ASSESSMENT OF DROUGHT IN SOLAPUR DISTRICT USING STANDARDIZED PRECIPITATION INDEX (SPI)

by

Mr. Ingole Nikesh Sureshrao
(Reg. No.019/325)

A thesis submitted to the

**MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI-413 722, DIST-AHMEDNAGAR,
MAHARASHTRA, INDIA**

In partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL METEOROLOGY

DEPARTMENT OF AGRICULTURAL METEOROLOGY

CENTRE FOR ADVANCED FACULTY TRAINING (CAFT) IN AGRICULTURAL METEOROLOGY

COLLEGE OF AGRICULTURE, PUNE-411 005

MAHATMA PHULE KRISHI VIDYAPEETH,

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2021

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part

there of has not been submitted

by me or other person to any

other University or Institute

for a Degree or

Diploma

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Date: / / 2021

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This is to certify that the thesis entitled **"ASSESSMENT OF DROUGHT IN SOLAPUR DISTRICT USING STANDARDIZED PRECIPITATION INDEX (SPI)"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL METEOROLOGY,** embodies the results of a piece of bonafide research work carried out by **Mr. INGOLE NIKESH SURESHRAO** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and the help received during the course of this investigation have been duly acknowledged.

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Date: / / 2021

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This is to certify that the thesis entitled **"ASSESSMENT OF DROUGHT IN SOLAPUR DISTRICT USING STANDARDIZED PRECIPITATION INDEX (SPI)"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfillment of the requirement for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL METEOROLOGY** embodies the results of a piece of bonafide research work carried out by **Mr. INGOLE NIKESH SURESHRAO** under the guidance and supervision of **Dr. P. B. PAWAR**, Assistant Professor of Agronomy, College of Agriculture, Karad and that no part of the thesis has been submitted for any other degree or diploma.

Place: Pune **(S. D. Masalkar)**

Date: / / 2021

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Before giving way to my feeling, I cordially salute the supreme comic consciousness, from which everything originates in the beginning and to which everything goes at end. Though formal words cannot carry the fragrance of emotions still they are only available means of expressing emotions. My acknowledgement is much more than what I am expressing here.

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***Place**: Pune*

***Date**: / / 2021*

(Nikesh S. Ingole)

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LIST OF ABBREVIATIONS

Abbreviations	**Description**
Apr.	April
Aug	August
Avg.	Average
Cm	Centimeter
Cont	Contribution
CV	Coefficient of Variance
Dept	Department
CRIDA	Central Research Institute for Dryland Agriculture
Dec	December
et al.	*et alli* (and others)
Feb	February
Fig	Figure
Ha	Hectare
i.e.	Id est (that is)
Jan	January
Jun.	June
Jul.	July
ICAR	Indian Council of Agriculture Research
kg/ha	Kilogram per hectare
Km	Kilometer
M	Meter
Mar	March
Max	Maximum
Min	Minimum
Mha-m	Million Hectare meter
Mm	Millimeter
mm/yr	Millimeter per year
MW	Meteorological week
NE	North-East
No.	Number
Nov	November
Oct	October
R.D.	Rainy day
RF	Rainfall
S.D.	Standard deviation
Sept	September
Signi.	Significance
SMW	Standard Meteorological week
SW	South-West
Viz	Videlicet (namely)
%	Per cent
^{0}C	Degree Celsius

ABSTRACT

ASSESSMENT OF DROUGHT IN SOLAPUR DISTRICT USING STANDARDIZED PRECIPITATION INDEX (SPI)

By

Mr. INGOLE NIKESH SURESHRAO

A candidate for the degree

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MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI - 413 722

2021

Research Guide:	**Dr. P. B. Pawar**
Department:	**Department of Agronomy**
	College of Agriculture, Karad

In India, rainfall received from south west monsoon (June to September) is a major source of water for agriculture. According to Guhathakurta and Rajeevan (2008) although average annual rainfall in the country is 119.4 cm, about 60 % of the country's total cultivable land still remain as *rainfed*. Under a climate variability scenario, the rainfall distribution pattern has become erratic and unpredictable; subsequently increasing the probability of occurrence of a long dry spell or drought-like situation in the country. Drought analysis is useful to examine frequency of drought events over different subdivisions. Knowledge and sequence of dry spells can assist to acquire specific information for agricultural planning. Understanding the events of occurrence of dry spells is crucial to decrease the adverse effect of dry spells at sensitive crop development stage. Rainfall pattern and the quantity decide the cropping system in the *rainfed* agriculture. Rainfall amount, distribution and intensity of rainfall mainly determine the choice of any particular crop and agronomic practices. Hence, the present study entitled, "Assessment of drought in Solpaur district using standardized precipitation index (SPI)", was conducted with the objectives;to analyze rainfall for drought using precipitation deciles (PD) and standardized precipitation index (SPI), to determine the onset and withdrawal of monsoon to determine probabilities of dry and wet weeks by using Markov-chain model and to suggest tehsilwise suitable cropping pattern.

The Study area Solapur district comprises 11 tehsils *viz.,* Akkalkot, Barshi, Karmala, Madha, Malshiras, Mangalwedha, Mohol, North Solapur, Pandharpur, Sangola and South Solapur. The daily rainfall data of all tehsils in Solapur district were collected from Department of Agricultural Meteorology, College of Agriculture, Pune, State Agriculture Department, Pune,

India Meteorological Department, Dune and downloaded from www.maharain.gov.in (www.krishi.maharashtra.gov.in) from the month of January to December.

The mean average annual rainfall of Solaria District is 603 mm and it received in 37 mean rainy days. It was varied from 107 mm at Marshals with 49.1 per cent variation to 1343.5 mm at Marshals with 49.1 per cent variation. The highest (71) rainy days during 1998 at Mohol tensil with 26.3 per cent variation and the lowest (11) rainy days during 1972 at Madha tehsil with 26.0 per cent variation is observed.

It is observed that September month contributes highest amount of mean rainfall 160.8 mm with 69.9 per cent variation followed by August, June. The September month contributes the highest amount of mean rainy days (8 days) with 48.5 per cent variation followed by August, July.cropping pattern in all tehsils depends on south west monsoon season and north east monsoon having additional benefits. This indicated that there was sufficient moisture for growing *Rabi* crops in all tehsils of the Solapur district. Hence, area is dominated by *Rabi* crops and short to medium duration *Kharif* crops.

From Drought analysis using Standardized Precipitation Index (SPI) in selected tehsils of Solapur district at 12 month's timescale showed that in each decade the two or three wet years happen, two or three dry years happens and four or five normal years happens. It was observed that the frequency of drought in Akkalkot, Pandharpur and Sangola tehsils during the last two decade (2001-2010, 2011-2019) was increased. Whereas, the 2011-2019 decade showed frequent rise in number of drought years in all other tehsils of Solapur district. This indicated that that a SPI value becomes more negative with increase in time scales in recent times.

Drought analysis using Precipitation deciles (PD) showed that there were 24 drought events during the period of 1961-2019 for all tehsils of Solapur district except North & South Solapur where 09 drought events were reported during the period of 1998-2019.

In case of Pandharpur and Sangola tehsils, it was observed that the frequency of the drought event was increased in the last three decade (1991-2000, 2001-2010, 2011-2019) as compared to previous decades. Whereas in Akkalkot and Malshiras tehsils the frequency of the drought event was increased in the last two decade (2001-2010, 2011-2019) as compared to previous decades. In all other remaining tehsils of Solapur district frequency of drought events was increased in recent decade which may become very severe in the upcoming decade. As severity of drought is more in recent decade, more efforts are needed for in situ moisture conservation.

Study revealed that in Solapur district, the mean week of onset of monsoon was 25th standard meteorological week (SMW) (*i.e.,* 18th June – 24th June) for all tehsils except Mangalwedha tehsil where mean onset was 26th standard meteorological week (SMW) (*i.e.,* 25th

June – 01st July). The mean week of withdrawal of monsoon was observed to be 45th SMW (*i.e.,* 5th November– 11th November) for Akkalkot, Barshi, Karmala, Madha, Malshiras, Pandharpur and Sangola tehsils. Whereas it was observed to be 43rd, 44th, 46th and 48th for South Solapur, North Solapur, Mohol and Mangalwedha tehsils respectively. Based on the onset and withdrawal of monsoon various field operations can be performed.

The Markov-chain probability analysis showed that probability of getting more wet weeks is observed during 37th to 39th SMWs in Akkalkot and Barshi tehsil. Similarly, 38th to 39th SMWs in Karmala, Malshiras and Mangalwedha tehsils, 38th to 40th SMWs in Madha, Mohol and Pandharpur, 37th to 40th SMWs in Sangola tehsil and during 34th to 40th SMWs in North & South Solapur tehsils. The dry and wet week initial, conditional and consecutive probabilities are helpful for crop management planning in different tehsils of Solapur district. Thus, chances of rainwater harvesting in wet weeks is more and judicious use of harvested water in dry spells as protective irrigation is beneficial for the sustainable yield.

By considering the overall situation of the Standardized Precipitation Index, and Precipitation Deciles, onset and withdrawal of monsoon, initial, conditional and consecutive dry and wet weeks probability at different critical growth stages of selected *kharif* crops ((Pearl millet, Pigeon Pea and sunflower) and *rabi* crops (Rabi sorghum and Chickpea) tehsilwise contingency measures *viz.,* SMW for sowing, protective irrigation and hoeing operation, etc. were suggested. The study useful in understanding the historic patterns and build future scenarios of drought for risk management and climate change adaptation planning. Increased the drought frequency facilitates for better preparedness, coping mechanisms and contingency measures.

1. INTRODUCTION

In predominantly agricultural country like India, national economy is largely dependent on the agricultural production. The major agricultural enterprise component is still under *rainfed* cropping and hence agricultural production is still dependent on vagaries of monsoon. This situation is likely to remain so in near future also. So, the economic prosperity of India is very intricately connected with monsoon. Indian monsoon is highly erratic in nature both in quantum as well as distribution. The monsoon, its time of arrival, cessation and distribution controls agricultural production and hence, the livelihood of the people. It is said, "Agriculture is gamble of monsoon and its failure and success mars or makes their destiny". Agricultural production in India is closely related with rainfall. In India about 70 per cent of the total cropped area is *rainfed* which accounts 45 per cent of food bowl. Crop production in this area is very uncertain due to erratic behavior of rainfall. The main reason for low and highly unstable yields in this area is the unavailability of adequate soil moisture during active physiological growth period of crops (Anonymous, 2014 b).

Water is limited resource and its efficient use is very important, especially in view of ever increasing population. The basic source of water is the precipitation in the form of rainfall or snowfall and is the most critical and key variable of hydrological cycle. The human activities such as rapid urbanization, ever increasing population and deforestation have interrupted the natural hydrological cycle. This ecological imbalance resulted in non-uniform distribution and erratic variation of rainfall pattern. The present world has to meet the challenges of increasing water demand, the depleting water resources along with non-uniform distribution of water. In the country like India, there are huge and abrupt variations in rainfall characteristics including rainfall amount and its distribution, onset and withdrawal of monsoon and occurrence of dry spells both temporally and spatially. Hence the crop planning and water resource management in the *rainfed* area is difficult and complex.

The Indian economy is inextricably linked with the monsoon and its prosperity is entirely dependent on the rainfall received during monsoon. However the rainfall in India is characterized by recurring cycles of floods and droughts. There is also great regional and temporal variation in the distribution of rainfall. Rainfall in the greater part of India is uncertain, erratic and subjected to vagaries of monsoon and also unevenly distributed Venkateswaralu, (2011). Similarly in the state of Maharashtra, the variability of rainfall is high and it affects the agricultural production and the economy of the state. Especially in Western Maharashtra more than 80 percent area falls under *rainfed* condition. Due to uneven and erratic temporal distribution of rainfall in these areas, there is a tendency to over explicit underground water resources for irrigations during dry spells, and hence the quality of natural resources in the rain fed ecosystem is gradually declining. *Rainfed* areas suffer from bio-physical and socio economic constraints affecting the productivity of crops

and livestock. Irrigated areas have reached plateau in the yield but *rainfed* areas are considered to offer future scope for increasing food production. Thus there is a need to understand rainfall pattern and drought characteristics in *rainfed* area to enable to plan crops and provide optimal protective irrigations during the dry spells for sustainable development of agriculture and increase crop production.

Irrigated agriculture has made a major contribution to food production and food security throughout the world. Without irrigation much of the impressive growth in agricultural productivity over the last 50 years could not have been achieved. Nevertheless it was widely accepted that the overall performance of irrigation investments has too often fallen short of the expectations of planners. With inadequate water resources for irrigation, India remains at least 60 percent under *rainfed* agriculture and as discussed before, in the state of Maharashtra more than 80 percent of cultivable area is still *rainfed*. As the vast portion of cultivable land is still unirrigated, in future the *rainfed* areas are also required to meet the challenge of rising demand of food, pulses, oilseeds, vegetables, fruits, etc. On sustained basis. But the crop production in *rainfed* areas remains unsustainable due to uncertainties in rainfall. Uncertainties in rainfall that influences the crop production are uneven spatial and temporal distribution of rainfall and unknown periods of dry spell in rainy season causing water stress to plant. Any extended period of water stress is especially injurious to plants and is termed as drought. Further delayed or advanced onset and withdrawal of monsoon are also results of uncertainties in rainfall. The crop production in rainy season in *rainfed* areas is thus dependent on vagaries of monsoon and is adversely influenced. The knowledge of different rainfall characteristics such as onset and withdrawal of monsoon, dry spell and drought would enable the optimal crop planning and implementation of protective irrigation strategies, thus mitigating the adverse impact of uncertainties of rainfall.

Even though the droughts are inevitable and unavoidable, but are manageable. Over decades, several technologies to mitigate drought affects at farm level have been evolved. The investigations related to characterization of droughts play very important role in planning of *rainfed* agriculture by providing guidelines for crop planning, and to implement the protective irrigation strategies.

However, the perception of drought is different for different people. To the farmer, drought is a period during which his/her normal farm operations are hampered. To the hydrologist, with prolonged deficiency of rainfall, drought occurs with marked depletion of surface water and consequent drying up of reservoirs, lakes, streams and rivers, cessation of spring flows and fall in ground water levels. To the meteorologist, it is a situation, when there is a significant decrease of rainfall from the normal values over a given area. On the other hand, to the agricultural scientist, it occurs when the soil moisture and rainfall are inadequate during the growing season to support

healthy crop growth to maturity and cause extreme water stress. Precipitation deficiency causes meteorological drought which subsequently causes the moisture deficiency in the root zone, influencing crop production thus triggering as agriculture drought. But unlike meteorological drought, agriculture drought depends on climate, soil, crop and their interaction. Therefore agriculture drought needs to be evaluated separately by considering these interactions in contrast to the consideration of only precipitation in meteorological drought. There is no single widely accepted indicator to characterize the agricultural drought. The indicators developed in the literature are mainly related to moisture deficit causing evapotranspiration or moisture deficits itself yield reduction. These indices normally consider the relative reduction in these actual values. Considering relative reduction in actual evapotranspiration and actual yield would be appropriate as they represent the influence of the moisture stress over the entire crop season, which is ultimately due to the deficit in precipitation. However considering the relative reduction in moisture in the root zone would not be appropriate as it does not represent the ability of different crops to withstand different moisture stress in the root zone.

Agricultural operations in *rainfed* area start with the onset of southwest monsoon. It is essential to forecast the calendar of onset of effective monsoon since a slight delay in sowing of *rainfed* crops may lead to drastic reduction in grain yield and adversely affects the next crop too. The duration of the *kharif* crops depends on the withdrawal of monsoon rainfall. It has been experienced that quite often the crops suffer from terminal drought due to the early cessation of rainfall. The knowledge of withdrawal of monsoon is also required for the planning of *rabi* season crops based on residual moisture in the root zone. Therefore it is necessary to know the onset and withdrawal of monsoon for appropriate crop planning and planning of water sources available for protective irrigation. There are enumerable criteria for deciding onset and withdrawal of monsoon Morris and Zandesta, (1979) and Babu and Laxminarayana, (1997). The information of onset and withdrawal of monsoon is mainly required for crop planning based on the moisture content in the root zone. Some criteria adopted in the literature consider only rainfall and some consider rainfall and evapotranspiration. However only rainfall and evapotranspiration do not reflect the optimum availability of moisture in the root zone for sowing/planting. For this purpose it is necessary to consider water holding capacity of soil which varies with soil type and perform the soil water balance in the root zone.

The climate of a region is determined by long-term average, frequency and extremes of several weather variables, notably precipitation and temperature. In a large semiarid country such as India, precipitation is precious and varies both in space and time. Thus, any departure in precipitation patterns seldom leads to widespread natural disasters such as drought and floods affecting natural habitats, ecosystems and, importantly, agricultural and economic sectors. Drought, in particular, is considered by many to be the most complex but least understood of all

natural hazards, affecting more people than any other hazard (Hagman, 1984). Generally, large-scale spatiotemporal variability in timing and duration of drought impact hinders a universal definition of drought. However, Wilhite and Glantz (1985) have categorized drought into meteorological (lack of precipitation); hydrological (drying of surface water storage); agricultural (lack of root zone soil moisture) and socio-economic (lack of water supply for socio-economic purpose). In the last century, many drought indices were formulated by integrating weather variables such as rainfall, evapotranspiration and temperature into a single number.

Although rainfall deviation from the long-term mean continues to be a widely adopted indicator for drought intensity assessment because of its simplicity, the application of this indicator is strongly limited by its inherent nature of dependence on mean. Rainfall deviations cannot be applied uniformly to different areas having different amounts of mean rainfall since a high rainfall area and a low rainfall area can have the same rainfall deviation for two different amounts of actual rainfall. Therefore, rainfall deviations across space and time need to be interpreted with utmost care.

The most commonly used drought indices include the Palmer drought severity index (PDSI) and the moisture anomaly index (*Z*-index) (Palmer, 1965), the standardized precipitation index (SPI) (McKee *et al.*, 1993, 1995), aridity index (Gore and Sinha Ray, 2002) and Percent Normal, Deciles (Gibbs and Maher, 1967). Drought indices, in general, enable the detection of the onset of drought events and enable their severity to be measured, thereby allowing an examination of the spatial and temporal characteristics of drought, and comparisons between different regions to be made (Alley, 1984). The majority of drought indices have a fixed time-scale. For example, the PDSI has a time-scale of about 9 months (Guttman, 1998), which does not allow identification of droughts at shorter time scales, as in the case of agricultural drought.

Standardized Precipitation Index (SPI) expresses the actual rainfall as standardized departure from rainfall probability distribution function and, hence, this index has gained importance in recent years as a potential drought indicator permitting comparisons across space and time. Computation of SPI requires long term data on precipitation to determine the probability distribution function which is then transformed to normal distribution with mean of zero and standard deviation of one. However, SPI is designed in such a way that it can detect drought over different periods at multiple time scales. This index is calculated by fitting a gamma distribution to observed values of precipitation totals at different time steps (e.g. 1, 2, 3, . . ., 48 months) and then transforming back to the normal distribution with mean zero and a variance of one. The SPI is equal to the *Z*-score applied to normally distributed precipitation totals at different time scales. For example, the 1-month SPI of September represents standard deviation in precipitation of September only; 3-month SPI of September represents the standard deviation in precipitation totals of September and the previous 2 months. Positive values in SPI

indicate greater than mean precipitation, and negative values indicate less than mean precipitation. The SPI is produced by standardizing the probability of observed precipitation for any duration. Durations of weeks or months can be used to apply this index to agricultural interests, and longer durations of years can be used to apply this index to water supply and water management interests (Guttman, 1999). The applicability of SPI varies with the time scale because the 1-month SPI reflects short-term conditions and its application can be related closely to soil moisture; the 3-month SPI provides a seasonal estimation of precipitation; 6- and 9-month SPI indicates medium term trends in precipitation patterns (Ji and Peters, 2003).

Maharashtra state of India has experienced recurring severe droughts in past few decades affecting thousands of villages, lakh of cattle and crores of people. The worst drought in Maharashtra has made water supply in the state a scary issue. The agriculture sector is badly affected; people had to migrate from their native places for water, livelihood and fodder for cattle. Not only loss of cattle and other livestock is a major issue but also increase in farmer suicides is a serious concern.

The appropriate knowledge of nature of occurrence of drought and its characteristic features is one of the important aspects in the *rainfed* farming, water resource planning and management, and allocation of water for protective irrigation. These studies provide basic information for evaluating climatic potential of an area for agricultural development, for evolving suitable cropping patterns, protective irrigation and for implementing cultural/conservation practices to rainfall distribution in the area. Various developmental agencies involved in tackling drought problems in the region lack the information about the drought characteristics. As a result, rainfall and water resources are utilised in an inefficient way leading to crop failure even in normal rainfall year. These facts call for the studies of the drought characterization to develop control measures and consequent management of drought with appropriate planning.

It is necessary to know the chances of occurrence of onset or withdrawal of monsoon in a particular week. This is particularly important to know the suitability of the crops for sowing/planting and the risks associated with these crops. It is also important to know the chances of occurrence of dry spells during the critical stages of the crops for deciding the sowing date, cropping pattern and planning for protective irrigation and intercultural operations. The Solapur district of Maharashtra being subjected to rainfall variabilities and large tract of this region being *rainfed*, has been chosen as the study area. It is recognized as the region of drought impacts which directed to study the analysis of drought band using Precipitation Deciles (PD) and Standardized Precipitation Index (SPI), onset and withdrawal for their occurrence, probability and crop planning for different tehsils in Solapur district.

Hence, the present investigation has been undertaken to study the **"Assessment of Drought in Solapur District using Standardized Precipitation Index (SPI)"** is planned

with following objectives

1. To analyze rainfall for drought using Precipitation Deciles (PD) and Standardized Precipitation Index (SPI) for different tehsils in Solapur district.
2. To determine the onset and withdrawal of monsoon for different tehsils in Solapur district.
3. To determine probabilities of dry and wet weeks by using Markov-chain model.
4. To suggest crop management planning based on rainfall analysis.

2. REVIEW OF LITERATURE

This chapter deals with the review of study carried out by various investigation on **"Assessment of Drought in Solapur District using Standardized Precipitation Index (SPI)"** is planned with following objectives.

Reviews on following selected points are studied to determine the present topic:

1. To analyse rainfall for drought using Precipitation Deciles (PD) and Standardized Precipitation Index (SPI) for different tehsils in Solapur district.
2. To determine the onset and withdrawal of monsoon for different tehsils in Solapur district.
3. To determine probabilities of dry and wet weeks by using Markov-chain model.
4. To suggest crop management planning based on rainfall analysis.

2.1 Rainfall Analysis

Rai *et al.* (1996) analysed variation of weekly rainfall pattern (35 years) at Raipur district of Chhattisgarh during crop growing season (23^{rd}–44^{th} MW). The mean weekly rainfall pattern showed that it has four peaks. The first peak appears during 27^{th} week. The second during 33^{rd} week, third during 35^{th} week and fourth during 37^{th} standard week for the *kharif* growing season. There is a sudden increase in rainfall from 23^{rd} to 27^{th} week and again decreases in 29^{th} and it remains steady for the next 3 to 4 weeks. It steeply declines after 37^{th} week. The rainfall suddenly decreases from 37^{th} week onwards, which means that the contribution by northeast monsoon rain is very low to the annual rainfall of Raipur.

Ghadekar *et al.* (1998) analysed 28 years (1962-1989) rainfall data of Nagpur and studied the rainfall suitability at various probability levels for sorghum crop. The total rainfall during *kharif* season was 861.5 mm. The coefficient of variation ranged between 74.3 per cent (25^{th} week) to 144.7 per cent (39^{th} week). The rainfall at 50 per cent probability was well distributed during 12 weeks (25-36^{th}) ranging between 44.5 to 36.3 mm. This was adequate and sufficient for sorghum crop considering its weekly demand (21-35 mm per week).

Pandey *et al*. (1999) analysed daily rainfall data for ninety years (1901-1990) of all the districts of Gujarat state to work out the occurrence of drought and floods in the state. The study revealed that the arid region of the state received rainfall of 500 mm or less in most of the years while humid region of the state received more than 1000 mm. However, the drought and floods were observed in both the regions.

Singh *et al*. (2002) analysed fifty years (1946-95) rainfall at Jhansi, Utter Pradesh to estimate occurrence of drought. Analysis showed that mean annual rainfall of Jhansi was 913.2 mm with 24.0 per cent variation. It was found that August was the wettest month followed by July.

Kumar (2003) studied rainfall data of varying length (15 to 27) at different stations in Shimla district of Himachal Pradesh on monthly, seasonal and annual basis. The statistical

parameters like mean, standard deviation, coefficient of variation and coefficient of skewness of the rainfall were determined. Mean annual rainfall was found to be maximum at Phancha (2086 mm) and minimum at Kumarsain (556 mm). The coefficient of variation of annual rainfall varied from 17 % to 50 %. The annual rainfall was found to be non-symmetrically distributed at all stations.

Basu *et al*. (2004) carried out statistical analysis of rainfall distribution and trend of rainfall anomalies district wise during monsoon period over West Bengal. The coefficients of skewness and kurtosis were significant (positively skewed and leptokurtic) for most of the districts in the months of August and September in Sub-Himalayan West Bengal. In Gangetic West Bengal, the coefficients were significant for most of the districts in June and for all the districts in September. High values of coefficient of skewness and kurtosis showed heavy rainfall cases. The trends of monsoon rainfall anomalies of Sub-Himalayan West Bengal showed both positive and negative slopes ranging from 6.639 at Coochbehar to -8.455 at Darjeeling. In case of districts of Gangetic West Bengal, the rainfall showed increasing trends for all the districts except in the district of Howrah.

Jat *et al.* (2005) analysed 81 years (1921-2001) of rainfall data for Udaipur region. The mean annual rainfall of the region was 623.7 mm with coefficient of variation of 33.3%. Of the total annual rainfall, 91.75% was contributed by monsoon season, whereas 5.24% and 3% were contributed by post- monsoon season and pre-monsoon season. The weekly average rainfall ranged from 0.07 mm (14^{th} week) to 48.52 mm (30^{th} week). The average weekly rainfall during the monsoon season of June to September (weeks 23^{rd} to 39^{th}) was higher than other season varying from 9.1 mm to 48.5 mm.

Soni *et al*. (2005) analysed rainfall pattern of south-west monsoon in Malwa region of Madhya Pradesh. The mean value of seasonal contribution of monsoon season to annual rainfall was found to be 74.7% in the region with highest (85.5%) in 1991 and lowest (61.3%) in 1999.

Jhajharia *et al.* (2007) analysed rainfall pattern for Guwahati, Assam. Analysis of monthly rainfall revealed that the month of December was found to be the most drought prone.

Geetha *et al*. (2015) analysed the 140-year daily rainfall data for the period of 1871-2010 of 25 coastal stations of Tamil Nadu and South Andhra Pradesh. The dates of onset and withdrawal of northeast monsoon (NEM) over coastal Tamil Nadu (CTN) were determined.

Jedhe *et al.* (2018) studied trend of rainfall and temperature in Konkan region of Maharashtra and result indicated that Minimum temperature has significant decreasing trend at Suksale and Wakawali during all seasons and significant increasing trend at Dapoli during all seasons. Average annual rainfall in the Konkan region varied from 2324.8 ± 591.1 mm/year at Harnai to 4098.0 ± 599.0 mm/year at Karak. Rainfall during *kharif* season also evinced significant increasing trend at Suksale, Bhatsanagar, Karak and Mulde and decreasing trend at

Karjat. During *rabi* season significant increasing rainfall trend was observed at Vengurla and decreasing trend at Harnai. Significant increasing rainfall trend was evidenced at Wakawali during summer season while remaining stations did not observe any significant trend. These changes in rainfall and temperature aggravated crop production and quality of produce in the region.

Wale (2019) studied trend analysis (increase or decrease) of all the independent weather parameters (*e.g.* annual, monthly, seasonal and weekly rainfall and rainy days) by using the non-parametric Mann Kendall test and Sen's slope method in Sangali district. The study revealed in Sangli district, September month contributes the highest amount of rainfall which was 120.95 mm with 62.53 percent variation. The annual rainfall and rainy days showed an increasing trend in Atpadi, Kavthemahankal, Miraj and Palus tehsils whereas, there was a decreasing trend in Jat, Shirala, Tasgaon, Walwa and Khanpur tehsils. The southwest monsoon rainfall showed an increasing trend in Atpadi, Kavthemahankal, Miraj Shirala and Palus tehsils whereas, there was a decreasing trend in Jat, Tasgaon, Walwa and Khanpur tehsils and rainy days showed an increasing trend in all tashils except Tasgaon and Khanapur tehsils. The weekly rainfall and rainy days showed an increasing trend in MW 23, MW 25, MW 30, MW 31 and MW 46 in most of the tehsils whereas, there was a decreasing trend in MW 24 and WM 26 in most of the tehsils of Sangli district.

Kamani *et al.* (2019) the long term monthly rainfall data for the period 1958-2017 (60 years) was studied to find drought years as per IMD criteria. The daily rainfall data of Anand (middle Gujarat) for the period 1958-2017 was analysed for drought assessment and monthly rainfall variability. The average annual rainfall was 861.3 mm in 36.12 rainy days. The maximum monthly rainfall was observed in the month July followed by August and minimum rainfall in the month of June and September. This indicates that the rainfall in the area under study was more assured during *rabi* season than *kharif* season. Hence, the *rabi* cropping pattern in this area may be more assured than the *kharif* cropping. Out of 60 years under study, 45 per cent years were drought years *i.e.,* there may be drought year after every two years. Hence, drought management strategies as well as contingent crop planning measures recommended by Agriculture University should be adopted by farmers as well as the different project implementing for sustainable crop production during aberrant weather condition.

2.2 Drought Characterization

2.2.1 Analysis of Drought by Standardized Precipitation Index

Paul (1993) proposed a methodology to characterize meteorological drought based on the normality of seasonal and deficit year's rainfall (mean and standard deviation). The years were classified as incipient, large, severe, disastrous and extreme droughts based on developed drought index.

Edwards and McKee (1997) developed the standardized precipitation index (SPI) to evaluate meteorological drought. The observed rainfall was categorized as a standardized departure with respect to a rainfall probability distribution function. It indicates how precipitation for any given duration (1-72 months) at a particular observing site compares with the long-term precipitation record at the same site of the same duration.

Wu *et al*. (2001) evaluated the SPI, China-Z Index (CZI) and the statistical Z-Score on 1, 3-, 6-, 9- and 12-month time scales using monthly precipitation totals for four locations in China from January 1951 to December 1998 representing humid and arid climates, and cases of drought and flood. The CZI and Z-Score provided results similar to the SPI for all time scales, and that the calculations of the CZI and Z-Score was relatively easily compared with the SPI, possibly offering better tools to monitor moisture conditions.

Lloyd-Hughes *et al.* (2002) analysed the incidence of 20th century European drought, based on the monthly SPIs calculated on a 0.5^0 grid over the European region 35– 70^0 N and 35^0 E–10^0 W at time scales of 3, 6, 9, 12, 18, and 24 months for the period 1901–1999. Their approach provided, for a given location or region, the time series of drought strength, the number, the mean duration, and the maximum duration of droughts of a given intensity, and the trend in drought incidence.

Bonaccorso et al. (2003) carried out an analysis of drought in Sicily from 1926 to 1996. Drought occurrence was estimated by means of the SPI. To study long-term drought variability, a Principal Component Analysis (PCA) was also applied to the SPI field. A combination of SPI and PCA was also used by Bordi *et al.,* (2004) for studying the time-space co-variability of dry and wet periods during the last 50 years in eastern China.

Min *et al.* (2003) showed that the occurrence of droughts over central eastern China, Manchuria, and the north coast of Japan was highly correlated with those in Korea. However, the time scales of occurrence of droughts over the three regions were different: droughts in eastern China represented in-phase variations with those in Korea with a time interval of 5–8 years; those in Manchuria occurred with a time interval of 15 years; and those in Japan had no coincident variations.

Quiring *et al* (2003) carried out a comparative performance analysis to determine the most appropriate index for monitoring agricultural drought and predicting spring wheat yield on the Canadian prairies. A series of curvilinear regression-based crop yield models were generated for each of the 43 crop districts (20 in Saskatchewan, 12 in Manitoba, and 11 in Alberta) based on four commonly used measures of agricultural drought (SPI, PDSI, Palmer's Z-index, and NOAA Drought Index). The significant variations in model performance between the four agricultural drought indices underscored the necessity of carrying out a performance evaluation prior to selecting the most appropriate agricultural drought index for a particular application.

Wu *et al.* (2004) developed an agricultural drought risk-assessment model for Nebraska, USA, for corn and soybeans on the basis of variables derived from the SPI and crop specific drought index using multivariate techniques. The model can be used to assess real time agricultural drought risk for specific crops at critical times before and during the growing season by retaining previous and adding current, weather information as the crops pass through the various growth stages.

Farda *et al*. (2012) investigated meteorological droughts in the Lankaran region of Azerbaijan. As chosen region was characterized by large precipitation, they preferred to use the SPI method to carry study. During the research, dry years were determined according to the seasonal and annual data from weather stations in the province.

Lin *et al.* (2014) investigated impact of meteorological drought on streamflow drought in Jinghe river basin of China. Streamflow drought was detected by using the Standardized Runoff. According to authors, results not only play an important theoretical role in understanding relationships between different drought categories, but also have practical implications for streamflow drought mitigation and regional water resources management**.**

Abari *et al.* (2015) showed fluctuations of the extremely drought and wet by SPI in different stations. All the stations had been affected by drought at different time scales. Calculation of standardized precipitation index in three different time scales (SPI3, SPI6 and SPI9) in different stations showed that station had been moderately wet from 1996 to 1998 and in 4 stations (Lordegan, MalKhalifeh, Naghan and Saman) observed the severe droughts in the scale 3 and 6 months (SPI6 and SPI9) in 1999, in the same year Borujen Station faced with extremely drought in scale 3 months (SPI3). The slightly drought in 2009 and 2012 observed on scale of 3, 6 and 9 months of the Borujen and Lordegan stations.

Shah *et al.* (2015) observed and described drought based on forty (40) year precipitation data of Surat district. Finding drought index with twelve-month time scale basis and compared with the actual drought of the station. Positive SPI values point to normal condition to wet condition and negative values indicate normal condition to dry condition. SPI method resulted in showing as 50% variation of normal to wet and normal to dry condition.

Juliani *et al.* (2017) observed that for a return period of 100 years, the estimated cumulative 12-month precipitation varies from 353 mm in a 1-month drought duration to 458 mm in a 12-month drought duration.

Bobadove *et al.* (2019) showed increase in negative SPI in recent decade in Kenya. Comparison of drought frequency in different decades and ranking rainy seasons based on drought persistence are extremely important in understanding historic drought patterns and assessment of future risk. Increased drought frequency between years 2000 – 2010 for both the long and short rainy season observed in this study facilitates better preparedness and

coping mechanisms. The SPI-based drought patterns can be integrated with agricultural and hydrological parameters for quantifying drought risk.

Zaidoon *et al.* (2019) showed that the northeast region has the higher rainfall indices and the southwest region has the lowest rainfall. An analysis of the drought and rain conditions showed that the quantity of extreme drought events was higher than that expected in the study area, especially in the south and southwest areas. Therefore, an alternate classification is proposed to describe the drought, which spatially classifies the drought type as mild, moderate, severe and extreme. In conclusion, the integration between TRMM data SPI data proved to be an effective tool to map the spatial distribution and drought assessment in the study area.

Das *et al.* (2020) revealed that Jalore station was the highest drought frequency station, while the lowest drought frequency was observed in Vijaynagar station. The annual SPI result showed that the following years witnessed major drought events: 1981, 1984, 1985, 1988, 1989, 1991, 1993, 1999, 2000, 2004, 2005, and 2008. Besides, the results of the Mann–Kendall test showed that a substantial portion of the eastern basin experienced an increase in the intensity of drought, while the western basin experienced a decrease in the severity of the drought. The comprehensive analysis is indicative of climate change, and there is a possibility that such droughts would become more common in the future in the Luni River Basin.

2.2.2 Analysis of Drought by Precipitation Deciles

Gibbs *et al.* (1967) made a study of drought in Australia by using annual rainfall deciles as drought indicator. Using a network of 100 stations, maps were prepared showing the decile ranges in which rainfall for each year had occurred.

Abed *et al.* (2005) assessed drought using four different indices; SPI, Normal Precipitation Index (PI), Deciles and Techniques to Evaluate Drought using Rainfall Data (TEDR)in Zarqa river basin, Jordan. They reported that PI and SPI could be used for drought forecasting and monitoring. The PI index provides probability of occurrence of below normal conditions used for each month Using SPI analysis several stages were identified such as normal, watch, warning and emergency conditions in study area. IS maps also showed the direction of drought movement according to time and geographical area.

Shah *et al.* (2013) assessed drought using SPI and Decile Index in Theobroma region of Gujarat for period from 1968 to 2010. As per deciles, the extreme drought decades were 1978, 1985, 1986, 1987,1988, 1993, 1998, 2003 and 2005 in their study.

Tadic *et al.* (2015) studied five drought identification methods for continental Croatia for 15 weather stations in the period from 1981 to 2011 namely SPI, Deciles percent of normal, rainfall anomaly index, and threshold level method. Results revealed that each of these methods

has its specific features but that all are applicable for the area under study. They concluded that there was a significant correlation between the SPI and deciles index as well as rainfall anomaly and percent of normal in study area.

Alami *et al.* (2017) examined meteorological drought in Kabul River Basin (KRB) Afghanistan, using monthly data of rainfall of 38-years, based on Standard Precipitation Index (SPI), Percent of Normal Precipitation Index (PNPI), Decile Index (DI) and China Z-Index (CZI). The results of analysis showed that the drought event occurs in year 2000 to 2004 in the study region. They also found that the SPI calculated using log and gamma distributions and decile captured the extreme and severe drought period successfully for the study location.

Dikici M. (2020) analysed drought risk using meteorological, hydrogeological and hydrological data of the Asia basin and as a result of the determination of different indices and indicators available in the literature. The DI (Deciles Index), SPI (Standardized Precipitation Index), SPEI (Standardized Precipitation Evapotranspiration Index) and SRI (Standardized Runoff Index) indices were described. Drought severity and magnitude were found according to these indices. Based on 1, 3, 6, 9, 12, 48 month recurrence intervals, analyses were made. Classification of droughts and their threshold values were determined. The indices were compared, the correlation between them was examined and a common conclusion was reached. The drought severities, which has a precipitation area of 7800 m^2, were evaluated for certain recurrence intervals. For this purpose, based on meteorological, hydrological and hydrogeological data for the years between 1970 and 2016, DI, SPI, SPEI, and SRI indices were analysed and compared.

2.3 Studies on onset and withdrawal of monsoon

Morris *et al* (1979) developed the criteria of onset of wet season by forward accumulation of rainfall in relation to cropping patterns, in *rainfed* low land rice. The authors used 75 mm accumulated rainfall as the onset time for growing season for dry seeded crops. The results show that 80 % probability is expected to receive at least 75 mm rainfall in 21^{th} to 26^{th} MW of week.

Samui *et al.* (1994) worked on the mean weekly rainfall and its rate of change at Tadong and Gangtok in Assam. He has analysed to fix dates of onset and withdrawal of south west monsoon. The study attempts to analyse broad aspects of rainfall precipitation distribution during the four seasons. The study was based on data of 12 stations and of varying period of 4 to 25 years and concluded the rainfall over this mountainous slope was found monomodal with a maximum in July-August. Rainfall in the valley shows striking difference in patterns even at short distance (4 km) and situated at a higher altitude.

Dash *et al.* (1992) developed the criteria of onset and withdrawal by forward and backward accumulation of rainfall. The authors used 75 mm accumulated rainfall as the onset

time for growing season for dry seeded crops and 300 mm as the termination of rain to sustain a second rice crop. The results show that 75 % probability is expected to receive at least 75 mm rainfall in 22nd week and 300 mm in 26th week.

Rath *et al.* (1996) determined the safe growing period during *kharif* season based on the onset and termination of the wet season. The authors used 75 mm forward accumulation of rainfall as the onset time for the growing season for dry seeded crops. The end of the wet season was determined by backward summing of 300 mm rainfall that would be expected to sustain a second rice crop or other short duration field crops.

Babu *et al.* (1997) determined the crop growing season by estimating beginning and end of the rainy season by fixing the forward accumulation and backward accumulation of rainfall respectively at 75 mm and 30 mm. The analysis of 26 years weekly rainfall data at Polkepad in Andhra Pradesh revealed that the rainy season begins in the 27th standard week and ends in the 40th standard week.

Panigrahi *et al.* (2002) considered forward accumulation of 75 mm rainfall and backward accumulation of 20 mm rainfall to ascertain the start and end of monsoon, respectively, in *rainfed* belt of Kharagpur area, West Bengal. The probabilities of occurrence of these values in different weeks were estimated. The analysis revealed that the monsoon starts effectively from 24th week and remains active up to 39th week.

