drought occurs in all the agroclimatic zones of Odisha. The frequency of moderate and severe meteorological drought were computed based on departures from the normal annual rain for all the districts, as per IMD criteria: 26-50% deficiency is moderate drought and more than 50% is severe drought. However, total of these two drought categories were added and calculated. The result was in percentage of total moderate and severe drought. Daily rainfall data of past 20 years was used to calculate the percentage of occurrence of drought with the help of module named as “Meteorological Drought”. The output result was like in the (fig.3.6).

3.2.4 Determination of length of growing period (LGP)

Length of growing period (FAO, 1978) was delaminated by taking monthly rainfall and Potential Evapotranspiration (PET). As monsoon arrives rainfall increases & PET decreases. The season starts when rainfall exceeds half of the PET. It was determined for one soil type differing available water holding capacity in 100cm soil profile: 50mm and 100mm storage. LGP was calculated through a simple water balance model of FAO. Further LGP was also calculated based on Thornthwaite water balance model to compute the start and end of growing period at two level of available water holding capacity (AWHC). It related rainfall and moisture stored in the soil to PET of a crop later being observed through Penman formula (Penman 1948). Rainfall and temperature to a lesser extent were widely recorded in the district. A number of parameters required to calculate PET, namely, Tmax, Tmin, RH1, RH2, WS, SS and EVP were used from the Bhubaneswar locations. LGP was calculated over sixteen years (1995-2010) of weather data. Annual total duration of growing period, start of growing season and end of growing season were separately calculated for each block of Khordha district. Two modules were used to determine LGP, namely, Length of Growing Period FAO and Length of Growing Period TW. Weekly precipitation (PPT) and potential evapotranspiration (PET) are the required data to calculate LGP through FAO module. But in TW module along with weekly PPT and PET data, additional informations like earliest week of start (EWS), latest week of start (LWS), earliest week of end (EWE), initial soil moisture (ISM) and available water holding capacity (AWHC) were required to get the result.

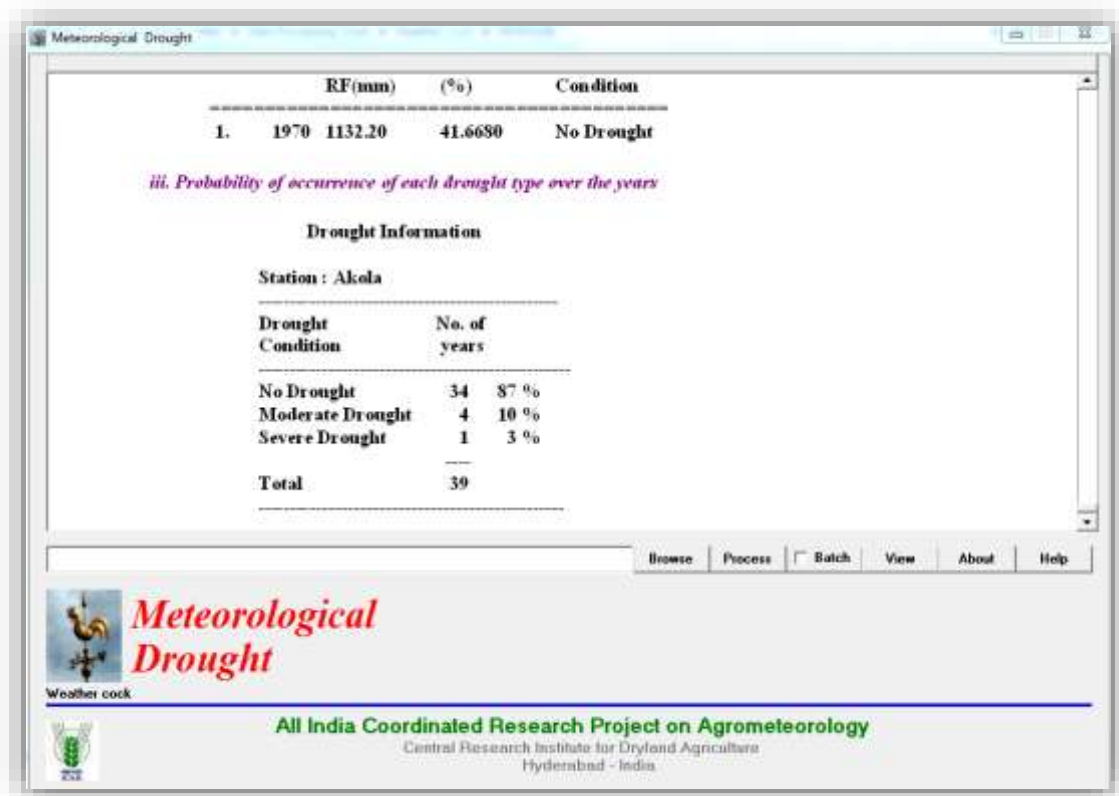


Fig. 3.6 Drought frequency output

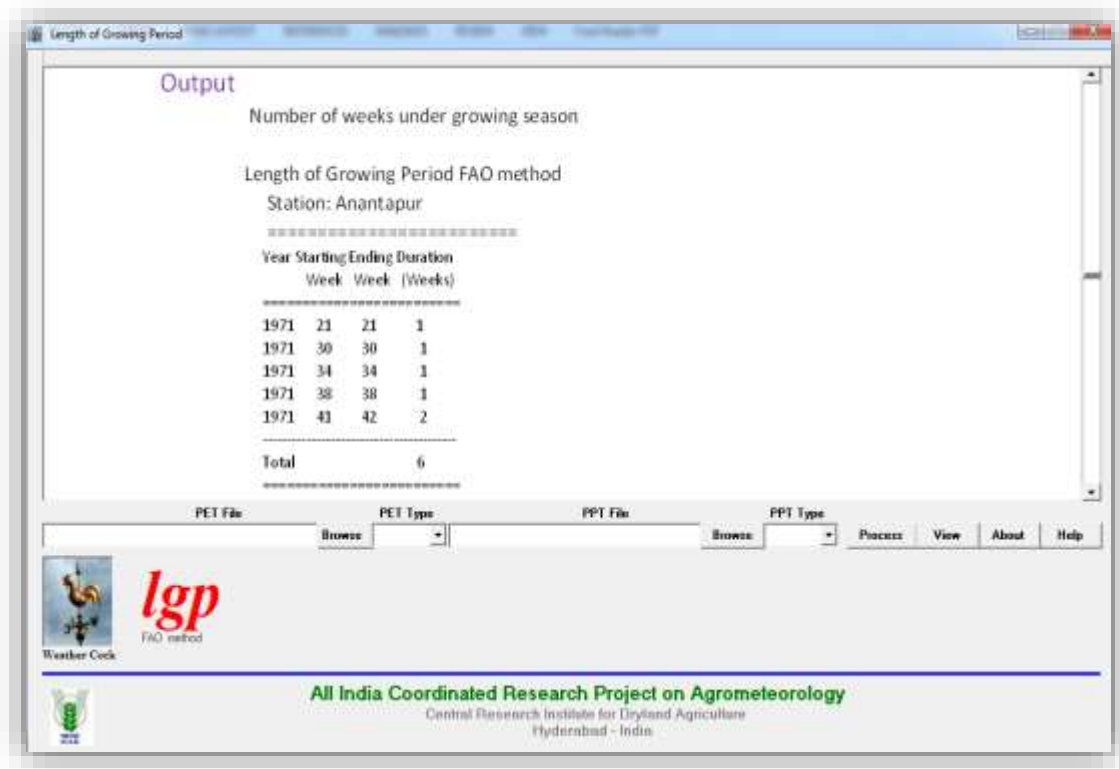


Fig.3.7 Length of growing period (FAO) output

The parameters, namely, EWS, LWS, EWE, ISM and AWHC were taken as 22, 27, 45, 8 and 50 respectively for Khordha district. Weekly precipitation (PPT) and potential evapotranspiration were used to find out total wet period along with start and end of growing period. The output file was like in the (fig.3.7 and fig.3.8).