Jat *et al.* (2003) estimated onset and withdrawal of rainy season for Bhilwara in Rajasthan by fixing forward accumulation of 75 mm rainfall from 22nd week and backward accumulation of 10 mm rainfall from 52nd week, respectively. Results indicated that rainy season starts in 28th week with 72 per cent probability and terminates in 39th week with 48 per cent probability. The coefficients of variation of onset and withdrawal were observed to be 5.39 and 13.0 %, respectively.

Benjamin et al. (2009) determined monsoon season onset, withdrawal, and length, using daily precipitation data from a network of weather stations across mainland Thailand. They applied a two-phase linear regression model to objectively determine the onset, withdrawal, and length of the summer monsoon season for the years 1951-2005. Onset metric proposed by authors compared favorably with an independent determination of onset. Both onset and withdrawal were associated with expected wind and geo potential height anomalies in the lower atmosphere. Comparisons between stations showed no coherent spatial variability in either onset or withdrawal, and trends at each station.

Kingpaiboon *et al.* (2015) determined of the dates of the southwest monsoon in north-eastern Thailand from the data on precipitable water vapor obtained by GPS. The dates of onset and withdrawal of monsoons calculated from this method were compared with those obtained with other methods. The difference equaled 1-2 day except years 2010 and 2012 when the errors

were more than two days.

Reddy *et al.* (2008) analysed onset and withdrawal of rainy season at Bangalore by fixing the forward accumulation and backward accumulation of rainfall respectively at 75 mm and 30 mm. The results revealed that the earliest, delayed and mean week of onset of rainy season was found to be 21st, 32nd and 24th MW and earliest, delayed and mean week of withdrawal of rainy season was found to be 41st, 48th and 45th MW.

Khardiwar *et al.* (2016) carried out study on effective monsoon onset and withdrawal in different taluka places of Buldhana district Results obtained in the present study, the average seasonal rainfall during *kharif* season in different talukas of Buldhana district ranges from 650 to 837.5 mm. Effective monsoon (OEM) normally starts from 20th June to 3rd July (25-27 MW). It may start earliest by 4th June to 18th June and latest by 30th June to 31st July. On an average, there are 2 to 3 CDS(s) occur in Buldhana district. First CDS of 13 to 18 days duration occurs immediately after OEM during 12-30 June (24-26 MW), whereas the second CDS of 13 to 24 days occurs during 20th July to 4th August (29-31 MW). Third CDS of duration 17 to 23 days occurs during 16th August to 10th September (33-37 MW). The knowledge is respect of normal dates of onset effective monsoon (OEM) its withdrawal, period and occurrences of critical dry spells (CDS) is useful for contingent crop planning and Planning of *in-situ*rainwater conservation measures.

Anil *et al.* (2017) carried out study The study of rainfall analysis in Mahbubnagar district was undertaken with specific objective of finding the onset of effective monsoon (OEM), withdrawal of effective monsoon and dry spells in Mahbubnagar district and observed that the average annual rainfall in Mahbubnagar district ranges from 438.1 to 1316 mm with an average of 728.9 mm with the coefficient of variation of 29 %. The mean date of onset and withdrawal of effective monsoon was 7th June and 7th September respectively. On an average the CDS during different monsoon months starts from June,19 having mean duration of 17 days, July, 22 having mean duration of 18 days, August, 18 having mean duration of 15 days and September, 13 having mean duration of 15 days. The probability of occurrence of different duration dry spell events was maximum in August and September followed by July and June.

Jena *et al.* (2019) carried out study on Assessment of onset, cessation of rain fall and length of growing period of different blocks of Dhenkanal district of Odisha for cultivation of winter pulses in rice fallow condition. This study reveals that there were 115-120 monsoon rainy days, so farmers may prefer short or mid duration rice variety in *kharif* followed by short duration winter pulses for better utilization of residual soil moisture in the rice-fallow. The LGP is 170-180 days for most of the blocks and above 180 days for Dhenkanal, sadar, Hindol and Kamakahyanagar. There is maximum scope for utilization of residual soil moisture in those blocks by sowing of pulses in rice-fallow during 41-42 MW in medium land by zero till method

and 41-43 MW in low land by *paira* method. This study further revealed that minimal irrigation is required for *rabi* pulses in Parajang during 48-49 MW for early withdrawal of moisture and less availability of post-monsoon rainfall. However, suitable strategies for adjustment in sowing window of both *kharif* rice and *rabi* pulse crops could be a boon for enhancing the system productivity and profitability of the farming system under challenging rice-fallow condition.

Shrivastava *et al.* (2020) carried out study on Effect of monsoon onset and withdrawal on rice production in Chhattisgarh. The main effort of this study was to analyse the impacts of the onset and withdrawal variability of the southwest monsoon on the production of *kharif* rice in Chhattisgarh. The date of onset and withdrawal of the southwest monsoon in Chhattisgarh is important for farmers as it affects the timing of crop sowing and the length of the southwest monsoon season. Comparing average rice production data for different categories of monsoon onset and withdrawal, we found that late monsoon withdrawal conditions are favorable for rice production and productivity. Based on the correlation study, we found that there is a significant association between the date of withdrawal of monsoon and the production of rice.

2.4 Probabilities of dry and wet weeks by using Markov-chain Model

Gaikwad *et al.* (1995) suggested the suitable sowing date for sunflower on rainfall probabilities. They carried a field study to evaluate the performance of sunflower and sunflower + red gram (2:1) intercropping system sown according to rainfall probabilities for 5 successive years during *kharif* season on 30 cm soil depths and observed that the yield of sunflower and sunflower + red gram intercropping were increased when crop was either sown during 24MW or 25MW.

Gaikwad *et al.* (1996) studied rainfall variability at Solapur station for which they used data of 29 years (1963-1992). Potential Evapotranspiration values were estimated. Probability analysis was based on first order Markov Chain through which dry seeding was suggested in early June for *kharif* crops.

Sahane *et al.* (1998) studied the rainfall probabilities at Vadgaon Maval by using 27 years data in which majority of weeks recorded more than 50 per cent probability receiving more than 25 mm rainfall and observed that out of 52 weeks, 12 weeks recorded more than 50 per cent initial probabilities for 25 mm rainfall followed by 8, 2 and 1 weeks for more than 50, 75 and 100 mm rainfall, respectively.

Jadhav *et al*. (1999) studied rainfall probability analysis for crop planning in scarcity zone of Maharashtra. They collected historical data of rainfall for 30 years (1966-1995) from 9 different stations of scarcity zone. Rainfall at various probability levels for weekly, monthly, seasonal and annual were estimated. Trends calculated separately for these stations. They concluded that MW 24 and MW 38 had the highest probability of rainfall. This helped in sowing of *kharif* and *rabi* crops for dry seeding.

Gare *et al.* (2000) studied rainfall variability analysis at Gadhinglaj (Maharashtra) on the basis of 28 years rainfall data (1969-1996) for weekly, monthly, seasonal and annual rainfall at different probability levels. They concluded that *kharif* season was more assured than the *rabi* season and MW 29 was suitable for dry seeding in that area.

Reddy *et al*. (2008) used Markov Chain Model to study spell distribution. They carried it to find the probabilities of occurrence of dry and wet weeks, onset and withdrawal of rainy season and weekly analysis of rainfall for Bangalore region. Higher values of coefficient of variation of weekly rainfall indicated the erratic distribution of rainfall. The average annual rainfall of GKVK campus, Bangalore was found to be 923.9 mm and coefficient of variation (CV) of 25.4 per cent. The data on onset and withdrawal of rainy season indicated that the monsoon starts effectively from 24th MW (11-17th June) and remains active up to 45th MW (5-11th November). During rainy season the probability of occurrence of wet week is more than 35 per cent except during 25th- 27th MW and 44th- 48th MW. The mean weekly rainfall is found to be more than 40 mm during 36th- 41th MW and found to be less than 20 mm during 20th MW, 25th- 27th MW and 44th- 48th MW. The results through analysis have been used for agricultural planning at Bangalore region.

Pandharinath (1991) estimated probabilities of dry, wet weeks, conditional probabilities of dry week preceded by dry week, wet week preceded by a wet week and consecutive 2 or 3 dry/wet weeks at nine stations in Andhra Pradesh during monsoon season (June- September) using Markov-Chain model. The study revealed that leaving the first two weeks of June; the probability of occurrence of a dry week was moderate to high (30 to 60 %) in North Andhra Pradesh and was 20 to 50 % in south coastal Andhra Pradesh. The conditional probability of occurrence of a dry week given the preceding week dry was also high, but the occurrence of two or three consecutive dry weeks was small.

Dash *et al.* (1992) used Markov-Chain model to study the probability of dry and wet spells for Bhubaneswar, Orissa. The study concluded that from 22nd week to 36th week, rainfall was adequate to grow rice crop. The authors also found that sowing rice crop in 25thweek has 7.5 % probability of two consecutive dry weeks. The study concluded that there are 40 % chances of recurring dry weeks till the 22nd week; hence a period is not suitable for crop planning.

Jat *et al.* (2005) determined dry and wet spells for agricultural planning in Udaipur region. The results revealed that, the probability of occurrence of a dry week was high (77 to 100 per cent) in the first 25 weeks of the year and then deceased subsequently. The probability of occurrence of dry week again increased from 36th to 52nd week of the year. Similarly, the probability of wet week was very low (0 to 27 %) up to 26th week and then started increasing up to 34th week. Thus, till 44th week except 51st week after which it reduces even to the level to 0%.

Reddy *et al.* (2008) evaluated dry and wet spells for Bangalore region. Markov chain Model was extensively used to study spell distribution. The results revealed that, during rainy season there are more than 50 % chances that two consecutive dry weeks may occur during 24th-26th MW and 44th-48th MW. Similarly, the probabilities of occurrence of three consecutive dry weeks were also very high (more than 35 %) during 23rd - 26th MW and 44th - 48th MW.

Admasu *et al.* (2014) presented the study after using Markov Chain probability model to explain long term frequency behaviour of wet and dry weather spells at Dhera, Ehiopia. Weekly rainfall data from 1984 to 2010 was used to study the probability of occurrences of dry and wet weeks. The probability of occurrences of initial and conditional probability is more than 50 per cent at 10 mm per week threshold limit in 26th MW and at 20 mm per week threshold limit in 28th MW, therefore land preparation and sowing could be undertaken in 26th and 28th MW respectively. Initial and conditional probabilities at 20 mm threshold limit per week showed that, supplementary irrigation moisture conservation practice need to be practiced between 38th and 40th MW. In addition, harvesting runoff water for supplementary irrigation and construction of soil erosion measures need to be practiced between 28th and 33rd MW for rainwater management.

Punitha *et al.* (2017) used Markov chain probability model to enlighten the long term frequency behaviour of wet or dry weather spells during the main rainy season. This study used 35 years (1981 to 2015) of rainfall data and aggregated weekly rainfall data (52 weeks) was considered as standard week to study the probability of occurrence of wet and dry weeks. The probability of occurrences of initial and conditional probability is more than 50 % on 35th week with threshold limit of 20 mm per week. Therefore the land preparation for sowing or planting could be undertaken in 35th week respectively for the main rainy season crop cultivation.

Dugal *et al*. (2018) collected and processed block wise historical rainfall data of 23 years (1995 to 2017) of Bhadrak District by using Weather cock software which revealed that the total mean annual rainfall of the district is 1431 mm. Bhadrak receives almost 70% of mean annual rainfall during SW monsoon. Monsoon starts effectively from 24th MW (12th June to 15th June) in Bhadrak district and remain active up to 41st MW (9th October to 13th October). The initial rainfall probability, P(W) of getting 20 mm rainfall per week was >30 per cent during 22nd MW at Bhadrak district, hence, field preparation should be done during this period. The initial as well as conditional probability of wet week followed by wet week P(W/W), of getting 20 mm rainfall was more than 50 per cent in 23rd MW, this week is more suitable for sowing of crops. During 44th to 46th MW (29th Oct. to 18th Nov.) probability of getting 10 mm rainfall per week was more than 30 per cent. This period is suitable for land preparation and sowing of *rabi* crops. Proper crop planning with suitable water conservation measures are needed to be adopted to enhance the acreage, production and productivity *rabi* crops of the district.

Joshi (2019) studied trends in weekly, monthly, seasonal and annual rainfall of Solapur district using Mann-Kendall test Z and Sen's slope method, to determine probabilities of dry and wet weeks by using Markov-Chain model and to suggest crop management and planning. The study revealed that maximum seasonal, monthly and weekly rainfall was observed in South-West monsoon season, September month and MW 38th and 39th respectively. Therefore, selected tehsils of Solapur district are *rabi* dominated as there is sufficient availability of residual moisture from rainfall at the end of the South-West monsoon season. However, short duration *kharif* crops with *in-situ* moisture conservation practices and proper crop planning are possible to grow in the study area. The mean date of onset of effective monsoon lies between 25th June and 16th July in the study area, hence this period should be considered for the sowing of selected *kharif* crops.

Dash *et al.* (2020) Understanding the probable period of onset and withdrawal of monsoon, amount of rainfall and its distribution over a cropping season is prerequisite to timely agricultural operations, selection of crop varieties and cropping pattern in a region. Dhanora block is one of the eight blocks of Seoni district with undulating landform, erratic rainfall and mainly *rainfed* farming with less irrigated area (22.02 %). Here, Markov chain model used for dry and wet spell analysis for weekly rainfall. If total amount of any week of rainfall is equal or more than 10 mm, 20 mm and 40 mm, it considered as wet weeks and less than this considered as dry weeks. Probability of two or three consecutive dry weeks at 20 mm rainfall is less than 40% during 25th MW to 39th MW and more than 50% from 1st to 23rd MW and 40th MW to 52nd MW. Probability of two and three consecutive wet weeks at 20 mm rainfall is more than 50% from 25th MW to 36th MW and 27th MW to 36th MW, respectively. Based on probability analysis of rainfall and moisture availability, various water management and crop planning strategies have been discussed in this paper for Dhanora block, Seoni.

2.5 Studies on Crop Management Planning Based on Rainfall Analysis

Manorama *et al.* (2007) carried out study on rainfall analysis and crop planning for the Nilgiris (Tamil Nadu). Weekly, monthly, seasonal and annual study was carried out at different probability levels. He suggested potato, cabbage, carrot etc., can be taken up in the 3rd week of April and the second crop can be planted at end of August rotating among these vegetables.

Sheoran *et al.* (2008) made rainfall analysis and suggested crop planning in lower Shivalika foot hills of Punjab. They recorded the daily rainfall data of Punjab for 26 years for long term averages of annual, seasonal, monthly and weekly rainfall and its temporal variability. They observed that there was an ample scope for rain water harvesting from July to September which can be utilised as crop saving irrigation as well as pre-sowing irrigation for succeeding *rabi* crops which are generally sown on residual soil moisture.

Singh *et al*. (2008) studied the rainfall distribution pattern and crop planning at Pusa in Bihar by collecting the daily data of fifty two years for establishing the long term averages of weekly, monthly, seasonal and annual rainfall and its variability. They observed that the average duration of the rainy season was from 26th to 40th MW. Pre-monsoon rains at 75 per cent probability level can be utilised for seedbed preparation and at 50 per cent probability level summer crops like cow pea and black gram could be grown successfully.

Jat *et al.* (2010) worked on crop planning in semi-arid tracts of Udaipur region based on analysis of weekly rainfall. Incomplete gamma distribution is used to predict the minimum assured rainfall at different probabilities of exceedance in all weeks of the whole year. The study reveals that chances of drought are more at critical stages of maize but there is a scope for *in-situ* moisture conservation and runoff collection in tanks for supplemental irrigation. *Rabi* crops are found to be grown under moisture stress.

Chand *et al.* (2011) analysed rainfall for crop planning in Jhansi district of Bundelkhand zone of Uttar Pradesh. The historical rainfall data for the period of 34 years (1975-2008) of Jhansi in Bundelkhand agroclimatic zone of U.P were analysed to know weekly, monthly, seasonal and annual probabilities at different levels of rainfall for suitable crop planning. The analysis revealed that, occurrence of 70 % of initial probability of a dry week from 1 to 24th week and the conditional probability of wet week preceded by a wet week is also high from 26th to 37th week. The *kharif* season crops and their varieties may be chosen with the growing period to avoid moisture stress. The sowing of *rainfed* crops in *rabi* season may be completed between 40th to 41nd standard weeks because subsequent week has rare chance to get rains.

Chinchorkar *et al*. (2012) analysed daily rainfall data of 30 years (1972-2002) of different 20 rain gauge stations from the scarcity zone of Maharashtra. Weekly actual rainfall was considered for calculating Moisture Availability Index (MAI). The wet and dry spells were calculated by Markov Chain model. The arrival and departure of monsoon were decided by weekly rainfall frequency distribution method. It was suggested to grow grasses and dry land horticulture *viz.*, custard apple, pomegranate etc. on shallow soil in addition to present cropping pattern. Similarly, in medium and deep soils during *kharif* season sunflower, pearl millet, pigeon pea, castor, groundnut etc. were suggested. During *rabi* season sunflower, safflower, rabi sorghum, gram etc. were suggested with the provision of supplemental irrigations. Fodder sorghum in *kharif* and safflower in *rabi*, pearl millet in *kharif* and gram in *rabi*, black gram in *kharif* and sorghum in *rabi*, green gram in *kharif* and sunflower in *rabi*, cowpea for fodder in *kharif* and sunflower in *rabi* were suggested.

Guhathakurta *et al.* (2013) reported that rainfall occurring from January to May in Maharashtra has fall down over 100 years. Vidharbha region was recognized as low rainfall area due to climate change, there is Vidharbha region increased over 100 years study. The trend of

receiving total annual rainfall in short period (*i.e.* length of monsoon decreased) was observed in Marathwada region. It means the decreasing trend of rainy days was observed regionally and mixed trend (*i.e.* decreasing and increasing) was observed intra districally *i.e.* within the district.

Admasu *et al.* (2014) presented the study after using Markov Chain probability model to explain long term frequency behaviour of wet and dry weather spells at Dhera, Ehiopia. Weekly rainfall data from 1984 to 2010 was used to study the probability of occurrences of dry and wet weeks. The probability of occurrences of initial and conditional probability is more than 50 per cent at 10 mm per week threshold limit in 26th MW and at 20 mm per week threshold limit in 28th MW, therefore land preparation and sowing could be undertaken in 26th and 28th MW respectively. Initial and conditional probabilities at 20 mm threshold limit per week showed that, supplementary irrigation moisture conservation practice need to be practiced between 38th and 40th MW. In addition, harvesting runoff water for supplementary irrigation and construction of soil erosion measures need to be practiced between 28th and 33rd MW for rainwater management.

Pali *et al*. (2015) worked on daily rainfall data for 20 years (1994-2013) collected from Durg, Dhamdha and Patan blocks of Durg district of Chhattisgarh and other climatic data on minimum and maximum temperatures, relative humidity and evaporation for the same period (1994-2013) were collected from Durg block only. Using rainfall and evaporation data, weekly and seasonal mean rainfall, expected rainwater availability at given probability levels and ET demands of the rice crop at different growth stages were estimated and analysed. This analysis showed that a severe drought situation may occur at all the blocks of Durg district. Thus, supplemental irrigation is essential at all the study blocks to obtain good rice yields.

Shaikh *et al.* (2017 a) reported the availability of water for crops in a season depends on the distribution and variability of rainfall. Hence, from crop management point of view, onset and withdrawal of monsoon is to be considered the ideal for crop planning, scheduling farm operations on land use operations and therefore the onset and withdrawal pattern of monsoon of each tehsil were worked out and presented in Table1. Onset and withdrawal of Satara district mean start of rainy season is 24 MW in most of the tehsils and early onset is at 23 MW in all the tehsils. While late onset observed from 25 MW to 26 MW. Mean termination of rainy season was noted in 42 MW to 48 MW. Early termination was observed during 41 MW to 43 MW in all the tehsils while late termination observed during 49 MW.

Shaikh *et al*. (2017 b) reported the average number of drought years of district for no drought, moderate drought and severe drought were 45, 8 and 2 and their contribution 82, 15 and 3 per cent, respectively. The information regarding different aspect of rainfall, like severity of drought in each tehsil along with the different soil types of Satara district is very meager. Hence,nit was necessary to undertake the characterization of rainfall for agricultural crop

planning to the farmers of the district. With these considerations, a systematic study was planned on meteorological drought pattern in different tehsils of Satara district

Punitha *et al.* (2017) used Markov chain probability model to enlighten the long term frequency behavior of wet or dry weather spells during the main rainy season. This study used 35 years (1981 to 2015) of rainfall data and aggregated weekly rainfall data (52 weeks) was considered as standard week to study the probability of occurrence of wet and dry weeks. The probability of occurrences of initial and conditional probability is more than 50 % on 35th week with threshold limit of 20 mm per week. Therefore the land preparation for sowing or planting could be undertaken in 35th week respectively for the main rainy season crop cultivation.

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Dash *et al.* (2020) understanding the probable period of onset and withdrawal of monsoon, amount of rainfall and its distribution over a cropping season is prerequisite to timely agricultural operations, selection of crop varieties and cropping pattern in a region. Dhanora

block is one of the eight blocks of Seoni district with undulating landform, erratic rainfall and mainly *rainfed* farming with less irrigated area (22.02 %). Here, Markov chain model used for dry and wet spell analysis for weekly rainfall. If total amount of any week of rainfall is equal or more than 10 mm, 20 mm and 40 mm, it considered as wet weeks and less than this considered as dry weeks. Probability of two or three consecutive dry weeks at 20.00 mm rainfall is less than 40% during 25th MW to 39th MW and more than 50% from 1st to 23rd MW and 40th MW to 52nd MW. Probability of two and three consecutive wet weeks at 20 mm rainfall is more than 50% from 25th MW to 36th MW and 27th MW to 36th MW, respectively. Based on probability analysis of rainfall and moisture availability, various water management and crop planning strategies have been discussed in this paper for Dhanora block, Seoni.

3. MATERIALS AND METHODS

This chapter gives detailed information about the study area, data and software used for rainfall analysis to study drought using Standardized Precipitation Index (SPI) and Precipitation Deciles (PD), Onset and Withdrawal of Monsoon, probabilities of dry and wet weeks by using Markov-chain Model for crop planning over Solapur district.

3.1 Study Area

Location map of study area Solapur district situated in the western part of Maharashtra state. Geographically district lies between $17^0$39'35.7120" N North latitude and $75^0$54′22.9932" E East longitude. The study area comprises of eleven tehsils of Solapur district. The district is situated on the south east fringe of Maharashtra State and lies entirely in the Bhima and Seena basins. Whole of the district is drain either by Bhima river or its tributaries. The district is bounded on the north by Ahmednagar and Osmanabad districtcs, on the east by Osmanabad and Gulbarga (Karnataka State) districts, on the south by Sangli and Bijapur (Karnataka State) and on the west by Satara and Pune districts. In the north of Barshi Taluka several spurs of Balaghat range pass south for a few kilometres. There are also a few scattered hills in Karmala, Madha and Malshiras Talukas. The district in general has flat or undulating terrain. The low table land and small separate hills in Karmala and Madha Talukas act as a Watershed between Bhima and Sina rivers.

Solapur district is situated at 457 M height above the mean sea level (MSL). The district covers geographical area of 14844.6 sq.km. which is 4.82% of the total area of Maharashtra State. Solapur falls under the category of dry (arid and semiarid) climate according to the Köppen climate classification. The tehsilwise map of the Solapur district is shown in fig. 3.1. It consists of 11 tehsils *viz.,* Akkalkot, Barshi, Karmala, Madha, Malshiras, Mangalwedha, Mohol, North and South Solapur, Pandharpur and Sangola. The Solapur district lies in scaracity agro-climatic zones as described below and depicted in fig 3.2.

3.2 Climate and Rainfall

Climate of Solapur district is hot arid and semi-arid climate bordering with tropical wet and dry. The district experiences three distinct seasons: summer, monsoon and winter. Typical summer months are from March to May, with maximum temperatures ranging from 30 to 45 ^{0}C. The warmest months in Solapur are April and May. The monsoon lasts from June to the end of September, with moderate rainfall. The Solapur district receives an average rainfall of 603.79 mm per year. Winter begins in November and lasts until the end of February, with the temperatures ooccasionally drops below 10^0C. (source: http://www.kvksolapur.org/district-profile.php).

3.2.1 Monsoon

June to September month is considered as Monsoon season. The rains start with the south-west winds. Nearly 76 % of the total average rainfall occurs in this season. The number of average annual rainy days in Solapur district is 28 as compared to 67 in Maharashtra state.

3.2.2 Post Monsoon

The good weather season with less rainfall between October to December month is called as Post Monsoon season. Nearly 18.5 % to total annual rainfall occurs in this season. Yield of *rabi* crops depends upon the weather during this season.

3.2.3 Winter

Winter season is described as a period of two months from January to February. Approximately, 0.9 % of annual rainfall occurs in winter. Most of the *rabi* crops depend upon the weather during these months.

3.2.4 Pre monsoon

Also known as summer, this season lasts for three months; March-May. Approximately, 5.1% of annual rainfall occurs in summer.

The average rainfall of Solapur district is approximately 603 mm which is only 58 % of the average rainfall of the state (1034 mm). Solapur district received rainfall from both south west and north east monsoon. The proportion of rainfall received from north east monsoon increases towards eastern tehsils while rainfall form south west monsoon increases towards eastern tehsils due to Sahyadri Mountain region.

3.3 Data Collection

For the present study, rainfall data of all eleven tehsils in Solapur district is downloaded for the period of 1961-2019 in some tehsils and 1998-2019 for North and South Solapur tehsils from following websites.

(1) Department of Agricultural Meteorology, College of Agriculture Pune

(2) State Agriculture Department, Pune

(3) India Meteorology Department, Pune

(4) Downloaded from www.maharain.gov.in (www.krishi.maharashtra.gov.in)

Weather cockis a software developed by CRIDA, Hyderabad is used to convert daily rainfall data into weekly, seasonal, monthly and annual data for further analysis. This weekly, monthly and annual rainfall data is presented in Appendix-1. Four different indices namely Precipitation Decile (PD), Standard Precipitation Index (SPI), Probability of dry and wet weeks

and Start and End of rainfall are calculated using this rainfall data. The geographical area of rain gauge stations and duration of rainfall data collected is presented in Table 3.1.

Table 3.1: Geographical area and duration of rainfall of study area.

Sr. No.	Name of tehsils	Geographical Area km^2	latitude	longitude	Period of year	No. of years
1	Akkalkot	1390.3	17^{0}31'N	76^{0}51'E	1961-2019	59
2	Barshi	1483.1	18^{0}13'N	75^{0}44'E	1961-2019	59
3	Karmala	1610	18^{0}24'N	75^{0}15'E	1961-2019	59
4	Madha	1544.9	18^{0}03'N	75^{0}52'E	1961-2019	59
5	Malshiras	1608	17^{0}55'N	74^{0}57'E	1961-2019	59
6	Mangalwedha	1140.9	17^{0}31'N	75^{0}28'E	1961-2019	59
7	Mohol	1325	17^{0}49'N	75^{0}40'E	1961-2019	59
8	Pandharpur	1293	17^{0}41'N	75^{0}23'E	1961-2019	59
9	Sangola	1567	17^{0}43'N	75^{0}19'E	1961-2019	59
10	Solapur North	736.3	17^{0}39'N	75^{0}52'E	1998-2019	22
11	Solapur South	1195.3	17^{0}39'N	75^{0}54'E	1998-2019	22

3.4 Software Used For Study

Microsoft office sub-module Microsoft-Excel-2010 is used for data analysis. The formulation and conditional statements were also executed in MS-excel. The Weather Cock-15 software developed by CRIDA, Hyderabad is used for the analysis of annual, seasonal, monthly and weekly rainfall, mean, standard deviation, coefficient of variation of rainfall, Probability of Wet and Dry weeks. The SPI_SL_6.exe software developed by T.B. McKee, N.J. Doesken and J. Kleist, Colorado State University, 1993 is used for analysis of drought by calculating standardized precipitation index (SPI). The DrinC (drought indices calculator) software developed at National Technical University of Athens is used for analysis of drought using Precipitation Deciles Index. The STENDRF.EXE software is used for analyzing start and end of monsoon.

Table 3.2: Software's used for rainfall data analysis

Indices	Software used	Developed by
Conversion of data for Daily, Weekly, Monthly, Seasonal, Annual	Weather cock-15	CRIDA, Hyderabad
Standardized Precipitation Index (SPI)	SPI_SL_6.exe Svoboda *et al.,*,(2012)	Edwards and McKee, (1997)
Precipitation Deciles	DrinC	National Technical University of Athens
Onset and Withdrawal of monsoon	STENDRF.EXE	CRIDA, Hyderabad
Markov chain probability model for dry and wet spell analysis	Weather cock-15	CRIDA, Hyderabad

3.5 Statistical Characteristics of Climatological Data

The statistical behavior or characteristics of series of any climatological variables can be described on the basis of several parameters. These parameters are mean, standard deviation, coefficient of variation. All these parameters were used to describe the variability of climatological variables (rainfall) in this study. The statistical characteristics of rainfall of 11 stations were determined on weekly, monthly, seasonal and annual basis v*iz.,* Akkalkot, Barshi, Karmala, Madha, Malshiras, Mangalwedha, Mohol, North and South Solapur, Pandharpur and Sangola.

3.5.1 Mean

Mean represents the measure of central tendency. It is the average of given values and given by

$$X = \frac{\sum_{i=1}^{n} Xi}{n} \qquad \text{……. (3.1)}$$

Where,

X = Mean

i= Variables

n = Total number of variables

3.5.2 Standard Deviation

Standard deviation is the best measure of dispersion. It gives more weight to extreme items and less to those which are near the mean. It is defined as the positive square root of the arithmetic mean of the squares of the deviations of the given values from the arithmetic mean.

$$\sigma = \sqrt{\frac{\sum (Xi-X)2}{n-1}} \qquad \text{…… (3.2)}$$

Where,

σ = Standard deviation

X_i= Variables

X= Mean

n= Total number of variables

3.5.3 Coefficient of Variation

The coefficient of variation is the percentage of variation in the mean, the standard deviation being treated as the total variation in the mean. The coefficient of variation (CV) is a statistical measure of how the individual data points vary about the mean value.

$$CV = \frac{\sigma}{X} 100 \qquad \text{……. (3.3)}$$

Where,

CV = Coefficient of variation

X = Mean

σ= Standard deviation

This measure is indicative of dependability of variable expressed in percentage. The threshold levels for CV for any interpretation are <25, <50, <100, <150 and <250 % for yearly, seasonal, monthly, weekly and daily rainfall respectively Manorama *et al.,* (2007).

3.6 Methodology

Meteorological Drought by various Indices

Meteorological drought was analysed by using Precipitation Deciles (PD) and Standardized Precipitation Index (SPI) for Solapur district.

3.6.1 Precipitation Deciles

One of the simplest meteorological drought indices is the method of Deciles which was introduced by Gibbs and Maher (1967). The precipitation totals for the preceding three months are ranked against climatological records and if the sum falls within the lowest decile of the historical distribution of 3-month totals, then the region is considered to be under drought conditions (Kininmonth *et al.,* 2000). The drought ends when:

(i) The precipitation measured during the past month already places the 3-month total in or above the fourth decile, or

(ii) The precipitation total for the past three months is in or above the eighth decile.

The advantage of the method of deciles is its computational ease but its simplicity can lead to conceptual difficulties. The deciles are grouped into five classes as presented in Table 3.3.

Table 3.3: Classification of drought conditions according to deciles

Decile Class	Description
Deciles 1-2: lowest 20%	Much below normal
Deciles 3-4: next lowest20%	Below normal
Deciles 5-6: middle 20%	Near normal
Deciles 7-8: next highest 20%	Above normal
Deciles 9-10: highest 20%	Much above normal

3.6.2 Standardized Precipitation Index (SPI)

The SPI index was designed by McKee *et al.,* to quantify the precipitation deficit in 1993 in University of Colorado. The calculation of the SPI index in any place is based on the

precipitation history over a long period corresponding to the period of time studied. This effort was accomplished by quantifying the rainfall deficit at multiple time scales. More specifically, McKee *et al.,* (1993) estimated the SPI for the time scales of 1, 3, 6, 12, 24, and 48 months. Drought at time scales 1-, 3-, and 6-month is relevant for agriculture, 12-month for hydrology and 24-month for socioeconomic impact. Any drought including meteorological and agriculture is a result of deficient rainfall. The SPI has been used widely to quantify the deficit of precipitation. It could be computed at different time scales from less than 1 month to 48 months or more. The calculation time period depends on the user's application. Short-term SPI is used to detect agricultural drought, and long-term SPI can be used for water supply management. In addition, the 1-month SPI reflects a short-term condition; the 3-month SPI provides a seasonal estimation of precipitation; the 12-month SPI also reflects medium-term trends in precipitation patterns and may provide an annual estimation of water condition. Therefore, this study used the SPI values at 1, 3 and 6-month scales to discover the drought discrepancy (Tan *et al.,* 2015). The advantage of SPI is, it needed only precipitation data and can be used for both dry and rainy seasons while some indices using specific data as per designed. It can describe drought conditions that are important for a range of meteorological, agricultural, and hydrological applications. Studies have shown that the SPI is suitable for quantifying most types of drought events (Guenang and Kamga, 2014). To calculate the SPI, a long-term precipitation record at the desired station is first fitted to a probability distribution (e.g. gamma distribution), which is then transformed into a normal distribution so that the mean SPI is zero (McKee *et al.,* 1993, McKee *et al.,* 1995, Edwards and McKee, 1997). The SPI value is derived from the inverse value of the cumulative probability function of the observed precipitation distribution. Standardized precipitation index was calculated according to the following formula Edwards and McKee, (1997).

$$\text{SPI} = \text{Z score} = \frac{X_i - \overline{X}}{\sigma} \ldots (3.4)$$

The SPI is equivalent to Z-score which is often used in statistics *i.e.* SPI=Z-score

Where,

X_i = Precipitation of the specified time scale for i^{th} year (*i.e.* for annual SPI is the precipitation of i^{th} year; for monthly SPI, it is the precipitation of particular month in i^{th} year; and for two month time scale, it is the sum of the precipitation of the particular month and the month preceding to this particular month)

$\overline{X}$= Long-term average precipitation of the specified time scale

σ = Standard deviation of the precipitation of the specified time scale

To adjust for this empirical fact, the precipitation data is transformed to a more normal or Gaussian symmetrical distribution by applying the gamma function. After the precipitation data

have been transformed, the SPI is calculated in a manner that mirrors the Z-score formula Edwards and Mckee, (1997). Procedure and formulae adopted for computation of SPI is;

I. The transformation of the precipitation value in to standardized precipitation index (SPI) with the purpose of:

a) Transforming the mean of the precipitation value adjusted to 0;
b) Standard deviation of the precipitation is adjusted to 1.0; and
c) Skewness of the existing data is readjusted to 0.

When these goals are achieved the standardized precipitation, index is interpreted as mean 0 and standard deviation of 1.0.

The precipitation needs to convert to lognormal values and the statistics, U shape and β scale parameters of gamma distribution are computed as:

$$\log \text{mean} = \overline{X}_{ln} = \ln\left(\overline{X}\right) \quad \text{... (3.5)}$$

$$U = \overline{X}_{ln} - \frac{\sum \ln(X)}{N}$$

$$\text{Shape parameter} = \beta = \frac{1+\sqrt{1+\frac{4U}{3}}}{4U} \quad \text{… (3.6)}$$

$$\text{Scale factor} = \alpha = \frac{\overline{X}}{\beta} \quad \text{… (3.7)}$$

The resulting parameters are then used to find the cumulative probability of an observed precipitation event. The cumulative probability is given by:

$$G(x) = \frac{\int_0^x x^{\alpha-1} e^{\frac{-x}{\beta}} dx}{\beta^{\alpha}\Gamma(\alpha)} \quad \text{… (3.8)}$$

Since the gamma function is undefined for x=0 and a precipitation distribution may contain zeros, the cumulative probability is becomes:

$$H(x) = q + (1 - q)G(x) \quad \text{… (3.9)}$$

Where

q = the probability of zero.

The cumulative probability H(x) is then transformed to the standard normal random variable Z with mean zero and variance of one, which is the value of the SPI (Edwards and McKee, 1997). Abramowitz and Stegun (1965) provide the approximate conversion as an alternative:

$$Z = SPI = -\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right) \; 0 < H(x) \leq 0.5 \quad \text{… (3.10)}$$

$$Z = SPI = +\left(t - \frac{c_0+c_1t+c_2t^2}{1+d_1t+d_2t^2+d_3t^3}\right) \; 0.5 < H(x) \leq 1 \quad \text{… (3.11)}$$

Where,

$$t = \sqrt{\ln\left(\frac{1}{H(x)^2}\right)} \quad 0 < H(x) \leq 0.5 \qquad \ldots (3.12)$$

$$t = \sqrt{\ln\left(\frac{1}{(1.0-H(x))^2}\right)} \quad 0.5 < H(x) \leq 1.0 \qquad \ldots (3.13)$$

C_0= 2.515517

C_1= 0.802583

C_2= 0.010328

d_1= 1.432788

d_2= 0.189269

d_3= 0.001308

The values of c_0, c_1, c_2, d_1, d_2 and d_3 given in equation are constants widely employed for SPI computation Edwards and McKee, (1997).

Anomalous behaviour of rainfall can be identified from SPI values as extraordinary heavy rainfall indicates more positive SPI while scanty rainfall shows deviation towards more negative SPI. Drought event is considered commencing when SPI goes below -1 and is said offsetting when SPI becomes positive (i.e. rainfall just above the mean rainfall). The region is said to have continuous drought when several consecutive months show negative SPI values. According to the SPI method the severity of a drought is determined. The negative value from zero shows the severity of dryness. The SPI value normally ranges from (-2) to (+ 2). The SPI is grouped into seven classes as presented in Table 3.4. In this study SPI value will be computed for four different time scale *i.e.* 3 month,6 months, 9 month and 12 month for all the 11 stations in Solapur districts of Maharashtra. The software SPI_SL_6.exe is used for analysis.

Table 3.4: Classification of Drought condition according to SPI Class

Index Class	Description
+2	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
(0.99) to (-0.99)	Near normal
(-1.0) to (-1.49)	Moderately dry
(-1.5) to (-1.99)	Severely dry
(-2.0) or Less	Extremely dry

3.6.3 Markov Chain Probability Model For Dry And Wet Spell Analysis

The success or failure of crops particularly under *rainfed* conditions is closely linked with the rainfall patterns. Simple criterion related to sequential phenomenon like dry and wet spell was used for analyzing rainfall data to obtain specific information needed for

crop planning and for carrying out agricultural operations including protective irrigation. It is always useful to ascertain the probability of sequential events like a wet week following another wet week or a dry week following a wet or dry week during the crop growing season. This is the basis for the analysis of rainfall for dry spell and wet spell using Markov-Chain process, which is described in this section.

Rainfall of 20 mm per week will be considered as adequate for all the growth stages of all the crops grown. Thus, if in a given week the rainfall received will be less than 20 mm, that week will be designated as a dry week and vice versa Pandharinath, (1991). On the basis of this criterion each week was categorized as a dry week and wet week and respective probabilities were calculated as follows:

3.6.3.1 Initial Probability of Dry and Wet Weeks

Based on historical data of weekly rainfall and following the above mentioned criteria of dry and wet week, the initial probabilities can be calculated as:

$$P(D) = F(D)/N \quad \ldots\ldots\ldots(3.7)$$

$$P(W) = F(W)/N \quad \ldots\ldots\ldots(3.8)$$

Where,

P(D) is the probability of occurrence of dry week,

P(W) is the probability of occurrence of wet week,

F(D) is the frequency of occurrence of dry week,

F(W) is the frequency of occurrence of wet week,

N is the total number of years

3.6.3.2 Conditional Probability of Dry and Wet Weeks

$$P(D/D) = F(DD)/F(D) \quad \ldots\ldots\ldots(3.9)$$

$$P(W/W) = F(WW)/F(W) \quad \ldots\ldots\ldots(3.10)$$

$$P(W/D) = 1\text{-}P(D/D) \quad \ldots\ldots\ldots(3.11)$$

$$P(D/W) = 1\text{-}P(W/W) \quad \ldots\ldots\ldots(3.12)$$

where,

P(D/D) = probability of a week being dry preceded by another dry week,

F(DD) = frequency of dry week preceded by another dry week,

P(W/W) = probability of a week being wet preceded by another wet week,

F(WW) = frequency of a wet week preceded by another wet week,

P(W/D) = probability of a wet week preceded by a dry week, and

P(D/W) = probability of a dry week preceded by a wet week.

3.6.3.3 Consecutive Probability of Dry and Wet Weeks

$$P(2D) = P(DW1)\times P(DDW2) \quad \ldots\ldots\ldots(3.13)$$

P(3D) = P(DW1)×P(DDW2)×P(DDW3) ……(3.14)

P(2W) = P(WW1)×P(WWW2) ……(3.15)

P(3W) = P(WW1)×P(WWW2)×P(WWW3) ……(3.16)

Where,

P(2D) = probability of two consecutive dry weeks starting with the week,

P(DW1) = probability of the first week being dry,

P(DDW2) = probability of the second week being dry, given the preceding week being dry,

P(3D) = probability of three consecutive dry weeks starting with the week,

P(DDW3) = probability of the third week being dry, given the preceding week dry,

P(2W) = probability of two consecutive dry weeks starting with the week,

P(WW1) = probability of the first week being wet,

P(WWW2) = probability of the second week being wet, given the preceding week being wet,

P(3W) = probability of three consecutive wet weeks starting with the week and

P(WWW3) = probability of the third week being wet, given the preceding week wet.

Dry spell of different duration will be estimated for different stations by using above procedure.

3.6.3.4 Markov chain model

The model assumes that the transition probability for a given week depends as the weather (dry or wet) of its previous week. Under such a model the following relations hold:

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

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

$P(W_i / D_{i-1}) = \frac{P(Di)) - P(Di-1)P(Di/Di-1)}{P(Wi-1)}$ and

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

Where,

$P(D_i/W_{i-1})$ is the transition probability that i^{th} week is dry given that $(i-1)^{th}$ week is wet and the other definitions automatically follow. It is interesting to note that only the initial probability the i^{th} week of a year is dry, $P(D_i)$ and the transition probability of i^{th} week that it is dry provided previous week is dry, $P(D_i/D_{i-1})$, need to be calculated from the original data and the other probabilities are easily obtained by substitution. On the basis of above methodology when applied on rainfall data the results are obtained and the tehsil wise crop management planning is suggested for Solapur District.

3.6.4 Determination of Onset and Withdrawal of Monsoon Season

Forward and backward accumulation methods were used for computation of onset and withdrawal of rainy season from weekly rainfall data. In this method weekly rainfall was summed by forward accumulation (20+21+…+52 weeks) until a certain amount of rainfall was accumulated. 75 mm of rainfall accumulation has been considered as the onset time for the growing season of dry seeded crops and land preparation (Babu and Lakshminarayana, 1997; Panigrahi and Panda, 2002). The withdrawal of rainy season was determined by backward accumulation of rainfall (48+47+46+…+30 weeks) data. 20 mm of rainfall accumulation was chosen for the end of rainy season, which is sufficient for ploughing of fields after harvesting the crops (Babu and Lakshminarayana, 1997).

By considering prevailing rainfall condition of selected area 50 mm of rainfall accumulation has been considered as the onset time and 10 mm rainfall accumulation has been considered as the withdrawal time.

3.7.1 Crop Planning and Management

Crop planning and management has its application to ensure the yield of the crop. Dry spell coincidence with sensitive phenological stages of crop is very likely to affect the crop development. Hence, it is very important to analyse the sequence of dry and wet weeks for crop planning purpose.

Crop calendar can be considered as a key or tool for crop management information when it is superimposed over dry and wet weeks sequence. Accordingly, from where the initial probability of week being wet increases land preparation starts and where the conditional probability of week being wet i.e. occurrence of rainfall at 20 mm per week is above 50 per cent, is the right week of planting. Supplementary irrigation and moisture conservation practices need to be undertaken if at 20 mm threshold the probability of dry week and dry week followed by dry week exceeds 50 per cent (Admasu *et al.,* 2014). The irrigation can be withheld for some time if there is a probability of wet week or apply irrigation during the dry week in a very sensitive phenological or critical growth stage of crop (Singh *et al.* 2014).

3.7.2 Crop Calender

The following crop calendar has been used as a key tool for crop planning which is recommended by Mahatma Phule Krishi Vidyapeeth, Rahuri in its University publication Krishidarshani (2020).

Table 3.5: Crop calender as suggested by M.P.K.V., Rahuri

Season	Crop	Sowing Window		Critical Growth Stages	Period		Total Water Requirement (cm)
		Sowing Date	MW		DAS	MW	
Kharif	Pearl Millet	15th June - 15th July	25-28	Panicle Emergence	25-30	29-30	25-30
				Booting	50-55	33-35	
	Pigeon Pea (Red Gram)	15th-30th June	25-26	Branching	35-40	30-31	40-45
				Flowering	65-70	35	
				Pod filling	90-95	39	
	Sun-flower	1st-15th July	26-28	Seedling leaf plant development stage	10-38	29-32	60-75
				Bud stage	35-45	32-35	
				Flowering	50-60	35-36	
				Grain filling	70-80	37-39	
Rabi	Rabi Sorghum	15th Sep-15th Oct	37-42	Growing point differentiation	30-40	43-44	45-50
				Booting	50-55	45-46	
				Flowering	70-75	48-49	
				Grain filling	90-95	51	
	Gram	2nd fortnight of Sep	39-40	Flowering	40-50	45-47	25-40
				Pod filling	75-80	51	

4. RESULT AND DISCUSSION

The results obtained from the analysis of rainfall data are presented in this chapter under following subtitles with keeping objectives of the study in mind.

1) Variation of rainfall and rainy days in Solapur District.

2) Drought analysis by using Standardized Precipitation Index (SPI).

3) Drought analysis by using Decile Index.

4) Onset and withdrawal of monsoon in Solapur district.

5) Initial, conditional and consecutive probabilities of dry and wet weeks.

6) Contingency crop management planning based on rainfall analysis.

4.1 Variation of Rainfall and Rainy Days in Solapur District

4.1.1 Variation of Annual Rainfall and Rainy Days in Solapur District

4.1.1.1 Annual rainfall variation

The statistical analysis of annual rainfall data is presented in Table 4.1. The annual rainfall for different years in eleven tehsils of Solapur district is used for calculation of variation of rainfall.

From the Table 4.1, It is revealed that the average annual rainfall of Solapur district was 603 mm. It was varied from 107 mm at Malshiras to 1343.5 mm at Malshiras, Further average annual rainfall recorded in various tehsils in descending order was 676.7 mm at Akkalkot, 648.9 mm at Barshi, 640.0 mm at Sangola, 622.1 mm at Pandharpur, 603.2 mm at Madha, 582.4 mm at South Solapur, 582.3 mm at Mangalwedha, 582.0 mm at Mohol, 579.1 mm at Karmala, 561.8 mm at Malshiras and 554.6 mm at North Solapur. The highest standard deviation was observed at Malshiras (275.7 mm) with 49.1 per cent variation whereas, the lowest was observed at South Solapur (187.4 mm) with 32.2 per cent variation.

Table 4.1: Tehsilwise annual rainfall variation in Solapur district

Tehsil	Maximum Rainfall		Minimum Rainfall		Mean Rainfall (mm)	S.D. (mm)	C.V. (%)
	Rainfall (mm)	Year	Rainfall (mm)	Year			
Solapur District							
Akkalkot	1257	1990	220.6	1972	676.7	221.9	32.8
Barshi	1149.1	1998	228.4	1991	648.9	195.3	30.1
Karmala	1234.2	1998	171.3	2018	579.1	218.1	37.7
Madha	1200.3	2010	191.9	2018	603.2	211.7	35.1
Malshiras	1343.5	1999	107	2003	561.8	275.7	49.1
Mangalwedha	1105.6	1981	154.4	1972	582.3	209.9	36.1
Mohol	1301.5	1998	220.1	2003	582.0	198.2	34.0
North Solapur	1208.6	1998	223	1999	554.6	213.5	38.5
Pandharpur	1216.7	1974	156.8	1972	622.1	244.6	39.3
Sangola	1974	1470.8	241.6	2018	640.0	250.7	39.2
South Solapur	1114.1	1998	266.8	2015	582.4	187.4	32.2
District average					603	220	36.7

4.1.1.2 Annual rainy days variation

The number of rainy days was a good indicator for distribution of annual rainfall. It will be helpful for region specific crop planning. Rainfall received more than 2.5 mm is called rainy days. The analysis of the annual rainy days and its variability are presented in Table 4.2. The annual rainy days for different years in eleven tehsils of Solapur district are used for calculation of variation of rainy days. From the Table 4.1, it is observed that the average annual rainfall of Solapur district was 603.0 mm which was received in 36.7 mean rainy days. The highest rainy days (71) observed during 1998 in Mohol tehsil and the lowest rainy days (11) observed during 1972 in Madha tehsil (Table 4.2).

Table 4.2: Tehsilwise annual rainy days variation in Solapur district

Tehsil	Maximum Rainy days		Minimum Rainy days		Mean Rainy Days	S.D.	C.V. (%)
	Rainy Days	Year	Rainy days	Year			
Solapur District							
Akkalkot	61	1975 2019	15	1972	41	10.7	26.5
Barshi	63	2019	25	1972	42	8.1	19.6
Karmala	52	2010	17	1972	34	8.6	25.6
Madha	62	1998	11	1972	36	9.4	26.0
Malshiras	56	1998	12	1972	32	8.6	27.1
Mangalwedh	51	1978	17	1972	35	7.6	21.9
Mohol	71	1998	18	2003	37	9.6	26.3
North Solapur	70	1998	17	1999	38	12.1	31.9
Pandharpur	57	1974 1998	13	1972	36	8.9	25.0
Sangola	55	1998	18	1972	35	8.1	23.0
South Solapur	70	1998	21	2003	40	10.6	26.6
District average					**37**	**9.3**	**25.4**

There was wide variation in the tehsils with respect to number of rainy days during the period under study. The average number of rainy days ranged from 32 rainy days in Malshiras to 42 rainy days in Barshi. The mean rainy days recorded in different tehsils of Solapur district were 42 rainy days in Barshi, 41 rainy days in Akkalkot, 40 rainy days in South Solapur, 38 rainy days in North Solapur. Similarly 37 rainy days in Mohol, 36 rainy days in Madha, 36 rainy days in Pandharpur, 35 rainy days in Sangola, 35 rainy days in Mangaledha, 34 rainy days in Karmala and 32 rainy days in Malshiras tehsils were recorded. The highest standard deviation was 12.1 at North Solapur with 31.9 per cent variation whereas; the lowest was 7.59 at

Mangalwedha tehsil with 21.9 per cent variation. All the above observations showed that the total number of rainy days varied across Solapur district.

4.1.2 Variation of Monthly Rainfall and Rainy Days in Solapur District

4.1.2.1 Monthly rainfall variation

Statistical analysis of rainfall data of Solapur districts shown in the Table 4.3 which showed that mean annual rainfall of Solapur district was 603.0 mm in which September month contributes highest amount of mean rainfall 160.8 mm with 69.9 per cent variation. Followed by August, June, July, October, November, May, April, December, March, January and lowest amount of mean rainfall in the month of February 1.7 mm with 329.3 per cent variation.

The rainfall from June to October showed less variation as compared to rainfall received during rest of month. The average monthly rainfall variation was in the range of 69.5 per cent to 335.7 per cent in June and January month respectively. In all the tehsil of Solapur district, it was observed that tehsils received more rainfall in the month of September. The highest monthly rainfall was observed at Sangola (185.4 mm) in the month of September followed by Pandharpur, Madha, Akkalkot, Barshi, Karmala, Mohol, South Solapur, Malshiras, North Solapur and Mangalwedha tehsils.

As far as tehsils wise monthly variability in rainfall was considered Sangola, Pandharpur, Madha, Akkalkot, Barshi, Karmala, Mohol, South Solapur, Malshiras, North Solapur and Mangalwedha tehsils were received highest rainfall in the month of September. Sangola received 185.4 mm rainfall with 67.9 per cent variation, Pandharpur received 171.6 mm rainfall with 85.2 per cent variation, Madha received 169.6 mm rainfall with 68.1 per cent variation, Akkalkot received 165.6 mm rainfall with 67.5 per cent variation, Barshi received 164.9 mm rainfall with 60.5 per cent variation, Karmala received 163.9 mm rainfall with 70.7 per cent variation, Mohol received 163.2 mm rainfall with 71.1 per cent variation, South Solapur received 156.2 mm rainfall with 65.7 per cent variation, Malshiras received 151.7 mm rainfall with 73.2 per cent variation, North Solapur received 139.1 mm rainfall with 69.4 per cent variation and Mangalwedha received 137.6 mm rainfall with 70.0 per cent variation in the month of September, respectively.

The lowest rainfall was received in the month of February for all tehsils in study period. As compared, Mangalwedha tehsil was received the highest 16 mm rainfall with 95.9 per cent variation in the month of February followed by North Solapur, South Solapur, Mohol, Pandharpur, Akkalkot, Barshi, Madha, Karmala, Sangola and Malshiras tehsil received lowest mm rainfall 0.6 mm with 406.7 per cent variation.

4.1.2.2 Per cent contribution of monthly rainfall to the annual rainfall

Average monthly rainfall contribution to the average annual rainfall for the Solapur district were calculated and presented in Table 4.4 which showed that the average annual rainfall

of Solapur district was 603.0 mm in which September month contributes the highest amount of rainfall 26.6 per cent followed by August, June, July, October, May, November, April,

Table 4.3: Tehsilwise monthly rainfall (mm) variation in Solapur district

Tehsil Name	Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Akkalkot	Mean	1.9	1.5	2.7	12.4	25.9	100.2	125.3	131.1	165.6	80.6	24.9	4.8
	S.D.	6.7	5.4	7.4	20.6	40.2	68.0	88.5	79.4	111.8	71.7	42.4	11.3
	C.V.	355.6	363.6	271.2	166.2	155.4	67.8	70.6	60.6	67.5	89.0	170.6	235.0
Barshi	Mean	1.5	1.4	6.2	8.2	18.6	109.8	119.2	120.7	165.0	71.8	22.8	3.8
	S.D.	6.0	3.7	14.1	13.0	32.9	59.7	79.1	86.5	99.8	72.4	34.6	9.5
	C.V.	402.7	272.9	227.7	158.3	177.2	54.4	66.4	71.7	60.5	100.9	151.9	251.6
Karmala	Mean	1.9	0.9	2.6	6.4	21.2	95.4	83.7	91.8	163.9	83.2	22.5	5.6
	S.D.	9.4	3.9	6.2	11.6	43.4	72.0	57.9	77.6	115.8	73.7	40.4	18.4
	C.V.	499.6	430.9	239.6	180.6	204.7	75.4	69.2	84.5	70.7	88.6	179.0	328.2
Madha	Mean	3.0	1.3	2.4	6.5	19.8	93.8	87.1	102.3	169.6	89.7	23.8	4.0
	S.D.	8.5	4.8	6.5	12.5	32.7	52.4	59.2	89.7	115.6	69.5	35.3	11.3
	C.V.	288.2	380.5	266.8	193.5	165.6	55.8	68.0	87.7	68.1	77.5	148.5	281.2
Malshiras	Mean	1.8	0.6	1.3	4.0	14.5	112.7	75.0	78.3	151.7	95.9	20.9	5.3
	S.D.	11.0	2.2	3.9	8.6	27.9	123.3	69.0	70.8	111.0	104.6	31.8	17.4
	C.V.	614.4	406.5	306.4	212.5	192.8	109.4	92.0	90.4	73.2	109.1	152.5	326.3
Mangalwedha	Mean	19.2	16.0	26.3	21.2	39.0	76.6	70.1	73.9	137.6	53.6	25.9	23.1
	S.D.	23.8	15.3	38.3	24.3	46.1	66.7	63.8	55.5	96.4	56.7	28.3	31.9
	C.V.	123.6	95.9	146.0	114.6	118.0	87.2	91.1	75.1	70.0	105.8	109.5	137.9
Mohol	Mean	4.3	2.0	3.6	8.7	23.5	87.8	81.6	103.3	163.2	77.0	21.3	5.6
	S.D.	9.4	6.8	6.2	13.9	36.4	55.7	53.8	80.5	116.1	61.3	28.1	12.5
	C.V.	218.4	334.6	171.7	159.7	154.6	63.4	66.0	77.9	71.1	79.5	131.5	222.8
North Solapur	Mean	1.7	2.9	2.5	4.8	9.6	78.8	101.2	116.7	139.1	83.9	12.8	0.7
	S.D.	4.0	10.2	5.1	10.1	17.4	46.5	84.4	74.9	96.6	71.6	24.8	2.0
	C.V.	232.3	348.7	205.9	209.1	181.9	59.1	83.4	64.2	69.4	85.4	194.0	272.6
Pandharpur	Mean	4.2	1.6	4.5	7.2	19.5	99.4	86.4	101.6	171.6	101.6	18.5	5.9
	S.D.	16.3	5.1	13.5	15.0	35.3	66.4	58.4	82.4	146.1	99.7	29.9	16.9
	C.V.	385.8	313.4	301.9	207.8	181.3	66.8	67.6	81.1	85.2	98.1	161.4	285.0
Sangola	Mean	2.8	0.7	5.2	9.1	27.0	104.9	70.6	94.4	185.4	106.2	27.3	6.4
	S.D.	9.7	2.6	11.6	13.4	40.6	76.4	49.5	77.4	125.9	116.2	48.0	18.9
	C.V.	341.6	368.5	222.4	147.0	150.1	72.8	70.1	82.0	67.9	109.4	175.7	295.4
South Solapur	Mean	1.7	2.9	1.9	4.9	12.1	81.6	107.0	122.4	156.2	80.7	10.6	0.6
	S.D.	3.9	8.8	4.3	10.3	22.3	42.5	75.9	70.2	102.6	59.2	21.9	1.9
	C.V.	230.6	307.2	224.6	209.1	184.9	52.1	71.0	57.4	65.7	73.4	206.5	299.2
Solapur District	**Mean**	**4**	**2.9**	**5.4**	**8.5**	**21.0**	**94.6**	**91.6**	**103.3**	**160.8**	**84.0**	**21.0**	**6.0**
	S.D.	**9.9**	**6.3**	**10.6**	**13.9**	**34.1**	**66.3**	**67.2**	**76.8**	**112.5**	**77.8**	**33.2**	**13.8**
	C.V.	**335.7**	**329.3**	**234.9**	**178.0**	**169.7**	**69.5**	**74.1**	**75.7**	**69.9**	**92.4**	**161.9**	**266.8**

December, March, January and the lowest in the month of February 0.5 per cent. Akkalkot, Barshi, Karmala, Madha, Malshiras, Mangalwedha, Mohol, North Solapur, Pandharpur, Sangola and South Solapur tehsils were received more rainfall in the month of September were 24.2 per cent, 25.4 per cent, 28.3 per cent, 28.1 per cent, 27.0 per cent, 23.6 per cent, 28.0 per cent, 25.1 percent, 27.6 per cent, 29.0 per cent and 26.8 per cent, respectively.

4.1.2.3 Monthly rainy days variation

The statistical analysis of monthly rainy days data of Solapur district is shown in the Table 4.5 which showed that the mean annual rainy days of Solapur district was 37 days in which September month contributes the highest amount of mean rainy days (8 days) with 48.5 per cent variation followed by August, July, June, October, June, November, April, March, December, January and lowest amount of mean rainy days in the month of February 0.2 day with 301.2 per cent variation. The average monthly rainy days variation was in the range of 46.4 per cent to 301.7 per cent in June and February month respectively. In all the tehsils of Solapur district, it was observed that tehsils received more rainy days in the month of September. The highest monthly rainy days was observed at South Solapur (9 days) in the month of September followed by Barshi, North Solapur, Akkalkot, Madha, Mohol, Sangola, Karmala, Pandharpur, Malshiras and Mangalwedha.

Table 4.4: Monthly rainfall contribution to the total annual rainfall

Tehsil Name	Annual R.F. (mm)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	June (%)	July (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)
Akkalkot	676.7	0.3	0.2	0.4	1.8	3.8	14.7	18.3	19.2	24.2	11.7	3.6	0.7
Barshi	648.9	0.2	0.2	1.0	1.3	2.9	16.9	18.4	18.6	25.4	11.1	3.5	0.6
Karmala	579.1	0.3	0.2	0.5	1.1	3.7	16.5	14.4	15.9	28.3	14.4	3.9	1.0
Madha	603.2	0.5	0.2	0.4	1.1	3.3	15.6	14.4	17.0	28.1	14.9	3.9	0.7
Malshiras	561.8	0.3	0.1	0.2	0.7	2.6	20.1	13.3	13.9	27.0	17.1	3.7	1.0
Mangal-wedha	582.3	3.3	2.7	4.5	3.6	6.7	13.2	12.0	12.7	23.6	9.2	4.4	4.0
Mohol	582.0	0.7	0.3	0.6	1.5	4.0	15.1	14.0	17.7	28.0	13.2	3.7	1.0
North Solapur	554.6	0.3	0.5	0.4	0.9	1.7	14.2	18.2	21.0	25.1	15.1	2.0	0.1
Pandharpur	622.1	0.7	0.3	0.7	1.2	3.1	16.0	13.9	16.3	27.6	16.3	3.0	1.0
Sangola	640.0	0.4	0.1	0.8	1.4	4.2	16.4	11.0	14.7	29.0	16.6	4.3	1.0
South Solapur	582.4	0.3	0.5	0.3	0.8	2.1	14.0	18.4	21.0	26.8	13.8	1.8	0.1
Average	**603.0**	**0.7**	**0.5**	**0.9**	**1.4**	**3.5**	**15.7**	**15.1**	**17.1**	**26.6**	**13.9**	**3.4**	**1.0**

Tehsilswise monthly variability in rainy days was considered, Akkalkot, Barshi, Karmala, Madha, Malshiras, Mangalwedha, Mohol, North Solapur, Pandharpur, Sangola and South Solapur tehsils were received highest rainy days in the month of September. South Solapur tehsil was received 9 rainy days with 45.7 per cent variation, Barshi received 9 rainy days with 39.1 per cent variation, North Solapur received 9 rainy days with 55.5 per cent variation, Akkalkot received 9 rainy days with 50.6 per cent variation, Madha received 9 rainy days with 47.6 per cent variation, Mohol received 8 rainy days with 49.9 per cent variation. Sangola received 8 rainy days with 44.8 per cent variation, Karmala received 8 rainy days with 48 per cent variation. Also, Pandharpur received 8 rainy days with 52.5 per cent variation, Malshiras received 8 rainy

days with 47.4 per cent variation and Mangalwedha received 6 rainy days with 52.6 per cent variation in the month of September. The lowest rainfall was received in the month February for all tehsils in study period.

Table 4.5: Tehsilwise monthly rainy days variation in Solapur district

Tehsil Name	Parameter	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Akkalkot	Mean	0.1	0.1	0.2	1	2	6	8	8	9	5	1	0.4
	S.D.	0.4	0.5	0.6	1.0	2.3	2.7	4.0	4.0	4.3	3.6	1.7	0.9
	C.V.	316.3	348.0	251.6	128.1	131.5	43.0	50.6	48.3	50.6	77.4	132.9	243.4
Barshi	Mean	0.1	0.2	0.5	1	1	7	8	8	9	5	1	0.3
	S.D.	0.3	0.5	1.1	1.2	2.1	2.7	3.6	3.9	3.6	3.1	1.5	0.8
	C.V.	299.8	271.8	220.3	160.8	143.2	38.5	43.2	49.9	39.1	68.4	116.7	260.7
Karmala	Mean	0.1	0.1	0.3	1	1	6	6	6	8	4	1	0.3
	S.D.	0.3	0.3	0.8	1.0	1.7	2.5	2.9	3.4	3.9	3.2	1.5	0.8
	C.V.	274.9	331.5	245.4	174.1	158.5	43.7	48.5	58.4	48.0	71.8	119.4	236.3
Madha	Mean	0.2	0.2	0.2	0.5	1	6	6	6	9	5	1	0.3
	S.D.	0.5	0.5	0.6	0.8	1.6	2.8	3.2	3.5	4.1	3.3	1.5	0.7
	C.V.	254.7	317.8	251.6	168.9	139.5	46.7	51.4	54.5	47.6	64.5	111.0	211.4
Malshiras	Mean	0.1	0.1	0.2	0.4	1	6	5	5	8	5	1	0.3
	S.D.	0.5	0.3	0.5	0.8	1.6	2.6	3.0	3.3	3.7	3.3	1.5	0.7
	C.V.	416.6	397.3	340.3	204.7	150.5	46.5	56.3	64.7	47.4	69.4	121.2	245.3
Mangal-wedha	Mean	1.2	1.2	1.4	1.5	2	4	5	5	6	3	2	1.3
	S.D.	1.0	1.0	1.0	1.2	2.2	2.4	3.0	2.9	3.4	2.7	1.2	1.0
	C.V.	88.0	80.6	72.0	77.4	92.0	54.6	61.3	57.6	52.6	81.6	72.0	78.3
Mohol	Mean	0.2	0.2	0.3	0.8	1	6	6	7	8	5	1	0.4
	S.D.	0.5	0.6	0.7	1.1	1.8	2.4	3.0	3.6	4.2	3.5	2.0	0.8
	C.V.	254.7	381.4	216.4	145.0	136.7	40.2	48.7	53.6	49.9	72.3	137.5	222.2
North Solapur	Mean	0.2	0.1	0.3	0.3	1	6	7	9	9	5	1	0.1
	S.D.	0.5	0.3	0.6	0.5	1.4	3.2	4.8	3.7	4.9	3.1	1.1	0.5
	C.V.	232.5	323.7	178.5	167.1	161.0	52.1	69.6	42.3	55.5	67.5	130.3	342.9
Pandh-arpur	Mean	0.2	0.2	0.3	0.5	1	6	6	7	8	5	1	0.4
	S.D.	0.9	0.5	0.7	0.9	2.4	2.7	3.4	3.9	4.1	3.8	1.5	0.7
	C.V.	369.9	271.8	245.3	182.7	159.1	43.4	54.3	56.9	52.5	76.9	129.7	207.1
Sangola	Mean	0.2	0.1	0.4	1	2	6	5	6	8	5	1	0.4
	S.D.	0.6	0.3	0.9	1.1	2.0	3.2	2.4	3.2	3.7	3.3	1.8	0.9
	C.V.	285.5	331.5	207.6	133.0	113.6	53.4	47.6	54.2	44.8	65.8	126.6	248.9
South Solapur	Mean	0.2	0.1	0.3	0.3	1	6	7	9	9	5	1	0.1
	S.D.	0.4	0.4	0.6	0.5	1.7	3.0	3.9	3.8	4.3	3.8	1.0	0.2
	C.V.	217.1	257.6	201.8	149.8	157.3	48.8	52.1	41.5	45.7	76.5	145.9	469.0
Solapur District	**Mean**	**0.3**	**0.2**	**0.4**	**1**	**1**	**6**	**6**	**7**	**8**	**5**	**1**	**0.4**
	S.D.	**0.5**	**0.5**	**0.7**	**0.9**	**1.9**	**2.7**	**3.4**	**3.5**	**4.0**	**3.3**	**1.5**	**0.7**
	C.V.	**273.6**	**301.2**	**221.0**	**153.8**	**140.3**	**46.4**	**53.0**	**52.9**	**48.5**	**72.0**	**122.1**	**251.4**

4.1.2.4 Per cent contribution of monthly rainy days to the annual rainy days

The average monthly rainy days contribution to the average annual rainy days for the Solapur district were calculated and presented in Table 4.6 which showed that the average annual rainy days of Solapur district was 37 days in which September month contributes highest amount of rainy days (22.5 per cent) followed by August, July, June, October, May, November, April, December, March, January and the lowest in the month of February 0.6 per cent. Malshiras, Karmala, Madha, Sangola, South Solapur, North Solapur, Mohol, Pandharpur, Barshi, Akkalkot and Mangalwedha tehsils were received more rainy days in the month of September with values of 24.4 per cent, 23.8 per cent, 23.6 per cent, 23.4 per cent, 23.4 per cent, 23.2 per cent, 22.5 per cent, 21.8 per cent, 21.7 per cent, 20.9 per cent and 18.5 per cent respectively.

Table 4.6: Monthly rainy days contribution to the total annual rainy days

Tehsil Name	Annual Rainy Day	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	June (%)	July (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)
Akkalkot	41	0.3	0.5	0.7	2.0	4.5	15.4	19.5	20.4	20.9	11.4	3.6	0.9
Barshi	41	0.2	0.4	0.8	1.6	3.6	17.1	20.0	18.6	21.7	12.0	3.2	0.8
Karmala	34	0.4	0.3	0.9	1.7	3.4	16.8	17.9	17.4	23.8	12.9	3.6	1.0
Madha	36	0.6	0.4	0.7	1.3	3.3	16.8	17.1	17.8	23.6	14.2	3.7	0.9
Malshiras	32	0.4	0.3	0.5	1.2	3.3	17.6	16.5	15.8	24.4	15.3	4.0	0.8
Mangal-wedha	35	3.3	3.5	4.0	4.5	6.9	12.6	14.1	14.6	18.5	9.5	4.9	3.7
Mohol	37	0.5	0.4	0.9	2.9	3.5	15.8	16.5	18.6	22.5	13.4	3.8	1.0
North Solapur	38	0.7	0.2	0.8	0.7	2.3	16.2	18.5	22.8	23.2	12.0	2.3	0.4
Pandharpur	36	0.7	0.5	0.8	1.4	4.1	16.9	17.3	18.8	21.8	13.8	3.1	1.0
Sangola	35	0.6	0.2	1.3	2.4	5.1	17.2	14.2	16.4	23.4	14.1	4.1	1.0
South Solapur	40	0.5	0.4	0.7	0.8	2.7	15.5	18.5	23.2	23.4	12.6	1.7	0.1
Average	**37**	**0.7**	**0.6**	**1.1**	**1.8**	**3.8**	**16.3**	**17.4**	**18.5**	**22.5**	**12.7**	**3.4**	**1.1**

4.2 Standardized Precipitation Index (SPI)

Drought is creeping environmental phenomenon which occurs notably in the arid and semi-arid regions and causes many damages and losses. Drought is normal recurrent feature of climate, although it is random event. In this study meteorological drought was analysed by using Standardized Precipitation Index (SPI). Any drought including meteorological and agriculture is a result of deficient rainfall. The SPI has been used widely to quantify the deficit of precipitation. It could be computed at different time scales from less than 1 month to 48 months or more. The calculation time period depends on the user's application. Short-term SPI is used to detect agricultural drought, and long-term SPI can be used for water supply management. According to the SPI method the severity of a drought is determined. The negative value from zero shows the severity of dryness. The positive value of SPI shows the degree of wetness. The SPI value

normally ranges from (-2) - (+ 2). An index of (+2) indicates extremely wet; (1.5) - (1.99) very wet; (1.0) - (1.49) moderately wet; (-0.99) - (0.99) near normal; (-1.0) - (-1.49) moderately dry; (-1.5) - (-1.99) severely dry; (-2.0) or (less) extremely dry.

4.2.1 SPI of Akkalkot Tehsil

Meteorological drought for Akkalkot tehsil is assessed for 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the Table 4.7, it is observed that extremely wet condition (Above +2) was observed for 1 year, very wet (1.5 to 1.99) condition was observed for 4 years, moderately wet (1.0 to 1.49) condition was observed for 5 years from 59 years of observed data. Near normal (-0.99 to 0.99) condition was seen for 40 years in which 23 were mild drought year which is high in number. Moderately dry (-1 to -1.49) condition was observed for 5 years. Severely dry (-1.50 to -1.99) condition was observed for 3 years, extreme dry (-2.0 or less) condition was observed for single year.

From the previous 59 years data it is observed that Akkalkot tehsil have 10 wet years, 40 near normal years and remaining 9 years shows dry or extreme drought condition. Probability of recurrence of mild drought is 39% means once in every 3 year, probability of recurrence of moderate drought is 8% means once in every 12 years, probability of recurrence of severe drought is 5% means once in every 20 year and probability of recurrence of extreme drought condition is 2% means once in every 50 years over Akkalkot tehsil (table 4.8). But after 1990-2000 and 2001-2019 during this period frequency of drought years and also comparative severity of droughts are increasing rapidly which had adverse impact on the cropping system. It is also observed from table 4.9 that a SPI value becomes more negative with increase in time scales. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1961-2019 is depicted in the Figure 4.1

4.2.2 SPI of Barshi Tehsil

Meteorological drought for Barshi tehsil is assessed for 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 1 year, very wet (1.5 to 1.99) condition was observed for 2 years, moderately wet (1.0 to 1.49) condition was observed for 4 years. Near normal (-0.99 to 0.99) condition was seen for 44 years in which 19 were mild drought year which is high in number. Moderately dry (-1 to -1.49) condition was observed for 1 years. Severely dry (-1.50 to -1.99) condition was observed for 5 years, extreme dry (-2.0 or less) condition was observed for 2 year from 59 years of observed data.

From the previous 59 years data it is observed that Barshi tehsil have 7 wet years, 44 near normal years and remaining 8 years shows dry or extreme drought condition. Probability of

recurrence of mild drought is 32% means once in every 3 year, probability of recurrence of moderate drought is 2% means once in every 50 years, probability of recurrence of severe drought is 8% means once in every 12 year and probability of recurrence of extreme drought condition is 3% means once in every 33 years over Barshi tehsil (table 4.8). But in 1980-1991 and after 2011 to 2019 during this period frequency of drought years and also comparative severity of droughts are increasing rapidly which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with increase in time scales. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1961-2019 is depicted in the Figure 4.2.

4.2.3 SPI of Karmala Tehsil

Meteorological drought for Karmala tehsil is assessed for 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 2 year, very wet (1.5 to 1.99) condition was observed for 2 years, moderately wet (1.0 to 1.49) condition was observed for 5 years. Near normal (-0.99 to 0.99) condition was seen for 40 years in which 18 were mild drought year. Moderately dry (-1 to -1.49) condition was observed for 6 years. Severely dry (-1.50 to -1.99) condition was observed for 1 years, extreme dry (-2.0 or less) condition was observed for 3 year from 59 years of observed data.

From the previous 59 years data it is observed that Karmala tehsil have 9 wet years, 40 near normal years and remaining 10 years shows dry or extreme drought condition. Probability of recurrence of mild drought is 30% means once in every 3 year, probability of recurrence of moderate drought is 10% means once in every 10 years, probability of recurrence of severe drought is 2% means once in every 50 year and probability of recurrence of extreme drought condition is 5% means once in every 20 years over Karmala tehsil (table 4.8). But in 1991-1997, 2001-2007 and after 2011 to 2019 during this period frequency of drought years and also comparative severity of droughts are increasing rapidly which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with increase in time scales. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1961-2019 is depicted in the Figure 4.3.

4.2.4 SPI of Madha Tehsil

Meteorological drought for Madha tehsil is assessed for 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 2 year, very wet (1.5-1.99) condition was observed for 3 years, moderately wet (1.0

to 1.49) condition was observed for 3 years. Near normal (-0.99 to 0.99) condition was seen for 43 years in which 23 were mild drought year which is high in number. Moderately dry (-1 to -1.49) condition was observed for 4 years. Severely dry (-1.50 to -1.99) condition was observed for 2 years, extreme dry (-2.0 or less) condition was observed for 2 year from 59 years of observed data.

From the previous 59 years data it is observed that Madha tehsil have 8 wet years, 43 near normal years and remaining 8 years shows dry or extreme drought condition. Probability of recurrence of mild drought is 39% means once in every 3 year, probability of recurrence of moderate drought is 7% means once in every 15 years, probability of recurrence of severe drought is 3% means once in every 33 year and probability of recurrence of extreme drought condition is 3% means once in every 33 years over Madha tehsil (table 4.8). But in 1975-1985, 2001-2007 and after 2011 to 2019 during this period frequency of drought years and also comparative severity of droughts are increasing rapidly which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with increase in time scales. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for period of 1961-2019 is depicted in the Figure 4.4.

4.2.5 SPI of Malshiras Tehsil

Meteorological drought for Malshiras tehsil is assessed for 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 3 year, very wet (1.5 to 1.99) condition was not observed for any years, moderately wet (1.0 to 1.49) condition was observed for 6 years. Near normal (-0.99 to 0.99) condition was seen for 42 years in which 21 were mild drought year which is half of near normal. Moderately dry (-1 to -1.49) condition was observed for 5 years. Severely dry (-1.50 to -1.99) condition was observed for 2 years, extreme dry (-2.0 or less) condition was observed for only one year from 59 years of observed data.

From the previous 59 years data it is observed that Malshiras tehsil have 9 wet years, 42 near normal years and remaining 8 years shows dry or extreme drought condition. Probability of recurrence of mild drought is 34% means once in every 3 year, probability of recurrence of moderate drought is 8% means once in every 12 years, probability of recurrence of severe drought is 2% means once in every 50 year and probability of recurrence of extreme drought condition is 3% means once in every 33 years over Malshiras tehsil (table 4.8). But in 2000-2007 and after 2011 to 2019 during this period frequency of drought years and also comparative severity of droughts are increasing rapidly which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with

increase in time scales in recent times. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1961-2019 is depicted in the Figure 4.5.

4.2.6 SPI of Mangalwedha Tehsil

Meteorological drought for Mangalwedha tehsil is assessed for 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 1 year, very wet (1.5 to 1.99) condition was observed for 2 years, moderately wet (1.0 to 1.49) condition was observed for 4 years. Near normal (-0.99 to 0.99) condition was seen for 42 years in which 15 were mild drought year which is half of near normal. Moderately dry (-1 to -1.49) condition was observed for 6 years. Severely dry (-1.50 to -1.99) condition was observed for 2 years, extreme dry (-2.0 or less) condition was observed for 2 year from 59 years of observed data.

From the previous 59 years data it is observed that Mangalwedha tehsil have 7 wet years, 42 near normal years and remaining 10 years shows dry or extreme drought condition. Probability of recurrence of mild drought is 25% means once in every 4 year, probability of recurrence of moderate drought is 10% means once in every 10 years, probability of recurrence of severe drought is 3% means once in every 33 year and probability of recurrence of extreme drought condition is 3% means once in every 33 years over Mangalwedha tehsil (table 4.8). From 2003-2010 near normal and moderately wet condition was observed but since 2010 to 2019 period frequency of drought years and also comparative severity of droughts are increasing rapidly which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with increase in time scales in recent times. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1961-2019 is depicted in the Figure 4.6.

4.2.7 SPI of Mohol Tehsil

Meteorological drought for Mohol tehsil is assessed for 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 1 year, very wet (1.5 to 1.99) condition was observed for 2 years, moderately wet (1.0 to 1.49) condition was observed for 5 years. Near normal (-0.99 to 0.99) condition was seen for 42 years in which 18 were mild drought year. Moderately dry (-1 to -1.49) condition was observed for 4 years. Severely dry (-1.50 to -1.99) condition was observed for 3 years, extreme dry (-2.0 or less) condition was observed for 2 year from 59 years of observed data.

From the previous 59 years data it is observed that Mohol tehsil have 8 wet years, 42 near normal years and remaining 9 years shows dry or extreme drought condition. Probability of

recurrence of mild drought is 30% means once in every 3 year, probability of recurrence of moderate drought is 7% means once in every 15 years, probability of recurrence of severe drought is 5% means once in every 20 year and probability of recurrence of extreme drought condition is 3% means once in every 33 years over Mohol tehsil (table 4.8). From 2004-2010 near normal and moderately wet condition was observed but from the period of 2011 to 2019 frequency of drought years and also comparative severity of droughts are increasing rapidly which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with increase in time scales in recent times. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1961-2019 is depicted in the Figure 4.7.

4.2.8 SPI of North Solapur Tehsil

Meteorological drought for North Solapur tehsil is assessed for 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 1 year, very wet (1.5-1.99) condition was not observed in any years, moderately wet (1.0 to 1.49) condition was observed for 2 years. Near normal (-0.99 to 0.99) condition was seen for 17 years in which 4 were mild drought year. Moderately dry (-1 to -1.49) condition was observed for 1 years. Severely dry (-1.50 to -1.99) condition was not observed for any years, extreme dry (-2.0 or less) condition was observed for only year from 22 years of observed data.

From the previous 22 years data it is observed that North Solapur tehsil have 3 wet years, 17 near normal years and remaining 2 years shows dry or extreme drought condition. Probability of recurrence of mild drought is 18% means once in every 6 year, probability of recurrence of moderate drought is 5% means once in every 20 years, probability of recurrence of severe drought is zero and probability of recurrence of extreme drought condition is 5% means once in every 20 years over North Solapur tehsil (table 4.8). From 2004-2014 near normal condition was observed but from the period of 2015 to 2019 frequency of drought years and also comparative severity of droughts are increasing which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with increase in time scales in recent times. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1998-2019 is depicted in the Figure 4.8.

4.2.9 SPI of Pandharpur Tehsil

Meteorological drought for Pandharpur tehsil is assessed for 4, 5, and 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 1 year, very wet (1.5 to 1.99) condition was observed for 5 years,

moderately wet (1.0 to 1.49) condition was observed for 4 years. Near normal (-0.99 to 0.99) condition was seen for 40 years in which 20 were mild drought year about half of it. Moderately dry (-1 to -1.49) condition was observed for 6 years. Severely dry (-1.50 to -1.99) condition was not observed for 1 years, extreme dry (-2.0 or less) condition was observed for 2 year from 59 years of observed data.