3.2.5 Probability of consecutive dry and wet spell during growing season

It is the probability of two or three or four weeks as a wet week consecutively for a given amount of rainfall. The probability for getting consecutive dry weeks refer to probability of getting less than the given amount of rainfall consecutively for two or three or four weeks. The given amount of rainfall limit was 20mm, and 40mm. This was because of the mean weekly rainfall in Khordha district was 60 mm during major growing season with SD of 20mm. The module named as “Probability of dry and wet weeks” analysed the probability of consecutive dry and wet spell on the basis of “Markov chain probability model”. Weekly rainfall data of past 20 years were used to determine the probability of consecutive dry and wet spell in Khordha district during major growing season. This model indicates the probability of changes in rainfall from one week to next week. On the basis of Markov chain equation probability of consecutive 2W, 3W and 4W wet and probability of consecutive 2W, 3W and 4W dry were computed. The output result was like in the following (Fig. 3.9).

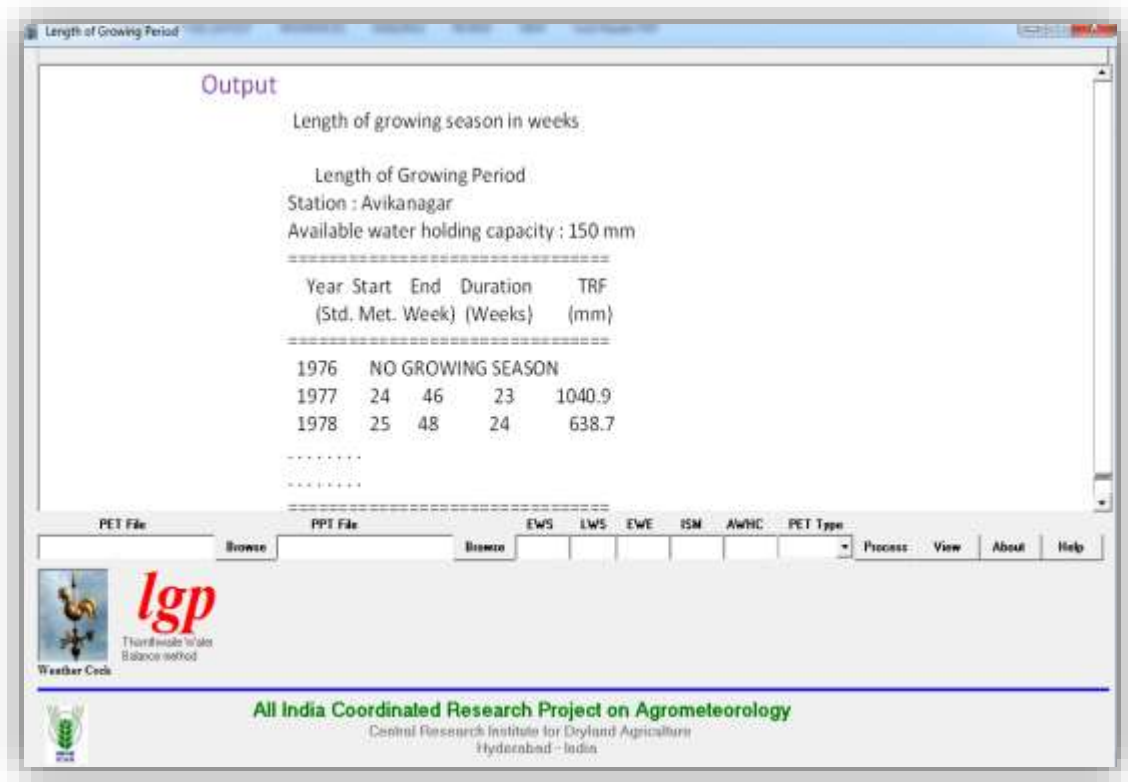


Fig.3.8 Length of growing period (TW) output

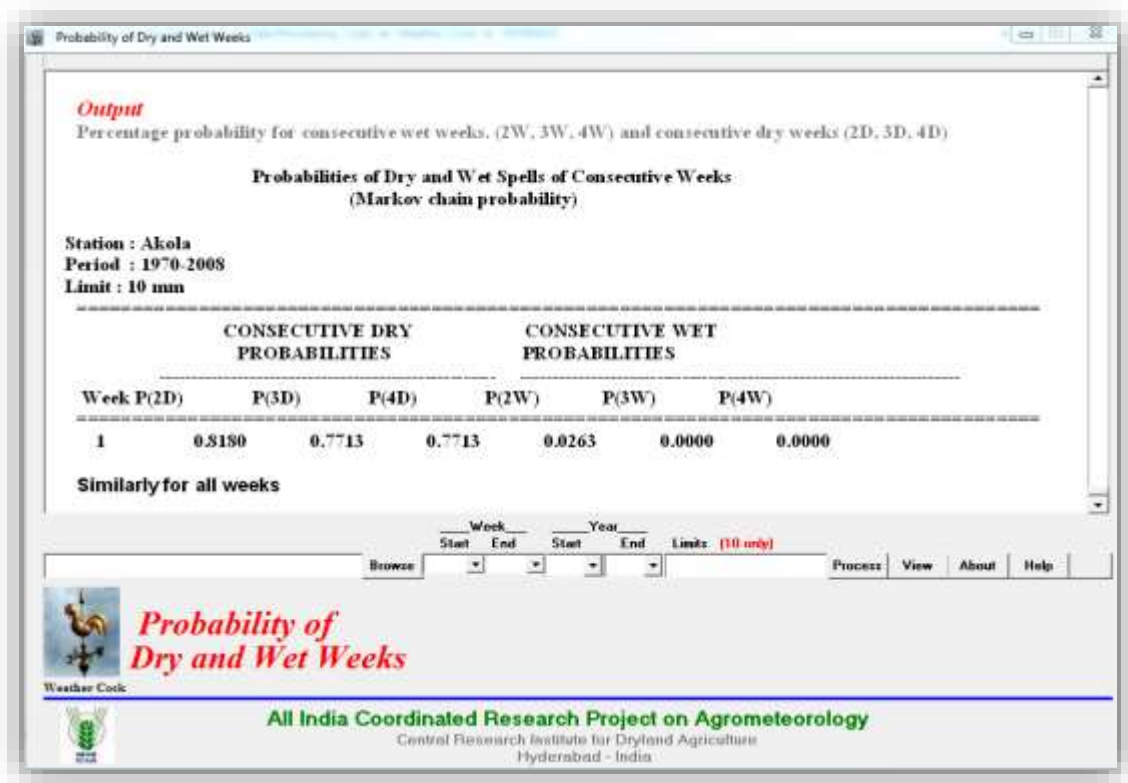


Fig. 3.9 Probability of consecutive dry and wet spell output

CHAPTER 4

RESULTS

RESULTS

4.1 Temperature

IMD data was used for temperature analysis of Khordha district. However IMD data was not available at block level. Therefore the temperature data of Bhubaneswar was used to analyse the temperature of entire Khordha district. Twenty years historical air temperature data of Bhubaneswar was observed to find out the annual extreme temperature frequency. Mean monthly and seasonal mean temperature were calculated.