From the previous 59 years data it is observed that Pandharpur tehsil have 10 wet years, 40 near normal years and remaining 9 years shows dry or extreme drought condition. Probability of recurrence of mild drought is 37% means once in every 3 year, probability of recurrence of moderate drought is 10% means once in every 10 years, probability of recurrence of severe drought is 2% means once in 50 years and probability of recurrence of extreme drought condition is 3% means once in every 33 years over the Pandharpur tehsil (table 4.8). From 1973 to 1990 occurrence of near normal and moderately to extreme wet condition had been more over long period of two decade but from 1991 to 2008 occurrence of drought became more frequent and trend is continue to be observed in this decade from the period of 2011 to 2019 with increased frequency of drought years and also comparative severity of droughts which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with increase in time scales in recent times. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1961-2019 is depicted in the Figure 4.9.

4.2.10 SPI of Sangola Tehsil

Meteorological drought for Sangola tehsil is assessed for 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 3 year, very wet (1.5 to 1.99) condition was observed for 1 years, moderately wet (1.0-1.49) condition was observed for 5 years. Near normal (-0.99 to 0.99) condition was seen for 40 years in which 19 were mild drought year about half of it. Moderately dry (-1 to -1.49) condition was observed for 8 years. Severely dry (-1.50 to -1.99) condition was not observed for 1 years, extreme dry (-2.0 or less) condition was observed for 1 year from 59 years of observed data.

From the previous 59 years data it is observed that Sangola tehsil have 9 wet years, 40 near normal years and remaining 10 years shows dry or extreme drought condition. Probability of recurrence of mild drought is 30% means once in every 3 year, probability of recurrence of moderate drought is 14% means once in every 7 years, probability of recurrence of severe drought is 2% means once in 50 years and probability of recurrence of extreme drought condition is 2% means once in every 50 years over the Sangola tehsil (table 4.8). From 1991 to 1995 occurrence of drought was observed followed by near normal condition over next 5 year

period from 1996 to 2000. Again occurrence of drought was observed in period of 2001 to 2005 followed by near normal condition over next 5 year period from 2006 to 2010. but from 2011 drought occurrence, frequency of drought years and comparative severity of droughts has suddenly increased which is of concern. Which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with increase in time scales in recent times. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1961-2019 is depicted in the Figure 4.10.

4.2.11 SPI of South Solapur Tehsil

Meteorological drought for South Solapur tehsil is assessed for 4, 5, and 12 month's timescales. The negative value of SPI indicates drought (dry) condition and positive value indicates wet condition. From the table 4.7, it is observed that that extremely wet condition (Above +2) was observed for 1 year, very wet (1.5 to 1.99) condition was observed for 1 years, moderately wet (1.0 to 1.49) condition was observed for 2 years. Near normal (-0.99 to 0.99) condition was seen for 14 years in which 6 were mild drought year. Moderately dry (-1 to -1.49) condition was observed for 2 years. Severely dry (-1.50 to -1.99) condition was observed for 2 years, extreme dry (-2.0 or less) condition was not observed for any year from 22 years of observed data.

From the previous 22 years data it is observed that South Solapur tehsil have 4 wet years, 14 near normal years and remaining 4 years shows dry or severely drought condition. Probability of recurrence of mild drought is 26% means once in every 4 year, probability of recurrence of moderate drought is 9% means once in every 11 years, probability of recurrence of severe drought is 9% means once in every 11 years and probability of recurrence of extreme drought condition is null over South tehsil station (table 4.8). From 2004-2011 near normal condition was observed but from the period of 2012 to 2018 frequency of drought years and also comparative severity of droughts are increasing which had adverse impact on the cropping system. It is also observed from Annual SPI table (table 4.9) that a SPI value becomes more negative with increase in time scales in recent times. This is due to the non-uniform, irregular and erratic pattern of rainfall. The graphical representation of annual SPI for the period of 1998-2019 is depicted in the Figure 4.11. Similar results were found by Shah *et al.,* (2015), Bobadove *et al.,* (2019) and Das *et al.,* (2020).

Table 4.7: Annual Frequency and Annual Probability of different tehsils of Solapur district

Annual Frequency (Annual Probability)								
Tehsil	**Extreme wet**	**Very wet**	**Moderate wet**	**Near norma**	**Moderate dry**	**Severe dry**	**Extreme dry**	**Total**
1. Akkalkot	1 (2)	4 (7)	5 (8)	40 (68)	5 (8)	3 (5)	1 (2)	59 (100)
2. Barshi	1 (2)	2 (3)	4 (7)	44 (75)	1 (2)	5 (8)	2 (3)	59 (100)
3. Karmala	2 (3)	2(3)	5(8)	40 (68)	6 (10)	1 (2)	3 (5)	59 (100)
4. Madha	2 (3)	3 (5)	3 (5)	43 (73)	4 (7)	2 (3)	2 (3)	59 (100)
5. Malshir-as	3 (5)	0 (0)	6 (10)	42 (71)	5 (8)	1 (2)	2 (3)	59 (100)
6. Mangal-wedha	1 (2)	2 (3)	4 (7)	42 (71)	6 (10)	2 (3)	2 (3)	59 (100)
7. Mohol	1 (2)	2 (3)	5 (8)	42 (71)	4 (7)	3 (5)	2 (3)	59 (100)
8. North Solapur	1 (5)	0 (0)	2 (9)	17 (77)	1 (5)	0 (0)	1 (5)	22 (100)
9. Pandhar-pur	1 (2)	5 (8)	4 (7)	40 (68)	6 (10)	1 (2)	2 (3)	59 (100)
10. Sangola	3 (5)	1 (2)	5 (8)	40 (68)	8 (14)	1 (2)	1 (2)	59 (100)
11. South Solapur	1 (5)	1 (5)	2 (9)	14 (64)	2 (9)	2 (9)	0 (0)	22 (100)

Table 4.8: Probability of recurrence of drought of different tehsils of Solapur district

Station	SPI	Drought Category	Number of times in 100 years	Severity of event
1. Akkalkot	0 to -0.99	Mild dryness	39	1 in 3 yrs
	-1.0 to -1.49	Moderate dryness	8	1 in 12 yrs
	-1.5 to -1.99	Severe dryness	5	1 in 20 yrs
	< -2.0	Extreme dryness	2	1 in 50 yrs
2. Barshi	0 to -0.99	Mild dryness	32	1 in 3 yrs
	-1.0 to -1.49	Moderate dryness	2	1 in 50 yrs
	-1.5 to -1.99	Severe dryness	8	1 in 12 yrs
	< -2.0	Extreme dryness	3	1 in 33 yrs
3. Karmala	0 to -0.99	Mild dryness	30	1 in 3 yrs
	-1.0 to -1.49	Moderate dryness	10	1 in 10 yrs
	-1.5 to -1.99	Severe dryness	2	1 in 50 yrs
	< -2.0	Extreme dryness	5	1 in 20 yrs
4. Madha	0 to -0.99	Mild dryness	39	1 in 3 yrs
	-1.0 to -1.49	Moderate dryness	7	1 in 15 yrs
	-1.5 to -1.99	Severe dryness	3	1 in 33 yrs
	< -2.0	Extreme dryness	3	1 in 33 yrs
5. Malshiras	0 to -0.99	Mild dryness	34	1 in 3 yrs
	-1.0 to -1.49	Moderate dryness	8	1 in 12 yrs
	-1.5 to -1.99	Severe dryness	2	1 in 50 yrs
	< -2.0	Extreme dryness	3	1 in 33 yrs
6. Mangalwedha	0 to -0.99	Mild dryness	25	1 in 4 yrs
	-1.0 to -1.49	Moderate dryness	10	1 in 10 yrs
	-1.5 to -1.99	Severe dryness	3	1 in 33 yrs
	< -2.0	Extreme dryness	3	1 in 33 yrs
7. Mohol	0 to -0.99	Mild dryness	30	1 in 3 yrs
	-1.0 to -1.49	Moderate dryness	7	1 in 15 yrs
	-1.5 to -1.99	Severe dryness	5	1 in 20 yrs
	< -2.0	Extreme dryness	3	1 in 33 yrs
8. North Solapur	0 to -0.99	Mild dryness	18	1 in 6 yrs
	-1.0 to -1.49	Moderate dryness	5	1 in 20 yrs
	-1.5 to -1.99	Severe dryness	0	-
	< -2.0	Extreme dryness	5	1 in 20 yrs
9. Pandharpur	0 to -0.99	Mild dryness	37	1 in 3 yrs
	-1.0 to -1.49	Moderate dryness	10	1 in 10 yrs
	-1.5 to -1.99	Severe dryness	2	1 in 50 yrs
	< -2.0	Extreme dryness	3	1 in 33 yrs
10. Sangola	0 to -0.99	Mild dryness	30	1 in 3 yrs
	-1.0 to -1.49	Moderate dryness	14	1 in 7 yrs
	-1.5 to -1.99	Severe dryness	2	1 in 50 yrs
	< -2.0	Extreme dryness	2	1 in 50 yrs
11. South Solapur	0 to -0.99	Mild dryness	26	1 in 4 yrs
	-1.0 to -1.49	Moderate dryness	9	1 in 11 yrs
	-1.5 to -1.99	Severe dryness	9	1 in 11 yrs
	< -2.0	Extreme dryness	0	-

Table 4.9: Annual SPI values (12 months basis) of different tehsils of Solapur district

Annual SPI Probability of tehsils						
Years	**Akkalkot**	**Barshi**	**Karmala**	**Madha**	**Malshiras**	**Mangalwedha**
1961	0.59	0.3	0.53	-0.91	-0.23	0.2
1962	1.57	0.04	0.35	0.5	0.28	-0.17
1963	0.95	0.02	1.2	-0.39	-0.34	0.8
1964	0.51	1.59	0.32	1.46	0.72	0.75
1965	0.5	-0.12	-1.02	-0.56	1.37	1.16
1966	0.26	0.62	0.35	0.76	-0.88	-0.9
1967	0.92	-0.14	-0.38	-0.14	-0.3	0.53
1968	-1.22	-0.29	-0.36	-0.03	0.08	0.98
1969	0.16	0.35	0.72	0	1.16	0.58
1970	1.13	1.21	1.01	-0.26	-0.23	0.9
1971	-1.77	0.99	-0.41	0.21	-0.41	-0.17
1972	-2.76	-2.31	-2.16	-2.13	-2.06	-2.75
1973	0.78	0.22	1.08	0.91	0.54	-1.34
1974	-0.38	0.51	0.03	0.56	1.09	1.09
1975	1.81	1.2	0.21	0.46	1.07	1.93
1976	-0.48	-1.54	-0.67	-1.56	-1.07	-0.35
1977	0.01	0.41	0.12	-1.11	0.14	-1.03
1978	1.53	0.93	0.82	-0.44	0.32	0.52
1979	1.26	0.5	0.31	1.21	0.32	0.35
1980	-0.35	0.55	0.42	-0.9	-0.08	-0.7
1981	1.02	-0.27	1.11	-0.07	0.64	2.02
1982	0.16	-0.62	0.65	-0.48	-0.88	0.26
1983	0.72	0.91	2.09	1.54	-0.18	0.5
1984	-0.52	-0.06	-0.16	-0.4	-0.3	0.12
1985	-0.62	-1.76	-1.13	-1.3	-1.28	-0.7
1986	-1.08	-1.88	-0.53	-0.26	-0.99	-0.63
1987	0.72	-0.75	0.94	0.51	0.14	1.32
1988	1.37	0.05	0.04	1.77	0.26	0.29
1989	1.44	0.11	0.22	0.51	0.26	0.93
1990	2.21	0.72	1.12	0.93	-0.07	0.57
1991	-0.38	-2.7	-0.22	-1.12	0.01	-1.61
1992	-0.22	-0.79	-0.63	0.35	-0.93	-0.97
1993	-0.38	0.75	0.89	1.81	1.41	1
1994	-0.85	-0.68	-1.37	-0.66	0.26	-1.13
1995	0.47	0.12	-0.35	1.06	0.78	0.08
1996	0.72	1.11	-0.22	0.95	2.13	0.39
1997	-0.61	-0.02	-0.95	-0.14	0.16	-0.65
1998	1.79	2.1	2.4	2.3	3.04	0.85
1999	0.11	-0.23	0.72	0.33	2.37	0.31
2000	0.82	0.92	1.91	0.81	-1.25	-1.01
2001	-0.34	0.54	-0.07	-0.52	-0.56	-0.21
2002	-0.57	-0.56	-1.19	-0.36	-0.74	0.75
2003	-1.68	-1.29	-2.17	-1.6	-2.69	-0.99
2004	-1.01	-0.75	0.26	-0.58	-0.41	0.67
2005	-0.25	0.59	0.04	0.24	-1.01	0.64
2006	-0.01	0.46	-0.33	-0.47	0.16	0.67
2007	-0.24	1.48	-1.23	0.55	0.51	1.75
2008	-1.09	0.4	0.76	0.37	0.37	0.11
2009	-0.37	0.62	0.42	0.38	1.23	0.91
2010	0.21	1.82	1.64	2.36	0.79	0.46
2011	-0.12	-0.47	-0.08	-0.91	-0.37	-1.23
2012	-0.45	-0.39	-1.63	-0.72	-0.52	-0.77
2013	-0.14	-0.44	-0.22	0.11	-0.34	-0.56
2014	-0.49	-0.7	-0.53	-0.67	-0.43	-0.66
2015	-1.7	-1.97	-1.2	-1.25	-1.22	-1.62
2016	-0.99	-0.13	-0.64	-0.18	-0.34	-1.28
2017	-1.44	0.72	0.12	0.18	0.03	-0.48
2018	-0.96	-1.68	-2.54	-2.67	-1.7	-2.44
2019	-0.26	-0.19	-0.38	-0.36	0.09	0.03

Table 4.9 cont…

Annual SPI Probability of tehsils					
Years	**Mohol**	**North Solapur**	**Pandharpur**	**Sangola**	**South solapur**
1961	0.68	NA	0.24	0.25	NA
1962	0.52	NA	0.67	0.2	NA
1963	-0.17	NA	-0.2	1.43	NA
1964	1.13	NA	0.01	0.58	NA
1965	-0.82	NA	0.56	0.33	NA
1966	-0.06	NA	-1.43	-0.71	NA
1967	0.02	NA	-1.33	0.07	NA
1968	-0.21	NA	-0.51	-1.33	NA
1969	1.39	NA	0.77	0.03	NA
1970	0.89	NA	-0.76	-0.63	NA
1971	-0.11	NA	-0.14	0.3	NA
1972	-1.91	NA	-2.72	-1.79	NA
1973	0.42	NA	0.99	0.73	NA
1974	0.84	NA	2.05	2.72	NA
1975	1.08	NA	1.54	2.23	NA
1976	-0.78	NA	-0.58	0.04	NA
1977	-1.66	NA	0.32	1.29	NA
1978	0.72	NA	1.49	1.34	NA
1979	0.06	NA	0.25	2.12	NA
1980	-0.9	NA	0.37	0.08	NA
1981	1.07	NA	1.86	1.19	NA
1982	-1.29	NA	-0.47	-0.14	NA
1983	0.92	NA	1.59	-0.51	NA
1984	-0.39	NA	1.09	0.29	NA
1985	-0.48	NA	0.32	-0.4	NA
1986	-0.35	NA	0.25	-0.8	NA
1987	1.54	NA	1.88	0.68	NA
1988	1.01	NA	1.81	0.68	NA
1989	0.93	NA	1.07	0.6	NA
1990	0.41	NA	0.31	0.09	NA
1991	0.25	NA	-0.09	-0.99	NA
1992	-0.7	NA	-0.48	-0.99	NA
1993	0.27	NA	0.34	0.8	NA
1994	-0.47	NA	-1.17	-1.45	NA
1995	0.04	NA	-0.46	-0.23	NA
1996	0.91	NA	0.51	1.15	NA
1997	-1.28	NA	-0.51	0.41	NA
1998	2.83	2.52	1.35	1.79	2.36
1999	0.11	-2	-0.83	0.25	-0.42
2000	0.46	0.3	-0.2	-0.35	0.38
2001	0.22	-0.99	0.19	-0.59	0.9
2002	0.06	-0.52	-0.22	0.19	0.1
2003	-2.34	-1.37	-1.81	-1.15	-1.81
2004	-0.48	0.23	-0.27	-1.17	0.18
2005	0.39	0.95	-0.03	-1.11	0.9
2006	0.32	0.2	-0.57	0.06	0.04
2007	0.45	0.36	0	0.63	0.22
2008	0.46	0.64	-0.21	-0.12	0.55
2009	0.18	0.77	0.61	0.39	0.69
2010	1.96	1.1	0.68	-0.08	1.06
2011	-0.21	0.49	-0.84	-1.4	0.37
2012	-1.49	-0.25	-1.12	-1.04	-0.51
2013	-0.15	0.08	-0.05	-0.73	-0.29
2014	-0.69	0.1	-0.7	-0.31	-0.55
2015	-1.79	-1.14	-1.21	-1.45	-2.03
2016	-1.44	0.31	-1.04	-0.61	-0.08
2017	-0.18	-0.55	-0.33	-0.18	-0.51
2018	-2.16	-1.7	-2	-2.13	-1.97
2019	-0.04	0.47	-0.83	-0.67	0.43

4.3 Precipitation Deciles (PD)

Drought is a complex phenomenon which can be characterized mainly by its severity, duration and areal extent. Among these three dimensions, drought severity is the key factor which can be used for drought analysis. DrinC (Drought Indices Calculator) is a software package which was developed for providing a simple, though adaptable interface for the calculation of drought indices like precipitation deciles. The drought is usually estimated by comparing the current situation to the historical average, often based on minimum 30 year period of record.

Precipitation decile (PD) is a one of the simplest meteorological drought indices. The precipitation totals for the preceding three months are ranked against climatologic records and if the sum falls within the lowest decile of the historical distribution of 3-month totals, then the region is considered to be under drought conditions. The drought ends when the precipitation measured during the past month already places the 3-month total in or above the fourth decile, or the precipitation total for the past three months is in or above the eighth decile. Decile is a meteorological drought measurement tool which uses rainfall. The threshold ranges of deciles used to define drought condition are presented in the table 4.20 (Gibbs and Maher). In this study deciles 1-2 and deciles 3-4 were considered as drought event. The advantage of the method of deciles is its computational ease, but its simplicity can lead to conceptual difficulties. The precipitation deciles for different tehsils of Solapur district is calculated and results are discussed below.

4.3.1 Precipitation Decile (PD) of Akkalkot Tehsil

For Akkalkot tehsil, Deciles were computed from the long term historical rainfall data of 59 years (1961-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.10A, it is observed that there were 24 drought events in the period of 1961-2019. Much below normal (Deciles 1-2) condition was observed for 12 years (1961, 1969, 1972, 1973, 1987, 2004, 2005, 2009, 2016, 2017, 2018 and 2019). Much above normal (Deciles 9-10) condition was observed for 12 years (1963, 1964, 1968, 1971, 1976, 1979, 1980, 1982, 1989, 1990, 1991 and 1999).

It is also observed that the frequency of the drought event is increasing in the last two decade as compared to previous decades which may become very severe in the upcoming decade. The shifting of rainfall from much above normal rainfall to much below normal rainfall is also observed from the table 4.10B. This gives an alert to the agriculture system to change the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. As severity of drought is more in recent decades, more focus is needed in moisture conservation by various means. The graphical representation of precipitation deciles for the period of 1961-2019 is depicted in the Figure 4.12.

Table 4.10A: Classification of drought conditions according to Deciles in Akkalkot tehsil during the period 1961-2019

Year	Decile Index	Drought Condition	Year	Decile Index	Drought Condition
1961 - 1962	1	Much Below Normal	**1991 - 1992**	10	Much Above Normal
1962 - 1963	8	Above Normal	**1992 - 1993**	4	Below Normal
1963 - 1964	10	Much Above Normal	**1993 - 1994**	5	Near Normal
1964 - 1965	9	Much Above Normal	**1994 - 1995**	4	Below Normal
1965 - 1966	7	Above Normal	**1995 - 1996**	3	Below Normal
1966 - 1967	7	Above Normal	**1996 - 1997**	7	Above Normal
1967 - 1968	7	Above Normal	**1997 - 1998**	8	Above Normal
1968 - 1969	9	Much Above Normal	**1998 - 1999**	3	Below Normal
1969 - 1970	2	Much Below Normal	**1999 - 2000**	10	Much Above Normal
1970 - 1971	7	Above Normal	**2000 - 2001**	6	Near Normal
1971 - 1972	9	Much Above Normal	**2001 - 2002**	8	Above Normal
1972 - 1973	1	Much Below Normal	**2002 - 2003**	5	Near Normal
1973 - 1974	1	Much Below Normal	**2003 - 2004**	3	Below Normal
1974 - 1975	8	Above Normal	**2004 - 2005**	1	Much Below Normal
1975 - 1976	4	Below Normal	**2005 - 2006**	2	Much Below Normal
1976 - 1977	10	Much Above Normal	**2006 - 2007**	5	Near Normal
1977 - 1978	4	Below Normal	**2007 - 2008**	6	Near Normal
1978 - 1979	6	Near Normal	**2008 - 2009**	5	Much Above Normal
1979 - 1980	10	Much Above Normal	**2009 - 2010**	2	Much Below Normal
1980 - 1981	9	Much Above Normal	**2010 - 2011**	4	Below Normal
1981 - 1982	5	Near Normal	**2011 - 2012**	7	Above Normal
1982 - 1983	9	Much Above Normal	**2012 - 2013**	6	Near Normal
1983 - 1984	6	Near Normal	**2013 - 2014**	4	Below Normal
1984 - 1985	8	Above Normal	**2014 - 2015**	6	Near Normal
1985 - 1986	3	Below Normal	**2015 - 2016**	3	Below Normal
1986 - 1987	3	Below Normal	**2016 - 2017**	1	Much Below Normal
1987 - 1988	2	Much Below Normal	**2017 - 2018**	2	Much Below Normal
1988 - 1989	8	Above Normal	**2018 - 2019**	1	Much Below Normal
1989 - 1990	9	Much Above Normal	**2019 - 2020**	2	Much Below Normal
1990 - 1991	10	Much Above Normal			

Table 4.10B: Decadal statistics of drought and wet years of Akkalkot tehsil according to Decile method

Period	Much Below Normal	Below Normal	Near Normal	Above Normal	Much Above Normal
1961-1969	2	0	0	4	3
1970-1979	2	2	1	2	3
1980- 1989	1	2	2	2	3
1990 -1999	0	4	1	2	3
2000- 2009	3	1	5	1	0
2010- 2019	4	3	2	1	0
Total	12	12	11	12	12

4.3.2 Precipitation Decile (PD) of Barshi Tehsil

For Barshi tehsil, Deciles were computed from the long term historical rainfall data of 59 years (1961-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.11A, it is observed that there were 24 drought events in the period of 1961-2019. Much below normal (Deciles 1-2) condition was observed for 12 years (1972, 1976, 1985, 1986, 1987, 2004, 1991, 1992, 2003, 2004, 2014, 2015 and 2018). Much above normal (Deciles 9-10) condition was observed for 12 years (1964, 1970, 1971, 1975, 1978, 1983, 1993, 1989, 1996, 1998, 2000, 2007 and 2010).

Table 4.11A: Classification of drought conditions according to Deciles in Barshi tehsil during the period 1961-2019

Year	Decile Index	Drought Condition	Year	Decile Index	Drought Condition
1961 - 1962	6	Near Normal	**1991 - 1992**	1	Much Below Normal
1962 - 1963	5	Near Normal	**1992 - 1993**	2	Much Below Normal
1963 - 1964	5	Near Normal	**1993 - 1994**	9	Much Above Normal
1964 - 1965	10	Much Above Normal	**1994 - 1995**	3	Below Normal
1965 - 1966	5	Near Normal	**1995 - 1996**	6	Near Normal
1966 - 1967	8	Above Normal	**1996 - 1997**	9	Much Above Normal
1967 - 1968	4	Below Normal	**1997 - 1998**	5	Near Normal
1968 - 1969	4	Below Normal	**1998 - 1999**	10	Much Above Normal
1969 - 1970	6	Near Normal	**1999 - 2000**	4	Below Normal
1970 - 1971	10	Much Above Normal	**2000 - 2001**	9	Much Above Normal
1971 - 1972	9	Much Above Normal	**2001 - 2002**	7	Above Normal
1972 - 1973	1	Much Below Normal	**2002 - 2003**	3	Below Normal
1973 - 1974	6	Near Normal	**2003 - 2004**	2	Much Below Normal
1974 - 1975	7	Above Normal	**2004 - 2005**	2	Much Below Normal
1975 - 1976	10	Much Above Normal	**2005 - 2006**	8	Above Normal
1976 - 1977	2	Much Below Normal	**2006 - 2007**	7	Above Normal
1977 - 1978	7	Above Normal	**2007 - 2008**	10	Much Above Normal
1978 - 1979	9	Much Above Normal	**2008 - 2009**	7	Above Normal
1979 - 1980	7	Above Normal	**2009 - 2010**	8	Above Normal
1980 - 1981	8	Above Normal	**2010 - 2011**	10	Much Above Normal
1981 - 1982	4	Below Normal	**2011 - 2012**	3	Below Normal
1982 - 1983	3	Below Normal	**2012 - 2013**	3	Below Normal
1983 - 1984	9	Much Above Normal	**2013 - 2014**	3	Below Normal
1984 - 1985	5	Near Normal	**2014 - 2015**	2	Much Below Normal
1985 - 1986	1	Much Below Normal	**2015 - 2016**	1	Much Below Normal
1986 - 1987	1	Much Below Normal	**2016 - 2017**	4	Below Normal
1987 - 1988	2	Much Below Normal	**2017 - 2018**	8	Above Normal
1988 - 1989	6	Near Normal	**2018 - 2019**	1	Much Below Normal
1989 - 1990	6	Near Normal	**2019 - 2020**	4	Below Normal
1990 - 1991	8	Above Normal			

Table 4.11B: Decadal statistics of drought and wet years of Barshi tehsil according to Decile method

Period	Much Below Normal	Below Normal	Near Normal	Above Normal	Much Above Normal
1961-1969	0	2	5	1	1
1970-1979	2	0	1	3	4
1980- 1989	3	2	3	1	1
1990 -1999	2	2	2	1	3
2000- 2009	2	1	0	5	2
2010- 2019	3	5	0	1	1
Total	12	12	11	12	12

It is observed that the frequency of the drought event is increasing since the last decade as compared to previous decades which may become very severe in the upcoming decade. The shifting of rainfall from much above normal rainfall to below normal and much below normal condition is also observed from the table 4.11B. This gives an alert to the agriculture system to make changes in the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. As severity of drought is more in recent decades, more concentration should be given in conserving maximum available moisture. The graphical representation of precipitation deciles for the period of 1961-2019 is depicted in the Figure 4.13.

4.3.3 Precipitation Decile (PD) of Karmala Tehsil

For Karmala tehsil, Deciles were computed from the long term historical rainfall data of 59 years (1961-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.12A, it is observed that there were 24 drought events in the period of 1961-2019. Much below normal (Deciles 1-2) condition was observed for 12 years (1965, 1972, 1976, 1985, 1994, 1997, 2002, 2003, 2007, 2012, 2015 and 2018). Much above normal (Deciles 9-10) condition was observed for 12 years (1963, 1970, 1973, 1978, 1981, 1983, 1987, 1990, 1993, 1998, 2000 and 2010).

It is also observed that the frequency of the drought event is increasing in the last decade as compared to previous decades which may become very severe in the upcoming decade. The shifting of rainfall from much above normal rainfall to below normal and much below normal rainfall is also observed from the table 4.12B. This gives an alert to the agriculture system to make changes in the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. As severity of drought is more in last decades, more attention required in water harvesting and moisture conservation by various means. The graphical representation of precipitation deciles for the period of 1961-2019 is depicted in the Figure 4.14.

Table 4.12A: Classification of drought conditions according to Deciles in Karmala tehsil during the period 1961-2019

Year	Decile Index	Drought Condition	Year	Decile Index	Drought Condition
1961 - 1962	8	Above Normal	**1991 - 1992**	4	Below Normal
1962 - 1963	7	Above Normal	**1992 - 1993**	3	Below Normal
1963 - 1964	10	Much Above Normal	**1993 - 1994**	9	Much Above Normal
1964 - 1965	7	Above Normal	**1994 - 1995**	1	Much Below Normal
1965 - 1966	2	Much Below Normal	**1995 - 1996**	4	Below Normal
1966 - 1967	7	Above Normal	**1996 - 1997**	4	Below Normal
1967 - 1968	4	Below Normal	**1997 - 1998**	2	Much Below Normal
1968 - 1969	4	Below Normal	**1998 - 1999**	10	Much Above Normal
1969 - 1970	8	Above Normal	**1999 - 2000**	8	Above Normal
1970 - 1971	9	Much Above Normal	**2000 - 2001**	10	Much Above Normal
1971 - 1972	3	Below Normal	**2001 - 2002**	5	Near Normal
1972 - 1973	1	Much Below Normal	**2002 - 2003**	2	Much Below Normal
1973 - 1974	9	Much Above Normal	**2003 - 2004**	1	Much Below Normal
1974 - 1975	5	Near Normal	**2004 - 2005**	7	Above Normal
1975 - 1976	6	Near Normal	**2005 - 2006**	6	Near Normal
1976 - 1977	2	Much Below Normal	**2006 - 2007**	4	Below Normal
1977 - 1978	6	Near Normal	**2007 - 2008**	1	Much Below Normal
1978 - 1979	9	Much Above Normal	**2008 - 2009**	8	Above Normal
1979 - 1980	7	Above Normal	**2009 - 2010**	8	Above Normal
1980 - 1981	7	Above Normal	**2010 - 2011**	10	Much Above Normal
1981 - 1982	9	Much Above Normal	**2011 - 2012**	5	Near Normal
1982 - 1983	8	Above Normal	**2012 - 2013**	1	Much Below Normal
1983 - 1984	10	Much Above Normal	**2013 - 2014**	5	Near Normal
1984 - 1985	5	Near Normal	**2014 - 2015**	3	Below Normal
1985 - 1986	2	Much Below Normal	**2015 - 2016**	2	Much Below Normal
1986 - 1987	3	Below Normal	**2016 - 2017**	3	Below Normal
1987 - 1988	9	Much Above Normal	**2017 - 2018**	6	Near Normal
1988 - 1989	6	Near Normal	**2018 - 2019**	1	Much Below Normal
1989 - 1990	6	Near Normal	**2019 - 2020**	4	Below Normal
1990 - 1991	10	Much Above Normal			

Table 4.12B: Decadal statistics of drought and wet years of Karmala tehsil according to Decile method

Period	Much Below Normal	Below Normal	Near Normal	Above Normal	Much Above Normal
1961-1969	1	2	0	5	1
1970-1979	2	1	3	1	3
1980- 1989	1	1	3	2	3
1990 -1999	2	4	0	1	3
2000- 2009	3	1	2	3	1
2010- 2019	3	3	3	0	1
Total	12	12	11	12	12

4.3.4 Precipitation Decile (PD) of Madha Tehsil

For Madha tehsil, Deciles were computed from the long term historical rainfall data of 59 years (1961-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.13A, it is observed that there were 24 drought events in the period of 1961-2019. Much below normal (Deciles 1-2) condition was observed for 12 years (1961, 1972, 1976, 1977, 1980, 1985, 1991, 2003, 2011, 2012, 2015 and 2018). Much above normal (Deciles 9-10) condition was observed for 12 years (1964, 1973, 1979, 1983, 1988, 1990, 1993, 1995, 1996, 1998, 2000 and 2010).

Table 4.13A: Classification of drought conditions according to Deciles in Madha tehsil during the period 1961-2019

Year	Decile Index	Drought Condition	Year	Decile Index	Drought Condition
1961 - 1962	2	Much Below Normal	**1991 - 1992**	2	Much Below Normal
1962 - 1963	8	Above Normal	**1992 - 1993**	7	Above Normal
1963 - 1964	4	Below Normal	**1993 - 1994**	10	Much Above Normal
1964 - 1965	10	Much Above Normal	**1994 - 1995**	3	Below Normal
1965 - 1966	3	Below Normal	**1995 - 1996**	9	Much Above Normal
1966 - 1967	8	Above Normal	**1996 - 1997**	9	Much Above Normal
1967 - 1968	5	Near Normal	**1997 - 1998**	5	Near Normal
1968 - 1969	6	Near Normal	**1998 - 1999**	10	Much Above Normal
1969 - 1970	6	Near Normal	**1999 - 2000**	7	Above Normal
1970 - 1971	5	Near Normal	**2000 - 2001**	9	Much Above Normal
1971 - 1972	6	Near Normal	**2001 - 2002**	3	Below Normal
1972 - 1973	1	Much Below Normal	**2002 - 2003**	4	Below Normal
1973 - 1974	9	Much Above Normal	**2003 - 2004**	1	Much Below Normal
1974 - 1975	8	Above Normal	**2004 - 2005**	3	Below Normal
1975 - 1976	7	Above Normal	**2005 - 2006**	7	Above Normal
1976 - 1977	1	Much Below Normal	**2006 - 2007**	4	Below Normal
1977 - 1978	2	Much Below Normal	**2007 - 2008**	8	Above Normal
1978 - 1979	4	Below Normal	**2008 - 2009**	7	Above Normal
1979 - 1980	9	Much Above Normal	**2009 - 2010**	7	Above Normal
1980 - 1981	2	Much Below Normal	**2010 - 2011**	10	Much Above Normal
1981 - 1982	6	Near Normal	**2011 - 2012**	2	Much Below Normal
1982 - 1983	3	Below Normal	**2012 - 2013**	2	Much Below Normal
1983 - 1984	10	Much Above Normal	**2013 - 2014**	6	Near Normal
1984 - 1985	4	Below Normal	**2014 - 2015**	3	Below Normal
1985 - 1986	1	Much Below Normal	**2015 - 2016**	1	Much Below Normal
1986 - 1987	5	Near Normal	**2016 - 2017**	5	Near Normal
1987 - 1988	8	Above Normal	**2017 - 2018**	6	Near Normal
1988 - 1989	10	Much Above Normal	**2018 - 2019**	1	Much Below Normal
1989 - 1990	8	Above Normal	**2019 - 2020**	4	Below Normal
1990 - 1991	9	Much Above Normal			

Table 4.13B: Decadal statistics of drought and wet years of Madha tehsil according to Decile method

Period	Much Below Normal	Below Normal	Near Normal	Above Normal	Much Above Normal
1961-1969	1	2	3	2	1
1970-1979	3	1	2	2	2
1980- 1989	2	2	2	2	2
1990 -1999	1	1	1	2	5
2000- 2009	1	4	0	4	1
2010- 2019	4	2	3	0	1
Total	12	12	11	12	12

It is also observed that the frequency of the drought event is increasing since last decade as compared to previous decades which may become very severe in the upcoming decade. The shifting of rainfall from much above normal rainfall to below normal to much below normal rainfall is also observed from the table 4.13B. This gives an alert to the agriculture system to changes in the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. As severity of drought is more in recent decades, more concentration should be given in water harvesting and moisture conservation. The graphical representation of precipitation deciles for the period of 1961-2019 is depicted in the Figure 4.15.

4.3.5 Precipitation Decile (PD) of Malshiras Tehsil

For Malshiras tehsil, Deciles were computed from the long term historical rainfall data of 59 years (1961-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.14A, it is observed that there were 24drought events in the period of 1961-2019. Much below normal (Deciles 1-2) condition was observed for 12 years (1966, 1972, 1976, 1982, 1985, 1986, 1992, 2000, 2003, 2005, 2015 and 2018). Much above normal (Deciles 9-10) condition was observed for 12 years (1964, 1965, 1969, 1974, 1975, 1993, 1995, 1996, 1998, 1999, 2009 and 2010).

It is also observed that the frequency of the drought event is increasing in the last two decade as compared to previous decades which may become very severe in the upcoming decade. The shifting of rainfall from much above normal rainfall to below normal rainfall is also observed from the table 4.14B. This gives an alert to the agriculture system to change s the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. As severity of drought is more in recent two decades, maximum concentration should be on water harvesting and in situ moisture conservation practices and its utilization for protective irrigation, during critical growth stages and for future use. The graphical representation of precipitation deciles for the period of 1961-2019 is depicted in the Figure 4.16.

Table 4.14A: Classification of drought conditions according to Deciles in Malshiras tehsil during the period 1961-2019

Year	Decile Index	Drought Condition	Year	Decile Index	Drought Condition
1961 - 1962	5	Near Normal	**1991 - 1992**	6	Near Normal
1962 - 1963	7	Above Normal	**1992 - 1993**	2	Much Below Normal
1963 - 1964	4	Below Normal	**1993 - 1994**	10	Much Above Normal
1964 - 1965	9	Much Above Normal	**1994 - 1995**	7	Above Normal
1965 - 1966	10	Much Above Normal	**1995 - 1996**	9	Much Above Normal
1966 - 1967	2	Much Below Normal	**1996 - 1997**	10	Much Above Normal
1967 - 1968	4	Below Normal	**1997 - 1998**	7	Above Normal
1968 - 1969	6	Near Normal	**1998 - 1999**	10	Much Above Normal
1969 - 1970	9	Much Above Normal	**1999 - 2000**	10	Much Above Normal
1970 - 1971	5	Near Normal	**2000 - 2001**	1	Much Below Normal
1971 - 1972	3	Below Normal	**2001 - 2002**	3	Below Normal
1972 - 1973	1	Much Below Normal	**2002 - 2003**	3	Below Normal
1973 - 1974	8	Above Normal	**2003 - 2004**	1	Much Below Normal
1974 - 1975	9	Much Above Normal	**2004 - 2005**	3	Below Normal
1975 - 1976	9	Much Above Normal	**2005 - 2006**	2	Much Below Normal
1976 - 1977	2	Much Below Normal	**2006 - 2007**	7	Above Normal
1977 - 1978	6	Near Normal	**2007 - 2008**	8	Above Normal
1978 - 1979	8	Above Normal	**2008 - 2009**	8	Above Normal
1979 - 1980	8	Above Normal	**2009 - 2010**	10	Much Above Normal
1980 - 1981	5	Near Normal	**2010 - 2011**	9	Much Above Normal
1981 - 1982	8	Above Normal	**2011 - 2012**	4	Below Normal
1982 - 1983	2	Much Below Normal	**2012 - 2013**	3	Below Normal
1983 - 1984	5	Near Normal	**2013 - 2014**	4	Below Normal
1984 - 1985	4	Below Normal	**2014 - 2015**	3	Below Normal
1985 - 1986	1	Much Below Normal	**2015 - 2016**	1	Much Below Normal
1986 - 1987	2	Much Below Normal	**2016 - 2017**	4	Below Normal
1987 - 1988	6	Near Normal	**2017 - 2018**	6	Near Normal
1988 - 1989	7	Above Normal	**2018 - 2019**	1	Much Below Normal
1989 - 1990	7	Above Normal	**2019 - 2020**	6	Near Normal
1990 - 1991	5	Near Normal			

Table 4.14B: Decadal statistics of drought and wet years of Malshiras tehsil according to Decile method

Period	Much Below Normal	Below Normal	Near Normal	Above Normal	Much Above Normal
1961-1969	1	2	2	1	3
1970-1979	2	1	2	3	2
1980- 1989	3	1	3	3	0
1990 -1999	1	0	2	2	5
2000- 2009	3	3	0	3	1
2010- 2019	2	5	2	0	1
Total	12	12	11	12	12

4.3.6 Precipitation Decile (PD) of Mangalwedha Tehsil

For Mangalwedha tehsil, Deciles were computed from the long term historical rainfall data of 59 years (1961-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.15A, it is observed that there were 24 drought events in the period of 1961-2019. Much below normal (Deciles 1-2) condition was observed for 12 years (1972, 1973, 1977, 1991, 1992, 1994, 2000, 2003, 2011, 2015, 2016 and 2018). Much above normal (Deciles 9-10) condition was observed for 12 years (1965, 1968, 1970, 1974, 1975, 1981, 1987, 1989, 1993, 1998, 2007 and 2009).

Table 4.15A: Classification of drought conditions according to Deciles in Mangalwedha tehsil during the period 1961-2019

Year	Decile Index	Drought Condition	Year	Decile Index	Drought Condition
1961 - 1962	6	Near Normal	**1991 - 1992**	1	Much Below Normal
1962 - 1963	5	Near Normal	**1992 - 1993**	2	Much Below Normal
1963 - 1964	8	Above Normal	**1993 - 1994**	9	Much Above Normal
1964 - 1965	8	Above Normal	**1994 - 1995**	2	Much Below Normal
1965 - 1966	10	Much Above Normal	**1995 - 1996**	5	Near Normal
1966 - 1967	3	Below Normal	**1996 - 1997**	6	Near Normal
1967 - 1968	7	Above Normal	**1997 - 1998**	3	Below Normal
1968 - 1969	9	Much Above Normal	**1998 - 1999**	9	Much Above Normal
1969 - 1970	7	Above Normal	**1999 - 2000**	6	Near Normal
1970 - 1971	9	Much Above Normal	**2000 - 2001**	2	Much Below Normal
1971 - 1972	4	Below Normal	**2001 - 2002**	4	Below Normal
1972 - 1973	1	Much Below Normal	**2002 - 2003**	8	Above Normal
1973 - 1974	1	Much Below Normal	**2003 - 2004**	2	Much Below Normal
1974 - 1975	10	Much Above Normal	**2004 - 2005**	8	Above Normal
1975 - 1976	10	Much Above Normal	**2005 - 2006**	8	Above Normal
1976 - 1977	4	Below Normal	**2006 - 2007**	8	Above Normal
1977 - 1978	2	Much Below Normal	**2007 - 2008**	10	Much Above Normal
1978 - 1979	7	Above Normal	**2008 - 2009**	5	Near Normal
1979 - 1980	6	Near Normal	**2009 - 2010**	9	Much Above Normal
1980 - 1981	3	Below Normal	**2010 - 2011**	7	Above Normal
1981 - 1982	10	Much Above Normal	**2011 - 2012**	2	Much Below Normal
1982 - 1983	6	Near Normal	**2012 - 2013**	3	Below Normal
1983 - 1984	7	Above Normal	**2013 - 2014**	4	Below Normal
1984 - 1985	5	Near Normal	**2014 - 2015**	3	Below Normal
1985 - 1986	3	Below Normal	**2015 - 2016**	1	Much Below Normal
1986 - 1987	4	Below Normal	**2016 - 2017**	1	Much Below Normal
1987 - 1988	10	Much Above Normal	**2017 - 2018**	4	Below Normal
1988 - 1989	6	Near Normal	**2018 - 2019**	1	Much Below Normal
1989 - 1990	9	Much Above Normal	**2019 - 2020**	5	Near Normal
1990 - 1991	7	Above Normal			

Table 4.15B: Decadal statistics of drought and wet years of Mangalwedha tehsil according to Decile method

Period	Much Below Normal	Below Normal	Near Normal	Above Normal	Much Above Normal
1961-1969	0	1	2	4	2
1970-1979	3	2	1	1	3
1980- 1989	0	3	3	1	3
1990 -1999	3	1	3	1	2
2000- 2009	2	1	1	4	2
2010- 2019	4	4	1	1	0
Total	12	12	11	12	12

It is observed that the frequency of the drought event is increased drastically in the last decade as compared to previous decades which may become very severe in the upcoming decade. The shifting of rainfall from much above normal rainfall to below normal and much below normal rainfall is also observed from the table 4.15B in the recent decade. This gives an alert to the agriculture system to change the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. As severity of drought is more in recent decades, concentration must be on maximum conservation of moisture for better crop growth. Hence efforts must be put forth to harvest monsoon water as soon as it is available. The graphical representation of precipitation deciles for the period of 1961-2019 is depicted in the Figure 4.17.

4.3.7 Precipitation Decile (PD) of Mohol Tehsil

For Mohol tehsil, Deciles were computed from the long term historical rainfall data of 59 years (1961-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.16A, it is observed that there were 24 drought events in the period of 1961-2019. Much below normal (Deciles 1-2) condition was observed for 12 years (1965, 1972, 1976, 1977, 1980, 1982, 1997, 2003, 2012, 2015, 2016 and 2018). Much above normal (Deciles 9-10) condition was observed for 12 years (1964, 1969, 1970, 1975, 1981, 1983, 1987, 1988, 1989, 1996, 1998 and 2010).

It is observed that the frequency of the drought event is increased drastically in the last decade as compared to previous decades which may become very severe in the upcoming decade. The shifting of rainfall from much above normal rainfall to below normal and much below normal rainfall is also observed from the table 4.16B in the recent decade. This gives an alert to the agriculture system to change the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. As severity of drought is more in recent decade (2010-2019), concentration must be on maximum conservation of moisture for better crop growth. Hence efforts must be put forth to harvest monsoon water as soon as it is

available. The graphical representation of precipitation deciles for the period of 1961-2019 is depicted in the Figure 4.18.

Table 4.16A: Classification of drought conditions according to Deciles in Mohol tehsil during the period 1961-2019

Year	Decile Index	Drought Condition	Year	Decile Index	Drought Condition
1961 - 1962	8	Above Normal	**1991 - 1992**	6	Near Normal
1962 - 1963	8	Above Normal	**1992 - 1993**	3	Below Normal
1963 - 1964	4	Below Normal	**1993 - 1994**	7	Above Normal
1964 - 1965	10	Much Above Normal	**1994 - 1995**	3	Below Normal
1965 - 1966	2	Much Below Normal	**1995 - 1996**	5	Near Normal
1966 - 1967	5	Near Normal	**1996 - 1997**	9	Much Above Normal
1967 - 1968	5	Near Normal	**1997 - 1998**	2	Much Below Normal
1968 - 1969	4	Below Normal	**1998 - 1999**	10	Much Above Normal
1969 - 1970	10	Much Above Normal	**1999 - 2000**	6	Near Normal
1970 - 1971	9	Much Above Normal	**2000 - 2001**	8	Above Normal
1971 - 1972	5	Near Normal	**2001 - 2002**	6	Near Normal
1972 - 1973	1	Much Below Normal	**2002 - 2003**	6	Near Normal
1973 - 1974	7	Above Normal	**2003 - 2004**	1	Much Below Normal
1974 - 1975	8	Above Normal	**2004 - 2005**	3	Below Normal
1975 - 1976	10	Much Above Normal	**2005 - 2006**	7	Above Normal
1976 - 1977	2	Much Below Normal	**2006 - 2007**	7	Above Normal
1977 - 1978	1	Much Below Normal	**2007 - 2008**	7	Above Normal
1978 - 1979	8	Above Normal	**2008 - 2009**	8	Above Normal
1979 - 1980	6	Near Normal	**2009 - 2010**	6	Near Normal
1980 - 1981	2	Much Below Normal	**2010 - 2011**	10	Much Above Normal
1981 - 1982	9	Much Above Normal	**2011 - 2012**	4	Below Normal
1982 - 1983	2	Much Below Normal	**2012 - 2013**	1	Much Below Normal
1983 - 1984	9	Much Above Normal	**2013 - 2014**	4	Below Normal
1984 - 1985	3	Below Normal	**2014 - 2015**	3	Below Normal
1985 - 1986	3	Below Normal	**2015 - 2016**	1	Much Below Normal
1986 - 1987	4	Below Normal	**2016 - 2017**	2	Much Below Normal
1987 - 1988	10	Much Above Normal	**2017 - 2018**	4	Below Normal
1988 - 1989	9	Much Above Normal	**2018 - 2019**	1	Much Below Normal
1989 - 1990	9	Much Above Normal	**2019 - 2020**	5	Near Normal
1990 - 1991	7	Above Normal			

Table 4.16B: Decadal statistics of drought and wet years of Mohol tehsil according to Decile method

Period	Much Below Normal	Below Normal	Near Normal	Above Normal	Much Above Normal
1961-1969	1	2	2	2	2
1970-1979	3	0	2	3	2
1980- 1989	2	3	0	0	5
1990 -1999	1	2	3	2	2
2000- 2009	1	1	3	5	0
2010- 2019	4	4	1	0	1
Total	12	12	11	12	12

4.3.8 Precipitation Decile (PD) of Pandharpur Tehsil

For Pandharpur tehsil, Deciles were computed from the long term historical rainfall data of 59 years (1961-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.17A, it is observed that there were 24 drought events in the period of 1961-2019. Much below normal (Deciles 1-2) condition was observed for 12 years (1966, 1967, 1972, 1994, 1999, 2003, 2011, 2012, 2015, 2016, 2018 and 2019). Much above normal (Deciles 9-10) condition was observed for 12 years (1969, 1973, 1974, 1975, 1978, 1981, 1983, 1984, 1987, 1988, 1989 and 1998).

It is also observed that the frequency of the drought event is increasing in the last three decade as compared to previous decades which may become very severe in the upcoming decade.

Table 4.17A: Classification of drought conditions according to Deciles in Pandharpur tehsil during the period 1961-2019

Year	Decile Index	Drought Condition	Year	Decile Index	Drought Condition
1961 - 1962	6	Near Normal	**1991 - 1992**	5	Near Normal
1962 - 1963	8	Above Normal	**1992 - 1993**	4	Below Normal
1963 - 1964	5	Near Normal	**1993 - 1994**	7	Above Normal
1964 - 1965	6	Near Normal	**1994 - 1995**	2	Much Below Normal
1965 - 1966	8	Above Normal	**1995 - 1996**	4	Below Normal
1966 - 1967	1	Much Below Normal	**1996 - 1997**	8	Above Normal
1967 - 1968	1	Much Below Normal	**1997 - 1998**	3	Below Normal
1968 - 1969	3	Below Normal	**1998 - 1999**	9	Much Above Normal
1969 - 1970	9	Much Above Normal	**1999 - 2000**	2	Much Below Normal
1970 - 1971	3	Below Normal	**2000 - 2001**	5	Near Normal
1971 - 1972	5	Near Normal	**2001 - 2002**	6	Near Normal
1972 - 1973	1	Much Below Normal	**2002 - 2003**	4	Below Normal
1973 - 1974	9	Much Above Normal	**2003 - 2004**	1	Much Below Normal
1974 - 1975	10	Much Above Normal	**2004 - 2005**	4	Below Normal
1975 - 1976	10	Much Above Normal	**2005 - 2006**	6	Near Normal
1976 - 1977	3	Below Normal	**2006 - 2007**	3	Below Normal
1977 - 1978	7	Above Normal	**2007 - 2008**	6	Near Normal
1978 - 1979	9	Much Above Normal	**2008 - 2009**	5	Near Normal
1979 - 1980	7	Above Normal	**2009 - 2010**	8	Above Normal
1980 - 1981	8	Above Normal	**2010 - 2011**	8	Above Normal
1981 - 1982	10	Much Above Normal	**2011 - 2012**	2	Much Below Normal
1982 - 1983	4	Below Normal	**2012 - 2013**	2	Much Below Normal
1983 - 1984	10	Much Above Normal	**2013 - 2014**	6	Near Normal
1984 - 1985	9	Much Above Normal	**2014 - 2015**	3	Below Normal
1985 - 1986	7	Above Normal	**2015 - 2016**	1	Much Below Normal
1986 - 1987	7	Above Normal	**2016 - 2017**	2	Much Below Normal
1987 - 1988	10	Much Above Normal	**2017 - 2018**	4	Below Normal
1988 - 1989	10	Much Above Normal	**2018 - 2019**	1	Much Below Normal
1989 - 1990	9	Much Above Normal	**2019 - 2020**	2	Much Below Normal
1990 - 1991	7	Above Normal			

Table 4.17B: Decadal statistics of drought and wet years of Pandharpur tehsil according to Decile method

Period	Much Below Normal	Below Normal	Near Normal	Above Normal	Much Above Normal
1961-1969	2	1	3	2	1
1970-1979	1	2	1	2	4
1980- 1989	0	1	0	3	6
1990 -1999	2	3	1	3	1
2000- 2009	1	3	5	1	0
2010- 2019	6	2	1	1	0
Total	12	12	11	12	12

The maximum dry condition observed in last decade receiving much below normal rainfall for 6 years in 2010-2019 period (table 4.17B). This gives an alert to the agriculture system to changes in the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. As severity of drought is more in recent decade, more efforts are needed for in situ moisture conservation. The graphical representation of precipitation deciles for the period of 1961-2019 is depicted in the Figure 4.19.

4.3.9 Precipitation Decile (PD) of Sangola Tehsil

For Sangola tehsil, Deciles were computed from the long term historical rainfall data of 59 years (1961-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.18A, it is observed that there were 24 drought events in the period of 1961-2019. Much below normal (Deciles 1-2) condition was observed for 12 years (1968, 1972, 1991, 1992, 1994, 2003, 2004, 2005, 2011, 2012, 2015 and 2018). Much above normal (Deciles 9-10) condition was observed for 12 years (1963, 1973, 1974, 1975, 1977, 1978, 1979, 1981, 1987, 1993, 1996 and 1998).

Table 4.18A: Classification of drought conditions according to Deciles in Sangola tehsil during the period 1961-2019

Year	Decile Index	Drought Condition	Year	Decile Index	Drought Condition
1961 - 1962	7	Above Normal	**1991 - 1992**	2	Much Below Normal
1962 - 1963	7	Above Normal	**1992 - 1993**	2	Much Below Normal
1963 - 1964	10	Much Above Normal	**1993 - 1994**	9	Much Above Normal
1964 - 1965	8	Above Normal	**1994 - 1995**	1	Much Below Normal
1965 - 1966	7	Above Normal	**1995 - 1996**	4	Below Normal
1966 - 1967	3	Below Normal	**1996 - 1997**	9	Much Above Normal
1967 - 1968	6	Near Normal	**1997 - 1998**	8	Above Normal
1968 - 1969	1	Much Below Normal	**1998 - 1999**	10	Much Above Normal
1969 - 1970	5	Near Normal	**1999 - 2000**	7	Above Normal
1970 - 1971	3	Below Normal	**2000 - 2001**	4	Below Normal
1971 - 1972	7	Above Normal	**2001 - 2002**	4	Below Normal

Table 4.18A cont…

1972 - 1973	1	Much Below Normal	**2002 - 2003**	6	Near Normal
1973 - 1974	9	Much Above Normal	**2003 - 2004**	2	Much Below Normal
1974 - 1975	10	Much Above Normal	**2004 - 2005**	2	Much Below Normal
1975 - 1976	10	Much Above Normal	**2005 - 2006**	2	Much Below Normal
1976 - 1977	6	Near Normal	**2006 - 2007**	6	Near Normal
1977 - 1978	9	Much Above Normal	**2007 - 2008**	8	Above Normal
1978 - 1979	10	Much Above Normal	**2008 - 2009**	5	Near Normal
1979 - 1980	10	Much Above Normal	**2009 - 2010**	8	Above Normal
1980 - 1981	6	Near Normal	**2010 - 2011**	5	Near Normal
1981 - 1982	9	Much Above Normal	**2011 - 2012**	1	Much Below Normal
1982 - 1983	5	Near Normal	**2012 - 2013**	2	Much Below Normal
1983 - 1984	4	Below Normal	**2013 - 2014**	3	Below Normal
1984 - 1985	7	Above Normal	**2014 - 2015**	4	Below Normal
1985 - 1986	4	Below Normal	**2015 - 2016**	1	Much Below Normal
1986 - 1987	3	Below Normal	**2016 - 2017**	3	Below Normal
1987 - 1988	9	Much Above Normal	**2017 - 2018**	5	Near Normal
1988 - 1989	8	Above Normal	**2018 - 2019**	1	Much Below Normal
1989 - 1990	8	Above Normal	**2019 - 2020**	3	Below Normal
1990 - 1991	6	Near Normal			

Table 4.18B: Decadal statistics of drought and wet years of Sangola tehsil according to Decile method

Period	Much Below Normal	Below Normal	Near Normal	Above Normal	Much Above Normal
1961-1969	1	1	2	4	1
1970-1979	1	1	1	1	6
1980- 1989	0	3	2	3	2
1990 -1999	3	1	1	2	3
2000- 2009	3	2	3	2	0
2010- 2019	4	4	2	0	0
Total	12	12	11	12	12

It is also observed that the frequency of the drought event is increasing in the last three decade as compared to previous decades which may become very severe in the upcoming decade. The maximum dry condition observed in last decade receiving much below normal and below normal rainfall for 4 years each respectively during 2010-2019 period (table 4.18B). This gives an alert to the agriculture system to changes in the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. As severity of drought is more in recent decade, more efforts are needed for in situ moisture conservation. The graphical representation of precipitation deciles for the period of 1961-2019 is depicted in the Figure 4.20.

4.3.10 Precipitation Decile (PD) of North Solapur Tehsil

For North Solapur, Deciles were computed from the long term historical rainfall data of 22 years (1998-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.19A, it is observed that there were 09 drought events in the period of 1998-2019. Much below normal (Deciles 1-2) condition was observed for 05 years (1999, 2001, 2003, 2015, 2018). Much above normal (Deciles 9-10) condition was observed for 05 years (1998, 2005, 2008, 2009 and 2010).

It is observed that the frequency of the drought event is increasing gradually. This gives an alert to the agriculture system to change the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. Table 4.19B shows severity of drought according to Precipitation Deciles index. As severity of drought is increasing gradually in recent decades, concentration must be on maximum conservation of moisture for better crop growth. Hence efforts must be put forth to harvest monsoon water as soon as it is available. in situ moisture conservation practices should also be undertaken to utilise monsoon and north east monsoon to its fullest. The graphical representation of precipitation deciles for the period of 1998-2019 is shown in the Figure 4.21.

4.3.11 Precipitation Decile (PD) of South Solapur Tehsil

For South Solapur tehsil, Deciles were computed from the long term historical rainfall data of 22 years (1998-2019) and historical drought events were identified which fall under deciles 1-2 and 3-4. From the Table 4.19A, it is observed that there were 09 drought events in the period of 1998-2019. Much below normal (Deciles 1-2) condition was observed for 05 years (2003, 2012, 2014, 2015, 2018). Much above normal (Deciles 9-10) condition was observed for 05 years (1998, 2001, 2005, 2009 and 2010).

Table 4.19A: Classification of drought conditions according to Deciles in North & South Solapur tehsil during the period 1998-2019

North Solapur			South Solapur		
Year	**Decile Index**	**Drought Condition**	**Year**	**Decile Index**	**Drought Condition**
1998 - 1999	10	Much Above Normal	**1998 - 1999**	10	Much Above Normal
1999 - 2000	1	Much Below Normal	**1999 - 2000**	3	Below Normal
2000 - 2001	6	Near Normal	**2000 - 2001**	7	Above Normal
2001 - 2002	2	Much Below Normal	**2001 - 2002**	9	Much Above Normal
2002 - 2003	3	Below Normal	**2002 - 2003**	5	Near Normal
2003 - 2004	1	Much Below Normal	**2003 - 2004**	1	Much Below Normal
2004 - 2005	6	Near Normal	**2004 - 2005**	6	Near Normal
2005 - 2006	10	Much Above Normal	**2005 - 2006**	10	Much Above Normal
2006 - 2007	5	Near Normal	**2006 - 2007**	5	Near Normal
2007 - 2008	7	Above Normal	**2007 - 2008**	6	Near Normal

Table 4.19A cont…

2008 - 2009	9	Much Above Normal	**2008 - 2009**	8	Above Normal
2009 - 2010	9	Much Above Normal	**2009 - 2010**	9	Much Above Normal
2010 - 2011	10	Much Above Normal	**2010 - 2011**	10	Much Above Normal
2011 - 2012	8	Above Normal	**2011 - 2012**	7	Above Normal
2012 - 2013	4	Below Normal	**2012 - 2013**	2	Much Below Normal
2013 - 2014	4	Below Normal	**2013 - 2014**	4	Below Normal
2014 - 2015	5	Near Normal	**2014 - 2015**	2	Much Below Normal
2015 - 2016	2	Much Below Normal	**2015 - 2016**	1	Much Below Normal
2016 - 2017	7	Above Normal	**2016 - 2017**	4	Below Normal
2017 - 2018	3	Below Normal	**2017 - 2018**	3	Below Normal
2018 - 2019	1	Much Below Normal	**2018 - 2019**	1	Much Below Normal
2019 - 2020	8	Above Normal	**2019 - 2020**	8	Above Normal

Table 4.19B: Decadal statistics of drought and wet years of North & South Solapur tehsil according to Decile method

North Solapur					
Period	**Much Below Normal**	**Below Normal**	**Near Normal**	**Above Normal**	**Much Above Normal**
1998 -1999	1	0	0	0	1
2000- 2009	2	1	3	1	3
2010- 2019	2	3	1	3	1
Total	5	4	4	4	5
South Solapur					
1998 -1999	0	1	0	0	1
2000- 2009	1	0	4	2	3
2010- 2019	4	3	0	2	1
Total	5	4	4	4	5

It is observed that the frequency of the drought event is increasing gradually. This gives an alert to the agriculture system to change the cropping pattern and water management at field level for the sustainable crop production and mitigate the drought impacts. Table 4.19B shows severity of drought according to Precipitation Deciles index. As severity of drought is increasing gradually in recent decades, concentration must be on maximum conservation of moisture for better crop growth. Hence efforts must be put forth to harvest monsoon water as soon as it is available. in situ moisture conservation practices should also be undertaken to utilise monsoon and north east monsoon to its fullest. The graphical representation of precipitation deciles for the period of 1998-2019 is depicted in the Figure 4.22. The results are in confirmation with Shal *et al*., (2013).

Table 4.20: Precipitation Deciles values of different tehsils of Solapur district (1961-2019)

Annual Precipitation Decile value table of different tehsils of soalpur district											
Years	**Akkalkot**	**Barshi**	**Karmala**	**Madha**	**Malshiras**	**Mangalwedha**	**Mohol**	**N.Sol**	**Pandharpur**	**Sangola**	**S. Sol**
1961	1	6	8	2	5	6	8	NA	6	7	NA
1962	8	5	7	8	7	5	8	NA	8	7	NA
1963	10	5	10	4	4	8	4	NA	5	10	NA
1964	9	10	7	10	9	8	10	NA	6	8	NA
1965	7	5	2	3	10	10	2	NA	8	7	NA
1966	7	8	7	8	2	3	5	NA	1	3	NA
1967	7	4	4	5	4	7	5	NA	1	6	NA
1968	9	4	4	6	6	9	4	NA	3	1	NA
1969	2	6	8	6	9	7	10	NA	9	5	NA
1970	7	10	9	5	5	9	9	NA	3	3	NA
1971	9	9	3	6	3	4	5	NA	5	7	NA
1972	1	1	1	1	1	1	1	NA	1	1	NA
1973	1	6	9	9	8	1	7	NA	9	9	NA
1974	8	7	5	8	9	10	8	NA	10	10	NA
1975	4	10	6	7	9	10	10	NA	10	10	NA
1976	10	2	2	1	2	4	2	NA	3	6	NA
1977	4	7	6	2	6	2	1	NA	7	9	NA
1978	6	9	9	4	8	7	8	NA	9	10	NA
1979	10	7	7	9	8	6	6	NA	7	10	NA
1980	9	8	7	2	5	3	2	NA	8	6	NA
1981	5	4	9	6	8	10	9	NA	10	9	NA
1982	9	3	8	3	2	6	2	NA	4	5	NA
1983	6	9	10	10	5	7	9	NA	10	4	NA
1984	8	5	5	4	4	5	3	NA	9	7	NA
1985	3	1	2	1	1	3	3	NA	7	4	NA
1986	3	1	3	5	2	4	4	NA	7	3	NA
1987	2	2	9	8	6	10	10	NA	10	9	NA
1988	8	6	6	10	7	6	9	NA	10	8	NA
1989	9	6	6	8	7	9	9	NA	9	8	NA
1990	10	8	10	9	5	7	7	NA	7	6	NA
1991	10	1	4	2	6	1	6	NA	5	2	NA
1992	4	2	3	7	2	2	3	NA	4	2	NA
1993	5	9	9	10	10	9	7	NA	7	9	NA
1994	4	3	1	3	7	2	3	NA	2	1	NA
1995	3	6	4	9	9	5	5	NA	4	4	NA
1996	7	9	4	9	10	6	9	NA	8	9	NA
1997	8	5	2	5	7	3	2	NA	3	8	NA
1998	3	10	10	10	10	9	10	10	9	10	10
1999	10	4	8	7	10	6	6	1	2	7	3
2000	6	9	10	9	1	2	8	6	5	4	7
2001	8	7	5	3	3	4	6	2	6	4	9
2002	5	3	2	4	3	8	6	3	4	6	5
2003	3	2	1	1	1	2	1	1	1	2	1
2004	1	2	7	3	3	8	3	6	4	2	6
2005	2	8	6	7	2	8	7	10	6	2	10
2006	5	7	4	4	7	8	7	5	3	6	5
2007	6	10	1	8	8	10	7	7	6	8	6
2008	5	7	8	7	8	5	8	9	5	5	8
2009	2	8	8	7	10	9	6	9	8	8	9
2010	4	10	10	10	9	7	10	10	8	5	10
2011	7	3	5	2	4	2	4	8	2	1	7
2012	6	3	1	2	3	3	1	4	2	2	2
2013	4	3	5	6	4	4	4	4	6	3	4
2014	6	2	3	3	3	3	3	5	3	4	2
2015	3	1	2	1	1	1	1	2	1	1	1
2016	1	4	3	5	4	1	2	7	2	3	4
2017	2	8	6	6	6	4	4	3	4	5	3
2018	1	1	1	1	1	1	1	1	1	1	1
2019	2	4	4	4	6	5	5	8	2	3	8

4.4 Onset and Withdrawal of Monsoon

The onset and withdrawal of rainy season was computed from mean weekly rainfall data by forward and backward accumulation methods as per the procedure suggested by Babu and Lakshminarayana (1997). In this method weekly rainfall was summed by forward accumulation (20+21+…+52 weeks) until a certain amount of rainfall was accumulated. Seventy five millimeters of rainfall accumulation has been considered as the onset time for the growing season of dry seeded crops and land preparation (Babu and Lakshminarayana, 1997; Panigrahi and Panda, 2002). The withdrawal of rainy season was determined by backward accumulation of rainfall (48+47+46+…+30 weeks) data. Twenty millimeters of rainfall accumulation was chosen for the end of rainy season, which is sufficient for ploughing of fields after harvesting the crops (Babu and Lakshminarayana, 1997).

By considering prevailing rainfall condition of selected area, 50 millimeter of rainfall accumulation has been considered as the onset time and 10 millimeter rainfall accumulation has been considered as the withdrawal time. For all tehsils of Solapur district 50 mm rainfall accumulation has been considered for deciding the onset of monsoon. Whereas 10 mm of rainfall accumulation was chosen for the end of rainy season, which is sufficient for ploughing of fields after harvesting the crops.

The results regarding the onset and withdrawal of monsoon for different tehsils in Solapur district is discussed below.

4.4.1 Onset and Withdrawal of Monsoon for Akkalkot Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in Akkalkot is given in Table 4.21. From the analysis of 59 years (1961 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon was 25th standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 45th MW (*i.e.,* 5 November –11 November). Therefore, mean length of rainy season was found to be 20 weeks (140 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4–10 June) and 30 MW (23–29 July) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 39 MW (24–30 September) and 52 MW (24–31 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 29 and 09 weeks respectively. Probability occurrence of onset of monsoon in 25 MW is 22% which is observed for 13 years when 59 years of data is considered. But when we considered 24 (11-17 June) and 25 MW (18 June – 24 June) Probability occurrence of onset of monsoon is 50% which is observed for 29 years out of total 59 years. Hence from 11 June – 24 June there are maximum chances of onset of monsoon during this period in Akklakot tehsil.

Table 4.21: Mean week of onset and withdrawal of rainfall in Akkalkot tehsil

Akkalkot									
Year	**Start**	**End**	**Duration**	**Rainfall**	**Year**	**Start**	**End**	**Duration**	**Rainfall**
1961	23	43	20	567	1991	23	47	24	449
1962	23	49	26	910.9	1992	24	46	22	562
1963	23	43	20	729	1993	28	49	21	499
1964	28	40	12	733.5	1994	26	43	17	391
1965	24	50	26	752.2	1995	26	42	16	618
1966	27	48	21	575.5	1996	23	45	22	823
1967	25	40	15	835	1997	23	50	27	448
1968	27	45	18	365.4	1998	24	42	18	1074
1969	24	45	21	617.1	1999	24	41	17	599.1
1970	25	40	15	693.5	2000	24	45	21	752.4
1971	25	39	14	273.5	2001	23	42	19	569
1972	25	44	19	181	2002	23	46	23	468.7
1973	26	44	18	829	2003	29	39	10	304.2
1974	26	41	15	550	2004	23	40	17	440.2
1975	23	44	21	1128	2005	24	42	18	585.6
1976	25	45	20	491	2006	23	45	22	635.1
1977	24	49	25	610.8	2007	25	41	16	580.6
1978	25	46	21	908.6	2008	30	40	10	418.7
1979	25	48	23	890	2009	25	45	20	549.2
1980	24	46	22	484	2010	24	43	19	672.1
1981	23	46	23	865	2011	27	42	15	544
1982	27	45	18	588	2012	25	40	15	526.3
1983	25	52	27	784.8	2013	24	44	20	590.8
1984	28	43	15	517	2014	27	50	23	473
1985	24	41	17	485	2015	24	41	17	229.2
1986	24	52	28	433	2016	25	40	15	413.3
1987	24	50	26	772	2017	23	42	19	378.6
1988	27	50	23	828.2	2018	23	47	24	232.8
1989	24	52	28	932	2019	25	45	20	563
1990	23	43	20	1085					
	Mean week of start of rainfall					**Mean week of end of rainfall**			
	Start	**Early**	**Late**	**SD**		**End**	**Early**	**Late**	**SD**
MW	25	23	30	1.7	**MW**	45	39	52	3.6
Period	18-06 to 24-06	04-06 to 10-06	23-07 to 29-07		**Period**	05-11 to 11-11	24-09 to 30-09	24-12 to 31-12	
	Mean duration					**Mean rainfall**			
	Dur	**Min**	**Max**	**SD**		**Avg**	**Min**	**Max**	**SD**
Total	20	10	28	4.2	**Rainfall**	606.9	181	1128	212.9
Days	140	70	196						

Hence we can suggest sowing of *kharif* crops like pearl millet, sunflower in the 24 (11-17 June) and 25 MW (18 June – 24 June). Based on the 140 days duration of monsoon season long season crop like pigeon pea can also be sown in this period. To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram and cowpea should be sown in this period to utilise maximum moisture for good germination. The land preparation operation

should be performed in summer by utilizing premonsoon shower rain. Conserve excess moisture during the monsoon season which can be utilise during critical growth stages of field crops and for production of *rabi* crops with the help of different *in-situ* soil moisture conservation techniques.

4.4.2 Onset and Withdrawal of Monsoon for Barshi Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in Barshi is given in Table 4.22. From the analysis of 59 years (1961 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon was 25th standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 45th MW (*i.e.,* 5 November – 11 November). Therefore, mean length of rainy

Table 4.22: Mean week of onset and withdrawal of rainfall in Barshi tehsil.

Barshi									
Year	**Start**	**End**	**Duration**	**Rainfall**	**Year**	**Start**	**End**	**Duration**	**Rainfall**
1961	23	50	27	556.9	1991	26	41	15	147.4
1962	27	49	22	513.3	1992	24	46	22	450.4
1963	24	45	21	534	1993	26	49	23	710.7
1964	24	45	21	977	1994	24	42	18	376.6
1965	24	50	26	560	1995	26	47	21	565.7
1966	27	46	19	552	1996	23	45	22	846.2
1967	24	51	27	600	1997	26	49	23	513.9
1968	24	45	21	475	1998	24	45	21	1138.7
1969	26	45	19	649.7	1999	24	41	17	447.3
1970	23	41	18	868	2000	23	41	18	727.1
1971	25	43	18	735	2001	23	41	18	703.2
1972	25	44	19	246.8	2002	24	46	22	462.7
1973	27	47	20	633.6	2003	25	44	19	313.7
1974	24	43	19	683	2004	26	40	14	420.7
1975	25	44	19	824.1	2005	25	42	17	712.5
1976	25	45	20	322.5	2006	25	45	20	674.2
1977	24	48	24	629.7	2007	23	41	18	951.3
1978	24	45	21	717.4	2008	24	47	23	651.3
1979	26	48	22	703.5	2009	24	46	22	717
1980	23	51	28	632	2010	24	46	22	1006.7
1981	25	39	14	460.1	2011	25	41	16	492.5
1982	24	45	21	462.7	2012	24	43	19	550.8
1983	26	52	26	803.7	2013	26	43	17	513.8
1984	24	43	19	588.5	2014	26	46	20	409.1
1985	24	41	17	266	2015	24	40	16	204.7
1986	24	44	20	293.8	2016	24	40	16	560
1987	26	50	24	437.6	2017	23	47	24	776.4
1988	24	40	16	554.7	2018	23	44	21	293.2
1989	25	52	27	554.9	2019	25	45	20	571
1990	23	46	23	662.4					

Table 4.22 cont…

	Mean week of start of rainfall					Mean week of end of rainfall			
	Start	**Early**	**Late**	**SD**		**End**	**Early**	**Late**	**SD**
MW	25	23	27	1.1	**MW**	45	39	52	3.3
Period	18-06 to 24-06	04-06 to 10-06	02-07 to 08-07		**Period**	05-11 to 11-11	24-09 to 30-09	24-12 to 31-12	
	Mean duration					**Mean rainfall**			
	Dur.	**Min.**	**Max.**	**SD**		**Avg**	**Min**	**Max**	**SD**
Total	20	14	28	3.3	**Rainfall**	583.2	147.4	1138.7	201.5
Days	140	98	196						

season was found to be 20 weeks (140 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4–10 June) and 27 MW (2–8 July) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 39 MW (24–30 September) and 52 MW (2 –31 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 29 and 12 weeks respectively. Probability occurrence of onset of monsoon in 25 MW is 19% which is observed for 11 years when 59 years of data is considered. But when we considered 24 (11-17 June) and 25 MW (18 June – 24 June) Probability occurrence of onset of monsoon is 59% which is observed for 35 years out of total 59 years. Hence from 11 June – 24 June there are maximum chances of onset of monsoon during this period in Barshi tehsil.

Hence we can suggest sowing of kharif crops like pearl millet, sunflower in the 24 (11-17 June) and 25 MW (18 June – 24 June). Based on the 140 days duration of monsoon season long season crop like pigeon pea can also be sown in this period. To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram and cowpea should be sown in this period for good germination. The land preparation operation should be carried out in summer by utilising premonsoon shower rain. Conserve excess moisture during the monsoon season which can be utilise during critical growth stages of field crops and for production of *rabi* crops with the help of different *in-situ* soil moisture conservation techniques.

4.4.3 Onset and Withdrawal of Monsoon for Karmala Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in Karmala is given in Table 4.23. From the analysis of 59 years (1961 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon was 25 standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 45 MW (*i.e.,* 5 November – 11 November). Therefore, mean length of rainy season was found to be 20 weeks (140 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4–10 June)

and 36 MW (3–9 September) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 37 MW (10–16 September) and 52 MW (24–31 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 29 and 01 weeks respectively. Probability occurrence of onset of monsoon in 25 MW is 10% which is observed for 06 years when 59 years of data is considered. But when we considered 23 (4–10 June) and 25 MW (18 June – 24 June) Probability occurrence of onset of monsoon is 59%, which is observed for 35 years out of total 59 years. Hence from 4 June – 24 June there are maximum chances of onset of monsoon during this period in Karmala tehsil.

Hence we can suggest sowing of *kharif* crops such as pearl millet, pigeon pea in the 23 (4–10 June) and 25 MW (18 June – 24 June). To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram should be sown in this period to

Table 4.23: Mean week of onset and withdrawal of rainfall in Karmala tehsil

Karmala									
Year	**Start**	**End**	**Duration**	**Rainfall**	**Year**	**Start**	**End**	**Duration**	**Rainfall**
1961	24	45	21	480.2	1991	23	42	19	427.9
1962	23	44	21	580.2	1992	23	47	24	428.6
1963	23	46	23	747.2	1993	26	49	23	713.8
1964	26	46	20	590	1994	28	46	18	236.8
1965	26	50	24	334.8	1995	29	47	18	451.6
1966	23	42	19	523.4	1996	27	44	17	472.3
1967	28	50	22	454.4	1997	26	49	23	336.7
1968	24	45	21	386	1998	24	44	20	1187
1969	23	45	22	703.5	1999	24	43	19	509.6
1970	24	41	17	708.6	2000	23	42	19	920.5
1971	25	43	18	421.5	2001	29	41	12	493.7
1972	36	44	8	174	2002	24	37	13	231.5
1973	23	43	20	802.4	2003	28	52	24	192.9
1974	26	43	17	507.8	2004	23	46	23	567.4
1975	27	44	17	564	2005	27	42	15	525.4
1976	23	45	22	420.1	2006	25	45	20	456.3
1977	25	48	23	515.2	2007	25	40	15	300.7
1978	24	45	21	616.6	2008	30	47	17	699.5
1979	30	48	18	575.2	2009	25	46	21	622.8
1980	23	52	29	509.4	2010	24	43	19	923.9
1981	23	46	23	699.2	2011	27	41	14	502.5
1982	23	45	22	639.2	2012	26	41	15	233.6
1983	24	41	17	1113.8	2013	26	42	16	441.6
1984	24	45	21	480.7	2014	23	47	24	422.5
1985	29	41	12	294	2015	23	47	24	288.5
1986	23	45	22	445.7	2016	23	40	17	413.9
1987	26	50	24	707.7	2017	24	42	18	554.7
1988	26	50	24	495.7	2018	25	47	22	114.3
1989	26	50	24	534.8	2019	26	45	19	446.4
1990	23	47	24	636.8					

Table 4.23 cont…

	Mean week of start of rainfall					Mean week of end of rainfall			
	Start	**Early**	**Late**	**SD**		**End**	**Early**	**Late**	**SD**
MW	25	23	36	2.5	**MW**	45	37	52	3.2
Period	18-06 to 24-06	04-06 to 10-06	03-09 to 09-09		**Period**	05-11 to 11-11	10-09 to 16-09	24-12 to 31-12	
	Mean duration					**Mean rainfall**			
	Dur.	**Min.**	**Max.**	**SD**		**Avg**	**Min**	**Max**	**SD**
Total	20	8	29	3.8	**Rainfall**	521.7	114.3	1187	207.4
Days	140	56	203						

utilise maximum moisture for good germination. The land preparation operation should be carried out in summer by utilizing premonsoon shower rain. Conserve excess moisture during the monsoon season which can be utilise during critical growth stages of field crops and for production of *rabi* crops with the help of different *in-situ* soil moisture conservation techniques.

4.4.4 Onset and Withdrawal of Monsoon for Madha Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in Madha is given in Table 4.24. From the analysis of 59 years (1961 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon was 25 standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 45 MW (*i.e.,* 5 November – 11 November). Therefore, mean length of rainy season was found to be 20 weeks (140 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4–10 June) and 36 MW (3–9 September) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 38 MW (17–23 September) and 52 MW (24–31 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 29 and 02 weeks respectively. Probability occurrence of onset of monsoon in 25 MW is 24% which is observed for 14 years when 59 years of data is considered. But when we considered 24 (11-17 June) and 25 MW (18 June – 24 June) Probability occurrence of onset of monsoon is 56%, which is observed for 33 years out of total 59 years. Hence from 11 June – 24 June there are maximum chances of onset of monsoon during this period in Madha tehsil.

Hence we can suggest sowing of kharif crops like pearl millet, sunflower in the 24 (11-17 June) and 25 MW (18 June – 24 June). Based on the 140 days duration of monsoon season long season crop like pigeon pea can also be sown in this period. To take the advantage of *rabi* season crop (crop like *rabi* sorghum) sowing of short duration crop like green gram, black gram should be taken in this period to utilise maximum moisture for good germination. The land preparation operation should be carried out in summer by utilizing premonsoon shower rain 3-4

weeks before sowing. Conserve excess moisture during the monsoon season which can be utilise during critical growth stages of field crops and for production of *rabi* crops.

Table 4.24: Mean week of onset and withdrawal of rainfall in Madha tehsil

Madha									
Year	**Start**	**End**	**Duration**	**Rainfall**	**Year**	**Start**	**End**	**Duration**	**Rainfall**
1961	25	48	23	378.3	1991	23	40	17	373.3
1962	23	49	26	633.7	1992	25	47	22	634.9
1963	23	38	15	440.4	1993	26	49	23	996.9
1964	25	46	21	905.7	1994	23	46	23	399.1
1965	25	50	25	421.9	1995	26	47	21	704
1966	23	46	23	613.1	1996	24	45	21	760.6
1967	28	41	13	507	1997	26	49	23	482.2
1968	23	45	22	535.5	1998	24	45	21	1086.6
1969	26	48	22	551.6	1999	24	42	18	524.2
1970	26	41	15	421.3	2000	23	52	29	604.4
1971	25	43	18	510.5	2001	30	45	15	388
1972	36	44	8	225	2002	24	46	22	351.6
1973	26	46	20	755.3	2003	25	44	19	283
1974	24	43	19	631.6	2004	27	40	13	395.8
1975	30	44	14	638.8	2005	26	42	16	579.8
1976	25	47	22	303.2	2006	25	45	20	443
1977	25	48	23	346.1	2007	24	41	17	623.2
1978	28	41	13	383.4	2008	30	47	17	627.2
1979	24	44	20	824.3	2009	25	46	21	618.3
1980	24	51	27	338.5	2010	24	46	22	1150.9
1981	23	46	23	509.5	2011	27	42	15	306.9
1982	25	45	20	394.8	2012	23	44	21	444.5
1983	24	44	20	885.3	2013	23	43	20	590.4
1984	28	52	24	437.7	2014	28	46	18	348.8
1985	26	45	19	266.4	2015	23	47	24	301.5
1986	23	52	29	486.9	2016	23	41	18	532.2
1987	26	50	24	654.6	2017	23	42	19	613.6
1988	23	40	17	1004	2018	25	47	22	149.7
1989	25	39	14	667	2019	25	45	20	474.6
1990	23	43	20	698					
	Mean week of start of rainfall					**Mean week of end of rainfall**			
	Start	**Early**	**Late**	**SD**		**End**	**Early**	**Late**	**SD**
MW	25	23	36	2.4	**MW**	45	38	52	3.3
Period	18-06 to 24-06	04-06 to 10-06	03-09 to 09-09		**Period**	05-11 to 11-11	17-09 to 23-09	24-12 to 31-12	
	Mean duration					**Mean rainfall**			
	Dur.	**Min.**	**Max.**	**SD**		**Avg**	**Min**	**Max**	**SD**
Total	20	8	29	4.1	**Rainfall**	545.1	149.7	1150.9	213.1
Days	140	56	203						

4.4.5: Onset and Withdrawal of Monsoon for Malshiras Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in Malshiras is given in Table 4.25. From the analysis of 59 years (1961 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon

Table 4.25: Mean week of onset and withdrawal of rainfall in Malshiras tehsil.