4.1.1 Mean monthly temperature

The annual maximum temperature of Khordha district was 33°C. However, the maximum temperature in the month of April and May maximum temperature exceeded 37°C and May was the hottest month (37.4°C) of the year (Table 4.1). Maximum temperature of the district varied from 30°-35°C during monsoon and post-monsoon whereas, it remained below 30°C during winter season.

Mean annual minimum temperature of Khordha district was 22.6°C. December was the coldest month (15.6°C) followed by January (16.2°C). Minimum temperature remained above 25°C during summer and monsoon season except March and remained below 20°C during winter season including November (Table 4.1).

Table 4.1 Mean monthly maximum and minimum temperatures

Month	Tmax	Tmin
January	29.5	16.2
February	32.3	19
March	35.6	22.9
April	37.1	25.4
May	37.4	26.6
June	35.3	26.5
July	32.4	25.7
August	32.2	25.6
September	32.3	25.3
October	32	23.5
November	30.8	19.2
December	29	15.6
Annual	33	22.6

4.1.2 Mean seasonal temperature

The maximum and minimum temperatures of Khordha district were 33°C and 26°C respectively, during SW monsoon. Maximum temperature remained highest in summer, while the minimum temperature was highest in SW monsoon. Maximum and minimum temperatures were lowest in winter season i.e. 30°C and 17°C, respectively (Table 4.2). The mean maximum and minimum temperatures were 32°C and 22°C, respectively during post-monsoon.

Table 4.2 Mean seasonal maximum and minimum temperatures

Season	Tmax	Tmin
SW Monsoon	33	26
Post Monsoon	32	22
Winter	30	17
Summer	37	25

4.1.3 Extreme temperature frequency (days)

Extreme temperature frequency ($\geq 40^\circ\text{C}$) increased from 6 days to 41 days during the period from 1995 to 2014 (Table 4.3), while frequency of ($\leq 15^\circ\text{C}$) decreased. Highest (41 days) number of frequency ($\geq 40^\circ\text{C}$) observed in 2014 and lowest (6 days) number of frequency in the year of 1995. From the Table 4.3 it was observed that number of occurrence of hotter days was in increasing trend from the last 20 years, while the frequency of occurrence of cold day was in decreasing trend. However during 1997 to 1999 occurrence of cold day increased and again it decreased gradually from 1999 to 2009.

Table 4.3 Extreme temperature frequency (days)

Year	1995	1996	1997	1998	1999	2002	2003	2004	2005	2009	2010	2013	2014
Tmax	6	5	11	12	16	15	20	16	16	25	21	29	41
Tmin	43	39	28	33	39	33	31	25	23	14	31	30	16

4.2 Rainfall

4.2.1 Distribution of rainfall and rainy days

Rainfall analyses were done on daily data at block level for all the 10 blocks of the district over the period of 1995 to 2014 (Source: Special Relief Commissioner, Government of Odisha, Bhubaneswar). Rainy day analysis was also done considering that a day with a minimum rainfall of 2.5mm was a rainy day.

4.2.2 Annual rainfall and rainy days

The average annual rainfall of the district was 1463mm. Most of the blocks received moderate rainfall (1300 to 1500 mm). Blocks with very high rainfall (>1500 mm) were Baliana, Bhubaneswar and Jatani and very low rainfall (<1300 mm) block was Balipatna (Table 4.4). Except four blocks, namely, Balipatna, Begunia, Bolagarh and Khordha, rest six blocks received more than the district's average rainfall. Bhubaneswar block received highest (1729 mm) rainfall among the all blocks of Khordha district. Total annual rainfall of Khordha district was highest (1873 mm) in 2013 and lowest (776 mm) in 1996. Variability of total annual rainfall and rainy day was 19% and 14%, respectively (Table 4.6).

The variability of annual rainfall in the district was about 24% CV (Tab 4.4). Three blocks, namely, Begunia, Khordha and Bolagarh had high variability (>25%), while 5 blocks, namely, Balipatna, Banapur, Chilika, Jatani and Tangi had low variability (<24%). Variability was maximum (31%) in Bolagarh block and minimum (20%) in Jatani block. Variability was close to district's average variability in 3 blocks, namely, Baliana, Bhubaneswar and Tangi.

The number of annual rainy days in the district was 63-65 days (Fig. 4.5). Out of total blocks 4 blocks had few rainy days (<62 days), while other 4 blocks had more rainy days (>65 days). Tangi block had the highest rainy days (69 days) and Bolagarh had the lowest rainy days (56 days). Both Baliana and Khordha blocks were close to district's average number of rainy days.

Bolagarh had the highest variability (21%) of rainy days, while the average variability of rainy days of the district was 15% (Fig. 4.5). Ten out of 7 blocks had the variability of 12-15 % of annual rainy days except Bolagarh, Balipatna and Chilika. Bhubaneswar and Banapur blocks had the minimum variability of rainy days (12 days).

Table 4.4 Block wise mean annual rainfall with standard deviation and CV (%)

BLOCK	MEAN	STDEV	CV (%)
Balianta	1603	385	24
Balipatna	1072	221	21
Banapur	1502	317	21
Begunia	1378	401	29
Bhubaneswar	1729	424	25
Bolagarh	1301	404	31
Chilika	1472	313	21
Jatani	1662	326	20
Khordha	1438	383	27
Tangi	1469	337	23
Khordha	1463	351	24

Table 4.5 Block wise mean annual rainy days with standard deviation and CV

BLOCK	MEAN	STDEV	CV (%)
Balianta	63	9	15
Balipatna	60	10	17
Banapur	67	8	12
Begunia	59	9	14
Bhubaneswar	66	8	12
Bolagarh	56	12	21
Chilika	60	9	16
Jatani	67	9	14
Khordha	62	9	15
Tangi	69	10	14
Khordha	63	9	15

Table 4.6 Annual rainfall and rainy days of Khordha district

Year	Rainy days	RF (mm)	Year	Rainy days	RF (mm)
1995	108	1858	2006	84	1685
1996	80	778	2007	93	1412
1997	93	1482	2008	99	1447
1998	127	1510	2009	77	1400
1999	102	1473	2010	86	1490
2000	95	1208	2011	93	1175
2001	84	1685	2012	87	1321
2002	84	1685	2013	105	1873
2003	109	1868	2014	81	1414
2004	78	1055	STDEV	13	276
2005	86	1436	CV (%)	14	19

4.2.3 Seasonal rainfall and rainy days

Seasonal analysis of rainfall was done for four season: SW monsoon (June to September), post-monsoon (October to November), winter (December to February) and summer (March to May).

4.2.3.1 South West monsoon

Normal rainfall during SW monsoon was 1075 ± 303 mm, which was nearly 75% of the normal annual rainfall (Table 4.7). Jatani, Baliana and Bhubaneswar blocks had high amount of monsoon rainfall (>1100 mm). Bhubaneswar block had the maximum (1275 mm) and Balipatna block had minimum (793 mm) of monsoon rainfall. Average amount of monsoon rainfall received by 4 blocks, namely, Banapur, Chilika, Tangi and Khordha.

Variability of rainfall during SW monsoon was 28% in the district. In general the district variability was relatively high, compared to the state average of 23%. Khordha, Bolagarh and Begunia blocks had high variability (>30%) of monsoon rainfall (Table 4.7). Begunia showed maximum (37%) variability while Tangi the minimum (21%).

Average number of rainy days spread over the SW monsoon period in the district was 48 days. Most of the blocks had average rainy days of 47-50 days except Bolagarh and Chilika block (Table 4.8). Bolagarh had the minimum (43 days) number of rainy days. Baliana and Balipatna blocks had the maximum (19%) variability of monsoon rainy days, while Khordha and Banapur the minimum (11%).

4.2.3.2 Post-monsoon

Normally Khordha district received 221 mm rainfall during the post monsoon period which was almost 15% of the total annual rainfall (Table 4.7). Balipatna and Begunia blocks had experienced less (<200 mm) post-monsoon rainfall, while Baliana, Bhubaneswar, Banapur and Jatani blocks received more (>240 mm). Maximum rainfall received in Baliana (266 mm) block and minimum in Balipatna (164 mm).

The variability of post-monsoon rainfall in the district was very high (96%). Maximum variability in Baliana block (114%) and minimum in Jatani (80%). All the blocks had $\geq 90\%$ variability of post-monsoon rainfall except 2 blocks, namely, Tangi and Jatani (Table 4.7).

Table 4.7 Mean seasonal rainfall with standard deviation and CV (%)

BLOCK	MONSOON			POSTMONSOON			WINTER			SUMMER		
	Mean mm	SD mm	CV %	Mean mm	SD mm	CV %	Mean mm	SD mm	CV %	Mean mm	SD mm	CV %
Baliana	1166	296	25	266	302	114	20	19	98	151	123	82
Balipatna	793	229	29	164	157	96	22	28	125	92	94	102
Banapur	1063	279	26	249	225	90	33	43	131	157	165	105
Begunia	1031	383	37	183	202	110	32	35	108	132	130	99
Bhubaneswar	1275	379	30	254	251	99	31	31	99	169	139	82
Bolagarh	968	297	31	210	216	103	28	30	110	95	129	136
Chilika	1061	284	27	227	203	90	30	44	145	154	170	111
Jatani	1219	295	24	242	194	80	36	37	102	165	141	86
Khordha	1087	361	33	204	187	92	30	33	109	117	141	121
Tangi	1087	228	21	213	178	83	24	30	123	144	144	99
Khordha	1075	303	28	221	212	96	29	33	115	138	138	102

Table 4.8 Mean seasonal rainy days with standard deviation and CV (%)

BLOCK	MONSOON			POSTMONSOON			WINTER			SUMMER		
	Mean mm	SD mm	CV %	Mean mm	SD mm	CV %	Mean mm	SD mm	CV %	Mean mm	SD mm	CV %
Balianta	49	9	19	8	6	81	1	1	99	5	3	56
Balipatna	47	9	19	7	5	74	1	1	114	5	2	32
Banapur	49	5	11	9	6	68	2	2	112	7	3	45
Begunia	45	7	15	8	5	59	2	2	111	5	3	47
Bhubaneswar	50	7	13	8	5	68	2	2	100	6	2	43
Bolagarh	43	7	17	7	6	78	2	2	110	4	3	77
Chilika	44	6	14	8	5	65	2	2	125	5	3	58
Jatani	50	6	12	8	6	66	2	2	103	6	3	51
Khordha	49	5	11	8	6	73	2	2	110	4	3	58
Tangi	53	7	14	8	5	56	1	2	126	7	3	50
Khordha	48	7	15	8	6	69	2	2	111	5	3	52

Number of rainy days during post-monsoon in Khordha district varied from 7 to 9 days. Most of the blocks had 8 number of average rainy days (Table 4.8), while Banapur had maximum (9 days) number of rainy days. Both Balipatna and Bolagarh blocks had minimum (7 days) number of rainy days. Average rainy days variability in the district was 69%. Balianta showed maximum (81%) variability and Tangi the minimum (56%).

4.2.3.3 Winter

The amount of winter rainfall in the district was very low (29 mm), which was <2% of the annual rainfall (Table 4.7). In general Balianta, Balipatna and Tangi blocks received low (< 25 mm) winter rainfall, while rest other blocks received relatively

higher (≥ 30 mm) winter rainfall except Bolagarh. Jatani received maximum (36 mm) winter rainfall and Baliana the minimum (20 mm).

Winter rainfall was highly (115%) variable in Khordha district (Table 4.7). Blocks namely Chilika, Baliana and Banapur show high ($>125\%$) variability while the maximum (145%) variability in Chilika. Baliana showed minimum (98%) variability.

Average rainy days of the district in winter was 2 days. Mean rainy days of <1 in Baliana, Balipatna and Tangi block. Rest of the block had 2 number of average rainy days (Table 4.8). Variability of rainy days in winter was 111%, which was relatively high. Tangi and Chilika showed high ($\geq 125\%$) variability while Baliana showed the minimum (99%) variability.

4.2.3.4 Summer

The amount of average summer rainfall in the district was 138 mm, which was about 10% of the annual rainfall. Bhubaneswar, Chilika, Jatani and Baliana received more than 150 mm rainfall while Bolagarh and Balipatna received less than 100 mm (Table 4.7). Bhubaneswar block received maximum rainfall (169 mm) and Balipatna the minimum (92 mm). Rainfall variability during summer season was high (102%). Bolagarh showed maximum variability of summer rainfall (136%) while Bhubaneswar and Baliana the minimum (82%).

Mean rainy days of summer season varied from 4-7 days. The block with <5 number of rainy days were Bolagarh and Khordha (Table 4.8). Tangi and Banapur had maximum (7 days) number of summer rainy days. Variability of rainy days during summer was 52%. Bolagarh showed maximum (77%) variability and Balipatna the minimum (32%).

4.2.4 Monthly rainfall and rainy days

Mean monthly rainfall was important for agricultural planning and management practices including sowing and water management. August was the month of highest (342 mm) rainfall in the district (Table 4.9). It was followed by July with 312 mm. December was the month of lowest rainfall (5 mm). Bhubaneswar received maximum (218 mm) amount of rainfall in the month of June, while Balipatna received the minimum (121 mm). Begunia received highest amount of rainfall in the month of January, while Bhubaneswar and Jatani in the month of February. In December

Banapur received >10 mm rainfall, while rest of the blocks receive less than 10 mm rainfall.

The variability was minimum (12%) in August, while July had a marginally higher CV of 13% (Table 4.9). Maximum (54%) variability sown in December followed by March (43%).

Table 4.9 Mean monthly rainfall (mm) with standard deviation (mm) and CV (%)

Block	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Balianta	4	11	9	33	109	175	309	382	300	242	24	4
Balipatna	9	10	7	17	68	121	214	263	195	144	20	3
Banapur	5	15	24	27	106	171	325	326	241	203	46	13
Begunia	17	12	6	28	98	175	293	343	220	161	23	3
Bhubaneswar	7	19	15	38	116	218	357	388	313	225	29	4
Bolagarh	13	10	8	15	73	156	314	286	212	171	40	5
Chilika	10	15	17	22	116	149	321	339	252	186	41	6
Jatani	13	19	11	45	109	209	368	388	254	205	37	4
Khordha	12	11	16	20	82	153	310	364	260	167	37	7
Tangi	6	15	18	26	100	186	313	340	249	173	40	4
Khordha	10	14	13	27	98	171	312	342	250	188	34	5
STDEV	4	4	6	10	17	29	41	42	37	31	9	3
CV	43	26	44	35	18	17	13	12	15	16	27	54

The number of rainy days was highest in August (15 days) followed by July (13 days, Tab 4.10). Four months, namely, January, February, March and April were the months with one rainy day only, whereas in December it was nil. Equal distribution of rainy days in all blocks during the February. In the month of May all blocks had less than five number of rainy days. June rainy day was most (11%) variable in SW monsoon. Rainy days in March was associated with maximum (50%) variability.