Malshiras									
Year	**Start**	**End**	**Duration**	**Rainfall**	**Year**	**Start**	**End**	**Duration**	**Rainfall**
1961	23	51	28	316.3	1991	23	46	23	518.5
1962	23	49	26	544.3	1992	23	41	18	322
1963	23	43	20	430.5	1993	23	49	26	950.4
1964	28	46	18	661.9	1994	24	46	22	355.5
1965	23	45	22	902.5	1995	25	43	18	613.5
1966	28	50	22	297.8	1996	24	43	19	1211
1967	23	45	22	404.1	1997	24	49	25	484
1968	27	45	18	504	1998	23	44	21	1664
1969	23	45	22	840.1	1999	24	42	18	1288.5
1970	24	41	17	392	2000	28	42	14	188
1971	25	43	18	329.7	2001	32	42	10	355.4
1972	36	44	8	130.9	2002	24	46	22	310
1973	26	44	18	648.1	2003	29	39	10	69
1974	26	43	17	724.1	2004	23	40	17	394.5
1975	28	44	16	769	2005	28	42	14	272
1976	23	47	24	302.8	2006	25	45	20	530.3
1977	23	48	25	558	2007	23	39	16	658.1
1978	24	48	24	504.4	2008	31	47	16	573.4
1979	23	45	22	597.6	2009	24	51	27	850.4
1980	24	51	27	390.5	2010	23	47	24	730.3
1981	23	44	21	673.2	2011	27	42	15	388.8
1982	23	45	22	291.6	2012	23	43	20	402.9
1983	23	39	16	465.9	2013	24	43	19	405.9
1984	29	49	20	402.4	2014	26	50	24	353.3
1985	24	40	16	260.6	2015	24	40	16	207.6
1986	26	45	19	248.5	2016	23	40	17	423.6
1987	26	50	24	523.4	2017	24	42	18	501.9
1988	24	40	16	548.7	2018	25	47	22	156.9
1989	25	40	15	551	2019	26	45	19	507.5
1990	24	47	23	440.4					
	Mean week of start of rainfall					**Mean week of end of rainfall**			
	Start	**Early**	**Late**	**SD**		**End**	**Early**	**Late**	**SD**
MW	25	23	36	2.6	**MW**	45	39	51	3.4
Period	18-06 to 24-06	04-06 to 10-06	03-09 to 09-09		**Period**	05-11 to 11-11	24-09 to 30-09	17-12 to 23-12	
	Mean duration					**Mean rainfall**			
	Dur.	**Min.**	**Max.**	**SD**		**Avg**	**Min**	**Max**	**SD**
Total	20	8	28	4.3	**Rainfall**	514.3	69	1664	281.7
Days	140	56	196						

was 25 standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 45 MW (*i.e.,* 5 November – 11 November). Therefore, mean length of rainy season was found to be 20 weeks (140 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4–10 June) and 36 MW (3–9 September) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 39 MW (24–30 September) and 51 MW (17–23 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 28 and 03 weeks respectively. Probability occurrence of onset of monsoon in 25 MW is 08% which is observed for 05 years when 59 years of data is considered. But when we considered 23 MW (4–10 June) and 25 MW (18 June – 24 June) Probability occurrence of onset of monsoon is 69%, which is observed for 41 years out of total 59 years. Hence from 4 June – 24 June there are maximum chances of onset of monsoon during this period in Malshiras tehsil.

Hence we can suggest sowing of *kharif* crops such as pearl millet, maize in the 24 (11-17 June) and 25 MW (18 June – 24 June). Based on the 140 days duration of monsoon season long season crop like pigeon pea can also be sown in this period. To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram and cowpea should be taken in this period to utilise maximum moisture for good germination. The land preparation operation should be carried out in summer by utilizing premonsoon shower rain. Conserve excess moisture during the monsoon season which can be utilise during critical growth stages of field crops and for production of *rabi* crops with the help of different *in-situ* soil moisture conservation techniques.

4.4.6 Onset and Withdrawal of Monsoon for Mangalwedha Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in Mangalwedha is given in Table 4.26. From the analysis of 59 years (1961 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon was 26 standard meteorological week (MW) (*i.e.,* 25 June – 01 July) and mean week of withdrawal is 48 MW (*i.e.,* 26 November – 02 December). Therefore, mean length of rainy season was found to be 22 weeks (154 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4–10 June) and 35 MW (27 August – 02 September) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 42 MW (15–21 October) and 52 MW (24–31 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 29 and 07 weeks respectively. Probability occurrence of onset of monsoon in 26 MW (25 June – 01 July) is 14 % which is observed for 08 years when 59 years of data is considered. But when we considered 24 (11-17 June) and 26 MW (25 June – 01 July) Probability occurrence of onset of monsoon is 53 %,

which is observed for 31 years out of total 59 years. Hence from 11 June – 01 July there are maximum chances of onset of monsoon during this period in Mangalwedha tehsil.

Table 4.26: Mean week of onset and withdrawal of rainfall in Mangalwedha tehsil

Mangalwedha									
Year	**Start**	**End**	**Duration**	**Rainfall**	**Year**	**Start**	**End**	**Duration**	**Rainfall**
1961	25	49	24	403.6	1991	26	46	20	191.8
1962	28	49	21	334.5	1992	24	49	25	208
1963	26	44	18	525.6	1993	30	49	19	462.1
1964	23	50	27	605.9	1994	35	49	14	138
1965	28	49	21	551.8	1995	26	49	23	459.9
1966	26	49	23	347.7	1996	28	49	21	519
1967	27	50	23	537.9	1997	31	48	17	259
1968	24	49	25	650.2	1998	24	50	26	647.7
1969	26	43	17	564	1999	25	49	24	379.9
1970	29	49	20	522.8	2000	32	49	17	289.8
1971	25	50	25	420	2001	28	45	17	427.6
1972	29	45	16	80.8	2002	24	45	21	380.3
1973	26	43	17	165.4	2003	25	45	20	327.3
1974	26	45	19	570.8	2004	23	49	26	579.8
1975	23	49	26	909.8	2005	29	42	13	573.3
1976	24	47	23	349.1	2006	24	49	25	613.3
1977	24	48	24	221.8	2007	24	49	25	849.3
1978	24	50	26	428.4	2008	23	50	27	472.6
1979	24	49	25	545	2009	25	50	25	584.1
1980	31	49	18	295.1	2010	24	49	25	547.4
1981	23	50	27	722.8	2011	23	45	22	227
1982	28	49	21	491.6	2012	23	49	26	334.6
1983	24	52	28	608.5	2013	28	49	21	373.9
1984	29	49	20	520.1	2014	27	50	23	393.7
1985	24	49	25	322	2015	24	49	25	145
1986	32	49	17	315.4	2016	29	46	17	237.5
1987	24	50	26	717.4	2017	24	50	26	428.6
1988	28	50	22	494.6	2018	28	47	19	119.9
1989	26	52	26	587.1	2019	25	45	20	453.2
1990	24	49	25	388.4					
	Mean week of start of rainfall					**Mean week of end of rainfall**			
	Start	**Early**	**Late**	**SD**		**End**	**Early**	**Late**	**SD**
MW	26	23	35	2.7	**MW**	48	42	52	2.2
Period	25-06 to 01-07	04-06 to 10-06	27-08 to 02-09		**Period**	26-11 to 02-12	15-10 to 21-10	24-12 to 31-12	
	Mean duration					**Mean rainfall**			
	Dur.	**Min.**	**Max.**	**SD**		**Avg**	**Min**	**Max**	**SD**
Total	22	13	28	3.7	**Rainfall**	437.7	80.8	909.8	177.1
Days	154	91	196						

Hence we can suggest sowing of *kharif* crops like pearl millet, sunflower in the 24 (11-17 June) and 26 MW (25 June – 01 July). Based on the 22 weeks (154 days) duration of monsoon season long season crop like pigeon pea can also be sown in this period. To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram and cowpea should be taken in this period. *rabi* crop such as *rabi* sorghum, gram, wheat can also be taken due to long duration period of monsoon over Mangalwedha. The land preparation operation should be performed in summer by utilizing premonsoon shower rain. Water harvesting should be carried out by construction of farm pond, constructing bund as well as moisture conservation practices should also be taken to harness excess moisture during the monsoon season which can be utilise during critical growth stages of field crops and for production of *rabi* crops.

4.4.7 Onset and Withdrawal of Monsoon for Mohol Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in Mohol is given in Table 4.27. From the analysis of 59 years (1961 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon was 25 standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 46 MW (*i.e.,* 12 November – 18 November). Therefore, mean length of rainy season was found to be 21 weeks (147 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4–10 June) and 32 MW (06–12 August) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 40 MW (01–07 October) and 52 MW (24–31 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 29 and 08 weeks respectively. Probability occurrence of onset of monsoon in 25 MW is 14% which is observed for 08 years when 59 years of data is considered. But when we considered 24 (11- 17June) and 25 MW (18 June – 24 June) Probability occurrence of onset of monsoon is 51%, which is observed for 30 years out of total 59 years. Hence from 11 June – 24 June there are maximum chances of onset of monsoon during this period in Mohol tehsil.

Hence we can suggest sowing of kharif crops such as maize, pigeon pea in the 24 (11-17 June) and 25 MW (18 June – 24 June). The observed duration of monsoon season is 21 week (141 days) which is good for long season crop like pigeon pea. To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram and should be sown in this period to get good germination. The land preparation operation should be performed in summer by utilizing premonsoon shower rain. Conserve excess moisture during the monsoon season which can be utilise during critical growth stages of field crops and for production of *rabi* crops with the help of different *in-situ* soil moisture conservation techniques.

Table 4.27: Mean week of onset and withdrawal of rainfall in Mohol tehsil

Mohol									
Year	**Start**	**End**	**Duration**	**Rainfall**	**Year**	**Start**	**End**	**Duration**	**Rainfall**
1961	23	45	22	600.1	1991	23	46	23	587.7
1962	27	49	22	540.6	1992	24	47	23	383.3
1963	23	43	20	445.7	1993	27	49	22	503.8
1964	24	46	22	730.2	1994	23	44	21	379.7
1965	26	50	24	372.1	1995	28	47	19	360.3
1966	24	46	22	367.1	1996	24	45	21	739.8
1967	24	50	26	556.2	1997	24	50	26	287.6
1968	25	45	20	454.2	1998	24	44	20	1166.9
1969	23	45	22	860.2	1999	24	42	18	481.8
1970	24	41	17	616.1	2000	24	52	28	493.7
1971	25	43	18	481.9	2001	23	45	22	568.5
1972	24	44	20	232.7	2002	24	42	18	378.7
1973	26	44	18	600.6	2003	28	40	12	180.1
1974	26	43	17	653.5	2004	23	45	22	452.4
1975	28	44	16	717.5	2005	24	42	18	523.9
1976	25	46	21	391.1	2006	24	45	21	598.9
1977	24	49	25	291.6	2007	24	40	16	572.5
1978	25	45	20	579.1	2008	30	47	17	613
1979	27	48	21	511.9	2009	25	46	21	575.1
1980	24	46	22	342.5	2010	24	46	22	964.7
1981	23	46	23	708.9	2011	27	42	15	484.5
1982	24	45	21	301.4	2012	25	43	18	305.8
1983	28	52	24	706	2013	24	43	19	504.6
1984	28	49	21	438.5	2014	27	47	20	343.6
1985	24	44	20	412.9	2015	32	47	15	203.4
1986	24	52	28	442	2016	28	40	12	277
1987	26	50	24	842.6	2017	23	42	19	520.9
1988	25	50	25	723.5	2018	25	47	22	184.2
1989	23	44	21	689.9	2019	26	45	19	528.8
1990	23	44	21	629.1					
	Mean week of start of rainfall					**Mean week of end of rainfall**			
	Start	**Early**	**Late**	**SD**		**End**	**Early**	**Late**	**SD**
MW	25	23	32	1.9	**MW**	46	40	52	3
Period	18-06 to 24-06	04-06 to 10-06	06-08 to 12-08		**Period**	12-11 to 18-11	01-10 to 07-10	24-12 to 31-12	
	Mean duration					**Mean rainfall**			
	Dur.	**Min.**	**Max.**	**SD**		**Avg**	**Min**	**Max**	**SD**
Total	21	12	28	3.3	**Rainfall**	515.3	180.1	1166.9	190.9
Days	147	84	196						

4.4.8 Onset and Withdrawal of Monsoon for Pandharpur Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in Pandharpur is given in Table 4.28. From the analysis of 59 years (1961 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon was 25 standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 45 MW (*i.e.,* 5 November – 11 November). Therefore, mean length of rainy season was found to be 20 weeks (140 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4–10 June) and 34 MW (20–26 August) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 40 MW (01–07 October) and 52 MW (24–31 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 29 and 06 weeks.

Table 4.28: Mean week of onset and withdrawal of rainfall in Pandharpur tehsil

Pandharpur									
Year	**Start**	**End**	**Duration**	**Rainfall**	**Year**	**Start**	**End**	**Duration**	**Rainfall**
1961	25	43	18	468.5	1991	23	40	17	570
1962	25	49	24	722.3	1992	24	41	17	472.9
1963	27	45	18	440.7	1993	26	49	23	592.3
1964	25	45	20	562	1994	26	45	19	168
1965	25	43	18	516.9	1995	26	47	21	457.9
1966	24	50	26	289.1	1996	24	45	21	672.3
1967	28	40	12	296.1	1997	23	49	26	477.1
1968	26	45	19	418	1998	24	45	21	893.6
1969	26	42	16	740.9	1999	24	43	19	362.7
1970	29	41	12	319.6	2000	26	45	19	366.3
1971	25	44	19	499.9	2001	24	42	18	552.8
1972	34	48	14	118.7	2002	23	42	19	416.7
1973	25	46	21	801.5	2003	25	43	18	228.7
1974	26	43	17	1066.5	2004	23	40	17	508.3
1975	30	44	14	983.5	2005	29	42	13	492
1976	23	47	24	459	2006	25	45	20	428.3
1977	24	49	25	598.7	2007	23	41	18	587.9
1978	24	45	21	941	2008	31	47	16	499.7
1979	24	48	24	619.1	2009	25	46	21	713.5
1980	23	50	27	632	2010	24	46	22	704.8
1981	23	45	22	1068	2011	27	41	14	366.7
1982	25	45	20	392	2012	27	43	16	336.4
1983	28	52	24	993.5	2013	23	43	20	571.7
1984	24	52	28	837	2014	27	47	20	368.7
1985	24	40	16	475.5	2015	24	47	23	258.6
1986	23	52	29	573.5	2016	23	44	21	371
1987	23	50	27	1131.9	2017	24	42	18	471.6
1988	23	50	27	1065.5	2018	23	47	24	211.7
1989	23	40	17	851.5	2019	26	45	19	377.1
1990	23	43	20	556.9					

Table 4.28 cont…

	Mean week of start of rainfall					Mean week of end of rainfall			
	Start	**Early**	**Late**	**SD**		**End**	**Early**	**Late**	**SD**
MW	25	23	34	2.3	**MW**	45	40	52	3.3
Period	18-06 to 24-06	04-06 to 10-06	20-08 to 26-08		**Period**	05-11 to 11-11	01-10 to 07-10	24-12 to 31-12	
	Mean duration					**Mean rainfall**			
	Dur	**Min**	**Max**	**SD**		**Avg**	**Min**	**Max**	**SD**
Total	20	12	29	4	**Rainfall**	558.3	118.7	1131.9	241.6
Days	140	84	203						

respectively. Probability occurrence of onset of monsoon in 25 MW is 17% which is observed for 10 years when 59 years of data is considered. But when we considered 24 (11-17 June) and 26 MW (25 June – 01 July) Probability occurrence of onset of monsoon is 54%, which is observed for 32 years out of total 59 years. Hence from 11 June – 01 July there are maximum chances of onset of monsoon during this period in Pandharpur tehsil.

Hence we can suggest sowing of kharif crops like pearl millet in the 24 (11-17 June) and 26 MW (25 June – 01 July). Based on the duration of monsoon season long season crop like pigeon pea can also be sown in this period. To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram should be taken in this period to get good germination. The land preparation operation should be carried out in summer by utilizing premonsoon shower rain. Conserve excess moisture during the monsoon season which can be utilise during critical growth stages of field crops and for production of *rabi* crops with the help of different *in-situ* soil moisture conservation techniques.

4.4.9 Onset and Withdrawal of Monsoon for Sangola Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in Sangola is given in Table 4.29. From the analysis of 59 years (1961 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon was 25 standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 45 MW (*i.e.,* 5 November – 11 November). Therefore, mean length of rainy season was found to be 20 weeks (140 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4 – 10 June) and 34 MW (20– 26 August) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 40 MW (01–07 October) and 52 MW (24–31 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 29 and 06 weeks respectively. Probability occurrence of onset of monsoon in 25 MW is 17% which is observed for 10 years when 59 years of data is

considered. But when we considered 24 (11 - 17 June) and 26 MW (25 June – 01 July) Probability occurrence of onset of monsoon is 51%, which is observed for 30 years out of total 59 years. Hence from 11 June – 01 July there are maximum chances of onset of monsoon during this period in Sangola tehsil.

Table 4.29: Mean week of onset and withdrawal of rainfall in Sangola tehsil

Sangola									
Year	**Start**	**End**	**Duration**	**Rainfall**	**Year**	**Start**	**End**	**Duration**	**Rainfall**
1961	23	45	22	481.4	1991	23	40	17	345.5
1962	23	49	26	511.8	1992	24	47	23	399.2
1963	23	44	21	825.5	1993	23	49	26	769.4
1964	26	44	18	700	1994	32	43	11	185.2
1965	23	47	24	625.9	1995	26	47	21	432.8
1966	26	50	24	430.3	1996	24	43	19	877
1967	24	50	26	618.3	1997	24	49	25	631.2
1968	29	45	16	309.4	1998	25	45	20	1072.8
1969	24	45	21	564.2	1999	24	43	19	632.4
1970	32	41	9	381	2000	24	52	28	471.7
1971	34	42	8	527.9	2001	28	46	18	457.6
1972	27	44	17	234.8	2002	23	42	19	582.5
1973	26	46	20	750	2003	25	41	16	346.4
1974	25	43	18	1131.8	2004	23	40	17	359
1975	27	43	16	1252.2	2005	30	42	12	341
1976	23	47	24	571.7	2006	24	45	21	568
1977	24	48	24	855.7	2007	23	40	17	769.5
1978	24	45	21	855.9	2008	31	47	16	527.1
1979	23	48	25	1181.4	2009	28	46	18	692
1980	24	46	22	541.8	2010	24	45	21	584.9
1981	23	44	21	782.1	2011	27	43	16	308.3
1982	25	45	20	515.6	2012	25	44	19	368.4
1983	28	52	24	443.2	2013	23	43	20	455
1984	25	49	24	656.2	2014	23	50	27	531.2
1985	26	45	19	393.9	2015	23	40	17	274.1
1986	23	45	22	384.6	2016	23	40	17	436.5
1987	26	50	24	684.4	2017	24	42	18	535
1988	25	50	25	751.4	2018	25	47	22	153.6
1989	25	40	15	594.6	2019	25	45	20	446.1
1990	24	47	23	529.4					
	Mean week of start of rainfall					**Mean week of end of rainfall**			
	Start	**Early**	**Late**	**SD**		**End**	**Early**	**Late**	**SD**
MW	25	23	34	2.6	**MW**	45	40	52	3.2
Period	18-06 to 24-06	04-06 to 10-06	06-08 to 12-08		**Period**	12-11 to 18-11	01-10 to 07-10	24-12 to 31-12	
	Mean duration					**Mean rainfall**			
	Dur.	**Min.**	**Max.**	**SD**		**Avg**	**Min**	**Max**	**SD**
Total	20	8	28	4.2	**Rainfall**	570.2	153.6	1252.2	233.4
Days	140	84	196						

Hence we can suggest sowing of *kharif* crops like pearl millet, sunflower, maize in the 24 (11 - 17 June) and 26 MW (25 June – 01 July). Based on the duration of monsoon season long season crop like pigeon pea can also be sown in this period. To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram and cowpea should be taken in this period of *kharif* season. The land preparation operation should be carried out in summer by utilizing premonsoon shower rain. Conserve excess moisture during the monsoon season which can be utilise during critical growth stages of field crops and for production of *rabi* crops with the help of different in-situsoil moisture conservation techniques.

4.4.10 Onset and Withdrawal of Monsoon for North Solapur Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in North Solapur is given in Table 4.30. From the analysis of 22 years (1998 – 2019) weekly rainfall data, it is observed that the mean week of onset of monsoon was 25th standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 44th MW (*i.e.,* 29 October – 04 November). Therefore, mean length of rainy season was found to be 20 weeks (140 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4 – 10 June)

Table 4.30: Mean week of onset and withdrawal of rainfall in North & South Solapur tehsil

North Solapur					South Solapur			
Year	**Start**	**End**	**Duration**	**Rainfall**	**Start**	**End**	**Duration**	**Rainfall**
1998	25	41	16	1150.1	25	42	17	1055.5
1999	33	42	9	193.2	24	42	18	407.7
2000	23	42	19	518.3	23	42	19	539.2
2001	24	41	17	311.4	24	41	17	670.2
2002	23	42	19	347.7	26	42	16	450.5
2003	29	41	12	258	29	39	10	255.4
2004	23	40	17	562	23	40	17	581.8
2005	24	43	19	692.7	24	43	19	692.7
2006	25	45	20	537	25	45	20	537
2007	25	40	15	569.1	25	40	15	569
2008	30	47	17	643.8	30	47	17	644.4
2009	24	46	22	661.7	24	46	22	661.7
2010	24	46	22	738.2	24	46	22	738.2
2011	27	42	15	582.2	27	42	15	582.2
2012	26	44	18	459.6	26	44	18	452.8
2013	24	44	20	513.7	24	43	19	479.2
2014	27	50	23	448.7	27	50	23	387.4
2015	24	47	23	260.5	27	47	20	201.1
2016	25	40	15	511	23	40	17	528.8
2017	23	49	26	416.1	23	42	19	454.2
2018	23	47	24	229	25	47	22	217.6
2019	25	45	20	597.9	23	45	22	642.5

Table 4.30 cont…

	North Solapur				South Solapur			
	Mean week of start of rainfall				**Mean week of start of rainfall**			
	Start	**Early**	**Late**	**SD**	**Start**	**Early**	**Late**	**SD**
MW	25	23	33	2.6	25	23	30	2
Period	18-06 to 24-06	04-06 to 10-06	13-08 to 19-08		18-06 to 24-06	04-06 to 10-06	23-07 to 29-07	
	Mean week of end of rainfall				**Mean week of end of rainfall**			
	End	**Early**	**Late**	**SD**	**End**	**Early**	**Late**	**SD**
MW	44	40	50	3	43	39	50	2.9
Period	29-10 to 04-11	01-10 to 07-11	10-12 to 16-12		22-10 to 28-10	24-09 to 30-09	10-12 to 16-12	
	Mean duration				**Mean duration**			
	Duratio	**Min**	**Max**	**SD**	**Duratio**	**Min**	**Max**	**SD**
Total	19	9	26	4	18	10	23	3
Days	133	72	182		126	70	161	
	Mean rainfall				**Mean rainfall**			
	Avg	**Min**	**Max**	**SD**	**Avg**	**Min**	**Max**	**SD**
Rainfall	509.2	193.2	1150.1	211.8	534	201.1	1055.5	189.3

and 27 MW (2–8 July) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 40 MW (01–07 October) and 50 MW (10–16 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 29 and 12 weeks respectively. Probability occurrence of onset of monsoon in 25 MW is 23% which is observed for 05 years when 22 years of data is considered. But when we considered 24 (11-17 June) and 25 MW (18 June – 24 June) Probability occurrence of onset of monsoon is 50%, which is observed for 11 years out of total 22 years. Hence from 11 June – 24 June there are maximum chances of onset of monsoon during this period in North Solapur tehsil.

Hence we can suggest sowing of *kharif* crops like green gram, black gram, pigeon pea, sunflower, maize in the 24 (11 - 17 June) and 25 MW (18 June – 24 June). To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram and cowpea should be taken in this period. Monocropping of *rabi* Sorghum is generally practiced in North Solapur. The land preparation operation should be performed in summer by utilizing premonsoon shower rain. Conserve excess moisture during the monsoon season. So that it can be utilise during critical growth stages of field crops and for production of *rabi* crops as duration of monsoon over North Solapur is less (19 weeks) as compared to other tehsils of Solapur district except South Solapur.

4.4.11 Onset and Withdrawal of Monsoon for South Solapur Tehsil

The onset, withdrawal and duration of the rainy season (difference between onset and withdrawal time) and its variability in South Solapur is given in Table 4.30. From the analysis of 22 years (1998 – 2019) weekly rainfall data, it is observed that the mean week of onset of

monsoon was 25th standard meteorological week (MW) (*i.e.,* 18 June – 24 June) and mean week of withdrawal is 43rd MW (*i.e.,* 20 October – 28 October). Therefore, mean length of rainy season was found to be 18 weeks (126 days) which include rainfall of both south west and north east monsoon. The earliest and delayed week of onset of rainy season was 23 MW (4–10 June) and 30 MW (23–29 July) respectively. Similarly the earliest and delayed week of withdrawal of rainy season was 39 MW (24–30 September) and 50 MW (10–16 December) respectively. The longest (subtraction of earliest rainy season and delayed withdrawal of rainy week) and shortest length of rainy season was found as 27 and 09 weeks respectively. Probability occurrence of onset of monsoon in 25 MW is 18% which is observed for 04 years when 22 years of data is considered. But when we considered 24 (11-17 June) and 26 MW (25 June – 01 July) Probability occurrence of onset of monsoon is 55%, which is observed for 12 years out of total 22 years.

Hence from 11 June – 01 July there are maximum chances of onset of monsoon during this period in South Solapur tehsil. Hence we can suggest sowing of *kharif* crops like pearl millet, pigeon pea in the 24 (11-17 June) and 26 MW (25 June – 01 July). To take the advantage of *rabi* season sowing of short duration crop like green gram, black gram should be taken in this period. The land preparation operation should be performed in summer by utilizing premonsoon shower rain. Conserve excess moisture during the monsoon season. So that it can be utilise during critical growth stages of field crops and for production of *rabi* crops as duration of monsoon over South Solapur is less (18 weeks) as compared to other tehsils of Solapur district. Similar results were found by Jadhav *et al.,* (2016) and Joshi (2019).

4.5 Markov-Chain Initial, Conditional and Consecutive Probabilities of Dry and Wet Weeks

The initial, conditional and consecutive probability of a week being dry or wet is useful in crop management planning as well as deciding contingent measures to be carried out to overcome the adverse effect of dry spells on crop productivity. The initial, conditional and consecutive probability of dry and wet week at threshold limit 20 mm of rainfall during the crop growth period (MW 23 to 42) is calculated for different tehsils of Solapur district using 'Weather Cock' software developed by CRIDA, Hyderabad and the results are presented in table 4.31 to 4.41 for all the 1 to 52 Standard Meteorological Weeks. Considering the period of rainy season *i.e.,* onset in the second week of June and withdrawal during the second week of October (23 MW – 41 MW) and the crop growth period of major *kharif* crops in different tehsils of Solapur district, the results obtained are discussed for this period in following sections.

4.5.1 Probability Distribution of Akkalkot Tehsil

The initial, conditional and consecutive dry and wet week probability observed in Akkalkot tehsil during crop growth period (MW 23 to 41) is given in table 4.31.

Table 4.31: Dry and wet week probability during crop growth period in Akkalkot tehsil

Akkalkot												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	100	100	0	97	95	95	0	0	0
2	3	97	0	0	97	3	95	95	95	0	0	0
3	2	98	0	100	98	2	98	98	97	0	0	0
4	0	100	0	100	100	0	100	98	98	0	0	0
5	0	100	0	0	100	0	98	98	98	0	0	0
6	2	98	0	0	98	2	98	98	98	0	0	0
7	0	100	0	100	100	0	100	100	98	0	0	0
8	0	100	0	0	100	0	100	98	98	0	0	0
9	0	100	0	0	100	0	98	98	95	0	0	0
10	2	98	0	0	98	2	98	95	95	0	0	0
11	0	100	0	100	100	0	97	97	92	0	0	0
12	3	97	0	0	97	3	97	92	88	0	0	0
13	0	100	0	100	100	0	95	92	87	0	0	0
14	5	95	0	0	95	5	92	87	82	2	0	0
15	5	95	33	67	96	4	90	85	79	0	0	0
16	5	95	0	100	95	5	90	83	82	0	0	0
17	5	95	0	100	95	5	88	87	74	0	0	0
18	7	93	0	100	93	7	92	79	71	2	1	0
19	3	97	25	75	98	2	83	75	62	2	1	0
20	15	85	50	50	86	14	76	63	37	5	1	1
21	14	86	33	67	90	10	71	42	21	3	2	1
22	19	81	25	75	82	18	47	24	14	10	5	2
23	**44**	**56**	**55**	**45**	**58**	**42**	**29**	**17**	**12**	**20**	**9**	**3**
24	**47**	**53**	**46**	**54**	**52**	**48**	**31**	**22**	**13**	**20**	**7**	**3**
25	**42**	**58**	**43**	**57**	**58**	**42**	**41**	**25**	**18**	**14**	**6**	**4**
26	**31**	**69**	**32**	**68**	**71**	**29**	**42**	**31**	**20**	**14**	**8**	**4**
27	**41**	**59**	**44**	**56**	**61**	**39**	**44**	**28**	**13**	**24**	**12**	**7**
28	**39**	**61**	**58**	**42**	**74**	**26**	**39**	**18**	**11**	**20**	**12**	**7**
29	**42**	**58**	**52**	**48**	**64**	**36**	**27**	**16**	**9**	**25**	**15**	**6**
30	**56**	**44**	**60**	**40**	**47**	**53**	**25**	**14**	**8**	**32**	**14**	**5**
31	**51**	**49**	**58**	**42**	**58**	**42**	**27**	**15**	**8**	**22**	**8**	**4**
32	**44**	**56**	**43**	**57**	**55**	**45**	**31**	**17**	**12**	**17**	**8**	**5**
33	**42**	**58**	**38**	**62**	**55**	**45**	**32**	**22**	**16**	**20**	**14**	**9**
34	**46**	**54**	**48**	**52**	**56**	**44**	**37**	**28**	**13**	**31**	**20**	**11**
35	**47**	**53**	**67**	**33**	**69**	**31**	**39**	**19**	**12**	**31**	**16**	**11**
36	**44**	**56**	**64**	**36**	**74**	**26**	**27**	**17**	**10**	**24**	**15**	**9**
37	**53**	**47**	**54**	**46**	**48**	**52**	**31**	**18**	**11**	**34**	**20**	**12**
38	**51**	**49**	**65**	**35**	**64**	**36**	**29**	**18**	**14**	**31**	**18**	**9**
39	**51**	**49**	**60**	**40**	**59**	**41**	**31**	**23**	**21**	**31**	**15**	**6**
40	**49**	**51**	**60**	**40**	**62**	**38**	**39**	**35**	**28**	**24**	**9**	**3**
41	**36**	**64**	**48**	**52**	**77**	**23**	**58**	**47**	**42**	**14**	**5**	**1**
42	20	80	38	62	89	11	64	57	50	7	1	0
43	22	78	33	67	81	19	69	60	56	3	0	0
44	12	88	15	85	89	11	76	70	68	0	0	0
45	12	88	0	100	87	13	81	78	76	3	0	0
46	10	90	29	71	92	8	86	83	80	0	0	0
47	3	97	0	100	96	4	93	90	87	2	1	0
48	5	95	50	50	96	4	92	88	88	2	0	0
49	5	95	33	67	96	4	92	92	90	0	0	0
50	3	97	0	100	96	4	97	95	0	0	0	0
51	0	100	0	100	100	0	98	0	0	0	0	0
52	2	98	0	0	98	2	100	0	0	0	0	0

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 31 to 56 per cent and dry week *i.e.,* P(D) ranges from 44 to 69 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 30-31, 37-39 MWs whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 47 to 77 per cent, 32 to 67 per cent, 23 to 53 per cent and 33 to 68 per cent respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 23-29, 31-36, 38- 41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 26, 28, 35, 36, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks.

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 25 to 58 and 14 to 47 per cent respectively during crop growth period.

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 24-28, 32-35, 37, 39-41 MWs and P(3D) greater than 20 per cent is observed in 24-27, 33-34, 39-41 MWs. The greater probability of being dry weeks was observed in 25, 26, 27, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks. Hence contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 14 to 34 and 5 to 20 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed in 30, 34-35, 37-39 MWs and P(3W) greater than 20 per cent is not observed in any MW. The greater probability of being wet weeks was observed in 30, 34, 37 MWs. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MWs, thus appropriate measures of water harvesting should be carried out in this period in Akkalkot tehsil so that it can be utilised during dry spell.

4.5.2 Probability Distribution of Barshi Tehsil

The initial, conditional and consecutive dry and wet week probability observed in Barshi tehsil during crop growth period (MW 23 to 41) is given in table 4.32.

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 27 to 61 per cent and dry week *i.e.,* P(D) ranges from 39 to 73 per cent. The probability of

Table 4.32: Dry and wet week probability during crop growth period in Barshi tehsil

Barshi												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	0	100	0	100	98	98	0	0	0
2	0	100	0	0	100	0	98	98	98	0	0	0
3	2	98	0	0	98	2	98	98	98	0	0	0
4	0	100	0	100	100	0	100	100	100	0	0	0
5	0	100	0	0	100	0	100	100	100	0	0	0
6	0	100	0	0	100	0	100	100	97	0	0	0
7	0	100	0	0	100	0	100	97	95	0	0	0
8	0	100	0	0	100	0	97	95	95	0	0	0
9	3	97	0	0	97	3	95	95	90	0	0	0
10	2	98	0	100	98	2	98	93	90	0	0	0
11	0	100	0	100	100	0	95	92	90	0	0	0
12	5	95	0	0	95	5	92	90	87	0	0	0
13	3	97	0	100	96	4	95	92	90	0	0	0
14	2	98	0	100	98	2	95	93	90	0	0	0
15	3	97	0	100	97	3	95	92	90	0	0	0
16	2	98	0	100	98	2	95	93	88	0	0	0
17	3	97	0	100	97	3	95	90	84	0	0	0
18	2	98	0	100	98	2	93	87	83	0	0	0
19	5	95	0	100	95	5	88	85	62	0	0	0
20	7	93	0	100	93	7	90	65	43	3	0	0
21	7	93	50	50	96	4	68	45	18	0	0	0
22	25	75	0	100	73	27	49	19	12	19	8	2
23	**44**	**56**	**73**	**27**	**66**	**34**	**22**	**13**	**8**	**19**	**5**	**1**
24	**53**	**47**	**42**	**58**	**39**	**61**	**29**	**17**	**10**	**14**	**4**	**1**
25	**32**	**68**	**26**	**74**	**61**	**39**	**41**	**25**	**16**	**8**	**3**	**2**
26	**36**	**64**	**26**	**74**	**60**	**40**	**39**	**25**	**16**	**12**	**6**	**3**
27	**37**	**63**	**33**	**67**	**61**	**39**	**41**	**26**	**18**	**20**	**10**	**6**
28	**42**	**58**	**55**	**45**	**65**	**35**	**37**	**26**	**19**	**20**	**12**	**8**
29	**41**	**59**	**48**	**52**	**65**	**35**	**41**	**30**	**24**	**24**	**15**	**5**
30	**42**	**58**	**58**	**42**	**69**	**31**	**42**	**34**	**25**	**27**	**10**	**4**
31	**42**	**58**	**64**	**36**	**74**	**26**	**46**	**34**	**22**	**15**	**7**	**3**
32	**27**	**73**	**36**	**64**	**79**	**21**	**54**	**36**	**27**	**12**	**5**	**4**
33	**31**	**69**	**44**	**56**	**74**	**26**	**46**	**35**	**19**	**14**	**10**	**6**
34	**37**	**63**	**44**	**56**	**66**	**34**	**47**	**27**	**16**	**27**	**16**	**10**
35	**42**	**58**	**73**	**27**	**76**	**24**	**32**	**19**	**8**	**25**	**16**	**10**
36	**51**	**49**	**60**	**40**	**56**	**44**	**29**	**12**	**6**	**32**	**21**	**12**
37	**53**	**47**	**63**	**37**	**59**	**41**	**20**	**10**	**6**	**34**	**20**	**8**
38	**61**	**39**	**65**	**35**	**43**	**57**	**19**	**12**	**9**	**36**	**15**	**7**
39	**56**	**44**	**58**	**42**	**48**	**52**	**29**	**22**	**18**	**24**	**10**	**2**
40	**39**	**61**	**42**	**58**	**65**	**35**	**47**	**38**	**35**	**17**	**3**	**1**
41	**31**	**69**	**43**	**57**	**78**	**22**	**56**	**51**	**50**	**5**	**2**	**0**
42	19	81	17	83	80	20	75	73	61	7	0	0
43	14	86	36	64	92	8	85	70	66	0	0	0
44	2	98	0	100	98	2	81	76	73	2	0	0
45	19	81	100	0	83	17	76	73	72	3	0	0
46	8	92	18	82	94	6	88	87	84	0	0	0
47	3	97	0	100	96	4	95	92	90	2	0	0
48	3	97	50	50	98	2	93	92	92	0	0	0
49	3	97	0	100	96	4	95	95	95	0	0	0
50	2	98	0	100	98	2	98	98	0	0	0	0
51	0	100	0	100	100	0	100	0	0	0	0	0
52	0	100	0	0	100	0	0	0	0	0	0	0

wet week *i.e.,* P(W) more than 50 per cent is observed in 24, 36-39 MWs whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 39 to 79 per cent, 26 to 73 per cent, 21 to 61 per cent and 27 to 74 per cent respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 23, 25-37, 40-41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 30-33, 35, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks.

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 19 to 56 and 10 to 51 per cent respectively during crop growth period.

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 25-35, 40-41 MWs and P(3D) greater than 20 per cent is observed in 25-34, 39-41 MWs. The greater probability of being dry weeks was observed in 29-33, 40, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks. Hence contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 5 to 36 and 2 to 21 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed in 36-38 MWs and P(3W) greater than 20 per cent is observed in 36 MW. The greater probability of being wet weeks was observed in 36, 37, 38 MWs. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MWs, thus appropriate measures of water harvesting should be carried out in this period in Barshi tehsil so that it can be utilised during dry spell.

4.5.3 Probability Distribution of Karmala Tehsil

The initial, conditional and consecutive dry and wet week probability observed in Karmala tehsil during crop growth period (MW 23rd to 41st) is given in table 4.33.