Table 4.10 Mean monthly rainy days with standard deviation and CV (%)

Block	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Balianta	1	1	0	1	3	8	13	15	12	7	1	0
Balipatna	0	1	1	1	3	8	12	14	12	6	1	0
Banapur	0	1	2	1	4	10	13	15	11	7	2	0
Begunia	1	1	0	2	3	8	12	14	11	7	1	0
Bhubaneswar	1	1	1	1	4	9	14	15	12	7	1	0
Bolagarh	1	1	1	1	2	7	12	14	10	6	1	0
Chilika	1	1	1	1	3	8	12	14	11	6	2	0
Jatani	1	1	1	1	4	10	14	15	12	7	1	0
Khordha	1	1	1	1	3	8	13	15	13	6	1	0
Tangi	0	1	1	2	4	10	15	16	12	7	2	0
Khordha	1	1	1	1	3	9	13	15	12	7	1	0
STDEV	0	0	0	0	1	1	1	1	1	0	0	0
CV	26	33	50	18	15	11	7	5	8	7	33	21

4.2.5 Dependable rainfall

Crop loss risk could be minimized, if crop management was guided by the level of probability of getting a certain amount of rainfall, which was otherwise known as dependable rainfall. In this study, probability analysis of block level annual rainfall was made at three levels of probability, 90%, 75% and 50% respectively. The 90% dependable rainfall was above 1100 mm in four blocks, namely, Bhubaneswar, Banapur, Balianta and Jatani (Table 4.11). Tangi and Banapur had 90% probable rainfall between 1000 mm to 1100 mm. On the other hand Balipatna, Begunia, Bolagarh and Khordha blocks had below 1000 mm of rainfall at 90% probability. At 75% probability, the probability level which was considered suitable for most of the crops, rainfall was above 1300 mm in three blocks, namely, Bhubaneswar, Balianta and Jatani (Table 4.11). The rainfall was below 1100 mm for the blocks, namely, Balipatna, Begunia and Bolagarh. Khordha received 1210 mm of rainfall at 75% probability.

Balipatna had below 1200 mm rainfall at 50% probability (Table 4.11). On the other hand, the same seven blocks at 75% probability had the maximum annual rainfall exceeding 1400 mm at 50% probability level.

Table 4.11 Rainfall (mm) at three probability

Block	50% Prob	75% Prob	90% Prob
Balianta	1573	1329	1132
Balipatna	1057	912	794
Banapur	1479	1272	1103
Begunia	1340	1089	892
Bhubaneswar	1698	1437	1227
Bolagarh	1261	1011	818
Chilika	1451	1251	1087
Jatani	1641	1427	1251
Khordha	1400	1143	941
Tangi	1444	1229	1054
Khordha	1434	1210	1030

4.2.6 Meteorological drought frequency

The probability of highest (25%) frequency of drought was in Bolagarh block. Four blocks namely, Balianta, Begunia, Khordha and Tangi were under moderate (15%-20%) frequency of drought and rest of the blocks had less (10%) frequency of drought (Table 4.12).

Table 4.12 Meteorological drought frequency

Block	Frequency (% year)
Balianta	20
Balipatna	10
Banapur	10
Begunia	20
Bhubaneswar	10
Bolagarh	25
Chilika	10
Jatani	10
Khordha	20
Tangi	15

4.3 Length of Growing Period (LGP)

4.3.1 Start of growing season

The onset of monsoon determines the start of growing season but the soil type had an important role to play on the feasibility of sowing of crops due to difference in depth of wetting by rainfall and workability of soil. Therefore the start of growing season in each block was computed and presented in Table 4.13 and Table 4.14 for two soil water holding capacities (SWC), 50 and 100 mm respectively. For soil water holding capacity of 50 mm and 100 mm the season commences on an average on 24th SMW in seven out of 10 blocks. In Banapur, Bhubaneswar and Chilika growing season commencements on 23rd SMW at 50 mm soil water holding capacity. But at 100 mm SWC, Bhubaneswar, Banapur and Jatani blocks had the same week (23rd SMW) of commencement.

4.3.2 End of growing season

In most of the blocks growing season terminates between 48th SMW and 49th SMW at 50 mm of soil water holding capacity (Table 4.13). At 100 mm SWC, growing season normally terminates in 50th SMW while in Banapur and Bolagarh growing season terminates in 51st SMW. Depending on soil moisture growing season ends one SMW earlier in case of 50 mm of SWC as compared to the soil water holding capacity of 100 mm. In seven out of 10 blocks, growing season terminates between 50th and 51st SMW at 100 mm of SWC (Table 4.14).

4.13 Length of growing period at 50 mm soil water holding capacity

Block	Start (SMW)	End (SMW)	Duration (week)	Duration (Days)
Balianta	24	50	27	189
Balipatna	24	50	26	182
Banapur	23	48	26	182
Begunia	24	48	25	175
Bhubaneswar	23	49	27	189
Bolagarh	24	49	27	189
Chilika	23	48	26	182
Jatani	24	50	27	189
Khordha	24	49	26	182
Tangi	24	49	26	182
Khordha	24	49	26	184
STDEV	0.5	0.8	0.7	4.7
CV (%)	2	2	3	3

4.3.3 Duration of growing season

The average duration of growing season for Khordha district was 26 and 27 weeks in soils having water holding capacity of 50 mm and 100 mm, respectively. In Baliana, Bolagarh and Jatani, the duration of growing season was above 26 weeks at 50 mm of SWC, while Begunia had the lowest (25 weeks) growing season duration (Table 4.13). The duration of growing season was longest (29 weeks) in Banapur block at 100 mm of soil WHC while Baliana, Balipatna and Begunia had the growing season duration of below 27 weeks (Table 4.14).

4.14 Length of growing period at 100 mm soil water holding capacity

Block	Start (SMW)	End (SMW)	Duration (week)	Duration (Days)
Baliana	24	49	26	182
Balipatna	24	49	26	182
Banapur	23	51	29	203
Begunia	24	49	26	182
Bhubaneswar	23	50	27	189
Bolagarh	24	51	28	196
Chilika	24	50	28	196
Jatani	23	50	27	196
Khordha	24	50	27	189
Tangi	24	50	27	189
Khordha	24	50	27	189
STDEV	0.48	0.74	0.99	6.96
CV	2	1	4	4

4.3.4 Total annual wet period

Total wet period in a year calculated by using FAO method. It calculates the total number of days during a year when precipitation exceeds half of the PET. In Khordha the total number of wet days was 131 days (Table 4.15). Tangi had the highest number of wet days (142 days) followed by Chilika and Banapur (140 days). Baliana

and Bolagarh had less number of wet days (<120 days). Banapur, Bhubaneswar, Chilika, Jatani and Tangi blocks had more number of wet days (>135 days), whereas the lowest number of wet days (115) was in Baliana block.

Table 4.15 Total annual wet period

Block	Duration (Days) of Wet Period
Baliana	115
Balipatna	123
Banapur	140
Begunia	131
Bhubaneswar	137
Bolagarh	118
Chilika	140
Jatani	139
Khordha	122
Tangi	142
Khordha	131
STDEV	10
CV (%)	8

4.4 Probability of consecutive dry and wet spell

Probability of consecutive dry and wet spell was computed on the basis of “Markove Chain Model”. Weekly rainfall data of past twenty years were subjected to the model to get the result in Table 4.16 and Table 4.17 at 20 mm and 40 mm of rainfall limit, respectively.

4.4.1 Probability of consecutive dry and wet spell at rainfall limit of 20 mm

The result indicated that probability of occurrence of two consecutive dry week was higher from week 1st to 17th and also from week 42nd to 51st. The probability range of occurrence of dry week in these weeks varied from 60% to 100%. Probability of occurrence of two consecutive wet week was higher from week 25th to 37th. The range of probability of wet week in these weeks varied from 60% to 85%. Week 1st to 15th

and 46th to 51st of the year remained under stress on an average, as there were 75% to 90% chances of occurrence of three consecutive dry weeks. The analysis showed that monsoon starts effectively from 25th SMW (18th June to 24th June) in Khordha district of Odisha (Table 4.16). Probability of occurrence of 2 weeks dry spell was highest in 12th week (100%), while the probability of occurrence of 4 weeks dry spell was highest in 46th and 47th week (86%). In other end the probability of occurrence of 2 weeks wet spell was highest in 30th, 33rd, 34th and 37th week (90%), while 4 weeks wet spell was highest in 30th, 31st and 32nd week. Probability of consecutive wet for 3 weeks was highest in 33rd week, while the consecutive dry was varied from 75% to 90% during winter and first half of the summer.

Table 4.16 Probability of consecutive dry and wet spell at 20 mm

SMW	Consecutive dry probability			Consecutive wet probability		
	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0.95	0.90	0.85	0.00	0.00	0.00
2	0.90	0.85	0.85	0.00	0.00	0.00
3	0.90	0.90	0.81	0.00	0.00	0.00
4	0.95	0.86	0.81	0.00	0.00	0.00
5	0.90	0.85	0.76	0.00	0.00	0.00
6	0.85	0.76	0.72	0.00	0.00	0.00
7	0.85	0.80	0.80	0.00	0.00	0.00
8	0.85	0.85	0.76	0.05	0.03	0.00
9	0.90	0.81	0.81	0.05	0.00	0.00
10	0.85	0.85	0.85	0.00	0.00	0.00
11	0.90	0.90	0.77	0.00	0.00	0.00
12	1.00	0.85	0.85	0.00	0.00	0.00
13	0.85	0.85	0.77	0.00	0.00	0.00
14	0.85	0.77	0.64	0.00	0.00	0.00
15	0.90	0.75	0.53	0.00	0.00	0.00
16	0.75	0.53	0.28	0.00	0.00	0.00
17	0.60	0.32	0.25	0.00	0.00	0.00
18	0.40	0.31	0.23	0.00	0.00	0.00
19	0.50	0.38	0.32	0.25	0.13	0.05
20	0.45	0.38	0.28	0.20	0.09	0.09
21	0.55	0.40	0.18	0.15	0.15	0.08
22	0.55	0.25	0.08	0.25	0.14	0.11
23	0.25	0.08	0.02	0.25	0.20	0.20
24	0.15	0.03	0.00	0.45	0.45	0.38
25	0.05	0.00	0.00	0.75	0.63	0.45

26	0.00	0.00	0.00	0.80	0.56	0.53
27	0.00	0.00	0.00	0.60	0.56	0.53
28	0.05	0.00	0.00	0.70	0.66	0.63
29	0.00	0.00	0.00	0.85	0.81	0.72
30	0.00	0.00	0.00	0.90	0.81	0.76
31	0.00	0.00	0.00	0.85	0.80	0.76
32	0.00	0.00	0.00	0.85	0.81	0.76
33	0.00	0.00	0.00	0.90	0.85	0.72
34	0.00	0.00	0.00	0.90	0.76	0.71
35	0.00	0.00	0.00	0.80	0.75	0.75
36	0.05	0.03	0.00	0.80	0.80	0.55
37	0.05	0.00	0.00	0.90	0.62	0.53
38	0.00	0.00	0.00	0.65	0.56	0.33
39	0.15	0.12	0.11	0.60	0.36	0.25
40	0.20	0.18	0.17	0.45	0.32	0.12
41	0.45	0.41	0.34	0.35	0.13	0.03
42	0.55	0.45	0.31	0.15	0.04	0.01
43	0.65	0.45	0.38	0.05	0.01	0.00
44	0.55	0.47	0.47	0.05	0.00	0.00
45	0.60	0.60	0.60	0.00	0.00	0.00
46	0.90	0.90	0.86	0.05	0.00	0.00
47	0.95	0.90	0.86	0.00	0.00	0.00
48	0.95	0.90	0.85	0.00	0.00	0.00
49	0.90	0.85	0.85	0.00	0.00	0.00
50	0.90	0.90	0.00	0.00	0.00	0.00
51	0.95	0.00	0.00	0.00	0.00	0.00

4.4.2 Probability of consecutive dry and wet spell at rainfall limit of 40 mm

The probability of getting two, three and four weeks consecutive dry was 100% from 1st -10th week and 50th to 51st week, while the probability of consecutive wet remained zero and it continued up to 21st week and beyond 43rd week till end. The study revealed that, in Khordha, the probability of two consecutive dry weeks < 20% during 24th to 38th weeks. The probability occurrence of three consecutive dry weeks was high from 41st week onwards (56.0 %) and probability of three consecutive dry weeks was less than 10% between 24th to 38th weeks. The analysis also revealed that the probability of three consecutive wet weeks was very low up to 23rd week (0-4%) and it increased as high as up to 52% in 32nd week and it reduced from 33rd week. It reduced to 0% by 43rd week. Consecutive dry probability for four days remained zero from 25th to 31st week which was during SW monsoon (Table 4.17).

During post-monsoon probability of consecutive dry for three and four weeks was 90-95%, which was comparatively higher than the late summer. In case of consecutive wet probability for four weeks it increased from 28th week and decreased from 32nd week onwards. During 31st and 32nd week probability of two and three consecutive wet weeks varied from 50 to 65%. Thus during this period sufficient rain will be available for plant growth.