From table it is observed that the initial probability of getting wet week *i.e.,* P(W) ranges from 19 to 58 per cent and dry week *i.e.,* P(D) ranges from 42 to 81 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 38-39 MWs whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

Table 4.33: Dry and wet week probability during crop growth period in Karmala tehsil

Karmala												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	0	100	0	100	98	98	0	0	0
2	0	100	0	0	100	0	98	98	97	0	0	0
3	2	98	0	0	98	2	98	97	97	0	0	0
4	0	100	0	100	100	0	98	98	98	0	0	0
5	2	98	0	0	98	2	98	98	98	0	0	0
6	0	100	0	100	100	0	100	100	98	0	0	0
7	0	100	0	0	100	0	100	98	98	0	0	0
8	0	100	0	0	100	0	98	98	97	0	0	0
9	2	98	0	0	98	2	98	97	97	0	0	0
10	0	100	0	100	100	0	98	98	98	0	0	0
11	2	98	0	0	98	2	98	98	97	0	0	0
12	0	100	0	100	100	0	100	98	95	0	0	0
13	0	100	0	0	100	0	98	95	93	0	0	0
14	2	98	0	0	98	2	95	93	93	0	0	0
15	3	97	0	100	97	3	95	95	92	0	0	0
16	2	98	0	100	98	2	98	95	90	0	0	0
17	0	100	0	100	100	0	97	92	85	0	0	0
18	3	97	0	0	97	3	92	85	79	0	0	0
19	5	95	0	100	95	5	88	81	61	3	2	0
20	10	90	67	33	93	7	83	62	40	5	1	0
21	12	88	50	50	92	8	66	43	26	2	1	1
22	24	76	14	86	75	25	49	30	22	15	8	2
23	**42**	**58**	**64**	**36**	**64**	**36**	**36**	**26**	**20**	**22**	**6**	**2**
24	**44**	**56**	**52**	**48**	**62**	**38**	**41**	**31**	**23**	**12**	**4**	**1**
25	**27**	**73**	**27**	**73**	**73**	**27**	**56**	**40**	**28**	**10**	**3**	**1**
26	**27**	**73**	**38**	**63**	**77**	**23**	**53**	**36**	**24**	**8**	**3**	**1**
27	**29**	**71**	**31**	**69**	**72**	**28**	**49**	**33**	**25**	**10**	**3**	**1**
28	**32**	**68**	**35**	**65**	**69**	**31**	**46**	**34**	**25**	**10**	**4**	**2**
29	**32**	**68**	**32**	**68**	**68**	**33**	**51**	**37**	**30**	**14**	**6**	**2**
30	**31**	**69**	**42**	**58**	**75**	**25**	**51**	**41**	**39**	**14**	**5**	**3**
31	**32**	**68**	**44**	**56**	**73**	**27**	**54**	**52**	**36**	**12**	**7**	**2**
32	**25**	**75**	**37**	**63**	**80**	**20**	**71**	**49**	**33**	**15**	**4**	**3**
33	**19**	**81**	**60**	**40**	**95**	**5**	**56**	**38**	**26**	**5**	**3**	**2**
34	**31**	**69**	**27**	**73**	**69**	**31**	**47**	**33**	**20**	**19**	**9**	**6**
35	**41**	**59**	**61**	**39**	**68**	**32**	**41**	**25**	**10**	**20**	**12**	**7**
36	**39**	**61**	**50**	**50**	**69**	**31**	**37**	**14**	**9**	**24**	**13**	**8**
37	**47**	**53**	**61**	**39**	**61**	**39**	**20**	**12**	**8**	**25**	**16**	**7**
38	**58**	**42**	**54**	**46**	**39**	**61**	**25**	**17**	**13**	**36**	**15**	**7**
39	**53**	**47**	**62**	**38**	**60**	**40**	**32**	**24**	**20**	**22**	**10**	**4**
40	**37**	**63**	**42**	**58**	**68**	**32**	**47**	**39**	**33**	**17**	**6**	**2**
41	**32**	**68**	**45**	**55**	**76**	**24**	**56**	**47**	**44**	**12**	**4**	**1**
42	24	76	37	63	83	18	64	60	56	8	1	0
43	20	80	36	64	84	16	75	69	60	3	1	0
44	8	92	17	83	94	6	85	74	72	2	0	0
45	8	92	20	80	93	7	80	78	77	0	0	0
46	12	88	0	100	87	13	86	85	83	2	1	0
47	3	97	14	86	98	2	95	93	87	2	0	0
48	3	97	50	50	98	2	95	88	88	0	0	0
49	2	98	0	100	98	2	92	92	92	0	0	0
50	7	93	0	100	93	7	93	93	0	0	0	0
51	0	100	0	100	100	0	100	0	0	0	0	0
52	0	100	0	0	100	0	0	0	0	0	0	0

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 39 to 95 per cent, 27 to 64 per cent, 5 to 61 per cent and 36 to 73 per cent respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 23-37, 39-41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 25-27, 30-33, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks.

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 20 to 71and 12 to 52 per cent respectively during crop growth period.

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 23-36, 39-41 MWs and P(3D) greater than 20 per cent is observed in 23-35, 39-41 MWs. The greater probability of being dry weeks was observed in 25, 26, 29-34, 40, 41 MWs. The probability of dry condition is at peak for karmala station, So there will be more moisture stress to crops in *kharif* season during these weeks. Hence stringent contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 5 to 36 and 3 to 16 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed only in 38 MW and P(3W) greater than 20 per cent is not observed in any MW. The greater probability of being wet weeks was observed in 37, 38 MWs. So, there will be less moisture stress to crops in *kharif* season during these two weeks. The more chances of water harvesting are likely to get in these two MWs, thus appropriate measures of water harvesting should be carried out in this period in Karmala tehsil so that it can be utilised during the large dry spell.

4.5.4 Probability Distribution of Madha Tehsil

The initial, conditional and consecutive dry and wet week probability observed in Madha tehsil during crop growth period (MW 23 to 41) is given in table 4.34.

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 22 to 68 per cent and dry week *i.e.,* P(D) ranges from 32 to 78 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 38-40 MWs, whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another

Table 4.34: Dry and wet week probability during crop growth period in Madha tehsil

Madha												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	100	100	0	98	95	95	0	0	0
2	2	98	0	0	98	2	95	95	95	0	0	0
3	3	97	0	100	97	3	97	97	97	0	0	0
4	0	100	0	100	100	0	100	100	98	0	0	0
5	0	100	0	0	100	0	100	98	98	0	0	0
6	0	100	0	0	100	0	98	98	97	0	0	0
7	2	98	0	0	98	2	98	97	97	0	0	0
8	0	100	0	100	100	0	98	98	98	0	0	0
9	2	98	0	0	98	2	98	98	97	0	0	0
10	0	100	0	100	100	0	100	98	98	0	0	0
11	0	100	0	0	100	0	98	98	95	0	0	0
12	2	98	0	0	98	2	98	95	88	0	0	0
13	0	100	0	100	100	0	97	90	88	0	0	0
14	3	97	0	0	97	3	90	88	88	0	0	0
15	7	93	0	100	93	7	92	92	90	0	0	0
16	2	98	0	100	98	2	98	97	90	0	0	0
17	0	100	0	100	100	0	98	92	88	0	0	0
18	2	98	0	0	98	2	92	88	82	0	0	0
19	7	93	0	100	93	7	90	84	64	0	0	0
20	3	97	0	100	96	4	90	69	37	0	0	0
21	7	93	0	100	93	7	71	39	30	0	0	0
22	22	78	0	100	76	24	42	33	22	8	4	1
23	**44**	**56**	**38**	**62**	**54**	**46**	**44**	**29**	**20**	**20**	**3**	**1**
24	**32**	**68**	**46**	**54**	**79**	**21**	**44**	**30**	**24**	**5**	**2**	**1**
25	**29**	**71**	**16**	**84**	**65**	**35**	**49**	**39**	**26**	**12**	**4**	**1**
26	**34**	**66**	**41**	**59**	**69**	**31**	**53**	**35**	**28**	**10**	**3**	**1**
27	**24**	**76**	**30**	**70**	**79**	**21**	**51**	**41**	**27**	**7**	**3**	**1**
28	**32**	**68**	**29**	**71**	**67**	**33**	**54**	**37**	**31**	**14**	**7**	**4**
29	**27**	**73**	**42**	**58**	**80**	**20**	**49**	**41**	**32**	**14**	**8**	**3**
30	**37**	**63**	**50**	**50**	**67**	**33**	**53**	**41**	**34**	**22**	**9**	**3**
31	**32**	**68**	**59**	**41**	**84**	**16**	**53**	**44**	**30**	**14**	**5**	**2**
32	**29**	**71**	**42**	**58**	**78**	**23**	**59**	**40**	**30**	**10**	**4**	**3**
33	**22**	**78**	**35**	**65**	**83**	**17**	**53**	**39**	**27**	**8**	**6**	**3**
34	**34**	**66**	**38**	**62**	**67**	**33**	**49**	**34**	**21**	**24**	**14**	**7**
35	**41**	**59**	**70**	**30**	**74**	**26**	**41**	**25**	**9**	**24**	**12**	**9**
36	**42**	**58**	**58**	**42**	**69**	**31**	**36**	**13**	**7**	**22**	**16**	**10**
37	**44**	**56**	**52**	**48**	**62**	**38**	**20**	**12**	**9**	**32**	**19**	**14**
38	**68**	**32**	**73**	**27**	**36**	**64**	**19**	**14**	**10**	**41**	**29**	**13**
39	**54**	**46**	**60**	**40**	**58**	**42**	**34**	**23**	**18**	**39**	**17**	**8**
40	**51**	**49**	**72**	**28**	**74**	**26**	**34**	**27**	**22**	**22**	**10**	**3**
41	**37**	**63**	**43**	**57**	**69**	**31**	**49**	**41**	**39**	**17**	**5**	**1**
42	31	69	45	55	78	22	58	55	46	8	2	0
43	20	80	28	72	83	17	76	64	60	5	0	0
44	8	92	25	75	96	4	76	72	65	0	0	0
45	15	85	0	100	83	17	80	72	70	2	0	0
46	7	93	11	89	94	6	85	82	80	0	0	0
47	8	92	0	100	91	9	88	87	84	0	0	0
48	3	97	0	100	96	4	95	92	92	0	0	0
49	2	98	0	100	98	2	95	95	93	0	0	0
50	3	97	0	100	97	3	97	95	0	0	0	0
51	0	100	0	100	100	0	98	0	0	0	0	0
52	2	98	0	0	98	2	0	0	0	0	0	0

Dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 36 to 84 per cent, 16 to 73 per cent, 16 to 64 per cent and 27 to 84 per cent respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 23-37, 39-41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 24, 27, 29, 31-33, 35, 40 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks.

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 19 to 59 and 12 to 44 per cent respectively during crop growth period.

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 23-36, 39-41 MWs and P(3D) greater than 20 per cent is observed in 23-35, 39-41 MWs. The greater probability of being dry weeks was observed in 26-28, 30-33 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks. Hence contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 5 to 41 and 2 to 29 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed in 38-39 MWs and P(3W) greater than 20 per cent is observed only in 38 MW. The greater probability of being wet weeks was observed in 38, 39 MWs. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MWs, thus appropriate measures of water harvesting should be carried out in this period in Madha tehsil so that it can be utilised during dry spell.

4.5.5 Probability Distribution of Malshiras Tehsil

The initial, conditional and consecutive dry and wet week probability observed in Malshiras tehsil during crop growth period (MW 23 to 41) is given in table 4.35.

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 17 to 63 per cent and dry week *i.e.,* P(D) ranges from 37 to 83 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 23, 38-39 MWs, whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 35 to 81 per cent, 8 to 74 per cent, 17 to 65 per cent and 26 to 92 per cent respectively.

Table 4.35: Dry and wet week probability during crop growth period in Malshiras tehsil

Malshiras												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	0	100	0	98	98	98	0	0	0
2	2	98	0	0	98	2	98	98	98	2	0	0
3	2	98	100	0	100	0	98	98	98	0	0	0
4	0	100	0	100	100	0	100	100	100	0	0	0
5	0	100	0	0	100	0	100	100	100	0	0	0
6	0	100	0	0	100	0	100	100	100	0	0	0
7	0	100	0	0	100	0	100	100	100	0	0	0
8	0	100	0	0	100	0	100	100	100	0	0	0
9	0	100	0	0	100	0	100	100	100	0	0	0
10	0	100	0	0	100	0	100	100	100	0	0	0
11	0	100	0	0	100	0	100	100	100	0	0	0
12	0	100	0	0	100	0	100	100	98	0	0	0
13	0	100	0	0	100	0	100	98	98	0	0	0
14	0	100	0	0	100	0	98	98	95	0	0	0
15	2	98	0	0	98	2	98	95	92	0	0	0
16	0	100	0	100	100	0	97	93	92	0	0	0
17	3	97	0	0	97	3	93	92	85	0	0	0
18	3	97	0	100	96	4	95	88	85	0	0	0
19	2	98	0	100	98	2	92	88	77	0	0	0
20	7	93	0	100	93	7	90	78	28	3	2	1
21	7	93	50	50	96	4	81	29	17	3	1	0
22	15	85	50	50	87	13	31	18	11	5	1	0
23	**59**	**41**	**33**	**67**	**36**	**64**	**24**	**15**	**11**	**17**	**4**	**1**
24	**34**	**66**	**29**	**71**	**58**	**42**	**42**	**31**	**22**	**8**	**2**	**1**
25	**32**	**68**	**25**	**75**	**64**	**36**	**49**	**35**	**29**	**8**	**3**	**1**
26	**27**	**73**	**26**	**74**	**73**	**28**	**53**	**42**	**32**	**10**	**5**	**1**
27	**31**	**69**	**38**	**63**	**72**	**28**	**56**	**43**	**32**	**14**	**3**	**1**
28	**27**	**73**	**44**	**56**	**80**	**20**	**56**	**42**	**35**	**7**	**3**	**1**
29	**24**	**76**	**25**	**75**	**77**	**23**	**58**	**48**	**39**	**10**	**3**	**0**
30	**29**	**71**	**43**	**57**	**76**	**24**	**59**	**48**	**37**	**8**	**1**	**0**
31	**20**	**80**	**29**	**71**	**83**	**17**	**64**	**50**	**35**	**2**	**1**	**0**
32	**17**	**83**	**8**	**92**	**81**	**19**	**64**	**45**	**37**	**8**	**3**	**1**
33	**27**	**73**	**50**	**50**	**78**	**22**	**51**	**42**	**31**	**10**	**4**	**2**
34	**32**	**68**	**38**	**63**	**70**	**30**	**56**	**42**	**30**	**14**	**7**	**5**
35	**25**	**75**	**42**	**58**	**83**	**18**	**56**	**41**	**14**	**14**	**10**	**6**
36	**32**	**68**	**53**	**47**	**75**	**25**	**49**	**17**	**10**	**24**	**14**	**8**
37	**42**	**58**	**74**	**26**	**73**	**28**	**20**	**12**	**6**	**25**	**14**	**7**
38	**63**	**37**	**60**	**40**	**35**	**65**	**22**	**11**	**7**	**36**	**17**	**6**
39	**51**	**49**	**57**	**43**	**59**	**41**	**24**	**17**	**13**	**24**	**9**	**5**
40	**49**	**51**	**47**	**53**	**48**	**52**	**36**	**27**	**23**	**19**	**9**	**4**
41	**34**	**66**	**38**	**62**	**70**	**30**	**51**	**43**	**40**	**17**	**7**	**1**
42	32	68	50	50	77	23	58	54	46	14	1	0
43	24	76	42	58	85	15	71	61	56	2	0	0
44	7	93	7	93	93	7	80	73	72	0	0	0
45	14	86	0	100	85	15	80	78	77	2	0	0
46	8	92	13	88	92	8	90	88	85	0	0	0
47	2	98	0	100	98	2	97	93	90	2	0	0
48	3	97	100	0	98	2	93	90	90	0	0	0
49	3	97	0	100	96	4	93	93	93	0	0	0
50	3	97	0	100	96	4	97	97	0	0	0	0
51	0	100	0	100	100	0	100	0	0	0	0	0
52	0	100	0	0	100	0	100	0	0	0	0	0

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 24-37, 39, 41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 26-33, 35-41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks.

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 20 to 59 and 11 to 50 per cent respectively during crop growth period.

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 24-36, 40-41 MWs and P(3D) greater than 20 per cent is observed in 24-35, 40-41 MWs. The greater probability of being dry weeks was observed in 27-32, 34, 35, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks. Hence contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 2 to 36 and 1 to 17 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed only in 38 MW and P(3W) greater than 20 per cent is not observed in any MW. The greater probability of being wet weeks was observed in 38 MW. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MW, thus appropriate measures of water harvesting should be carried out in this period in Malshiras tehsil so that it can be utilised during dry spell.

4.5.6 Probability Distribution of Mangalwedha Tehsil

The initial, conditional and consecutive dry and wet week probability observed in Mangalwedha tehsil during crop growth period (MW 23 to 41) is given in table 4.36.

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 3 to 61 per cent and dry week *i.e.,* P(D) ranges from 39 to 97 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 38, 39 MWs whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 44 to 100 per cent, 0 to 68 per cent, 0 to 56 per cent and 32 to 100 per cent, respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 23-37, 40-41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 25-29, 31, 33, 35, 36, 40, 41 MWs. So,

Table 4.36: Dry and wet week probability during crop growth period in Mangalwedha tehsil

Mangalwedha												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	7	93	0	100	93	7	71	70	70	0	0	0
2	22	78	0	100	76	24	76	76	76	2	0	0
3	3	97	8	92	98	2	97	97	66	0	0	0
4	0	100	0	100	100	0	100	68	68	0	0	0
5	0	100	0	0	100	0	68	68	67	0	0	0
6	32	68	0	0	68	32	68	67	66	0	0	0
7	0	100	0	100	100	0	98	97	65	0	0	0
8	2	98	0	0	98	2	97	65	62	0	0	0
9	2	98	0	100	98	2	66	63	63	0	0	0
10	32	68	0	100	67	33	64	64	64	0	0	0
11	3	97	0	100	95	5	97	97	87	0	0	0
12	0	100	0	100	100	0	100	90	81	0	0	0
13	0	100	0	0	100	0	90	81	80	0	0	0
14	10	90	0	0	90	10	81	80	80	3	0	0
15	12	88	33	67	91	9	86	86	78	0	0	0
16	2	98	0	100	98	2	98	88	62	0	0	0
17	0	100	0	100	100	0	90	63	55	0	0	0
18	10	90	0	0	90	10	63	55	50	3	0	0
19	31	69	33	67	70	30	61	55	52	3	1	0
20	12	88	11	89	88	12	80	75	53	3	1	0
21	12	88	29	71	90	10	83	58	36	3	1	0
22	8	92	29	71	94	6	64	40	31	2	1	0
23	**29**	**71**	**20**	**80**	**70**	**30**	**44**	**35**	**28**	**8**	**3**	**1**
24	**36**	**64**	**29**	**71**	**62**	**38**	**51**	**40**	**37**	**14**	**5**	**1**
25	**27**	**73**	**38**	**62**	**79**	**21**	**58**	**52**	**42**	**10**	**2**	**0**
26	**25**	**75**	**38**	**63**	**79**	**21**	**68**	**55**	**41**	**5**	**0**	**0**
27	**12**	**88**	**20**	**80**	**91**	**9**	**71**	**54**	**35**	**0**	**0**	**0**
28	**17**	**83**	**0**	**100**	**81**	**19**	**63**	**40**	**39**	**3**	**2**	**0**
29	**24**	**76**	**20**	**80**	**76**	**24**	**49**	**48**	**33**	**12**	**2**	**1**
30	**39**	**61**	**50**	**50**	**64**	**36**	**59**	**41**	**29**	**7**	**3**	**0**
31	**8**	**92**	**17**	**83**	**97**	**3**	**63**	**45**	**31**	**3**	**1**	**0**
32	**32**	**68**	**40**	**60**	**69**	**31**	**49**	**34**	**27**	**5**	**2**	**1**
33	**24**	**76**	**16**	**84**	**73**	**28**	**53**	**42**	**31**	**8**	**4**	**1**
34	**32**	**68**	**36**	**64**	**69**	**31**	**54**	**40**	**24**	**17**	**4**	**2**
35	**31**	**69**	**53**	**47**	**80**	**20**	**51**	**31**	**14**	**7**	**4**	**2**
36	**25**	**75**	**22**	**78**	**73**	**27**	**46**	**20**	**10**	**14**	**9**	**6**
37	**42**	**58**	**53**	**47**	**61**	**39**	**25**	**12**	**12**	**29**	**18**	**1**
38	**61**	**39**	**68**	**32**	**44**	**56**	**19**	**19**	**13**	**37**	**2**	**1**
39	**58**	**42**	**61**	**39**	**48**	**52**	**42**	**30**	**25**	**3**	**2**	**1**
40	**3**	**97**	**6**	**94**	**100**	**0**	**69**	**58**	**50**	**2**	**1**	**0**
41	**29**	**71**	**50**	**50**	**72**	**28**	**59**	**51**	**49**	**14**	**5**	**0**
42	25	75	47	53	83	17	64	62	44	10	1	0
43	20	80	40	60	86	14	76	54	51	2	1	0
44	5	95	8	92	96	4	68	63	61	2	0	0
45	29	71	33	67	71	29	66	64	64	0	0	0
46	5	95	0	100	93	7	92	92	71	3	0	0
47	7	93	67	33	96	4	93	73	65	0	0	0
48	0	100	0	100	100	0	78	69	69	0	0	0
49	22	78	0	0	78	22	69	69	68	2	0	0
50	10	90	8	92	89	11	90	88	0	0	0	0
51	0	100	0	100	100	0	98	0	0	0	0	0
52	2	98	0	0	98	2	0	0	0	0	0	0

there will be more moisture stress to crops in *kharif* season during these weeks.

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 19 to 71 and 12 to 58 per cent respectively during crop growth period.

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 23-36, 39-4^{t} MWs and P(3D) greater than 20 per cent is observed in 23-35, 39-41 MWs. The greater probability of being dry weeks was observed in 25-28, 30-31, 40-41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks. Hence contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 0 to 37 and 0 to 18 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed only in 38 MW and P(3W) greater than 20 per cent is not observed in any MW. As the probability of consecutive wet weeks ranges from 0 to 37 per cent and probability of dry week preceded by wet is ranges from 32 to 100 per cent, different agronomic and mechanical measures are need to be followed for maximum conservation of soil moisture, rain water harvesting and its storage for future use. The greater probability of being wet weeks was observed in 37, 38 MWs. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MWs, thus appropriate measures of water harvesting should be carried out in this period in Mangalwedha tehsil so that it can be utilised during dry spell.

4.5.7 Probability Distribution of Mohol Tehsil

The initial, conditional and consecutive dry and wet week probability observed in Mohol tehsil during crop growth period (MW 23 to 41) is given in table 4.37.

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 22 to 64 per cent and dry week *i.e.,* P(D) ranges from 36 to 78 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 38-40 MWs whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 44 to 80 per cent, 13 to 74 per cent, 22 to 56 per cent and 26 to 87 per cent respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 23, 25-37, 39-41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 25-31, 33-36 MWs. So, there will be more

Table 4.37: Dry and wet week probability during crop growth period in Mohol tehsil

Mohol												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	100	100	0	98	93	93	0	0	0
2	2	98	0	0	98	2	93	93	93	2	0	0
3	7	93	100	0	95	5	93	93	93	0	0	0
4	0	100	0	100	100	0	100	100	98	0	0	0
5	0	100	0	0	100	0	100	98	97	0	0	0
6	0	100	0	0	100	0	98	97	95	0	0	0
7	2	98	0	0	98	2	97	95	95	0	0	0
8	2	98	0	100	98	2	97	97	97	0	0	0
9	2	98	0	100	98	2	98	98	98	0	0	0
10	0	100	0	100	100	0	100	100	100	0	0	0
11	0	100	0	0	100	0	100	100	98	0	0	0
12	0	100	0	0	100	0	100	98	92	0	0	0
13	0	100	0	0	100	0	98	92	92	0	0	0
14	2	98	0	0	98	2	92	92	88	0	0	0
15	7	93	0	100	93	7	93	90	88	0	0	0
16	0	100	0	100	100	0	97	95	90	0	0	0
17	3	97	0	0	97	3	95	90	85	0	0	0
18	2	98	0	100	98	2	93	88	77	0	0	0
19	5	95	0	100	95	5	90	78	60	2	1	0
20	7	93	33	67	95	5	81	62	36	3	0	0
21	15	85	50	50	87	13	64	38	18	2	1	0
22	22	78	11	89	76	24	46	22	16	12	5	1
23	**44**	**56**	**54**	**46**	**59**	**41**	**27**	**20**	**15**	**20**	**5**	**1**
24	**49**	**51**	**46**	**54**	**48**	**52**	**37**	**28**	**21**	**12**	**3**	**0**
25	**25**	**75**	**24**	**76**	**73**	**27**	**56**	**42**	**30**	**7**	**1**	**0**
26	**25**	**75**	**27**	**73**	**75**	**25**	**56**	**40**	**32**	**3**	**1**	**1**
27	**22**	**78**	**13**	**87**	**75**	**25**	**56**	**45**	**32**	**8**	**4**	**2**
28	**31**	**69**	**38**	**62**	**72**	**28**	**56**	**40**	**30**	**15**	**9**	**6**
29	**29**	**71**	**50**	**50**	**80**	**20**	**51**	**38**	**26**	**17**	**11**	**3**
30	**37**	**63**	**59**	**41**	**71**	**29**	**47**	**32**	**24**	**24**	**7**	**3**
31	**39**	**61**	**64**	**36**	**76**	**24**	**41**	**31**	**23**	**12**	**4**	**3**
32	**32**	**68**	**30**	**70**	**67**	**33**	**51**	**38**	**29**	**12**	**8**	**3**
33	**29**	**71**	**37**	**63**	**75**	**25**	**53**	**41**	**29**	**19**	**8**	**4**
34	**37**	**63**	**65**	**35**	**74**	**26**	**49**	**35**	**20**	**17**	**8**	**4**
35	**31**	**69**	**45**	**55**	**78**	**22**	**49**	**28**	**12**	**15**	**8**	**6**
36	**36**	**64**	**50**	**50**	**71**	**29**	**37**	**16**	**10**	**19**	**14**	**8**
37	**46**	**54**	**52**	**48**	**58**	**42**	**24**	**15**	**10**	**34**	**20**	**14**
38	**64**	**36**	**74**	**26**	**44**	**56**	**22**	**14**	**10**	**37**	**26**	**11**
39	**51**	**49**	**58**	**42**	**62**	**38**	**32**	**22**	**19**	**36**	**15**	**6**
40	**53**	**47**	**70**	**30**	**66**	**34**	**32**	**28**	**22**	**22**	**9**	**2**
41	**37**	**63**	**42**	**58**	**68**	**32**	**54**	**42**	**40**	**15**	**3**	**0**
42	24	76	41	59	86	14	59	57	45	5	0	0
43	22	78	21	79	78	22	75	59	55	0	0	0
44	3	97	0	100	96	4	76	71	64	2	0	0
45	22	78	50	50	79	21	73	65	65	2	0	0
46	7	93	8	92	93	7	83	83	80	0	0	0
47	10	90	0	100	89	11	90	87	82	3	2	0
48	3	97	33	67	100	0	93	88	88	2	0	0
49	5	95	50	50	96	4	90	90	87	0	0	0
50	5	95	0	100	95	5	95	92	0	0	0	0
51	0	100	0	100	100	0	97	0	0	0	0	0
52	3	97	0	0	97	3	100	0	0	0	0	0

moisture stress to crops in *kharif* season during these weeks.

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 22 to 56 and 14 to 45 per cent respectively during crop growth period.

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 24-36, 39-41 MWs and P(3D) greater than 20 per cent is observed in 24-35, 39-41 MWs. The greater probability of being dry weeks was observed in 25-28, 32-33, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks. Hence contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 3 to 37 and 1 to 26 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed in 37-39 MWs and P(3W) greater than 20 per cent is observed only in 36 MW. The greater probability of being wet weeks was observed in 37, 38, 39 MWs. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MWs, thus appropriate measures of water harvesting should be carried out in this period in Mohol tehsil so that it can be utilised during dry spell.

4.5.8 Probability Distribution of North Solapur Tehsil

The initial, conditional and consecutive dry and wet week probability observed in North Solapur tehsil during crop growth period (MW 23 to 41) is given in table 4.38.

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 23 to 59 per cent and dry week *i.e.,* P(D) ranges from 41 to 77 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 34, 35, 40 MWs whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 41 to 88 per cent, 0 to 83 per cent, 12 to 59 per cent and 17 to 100 per cent, respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 23-33, 35-39, 41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 24, 26, 28, 31-33, 35, 38, 39 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks.

Table 4.38: Dry and wet week probability during crop growth period in North Solapur tehsil

North Solapur												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	0	100	0	100	100	100	0	0	0
2	0	100	0	0	100	0	100	100	100	0	0	0
3	0	100	0	0	100	0	100	100	100	0	0	0
4	0	100	0	0	100	0	100	100	95	0	0	0
5	0	100	0	0	100	0	100	95	95	0	0	0
6	0	100	0	0	100	0	95	95	95	0	0	0
7	5	95	0	0	95	5	95	95	95	0	0	0
8	0	100	0	100	100	0	100	100	100	0	0	0
9	0	100	0	0	100	0	100	100	100	0	0	0
10	0	100	0	0	100	0	100	100	100	0	0	0
11	0	100	0	0	100	0	100	100	100	0	0	0
12	0	100	0	0	100	0	100	100	95	0	0	0
13	0	100	0	0	100	0	100	95	91	0	0	0
14	0	100	0	0	100	0	95	91	91	0	0	0
15	5	95	0	0	95	5	91	91	91	0	0	0
16	5	95	0	100	95	5	95	95	91	0	0	0
17	0	100	0	100	100	0	100	95	95	0	0	0
18	0	100	0	0	100	0	95	95	95	0	0	0
19	5	95	0	0	95	5	95	95	87	5	0	0
20	5	95	100	0	100	0	95	87	43	0	0	0
21	0	100	0	100	100	0	91	45	33	0	0	0
22	9	91	0	0	91	9	45	33	20	5	2	0
23	**50**	**50**	**50**	**50**	**50**	**50**	**36**	**22**	**19**	**18**	**0**	**0**
24	**32**	**68**	**36**	**64**	**73**	**27**	**41**	**36**	**25**	**0**	**0**	**0**
25	**27**	**73**	**0**	**100**	**60**	**40**	**64**	**45**	**37**	**14**	**3**	**1**
26	**23**	**77**	**50**	**50**	**88**	**13**	**55**	**44**	**39**	**5**	**2**	**1**
27	**27**	**73**	**20**	**80**	**71**	**29**	**59**	**52**	**34**	**9**	**5**	**4**
28	**23**	**77**	**33**	**67**	**81**	**19**	**68**	**44**	**37**	**14**	**11**	**9**
29	**23**	**77**	**60**	**40**	**88**	**12**	**50**	**42**	**35**	**18**	**15**	**6**
30	**45**	**55**	**80**	**20**	**65**	**35**	**45**	**38**	**31**	**36**	**15**	**5**
31	**45**	**55**	**80**	**20**	**83**	**17**	**45**	**37**	**15**	**18**	**6**	**2**
32	**27**	**73**	**40**	**60**	**83**	**17**	**59**	**24**	**19**	**9**	**4**	**3**
33	**23**	**77**	**33**	**67**	**81**	**19**	**32**	**25**	**15**	**9**	**8**	**4**
34	**55**	**45**	**40**	**60**	**41**	**59**	**36**	**22**	**13**	**45**	**23**	**14**
35	**55**	**45**	**83**	**17**	**80**	**20**	**27**	**16**	**12**	**27**	**16**	**12**
36	**45**	**55**	**50**	**50**	**60**	**40**	**32**	**23**	**17**	**27**	**20**	**11**
37	**50**	**50**	**60**	**40**	**58**	**42**	**36**	**26**	**12**	**36**	**20**	**13**
38	**50**	**50**	**73**	**27**	**73**	**27**	**36**	**17**	**11**	**27**	**18**	**8**
39	**41**	**59**	**55**	**45**	**73**	**27**	**27**	**18**	**15**	**27**	**13**	**6**
40	**59**	**41**	**67**	**33**	**46**	**54**	**27**	**23**	**23**	**27**	**12**	**2**
41	**41**	**59**	**46**	**54**	**67**	**33**	**50**	**50**	**50**	**18**	**3**	**0**
42	27	73	44	56	85	15	73	73	66	5	0	0
43	5	95	17	83	100	0	95	87	87	0	0	0
44	0	100	0	100	100	0	91	91	83	0	0	0
45	9	91	0	0	91	9	91	83	83	0	0	0
46	0	100	0	100	100	0	91	91	91	0	0	0
47	9	91	0	0	91	9	91	91	91	0	0	0
48	0	100	0	100	100	0	100	100	100	0	0	0
49	0	100	0	0	100	0	100	100	100	0	0	0
50	0	100	0	0	100	0	100	100	0	0	0	0
51	0	100	0	0	100	0	100	0	0	0	0	0
52	0	100	0	0	100	0	100	0	0	0	0	0

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 27 to 68 and 16 to 52 per cent respectively during crop growth period.

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 23-34, 36-38, 41 MWs and P(3D) greater than 20 per cent is observed in 23-34, 36-37, 40- 41 MWs. The greater probability of being dry weeks was observed in 25-28, 32 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks. Hence contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 0 to 45 and 0 to 23 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed in 30, 34, 37 MWs and P(3W) greater than 20 per cent is observed in 34 MW. As the probability of consecutive wet weeks ranges from 0 to 45 per cent and probability of dry week preceded by wet is ranges from 17 to 100 per cent, different agronomic and mechanical measures are need to be followed for maximum conservation of soil moisture, rain water harvesting and its storage for future use. The greater probability of being wet weeks was observed in 30, 34, 37 MWs. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MWs, thus appropriate measures of water harvesting should be carried out in this period in North Solapur tehsil so that it can be utilised during dry spell.

4.5.9 Probability Distribution of Pandharpur Tehsil

The initial, conditional and consecutive dry and wet week probability observed in Pandharpur tehsil during crop growth period (MW 23 to 41) is given in table 4.39.

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 24 to 56 per cent and dry week *i.e.,* P(D) ranges from 44 to 76 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 38-40 MWs whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 50 to 81 per cent, 24 to 74 per cent, 19 to 50 per cent and 26 to 76 per cent respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 23-37, 39-41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 26-29, 31-35, 36, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks.

Table 4.39: Dry and wet week probability during crop growth period in Pandharpur tehsil

Pandharpur												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	100	100	0	97	93	92	0	0	0
2	3	97	0	0	97	3	93	92	92	0	0	0
3	3	97	0	100	96	4	95	95	95	0	0	0
4	2	98	0	100	98	2	98	98	97	0	0	0
5	0	100	0	100	100	0	100	98	98	0	0	0
6	0	100	0	0	100	0	98	98	95	0	0	0
7	2	98	0	0	98	2	98	95	95	0	0	0
8	0	100	0	100	100	0	97	97	95	0	0	0
9	3	97	0	0	97	3	97	95	95	0	0	0
10	0	100	0	100	100	0	98	98	97	0	0	0
11	2	98	0	0	98	2	98	97	93	0	0	0
12	0	100	0	100	100	0	98	95	88	0	0	0
13	2	98	0	0	98	2	95	88	88	0	0	0
14	3	97	0	100	97	3	90	90	88	0	0	0
15	7	93	0	100	93	7	93	92	88	0	0	0
16	0	100	0	100	100	0	98	95	90	0	0	0
17	2	98	0	0	98	2	95	90	84	0	0	0
18	3	97	0	100	97	3	92	85	79	0	0	0
19	5	95	0	100	95	5	88	82	64	0	0	0
20	7	93	0	100	93	7	86	68	36	5	1	0
21	12	88	75	25	93	7	69	36	22	3	1	0
22	22	78	29	71	79	21	41	25	17	7	3	1
23	**44**	**56**	**31**	**69**	**52**	**48**	**34**	**24**	**18**	**17**	**5**	**2**
24	**39**	**61**	**38**	**62**	**61**	**39**	**42**	**32**	**23**	**12**	**5**	**1**
25	**31**	**69**	**30**	**70**	**69**	**31**	**53**	**38**	**27**	**12**	**3**	**1**
26	**29**	**71**	**39**	**61**	**76**	**24**	**51**	**37**	**26**	**7**	**3**	**1**
27	**27**	**73**	**24**	**76**	**71**	**29**	**53**	**37**	**26**	**10**	**4**	**3**
28	**31**	**69**	**38**	**63**	**72**	**28**	**49**	**34**	**26**	**12**	**9**	**4**
29	**32**	**68**	**39**	**61**	**71**	**29**	**47**	**36**	**29**	**24**	**10**	**3**
30	**44**	**56**	**74**	**26**	**70**	**30**	**42**	**34**	**24**	**19**	**6**	**3**
31	**32**	**68**	**42**	**58**	**76**	**24**	**54**	**39**	**28**	**10**	**4**	**2**
32	**24**	**76**	**32**	**68**	**80**	**20**	**54**	**39**	**30**	**10**	**4**	**2**
33	**32**	**68**	**43**	**57**	**71**	**29**	**49**	**37**	**27**	**12**	**7**	**4**
34	**31**	**69**	**37**	**63**	**73**	**28**	**53**	**39**	**23**	**19**	**10**	**6**
35	**36**	**64**	**61**	**39**	**76**	**24**	**47**	**29**	**14**	**19**	**11**	**6**
36	**36**	**64**	**52**	**48**	**74**	**26**	**39**	**19**	**12**	**20**	**12**	**8**
37	**46**	**54**	**57**	**43**	**61**	**39**	**27**	**16**	**9**	**27**	**18**	**12**
38	**54**	**46**	**59**	**41**	**50**	**50**	**27**	**15**	**12**	**36**	**23**	**9**
39	**54**	**46**	**66**	**34**	**59**	**41**	**25**	**21**	**17**	**36**	**14**	**5**
40	**56**	**44**	**66**	**34**	**56**	**44**	**36**	**29**	**23**	**22**	**9**	**3**
41	**31**	**69**	**39**	**61**	**81**	**19**	**56**	**46**	**44**	**12**	**5**	**1**
42	25	75	39	61	80	20	61	58	50	10	2	0
43	24	76	40	60	82	18	73	62	60	5	0	0
44	8	92	21	79	96	4	78	75	70	0	0	0
45	14	86	0	100	85	15	83	77	76	2	0	0
46	5	95	13	88	96	4	88	87	85	0	0	0
47	7	93	0	100	93	7	92	90	85	2	1	0
48	3	97	25	75	98	2	95	90	90	2	0	0
49	3	97	50	50	98	2	92	92	90	0	0	0
50	5	95	0	100	95	5	95	93	0	0	0	0
51	0	100	0	100	100	0	98	0	0	0	0	0
52	2	98	0	0	98	2	0	0	0	0	0	0

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 25 to 56 and 15 to 46 per cent respectively during crop growth period.

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 23-36, 40-41 MWs and P(3D) greater than 20 per cent is observed in 23-35, 39-41 MWs. The greater probability of being dry weeks was observed in 25-27, 31-32, 34, 41 MWs. So, there will be more mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 7 to 36 and 3 to 23 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed in 38-39 MWs and P(3W) greater than 20 per cent is observed only in 38 MW. The greater probability of being wet weeks was observed in 38, 39 MWs. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MWs, thus appropriate measures of water harvesting should be carried out in this period in Pandharpur tehsil so that it can be utilised during dry spell.

4.5.10 Probability distribution of Sangola tehsil

The initial, conditional and consecutive dry and wet week probability observed in Sangola tehsil during crop growth period (MW 23 to 41) is given in table 4.40.

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 17 to 64 per cent and dry week *i.e.,* P(D) ranges from 36 to 83 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 23, 37-40 MWs whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 38 to 87 per cent, 19 to 73 per cent, 19 to 50 per cent and 27 to 81 per cent respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 24-37, 41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 24, 26, 28-30, 32, 33, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks.

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 15 to 59 and 7 to 48 per cent respectively during crop growth period.