Table 4.17 Probability of consecutive dry and wet spell at 40mm

SMW	Consecutive dry probability			Consecutive wet probability		
	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	1.00	1.00	1.00	0.00	0.00	0.00
2	1.00	1.00	1.00	0.00	0.00	0.00
3	1.00	1.00	1.00	0.00	0.00	0.00
4	1.00	1.00	1.00	0.00	0.00	0.00
5	1.00	1.00	1.00	0.00	0.00	0.00
6	1.00	1.00	1.00	0.00	0.00	0.00
7	1.00	1.00	1.00	0.00	0.00	0.00
8	1.00	1.00	1.00	0.00	0.00	0.00
9	1.00	1.00	1.00	0.00	0.00	0.00
10	1.00	1.00	1.00	0.00	0.00	0.00
11	1.00	1.00	0.95	0.00	0.00	0.00
12	1.00	0.95	0.95	0.00	0.00	0.00
13	0.95	0.95	0.90	0.00	0.00	0.00
14	0.95	0.90	0.81	0.00	0.00	0.00
15	0.95	0.85	0.85	0.00	0.00	0.00
16	0.85	0.85	0.81	0.00	0.00	0.00
17	0.90	0.86	0.81	0.00	0.00	0.00
18	0.95	0.90	0.75	0.00	0.00	0.00
19	0.90	0.75	0.62	0.05	0.00	0.00
20	0.75	0.62	0.58	0.00	0.00	0.00
21	0.70	0.66	0.25	0.00	0.00	0.00
22	0.80	0.30	0.10	0.15	0.04	0.03
23	0.30	0.10	0.03	0.05	0.04	0.02
24	0.15	0.05	0.01	0.40	0.26	0.14
25	0.10	0.01	0.00	0.45	0.24	0.07
26	0.05	0.01	0.00	0.35	0.11	0.08
27	0.05	0.01	0.00	0.20	0.14	0.08
28	0.05	0.00	0.00	0.35	0.20	0.17
29	0.00	0.00	0.00	0.45	0.38	0.31
30	0.10	0.00	0.00	0.55	0.45	0.34

31	0.00	0.00	0.00	0.65	0.50	0.40
32	0.05	0.03	0.01	0.65	0.52	0.37
33	0.15	0.03	0.01	0.60	0.43	0.34
34	0.05	0.02	0.01	0.50	0.40	0.19
35	0.10	0.04	0.01	0.60	0.28	0.20
36	0.10	0.02	0.01	0.35	0.25	0.11
37	0.10	0.04	0.03	0.35	0.16	0.08
38	0.10	0.07	0.06	0.35	0.18	0.11
39	0.35	0.32	0.28	0.25	0.16	0.10
40	0.55	0.47	0.44	0.25	0.17	0.06
41	0.60	0.56	0.46	0.20	0.07	0.02
42	0.65	0.54	0.47	0.10	0.03	0.00
43	0.70	0.61	0.58	0.05	0.00	0.00
44	0.70	0.66	0.66	0.00	0.00	0.00
45	0.85	0.85	0.85	0.00	0.00	0.00
46	0.95	0.95	0.90	0.00	0.00	0.00
47	1.00	0.95	0.95	0.00	0.00	0.00
48	0.95	0.95	0.95	0.00	0.00	0.00
49	0.95	0.95	0.95	0.00	0.00	0.00
50	1.00	1.00	0.00	0.00	0.00	0.00
51	1.00	0.00	0.00	0.00	0.00	0.00

CHAPTER 5
DISCUSSION

DISCUSSION

5.1 Thermal characteristics of Khordha districts

Temperature analysis of Khordha district revealed that the district, as expected, experienced hotter days in summer season as compare to SW monsoon. Variation between maximum temperature and minimum temperature was minimum during SW monsoon (Table 4.1 and Table 4.2). Occurrence of warm days was increased progressively from 1995 to 2014 (Table 4.3). In case of extreme maximum temperature ($\geq 40^{\circ}\text{C}$), the number of occurrence was 6 days in 1995, while in 2014 it increased up to 41 days. On the other hand occurrence of cold days ($\leq 15^{\circ}\text{C}$) decreased from 1999 to 2008. However in 2009 it suddenly increased and again decreased gradually up to 2014, but remained still higher than that of 1995. Thus it was a clear evidence of global climate change. Kumar *et al.* (2011) found that, the seasonal mean maximum temperature of Odisha is 32°C and predicted an increase of 1°C temperature and 10% increase in rainfall in coastal districts of Odisha by 2030.

The results corroborate that of Pasupalak (2015) that the entire coastal districts of Odisha became warmer in SW monsoon season and post monsoon season. Kandhamal and Boudh are two coldest districts and recorded increasing temperatures even in summer. In fact during summer, the entire western, southern and two central districts, namely, Angul and Dhenkanal are in the hottest zone exceeding 38°C .

5.2 Spatial and temporal variability of rainfall

Mean annual rainfall (1463 mm) of the district was almost similar to the state average rainfall (1451 mm). From Table 4.4 it was concluded that the blocks of less amount of rainfall have high variability and few rainy days while blocks of high amount of rainfall and rainy days have low variability. Deviation was more in blocks of more rainfall and deviation was less, which have less annual rainfall. However, Bhubaneswar block has annual rainfall variability of 25% with highest amount of rainfall (1729) while Jatani with second highest amount of annual rainfall (1662) has less variability (20%). In general the blocks of Khordha district receives a good amount of annual rainfall except Balipatna. Annual rainy day variability was maximum (21%) in Bolagarh having 56 number of mean

rainy days, which was lowest in the district (Table 4.5). Except Begunia and Bolagarh, rest of the blocks have ≥ 60 days of rainy days. Four out of 10 blocks namely, Begunia, Bhubaneswar, Bolagarh and Khurda have high variability ($\geq 25\%$) of rainy days. Similar result was found by Pasupalak (2015), The variability of annual rainfall in Odisha was 21% CV. Eight districts had high variability ($>23\%$), while 10 districts had low variability ($<20\%$). Variability was maximum (25%) in Sonepur district and minimum (16%) in Sundargarh district. In general district of low rainfall have high variability and few rainy days.

During the past 20 years (1995-2014), Khordha received maximum amount of rainfall in 2013 (1873 mm), while minimum (778 mm) in 1996. But in case of rainy days 2009 has lowest number (77days), while 2003 has the highest (109 days). In fifteen out of 20 years, Khordha received >1400 mm of rainfall. So rainfall is not a limiting factor for crop production in Khordha district. Spatial variability of annual rainfall was more than temporal variability while spatial and temporal variability of rainy days were almost the same (Table 4.4, Table 4.5 and Table 4.6). Similar results were obtained by Saha *et al.* (2015) that the spatial distribution of rainfall in Mizoram was highly variable.

In case of seasonal rainfall Khordha receives 75% of mean annual rainfall during SW monsoon (Table 4.7). Most of the blocks received ≥ 1000 mm rainfall except Balipatna and Bolagarh during this period and Begunia has the highest variability (37%). Lowest (29 mm) amount of rainfall was received during winter and variability was also maximum (115%) during this period. It was thus clear that SW monsoon accounts a major part of rainfall distribution out of all the seasons. During SW monsoon four out of 10 blocks namely, Begunia, Bhubaneswar, Bolagarh and Khurda had high variability ($\geq 30\%$) while three blocks namely, Balianata, Jatani and Tangi had low variability ($\leq 25\%$). Rainfall variability varied from 80% to 114% during post-monsoon and 82% to 136% in summer season.

Korecha and Barnston, (2007) observed that the summer rainfall that accounts for the major part (approx. 65–95%) of total annual rainfall over Ethiopia is governed by the El Niño-Southern Oscillation (ENSO) and further enhanced by local climatic forcing which is contradictory to this result.

Monthly rainfall variability was maximum in December (54%) followed by March (44%), while minimum in the month of August (12%) followed by July (13%). Five out of twelve months, namely, June, July, August, September and October had low variability (<20%) of monthly rainfall. Monthly rainfall variability was high (>30%) in the month of January, March, April and December (Table. 4.9).

5.3 Length of growing period (LGP)

The average length of growing season in Khordha is 184 days. All blocks have >180 days of growing season length except Begunia at 50 mm of soil water storage. Variability in total duration was less among all blocks i.e. <4%. Growing season normally commences at 24th SMW in the district, while it terminates in 49th SMW. Balipatna, Bhubaneswar, Nolagarh and Jatani have maximum duration (189 days), while Begunia have the minimum (175 days) at 50 mm soil water holding capacity (Table 4.13).

At 100 mm soil water storage Banapur has the maximum duration of growing period (203 days). Four out of ten blocks namely, Banapur, Bolagarh, Chilika and Jatani have greater LGP (>195 days) while three blocks namely, Baliana, Balipatna and Begunia have lesser LGP (<185 days) at 100 mm soil water storage. Variability in start and end of growing period in all the blocks was less than 3% (Table 4.14). LGP ends normally between 49th and 51st SMW. From Table 4.14 and Table 4.15 it was concluded that growing season starts with onset of SW monsoon and it lasts up to the end of the year i.e. 51st week. Similar results were found by Pasupalak (2015) that the average duration of growing season for Odisha is 27, 28, 31 and 37 weeks in soils having water holding capacity of 50, 100, 150 and 200mm of soil WHC. Inthavong *et al.* (2010) observed that LGP varied greatly from year to year, particularly in locations with sandy soils, due mostly to variation in monthly rainfall occurring at the early part of the growing season (April), but also to some extent by variation at the end of growing season (October).

5.4 Probability of consecutive dry and wet spell

Probability of consecutive dry for two weeks during SW monsoon was <1% while consecutive wet was increased progressively during SW monsoon (25th -39th week). During this period the probability of consecutive wet for two weeks varies from 65% to 90% at 20

mm rainfall limit (Table 4.16). Consecutive dry probability for two, three and four week was high (70%) during 46th to 13th week. Thus supplementary irrigation is required during this period. Consecutive wet probability for two and three weeks was high >60% during 28th to 35th week at 20 mm rainfall limit. So this can be a deciding factor for crop and field management practices.

At 40 mm rainfall limit consecutive dry spell probability for two weeks varied from 80% to 100% during 45th to 18th week, while consecutive wet spell remained 0%. Probability of getting two consecutive wet weeks of >50% was 6 weeks (30th -35th week) only (Table 4.17). Probability of getting three and four consecutive wet weeks at 40 mm rainfall limit was <40% during SW monsoon except 30th to 34th week. So consecutive wet probability for two, three and four weeks at 40 mm rainfall limit was comparatively very short than the probability of 20 mm of rainfall limit. Similar to this result Gaikwad and Maniyar, (2015) found that the more chance of occurrence of dry spell at MW 44 to 45 in all talukas of Jalna district. The data studied in the project revealed that the probability of occurrence of 2 weeks dry spell was highest in 44th MW while the probability of occurrence of 4 weeks dry spell was highest in 42th MW. Another similar result was found by Nema *et al.* (2013) that the probability of 2 consecutive wet weeks are more than 50% during 26th to 36th SMW.

Panigrahi and Panda, (2002) observed that during 24th to 39th week probability of two and three consecutive wet weeks is varies from 52.8 to 100% and 28.81 to 100% respectively which are alike to the results of the present investigation.

CHAPTER 6

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

1. The mean annual maximum temperature of Khordha district was 33°C, while minimum temperature was 22.6°C. Maximum temperature was highest during the months of April and May, after which it gradually decreased in SW monsoon period (June to September) and became lowest in the month of December. Minimum temperature remained lowest in the month of December followed by January (Table 4.1).
2. Mean seasonal maximum temperature was highest during summer (37°C) and lowest in winter (17°C, Table 4.2). On the other hand minimum temperature was highest during SW monsoon (26°C). From the year 1995 onwards, frequency of extreme hot days ($\geq 40^\circ\text{C}$) increased while, extreme cold days ($\leq 15^\circ\text{C}$) decreased (Table 4.3).
3. For Khordha district mean annual rainfall and rainy days were 1463 mm 63 days respectively. Variability of annual rainfall among the all blocks of Khordha district varied from 21% to 31% (Table 4.4) while annual rainy days varied from 12% to 21%. More variations were observed in blocks of maximum rainfall and rainy days, however, less variation in blocks of minimum rainfall and rainy days.
4. Seasonal rainfall and rainy days varied more during winter than the other seasons in Khordha district. Seasonal rainfall (1075 mm) and rainy days (48 days) were highest in SW monsoon followed by post-monsoon (Table 4.5 and Table 4.6). As a whole Khordha received 90% of the mean annual rainfall during SW monsoon and post-monsoon period (June to November).
5. Monthly rainfall (342 mm) and rainy days (15) were highest in August and lowest in the month of December (Table 4.7 and Table 4.8). Monthly rainfall variability was highest (54%) in December while rainy days variability was highest in March (50%). Lowest variability of monthly rainfall was seen in August (12%) followed by July (13%). June, July, August and September together received 75% of the annual rainfall.

6. At 75% probability Khordha received 1210 mm rainfall, which is good amount of rainfall for crop production. Bhubaneswar block received highest amount of rainfall at 75% of probability (1437 mm), while Balipatna received the lowest (912 mm). At 75% probability most of the blocks received >1100 mm rainfall.
7. Although Khordha received a good amount of annual rainfall, sometimes it experienced drought in some blocks due to high variability of rainfall. Bolagarh had the highest percentage of drought frequency.
8. Length of growing season started in Khordha district in 24th SMW. But in Banapur, Bhubaneswar and Chilika it starts one week earlier. In most of the blocks LGP ends in 49th to 50th SMW. Average duration of LGP in district is 26 number of weeks.
9. Length of growing period ends in later (51st SMW) in case of Bolagarh and Banapur block (Table 4.12), while earlier in Banapur, Bhubaneswar and Jatani block.
10. Average wet period for Bhubaneswar is 131 days. Chilika and Banapur have highest number of wet period (140 days), while Baliana have the lowest (115 days). Six out of 10 blocks have more than 130 days of annual wet period.
11. Probability of consecutive wet for 2 weeks gradually increased from 25th week to 37th week and then it gradually decreased. It was Zero percent during winter, especially in the month of December and January. Probability of occurrence of two weeks wet spell was highest in 30th, 34th and 37th week (90%). The range of probability of wet weeks during SW monsoon varies from 60% to 90%. Probability of occurrence of three weeks wet spell was highest in 33rd SMW.
12. Probability of consecutive dry weeks varies from 75% to 90% during winter and summer season. It gradually increased from 39th week for consecutive dry of two, three and four days. During monsoon it remains Zero (26th to 35th week, Table 4.14). Probability of consecutive two week dry was highest (100%) in 12th SMW while consecutive three and four weeks dry was 85% for the same week.

Conclusion

Occurrence of warm days is gradually increasing in Khordha district, while occurrence of cold days varies considerably. This result clearly indicates the global climate change. The district receives a good amount of rainfall for crop production. On the basis of soil water storage, Khordha has 190 days of average growing period. Hence more than one number of long duration crop (150 days) can't be grown without supplementary irrigation. So there is a need of reorientation of cropping pattern by taking a cereal crop of 120 days duration followed by a pulse crop of 60 days duration to exploit limited cropping season. It was also concluded that during 25th to 37th week, probability of two and three consecutive wet weeks varies from 75% to 90% and 55% to 85% respectively. This indicates that during this period sufficient rain will be available for plant growth. So this period can be taken as a deciding factor for both crop and field management practices.

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