Table 4.40: Dry and wet week probability during crop growth period in Sangola tehsil

Sangola												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	0	100	0	97	95	93	0	0	0
2	3	97	0	0	97	3	95	93	93	0	0	0
3	2	98	0	100	98	4	97	97	97	0	0	0
4	2	98	0	100	98	2	98	98	98	0	0	0
5	0	100	0	100	100	0	100	100	100	0	0	0
6	0	100	0	0	100	0	100	100	100	0	0	0
7	0	100	0	0	100	2	100	100	100	0	0	0
8	0	100	0	0	100	0	100	100	98	0	0	0
9	0	100	0	0	100	3	100	98	93	0	0	0
10	0	100	0	0	100	0	98	93	92	0	0	0
11	2	98	0	0	98	2	93	92	88	0	0	0
12	5	95	0	100	95	0	93	90	87	2	0	0
13	3	97	33	67	98	2	93	90	90	0	0	0
14	3	97	0	100	96	3	93	93	93	0	0	0
15	3	97	0	100	96	7	97	97	88	0	0	0
16	0	100	0	100	100	0	100	92	86	0	0	0
17	0	100	0	0	100	2	92	86	79	0	0	0
18	8	92	0	0	92	3	86	79	69	0	0	0
19	5	95	0	100	94	5	86	75	62	0	0	0
20	8	92	0	100	91	7	80	65	33	3	2	1
21	15	85	40	60	87	7	69	35	26	7	5	1
22	22	78	44	56	82	21	39	29	20	15	4	1
23	**54**	**46**	**69**	**31**	**50**	**48**	**34**	**24**	**18**	**15**	**5**	**2**
24	**27**	**73**	**28**	**72**	**74**	**39**	**51**	**38**	**26**	**8**	**3**	**1**
25	**31**	**69**	**31**	**69**	**70**	**31**	**53**	**35**	**26**	**10**	**3**	**1**
26	**27**	**73**	**33**	**67**	**76**	**24**	**49**	**36**	**27**	**7**	**3**	**1**
27	**31**	**69**	**25**	**75**	**67**	**29**	**51**	**38**	**30**	**12**	**3**	**1**
28	**31**	**69**	**39**	**61**	**73**	**28**	**53**	**41**	**27**	**8**	**3**	**1**
29	**25**	**75**	**28**	**72**	**76**	**29**	**58**	**39**	**31**	**10**	**4**	**1**
30	**27**	**73**	**40**	**60**	**77**	**30**	**49**	**39**	**34**	**12**	**2**	**1**
31	**36**	**64**	**44**	**56**	**67**	**24**	**51**	**44**	**31**	**7**	**2**	**1**
32	**20**	**80**	**19**	**81**	**79**	**20**	**69**	**48**	**34**	**7**	**3**	**1**
33	**17**	**83**	**33**	**67**	**87**	**29**	**58**	**40**	**24**	**7**	**4**	**2**
34	**32**	**68**	**40**	**60**	**69**	**28**	**47**	**28**	**16**	**17**	**8**	**6**
35	**37**	**63**	**53**	**47**	**70**	**24**	**37**	**21**	**8**	**19**	**14**	**9**
36	**44**	**56**	**50**	**50**	**59**	**26**	**32**	**12**	**5**	**32**	**21**	**13**
37	**56**	**44**	**73**	**27**	**58**	**39**	**17**	**7**	**3**	**37**	**23**	**13**
38	**64**	**36**	**67**	**33**	**38**	**50**	**15**	**7**	**6**	**39**	**22**	**11**
39	**59**	**41**	**61**	**39**	**43**	**41**	**19**	**15**	**13**	**34**	**16**	**9**
40	**56**	**44**	**57**	**43**	**46**	**44**	**36**	**31**	**27**	**27**	**14**	**4**
41	**36**	**64**	**48**	**52**	**81**	**19**	**56**	**48**	**44**	**19**	**6**	**1**
42	27	73	52	48	87	20	63	57	49	8	1	0
43	19	81	31	69	86	18	75	64	61	2	1	0
44	8	92	9	91	92	4	78	75	66	3	0	0
45	17	83	40	60	85	15	80	70	67	0	0	0
46	3	97	0	100	96	4	85	81	80	0	0	0
47	12	88	0	100	88	7	85	83	79	2	0	0
48	5	95	14	86	96	2	93	88	88	0	0	0
49	2	98	0	100	98	2	93	93	93	0	0	0
50	5	95	0	100	95	5	95	95	0	0	0	0
51	0	100	0	100	100	0	100	0	0	0	0	0
52	0	100	0	0	100	2	100	0	0	0	0	0

The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 24-36, 40- 41 MWs and P(3D) greater than 20 per cent is observed in 23-35, 40-41 MWs. The greater probability of being dry weeks was observed in 27-29, 31-33, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks. Hence contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 7 to 39 and 2 to 23 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed in 36-39 MWs and P(3W) greater than 20 per cent is observed in 36-38 MWs. The greater probability of being wet weeks was observed in 36, 37, 38 MWs. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MWs, thus appropriate measures of water harvesting should be carried out in this period in Sangola tehsil so that it can be utilised during dry spell.

4.5.11 Probability Distribution of South Solapur Tehsil

The initial, conditional and consecutive dry and wet week probability observed in South Solapur tehsil during crop growth period (MW 23 to 41) is given in table 4.41.

From table it is observed that, the initial probability of getting wet week *i.e.,* P(W) ranges from 18 to 64 per cent and dry week *i.e.,* P(D) ranges from 36 to 82 per cent. The probability of wet week *i.e.,* P(W) more than 50 per cent is observed in 30, 34-35, 38-40 MWs whereas in the remaining weeks during crop growth period probability of dry week *i.e.,* P(D) is greater than 50 per cent.

The conditional probability of wet and dry weeks *i.e.,* dry week preceded by another dry week (PDD), wet week preceded by another wet week (PWW), wet week preceded by another dry week (PWD) and dry week preceded by another wet week (PDW) ranges from 35 to 88 per cent, 0 to 85 per cent, 13 to 65 per cent and 15 to 100 per cent, respectively.

The probability of getting dry week preceded by another dry week (PDD) greater than 50 per cent is observed in 24-33, 35, 37-39, 41 MWs. The greater probability of being dry week preceded by another dry week (PDD) was observed in 24, 26, 28, 29, 31-33 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks.

The probability of two and three consecutive dry weeks *i.e.,* P(2D), P(3D) ranges from 18 to 64 and 10 to 47 per cent respectively during crop growth period. The probability of getting two consecutive dry weeks P(2D) greater than 30 per cent is observed in 23-32, 41 MWs and P(3D) greater than 20 per cent is observed in 23-31, 40-41 MWs.

Table 4.41: Dry and wet week probability during crop growth period in South Solapur tehsil

South Solapur												
	Initial Probability (%)		Conditional probability				Dry probabilities			Wet probabilities		
MW	P(W)	P(D)	P(W/W)	P(D/W)	P(D/D)	P(W/D)	P(2D)	P(3D)	P(4D)	P(2W)	P(3W)	P(4W)
1	0	100	0	0	100	0	100	100	100	0	0	0
2	0	100	0	0	100	0	100	100	100	0	0	0
3	0	100	0	0	100	0	100	100	95	0	0	0
4	0	100	0	0	100	0	100	95	95	0	0	0
5	0	100	0	0	100	0	95	95	95	0	0	0
6	5	95	0	0	95	5	95	95	95	0	0	0
7	0	100	0	100	100	0	100	100	100	0	0	0
8	0	100	0	0	100	0	100	100	100	0	0	0
9	0	100	0	0	100	0	100	100	100	0	0	0
10	0	100	0	0	100	0	100	100	100	0	0	0
11	0	100	0	0	100	0	100	100	100	0	0	0
12	0	100	0	0	100	0	100	100	95	0	0	0
13	0	100	0	0	100	0	100	95	91	0	0	0
14	0	100	0	0	100	0	95	91	91	0	0	0
15	5	95	0	0	95	5	91	91	91	0	0	0
16	5	95	0	100	95	5	95	95	91	0	0	0
17	0	100	0	100	100	0	100	95	91	0	0	0
18	0	100	0	0	100	0	95	91	91	0	0	0
19	5	95	0	0	95	5	91	91	83	5	0	0
20	9	91	100	0	95	5	91	83	41	0	0	0
21	0	100	0	100	100	0	91	45	33	0	0	0
22	9	91	0	0	91	9	45	33	21	5	1	0
23	**50**	**50**	**50**	**50**	**50**	**50**	**36**	**23**	**20**	**14**	**0**	**0**
24	**27**	**73**	**27**	**73**	**73**	**27**	**45**	**40**	**27**	**0**	**0**	**0**
25	**27**	**73**	**0**	**100**	**63**	**38**	**64**	**42**	**36**	**9**	**5**	**2**
26	**18**	**82**	**33**	**67**	**88**	**13**	**55**	**47**	**36**	**9**	**3**	**1**
27	**36**	**64**	**50**	**50**	**67**	**33**	**55**	**42**	**23**	**14**	**5**	**5**
28	**23**	**77**	**38**	**63**	**86**	**14**	**59**	**33**	**27**	**9**	**8**	**6**
29	**27**	**73**	**40**	**60**	**76**	**24**	**41**	**33**	**27**	**23**	**17**	**9**
30	**55**	**45**	**83**	**17**	**56**	**44**	**36**	**30**	**23**	**41**	**22**	**6**
31	**50**	**50**	**75**	**25**	**80**	**20**	**41**	**32**	**11**	**27**	**7**	**3**
32	**36**	**64**	**55**	**45**	**82**	**18**	**50**	**18**	**12**	**9**	**4**	**3**
33	**23**	**77**	**25**	**75**	**79**	**21**	**27**	**18**	**9**	**9**	**8**	**4**
34	**59**	**41**	**40**	**60**	**35**	**65**	**27**	**14**	**7**	**50**	**25**	**14**
35	**64**	**36**	**85**	**15**	**67**	**33**	**18**	**10**	**5**	**32**	**17**	**14**
36	**50**	**50**	**50**	**50**	**50**	**50**	**27**	**15**	**9**	**27**	**22**	**13**
37	**50**	**50**	**55**	**45**	**55**	**45**	**27**	**17**	**8**	**41**	**23**	**15**
38	**64**	**36**	**82**	**18**	**55**	**45**	**23**	**10**	**7**	**36**	**23**	**11**
39	**50**	**50**	**57**	**43**	**63**	**38**	**23**	**15**	**13**	**32**	**15**	**10**
40	**59**	**41**	**64**	**36**	**45**	**55**	**27**	**23**	**21**	**27**	**18**	**2**
41	**41**	**59**	**46**	**54**	**67**	**33**	**50**	**46**	**46**	**27**	**3**	**0**
42	36	64	67	33	85	15	59	59	56	5	0	0
43	9	91	13	88	93	7	91	87	87	0	0	0
44	0	100	0	100	100	0	95	95	87	0	0	0
45	5	95	0	0	95	5	95	87	87	0	0	0
46	0	100	0	100	100	0	91	91	91	0	0	0
47	9	91	0	0	91	9	91	91	91	0	0	0
48	0	100	0	100	100	0	100	100	100	0	0	0
49	0	100	0	0	100	0	100	100	100	0	0	0
50	0	100	0	0	100	0	100	100	0	0	0	0
51	0	100	0	0	100	0	100	0	0	0	0	0
52	0	100	0	0	100	0	0	0	0	0	0	0

The greater probability of being dry weeks was observed in 25-28, 41 MWs. So, there will be more moisture stress to crops in *kharif* season during these weeks. Hence contingency measures like hoeing, mulching, foliar spray, protective irrigation, etc. to be taken to reduce the impact of dry spell.

The probability of two and three consecutive wet weeks *i.e.,* P(2W) and P(3W) ranges from 0 to 50 and 0 to 25 per cent respectively during crop growth period. The probability of getting two consecutive wet weeks greater than 30 per cent is observed in 34-35, 38-39 MWs and P(3W) greater than 20 per cent is observed in 30, 34, 36-38 MWs. As the probability of consecutive wet weeks ranges from 0 to 45 per cent and probability of dry week preceded by wet is ranges from 15 to 100 per cent, different agronomic and mechanical measures are need to be followed for maximum conservation of soil moisture, rain water harvesting and its storage for future use. The greater probability of being wet weeks was observed in 30, 34, 37, 38 MWs. So, there will be less moisture stress to crops in *kharif* season during these weeks. The more chances of water harvesting are likely to get in these MWs, thus appropriate measures of water harvesting should be carried out in this period in South Solapur tehsil so that it can be utilised during dry spell. Similar results were found by Dugal *et al.,* (2018).

4.6 Contingency Crop Management and Planning Based on Rainfall Analysis

Solapur districts fall under Western Maharashtra plain scarcity zone of Maharashtra as classified under National Agril. Research Project (NARP). Tehsilwise historical rainfall data of 59 years (1961 to 2019) of Solapur district were collected and processed by using Weather cock software which revealed that the total mean annual rainfall of the district is 535 mm. Solapur receives almost 70% of mean annual rainfall during SW monsoon. The knowledge and information on the rainfall dynamics and its distribution over the cropping seasons are very important for selection of crop varieties and choice of cropping pattern. Monsoon starts effectively from 25th MW (18 June to 24 June) in Solapur district which shows sudden rise in the rainfall assuring sufficient moisture for crop germination and remain active up to 45th MW (9 October to 13 October) with a total length of 20 weeks (140 days). Therefore, we expected good monsoon shower during monsoon period of 20 weeks (24 to 41 MW) in the region. The major *kharif* crops viz. Pearl millet, and pigeon pea and sunflower and major *rabi* crops are Rabi sorghum, gram which are considered for planning. Forward and backward accumulation methods were used for computation of onset and withdrawal of rainy season from weekly rainfall data.

By considering the overall situation of the onset and withdrawal of monsoon, initial, conditional and consecutive dry and wet weeks probability, Standardized Precipitation Index, and Precipitation Deciles, the tehsil wise cropping pattern is suggested for different tehsils in Solapur district. Initial, conditional and consecutive dry and wet week probabilities showed that chances of occurrence of a week getting dry is high during early part of the season and chances

of occurrence of a week getting wet is high from 30 week onwards upto 37 week. The initial rainfall probability {P (W)} of getting 20 mm rainfall per week was >30% at the beginning of *Kharif* season indicates that summer ploughing and initial seed bed preparations shall be taken up in the 20 – 22 MWs (14 May - 3 June) at Solapur district, hence field preparation should be done during this period. The initial as well as conditional probability of wet week followed by wet week {P (W/W)} of getting 20 mm rainfall was more than 50% in 23 MW, this week is more suitable for sowing of *kharif* crop. Hence, sowing operations can be taken up since 23 MW (4–10 June). On the basis of initial, conditional and consecutive dry and wet weeks probability MWs with adequate rainfall availability are found out.

For any particular area the crop irrigation planning should be based on the date of onset of monsoon. This rainfall coincides with reproductive stage of *kharif* crops as well as timely sowing of *rabi* crops. It was observed that maximum rainfall received between 37 to 40 MWs which can be conserved for *rabi* season crops. This indicated that there was sufficient moisture for growing *rabi* crops in tehsils. Therefore, all tehsils of the Solapur district are found to be *rabi* dominated. Chances of rainfall variation are more during *kharif* season. Hence some short duration and medium duration crops can also be grown on stored soil moisture in this region. However, for most of the crops provision of supplementary irrigation is needed. The rescheduling of protective irrigation can be carried out accordingly. Study on coincidence of critical growth stages of main seasonal crops of the district and initial and conditional wet weeks probabilities are considered as a tool for protective irrigation planning. Similar results were reported by (Admasu *et al*; 2014).

Based on mean onset and withdrawal of monsoon, initial and conditional probability, Standardized Precipitation Index and Precipitation Deciles the tehsil wise contingency planning measures *viz.,* MW for sowing, protective irrigation and hoeing operation for main seasonal *kharif* and *rabi* crops of different tehsils of Solapur district is given in table 4.42 to 4.46.

4.6.1 Contingency Crop Planning for Akkalkot Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18th June – 24thJune) in Akkalkot tehsil of Solapur district. Hence, sowing of *kharif* crop (Pearl millet and Pigeon pea) can be undertaken during this week or following this week i.e. 26 MW. The land preparation operation can be done during the summer in 22 to 23 MW. The 28, 29, 31, 34, 35 and 41 MWs coincides with critical growth stages of *kharif* crop during which the probability of dry weeks *i.e.,* P(D) is 61, 58, 49, 54, 53 and 64 % and the probability of getting dry week preceded by another dry week (PDD) is 74, 64, 58, 56, 69 and 77% respectively which is greater than 50%, hence irrigation can be given during this period. As 28 and 29 MW coincides with panicle emergence stage which decides the number of grains in the panicle and tillering decides the number of panicles and hence capacity for higher yield, 30 MW coincides with branching

stage of tur crop, the availability of water during these periods is critical. It is important to ensure availability of irrigation water during the period to these crops. Hence contingency measures like hoeing, mulching, foliar spray, organic straw application, *in-situ* soil moisture conservation practices to be taken to reduce the impact of dry spell. Give protective irrigation to bajara crop in this week.

Akkalkot tehsil has more probability of at least 20 mm rainfall in 30-31, 37-39 MWs. Water harvesting and moisture conservation can be taken during this period that will help to irrigate crops during critical growth stages. Conserved moisture during these weeks can be used for sowing of *rabi* crops. The 34 -35 and 41 MWs coincides with grain filling stage of bajara and flowering and grain filling stage of tur crop respectively. Hence, protective irrigation can be given during this critical stage using previously harvested rain water without which yield will be reduced to large extent.

As maximum rainfall received between 37 MW to 40 MWs. During this period sufficient moisture present in soil which can be used for sowing of *rabi* season crops. Hence sowing Rabi sorghum and Gram can be undertaken during 38th and 40th MWs respectively. The 43, 44, 45, 46, 47, 48, 49 and 51 MWs coincides with critical growth stages of *rabi* crops (Rabi sorghum and Gram). During these weeks probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) is greater than 50%. Hence protective irrigation and moisture conservation practices can be undertaken during this period without which yield will be reduced to large extent.

4.6.2 Contingency Crop Planning for Barshi Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18 June – 24 June) in Barshi tehsil of Solapur district. Hence, sowing of *kharif* crop (Pearl millet, Pigeon pea) can be undertaken during this week or following this week i.e. 26 MW. In *kharif* season, it is observed that the probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) is greater than 50% in 28, 29, 30, 31, 34, 35 and 41 MWs which coincides with critical growth stages of *kharif* crop (Pearl millet and Pigeon pea).

Barshi tehsil has more probability of at least 20 mm rainfall in 24, 36-39 MWs. Hence water harvesting and moisture conservation can be taken during this period that will help to irrigate crops during their critical growth stages and sowing of *rabi* crops can also be undertaken by utilizing it. In *rabi* season, it is observed that P(D) and PDD is greater than 50% in 39, 40, 43 to 49 and 51 MWs which coincides with critical growth stages of *rabi* crop (Rabi sorghum and Gram). So availability of water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

4.6.3 Contingency Crop Planning for Karmala Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18 June – 24 June)

in Karmala. Hence, sowing of *kharif* crop (Pearl millet, Pigeon pea) can be undertaken during this week or following this week i.e. 26 MW. In *kharif* season, It is observed that the probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) is greater than 50% in 28, 29, 30, 31, 34, 35 and 41 MWs which coincides with critical growth stages of *kharif* crop (Pearl millet and Pigeon pea). Karmala tehsil has more probability of at least 20 mm rainfall in 38, 39 MWs. Hence water harvesting and moisture conservation can be taken during this period that will help to irrigate crops during their critical growth stages and sowing of *rabi* crops can also be undertaken by utilizing it. In *rabi* season, it is observed that P(D) and PDD is greater than 50% in 39, 40, 43 to 49 and 51 MWs which coincides with critical growth stages of *rabi* crop (Rabi sorghum and Gram). So availability of water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

4.6.4 Contingency Crop Planning for Madha Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18 June – 24 June) in Madha. Hence, sowing of *kharif* crop (Pearl millet, Pigeon pea and Sunflower) can be undertaken during this week or following this week i.e. 26 MW. Madha tehsil has more probability of at least 20 mm rainfall in 38-40 MWs. Hence water harvesting and moisture conservation can be taken during this period that will help to irrigate crops during their critical growth stages and also sowing of *rabi* crops can be undertaken by conserving it. It is observed that 28 to 39, and 41 MWs in *kharif* season and from 43 to 49 and 51 MWs in *rabi* season have probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) greater than 50% which coincides with critical growth stages of *kharif* crop (Pearl millet and pigeon pea) and *rabi* crops (Rabi Sorghum and Gram) respectively. So availability of water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

4.6.5 Contingency Crop Planning for Malshiras Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18 June – 24 June) in Malshiras. Hence, sowing of *kharif* crop (Pearl millet, Pigeon pea and Sunflower) can be undertaken during this week or following this week i.e. 26 MW. Malshiras tehsil has more probability of at least 20 mm rainfall in 23, 38 and 39 MWs. Hence there are more chances of water harvesting and moisture conservation during these weeks. This can be utilise during critical growth stages of crops and for sowing of *rabi* crops. It is observed that 28 to 39, and 41 MWs in *kharif* season and from 43 to 49 and 51 MWs in *rabi* season have probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) greater than 50% which coincides with critical growth stages of *kharif* crop (Pearl millet, Pigeon pea and Sunflower) and *rabi* crops (Rabi sorghum and Gram) respectively. So availability of

water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

4.6.6 Contingency Crop Planning for Mangalwedha Tehsil

It is observed that the mean week of onset of monsoon is 26th MW (*i.e.,* 18 June – 24 June) in Mangalwedha. Hence, sowing of *kharif* crop (Pearl millet, Pigeon pea and Sunflower) can be undertaken during this week or following this week i.e. 27 MW. Mangalwedha tehsil has more probability of at least 20 mm rainfall in 38 and 39 MWs. Hence there are more chances of water harvesting and moisture conservation during these weeks. This can be utilise during critical growth stages of crops and for sowing of *rabi* crops. It is observed that 28 to 37, and 41 MWs in *kharif* season and from 43 to 49 and 51 MWs in *rabi* season have probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) greater than 50% which coincides with critical growth stages of *kharif* crop (Pearl millet, Pigeon pea and Sunflower) and *rabi* crops (Rabi sorghum and Gram) respectively. So availability of water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

4.6.7 Contingency Crop Planning for Mohol Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18 June – 24 June) in Mohol. Hence, sowing of *kharif* crop (Pearl millet and Pigeon pea) can be undertaken during this week or following this week i.e. 26 MW. Mohol tehsil has more probability of at least 20 mm rainfall in 38-40 MWs. Hence there are more chances of water harvesting and moisture conservation during these weeks. This can be utilise during critical growth stages of crops and for sowing of *rabi* crops. It is observed that 28 to 31, 34 to 35 and 41 MWs in *kharif* season and from 43 to 49 and 51 MWs in *rabi* season have probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) greater than 50% which coincides with critical growth stages of *kharif* crop (Pearl millet and Pigeon pea) and *rabi* crops (Rabi sorghum and Gram) respectively. So availability of water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

4.6.8 Contingency Crop Planning for North Solapur Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18 June – 24 June) in North Solapur. Hence, sowing of *kharif* crop (Pearl millet and Pigeon pea) can be undertaken during this week or following this week i.e. 26 MW. North Solapur tehsil has more probability of at least 20 mm rainfall in 23, 34, 35, 37, 38 and 40 MWs. Hence there are more chances of water harvesting and moisture conservation during these weeks. This can be utilise during critical growth stages of crops and for sowing of *rabi* crops. It is observed that 28 to 31 and 41 MWs in *kharif* season and 43 to 49 and 51 MWs in *rabi* season have probability of dry

weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) greater than 50% which coincides with critical growth stages of *kharif* crop (Pearl millet and Pigeon pea) and *rabi* crops (Rabi sorghum and Gram) respectively. So availability of water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

4.6.9 Contingency Crop Planning for Pandharpur Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18 June – 24 June) in Pandharpur. Hence, sowing of *kharif* crop (Pearl millet, Pigeon pea and Sunflower) can be undertaken during this week or following this week i.e. 26 MW. Pandharpur tehsil has more probability of at least 20 mm rainfall in 38-40 MWs. Hence there are more chances of water harvesting and moisture conservation during these weeks which can be utilise during critical growth stages of crops and for sowing of *rabi* crops. It is observed that 28 to 39, and 41 MWs in *kharif* season and from 43 to 49 and 51 MWs in *rabi* season have probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) greater than 50% which coincides with critical growth stages of *kharif* crop (Pearl millet, Pigeon pea and Sunflower) and *rabi* crops (Rabi sorghum and Gram) respectively. So availability of water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

4.6.10 Contingency Crop Planning for Sangola Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18 June – 24 June) in Sangola. Hence, sowing of *kharif* crop (Pearl millet and Pigeon pea) can be undertaken during this week or following this week i.e. 26 MW. Sangola tehsil has more probability of at least 20 mm rainfall in 23, 37-40 MW. Hence there are more chances of water harvesting and moisture conservation during these weeks which can be utilise during critical growth stages of crops and for sowing of *rabi* crops. It is observed that 28 to 31, 34 to 35 and 41 MWs in *kharif* season and from 43 to 49 and 51 MWs in *rabi* season have probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) greater than 50% which coincides with critical growth stages of kharif crop (Pearl millet and Pigeon pea) and *rabi* crops (Rabi sorghum and Gram) respectively. So availability of water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

4.6.11 Contingency Crop planning for South Solapur Tehsil

It is observed that the mean week of onset of monsoon is 25th MW (*i.e.,* 18 June – 24 June) in South Solapur. Hence, sowing of *kharif* crop (Pearl millet, Pigeon pea and Sunflower) can be undertaken during this week or following this week i.e. 26 MW. South Solapur tehsil has more probability of at least 20 mm rainfall in 23, 30, 31, 34-40 MWs. Hence there are more chances of water harvesting and moisture conservation during these weeks. This can be utilise during

critical growth stages of crops and for sowing of *rabi* crops. It is observed that 28 to 31 and 41 MWs in *kharif* season and from 43 to 49 and 51 MWs in *rabi* season have probability of dry weeks *i.e.,* P(D) and probability of getting dry week preceded by another dry week (PDD) greater than 50% which coincides with critical growth stages of *kharif* crop (Pearl millet, Pigeon pea and Sunflower) and *rabi* crops (Rabi sorghum and Gram) respectively. So availability of water is crucial to crops during this period. Hence, it is important to ensure availability of irrigation water to crops during this period.

As per Standardized Precipitation Index and Precipitation Deciles the frequency of drought is increasing gradually in some tehsils (Barshi, Karmala, Madha, Malshiras, Mohol, North Solapur and South Solapur) while more severity observed in other tehsils (Akkalkot, Mangalwedha, Pandharpur and Sangola). So appropriate conservation measures need to be taken. Traditional water harvesting structures like ponds and tanks should be rejuvenated to enhance storage of runoff water and increase groundwater recharge. Water harvesting measures such as farm pond, tube well recharging, on farm contour bunding, ridges and furrows and tied ridges can be necessarily carried out before the commencement of monsoon in the study area. Different *in-situ* soil moisture conservation conservation practices need to be undertaken like hoeing, harrowing after effective rainfall, broad bed furrows, mulching, organic residue application or vertical mulching, vegetative barriers, minimum tillage, foliar spray in case of extreme situation and storing excess rain water received during the monsoon season, etc., which can be utilised during critical growth stages of field crops and for production of *rabi* crops. Judicious utilization of harvested water for protective and supplemental irrigation will assure availability of moisture in the soil for sustainable crop production.

Balanced fertilizer application *i.e.,* application of phosphorus and potash along with nitrogen (urea) can give the crop a certain extent of drought tolerance. By ensuring the release of irrigation water during the critical phases the crop failure and yield reduction can be avoided. Similar results were found by Dhanawade (2016).

Table 4.42: Contingency Crop Managemnt and Planning of Pearl millet crop in *kharif* season

Crop - Pearl millet					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Akkalkot	**Barshi**	**Karmala**
Ploughing & land preparation	2-3 Weeks before sowing	22-23	22-23	22-23	22-23
Sowing (with seed cum fert seed drill)	15 June - 15 July	24-28	25	25	25
Fertilizer application	At the time of	25	25	25	25
Pre emergence spraying of herbicide	1-2	25	25	25	25
Thinning 1st	10	27	27	27	27
Hoeing & Weeding 1st	15	28	28	28	28
Panicle emergence stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**14 -21**	**28-29**	28-29 (Hoeing, Mulching, broad bed furrows, residue cover)	28-29 (Hoeing, Mulching, broad bed furrows, residue cover)	28-29 (Hoeing, Mulching, broad bed furrows, residue cover)
Thinning 2nd	20	28-29	28-29	28-29	28-29
Hoeing & Weeding 2nd	25-30	29	29	29	29
fertilizer application (Half N)	25-30	29-30	29-30	29-30	29-30
Booting stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**28-35**	**31**	31 (Hoeing, mulching, protective irrigation)	31 (Hoeing, mulching, protective irrigation)	31 (Hoeing, mulching, protective irrigation)
Plant protection spray	30	31	31	31	31
50% flowering	35-45	32	31	31	31
Grain filling stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-65**	**35**	35 (Use conserved monsoon water for protective irrigation)	35 (Use conserved monsoon water for protective irrigation)	35 (Use conserved monsoon water for protective irrigation)
Maturity/Harvesting	80-85	39	39-40	39-40	39-40
Varieties: Phule Adishakti (80-85 days), Phule mahashakti (85-90 days), Dhanshakti (Hybrid 74-78 days)					
Spacing: 45×15 cm Seed rate: 3-4kg/ha			Diseases: Ergot, Downy mildew, smut Pest: Shoot fly		
Fertilizer dose: 50:25:25 Kg NPK/ha			Suitable for Inter cropping with Pigeon pea (2:1) with 30 cm Row to Row spacing.		

Crop - Pearl millet					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Madha	**Malshiras**	**Mangalwedha**
Ploughing & land preparation	2-3 Weeks before sowing	22-23	22-23	22-23	22-23
Sowing (with seed cum fert seed drill)	15 June - 15 July	24-28	26	25	26
Fertilizer application	At the time of	25	26	25	26
Pre emergence spraying of herbicide	1-2	25	26	25	26
Thinning 1st	10	27	28	27	28
Hoeing & Weeding 1st	15	28	29	28	29
Panicle emergence stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**14 -21**	**28-29**	29-30 (Hoeing, Mulching, broad bed furrows, residue cover)	28-29 (Hoeing, Mulching, broad bed furrows, residue cover)	29-30 (Hoeing, Mulching, broad bed furrows, residue cover)
Thinning 2nd	20	28-29	29-30	28-29	29-30
Hoeing & Weeding 2nd	25-30	29	30	29	30
fertilizer application (Half N)	25-30	29-30	30-31	29-30	30-31
Booting stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**28-35**	**31**	32 (Hoeing, mulching, protective irrigation)	31(Hoeing, mulching, protective irrigation)	32(Hoeing, mulching, Supplemental irrigation)
Plant protection spray	30	31	32	31	32
50% flowering	35-45	32	32	31	32
Grain filling stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-65**	**35**	36 (Use conserved monsoon water for protective irrigation)	35 (Use conserved monsoon water for protective irrigation)	36(Use conserved monsoon water for protective irrigation)
Maturity/Harvesting	80-85	39	40-41	39-40	40-41
Varieties: Phule Adishakti (80-85 days), Phule mahashakti (85-90 days), Dhanshakti (Hybrid 74-78 days)					
Spacing: 45×15 cm Seed rate: 3-4kg/ha			Diseases: Ergot, Downy mildew, smut Pest: Shoot fly		
Fertilizer dose: 50:25:25 Kg NPK/ha			Suitable for Inter cropping with Pigeon pea (2:1) with 30 cm Row to Row spacing.		

Table 4.42 cont…

Crop - Pearl millet				
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**	
			Mohol	**Pandharpur**
Ploughing & land preparation	2-3 Weeks before sowing	22-23	22-23	22-23
Sowing (with seed cum fert seed drill)	15 June - 15 July	24-28	25	25
Fertilizer application	At the time of sowing	25	25	25
Pre emergence spraying of herbicide	1-2	25	25	25
Thinning 1st	10	27	27	27
Hoeing & Weeding 1st	15	28	28	28
Panicle emergence stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**14 -21**	**28-29**	28-29 (Hoeing, mulching, residue cover, protective irrigation)	28-29 (Hoeing mulching, straw application)
Thinning 2nd	20	28-29	28-29	28-29
Hoeing & Weeding 2nd	25-30	29	29	29
fertilizer application (Half N)	25-30	29-30	29-30	29-30
Booting stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**28-35**	**31**	31 (Straw application, mulching, use conserved water at this stage)	31(Hoeing, mulching, Supplemental irrigation)
Plant protection spray	30	31	31	31
50% flowering	35-45	32	31	31
Grain filling stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-65**	**35**	35 (Use conserved monsoon water for protective irrigation)	35 (Use conserved monsoon water for protective irrigation)
Maturity/Harvesting	80-85	39	39-40	39-40
Varieties: Phule Adishakti (80-85 days), Phule mahashakti (85-90 days), Dhanshakti (Hybrid 74-78 days)				
Spacing: 45×15 cm Seed rate: 3-4kg/ha			Diseases: Ergot, Downy mildew, smut Pest: Shoot fly	
Fertilizer dose: 50:25:25 Kg NPK/ha			Suitable for Inter cropping with Pigeon pea (2:1) with 30 cm Row to Row spacing.	

Table 4.42 cont…

Crop - Pearl millet					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Sangola	**North Solapur**	**South Solapur**
Ploughing & land preparation	2-3 Weeks before sowing	22-23	22-23	22-23	22-23
Sowing (with seed cum fert seed drill)	15 June - 15 July	24-28	25	25	25
Fertilizer application	At the time of sowing	25	25	25	25
Pre emergence spraying of herbicide	1-2	25	25	25	25
Thinning 1st	10	27	27	27	27
Hoeing & Weeding 1st	15	28	28	28	28
Panicle emergence stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**14 -21**	**28-29**	28-29 (Hoeing, residue cover, mulching, BBF)	28-29 (Hoeing, residue cover, mulching, BBF)	28-29 (Hoeing, residue cover, mulching, BBF)
Thinning 2nd	20	28-29	28-29	28-29	28-29
Hoeing & Weeding 2nd	25-30	29	29	29	29
fertilizer application (Half N)	25-30	29-30	29-30	29-30	29-30
Booting stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**28-35**	**31**	31 (Hoeing, mulching, protective irrigation)	31 (Hoeing, mulching, protective irrigation)	31 (Hoeing, mulching, protective irrigation)
Plant protection spray	30	31	31	31	31
50% flowering	35-45	32	31	31	31
Grain filling stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-65**	**35**	35 (supplementary irrigation as wet probability is more)	35 (Protective irrigation, using conserved monsoon	35 (Protective irrigation, using conserved monsoon water)
Maturity/Harvesting	80-85	39	39	39-40	39
Varieties: Phule Adishakti (80-85 days), Phule mahashakti (85-90 days), Dhanshakti (Hybrid 74-78 days)					
Spacing: 45×15 cm Seed rate: 3-4kg/ha			Diseases: Ergot, Downy mildew, smut Pest: Shoot fly		
Fertilizer dose: 50:25:25 Kg NPK/ha			Suitable for Inter cropping with Pigeon pea (2:1) with 30 cm Row to Row		

Table 4.43: Contingency Crop Management and Planning of Pigeon Pea crop in *kharif* season

Crop - Pigeon Pea					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Akklakot	**Barshi**	**Karmala**
Ploughing & land preparation	2-3 Weeks before sowing	22-23	22-23	22-23	22-23
Sowing (with seed cum fert seed drill)	15 June - 10 July	24-28	25	25	24
Fertilizer application	At the time of sowing	25	25	25	24
Pre emergence spraying	2-3	25	25	25	24
Thinning & gap filling	10-15	27	27	27	26
Hoeing	15-20	28	28	28	27
Weeding 1st	25-30	29	29-30	29	28
Branching stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**30-35**	**30**	**30***	30 (Hoeing, mulching, protective irrigation)	29 (Hoeing, mulching, protective
1st Plant protection spray (Bud initiation stage- 5% NSKE)	35-45	31-32	31-32	31-32	30-31
Tipping	45	32	32	32	31
Hoeing & Weeding 2nd	45-50	32	32	32	31
Flowering stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-70**	**34-35**	34-35 (Protective irrigation)	34-35 (Protective irrigation)	33-34 (Protective irrigation)
2nd protection spray (50% flowering)	60-70	35-35	34-35	35	34
50% flowering (multi -nutrient spray)	65-75	35-36	35-36	35	34
Pod filling stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**110**	**41**	41 (Protective irrigation)	41 (Protective irrigation)	40 (Protective irrigation)
3rd Plant protection spray	110	41	41	41	40
Maturity/Harvesting	130-140	44-45	44-45	44-45	43-45
Varieties: Early duration- ICPL 87 (120-130 days), Phule Rajeshwari (140-150 days). Medium duration - BDN 711 (150-160 days), Vipula (150-170 days) Long duration - BSMR 853 (160-170 days), PKV Tara (170-180 days)					
Seed rate: 3-4kg/ha, Spacing: Short duration (ICPL 87) - 45×10 cm Medium duration - 60×20 cm, 90×20 cm			Diseases: Fusarium wilt, Sterility mossaic Pest: Tur pod fly		
Fertilizer dose: 25:50:50 Kg NPK/ha			Suitable for Inter cropping with Bajara (1:2) and sunflower (1:2)		

Table 4.43 cont…

Crop - Pigeon Pea					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Madha	**Malshiras**	**Mangalwedha**
Ploughing & land preparation	2-3 Weeks before sowing	22-23	22-23	22-23	22-23
Sowing (with seed cum fert seed drill)	15 June - 10 July	24-28	25	25	26
Fertilizer application	At the time of sowing	25	25	25	26
Pre emergence spraying	2-3	25	25	25	26
Thinning & gap filling	10-15	27	27	27	28
Hoeing	15-20	28	28	28	29
Weeding 1st	25-30	29	29	29	30-31
Branching stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**30-35**	**30**	30 (Hoeing, mulching, protective irrigation)	30 (Hoeing, mulching, protective irrigation)	31 (Hoeing, mulching, protective irrigation)
1st Plant protection spray (Bud initiation stage- 5% NSKE)	35-45	31-32	31-32	31-32	32-33
Tipping	45	32	32	32	33
Hoeing & Weeding 2nd	45-50	32	32	32	33
Flowering stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-70**	**34-35**	34-35 (protective irrigation)	34-35 (Protective irrigation)	35-36 (protective irrigation)
2nd protection spray (50% flowering)	60-70	35	35	35	35-36
50% flowering (multi -nutrient spray)	65-75	35	35	35	36-37
Pod filling stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**110**	**41**	41 (Use harvested water as protective irrigation)	41(Use harvested water as protective irrigation)	42 (Protective irrigation)
3rd Plant protection spray	110	41	41	41	42
Maturity/Harvesting	130-140	44-45	44-45	44-45	45-46
Varieties: Early duration- ICPL 87 (120-130 days), Phule Rajeshwari (140-150 days). Medium duration - BDN 711 (150-160 days), Vipula (150-170 days) Long duration - BSMR 853 (160-170 days), PKV Tara (170-180 days)					
Seed rate: 3-4kg/ha, Spacing: Short duration (ICPL 87) - 45×10 cm Medium duration - 60×20 cm, 90×20 cm			Diseases: Fusarium wilt, Sterility mossaic Pest: Tur pod fly		
Fertilizer dose: 25:50:50 Kg NPK/ha			Suitable for Inter cropping with Bajara (1:2) and sunflower (1:2)		

Table 4.43 cont…

Crop - Pigeon Pea					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Mohol	**Pandharpur**	**Sangola**
Ploughing & land preparation	2-3 Weeks before sowing	22-23	22-23	22-23	22-23
Sowing (with seed cum fert seed drill)	15 June - 10 July	24-28	25	25	25
Fertilizer application	At the time of sowing	25	25	25	25
Pre emergence spraying	2-3	25	25	25	25
Thinning & gap filling	10-15	27	27	27	27
Hoeing	15-20	28	28	28	28
Weeding 1st	25-30	29	29	29	29
Branching stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**30-35**	**30**	30 (Hoeing, mulching, protective irrigation)	30 (Hoeing, mulching, protective irrigation)	30 (Hoeing, mulching, protective irrigation)
1st Plant protection spray (Bud initiation stage- 5% NSKE)	35-45	31-32	31-32	31-32	31-32
Tipping	45	32	32	32	32
Hoeing & Weeding 2nd	45-50	32	32	32	32
Flowering stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-70**	**34-35**	34-35 (protective irrigation)	34-35 (protective irrigation)	34-35 (protective irrigation)
2nd protection spray (50% flowering)	60-70	35	35	35	35
50% flowering (multi -nutrient spray)	65-75	35	35	35	35
Pod filling stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**110**	**41**	41 (Protective irrigation)	41 (Protective irrigation)	41 (Protective irrigation)
3rd Plant protection spray	110	41	41	41	41
Maturity/Harvesting	130-140	44-45	44-45	44-45	44-45
Varieties: Early duration- ICPL 87 (120-130 days), Phule Rajeshwari (140-150 days). Medium duration - BDN 711 (150-160 days), Vipula (150-170 days) Long duration - BSMR 853 (160-170 days), PKV Tara (170-180 days)					
Seed rate: 3-4kg/ha, Spacing: Short duration (ICPL 87) - 45×10 cm Medium duration - 60×20 cm, 90×20 cm			Diseases: Fusarium wilt, Sterility mossaic Pest: Tur pod fly		
Fertilizer dose: 25:50:50 Kg NPK/ha			Suitable for Inter cropping witt Bajara (1:2) and sunflower (1:2)		

Table 4.43 cont…

Crop - Pigeon Pea				
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**	
			North Solapur	**South Solapur**
Ploughing & land preparation	2-3 Weeks before sowing	22-23	22-23	22-23
Sowing (with seed cum fert seed drill)	15 June - 10 July	24-28	25	25
Fertilizer application	At the time of sowing	25	25	25
Pre emergence spraying	2-3	25	25	25
Thinning & gap filling	10-15	27	27	27
Hoeing	15-20	28	28	28
Weeding 1st	25-30	29	29	29
Branching stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**30-35**	**30**	30 (Hoeing, mulching, protective irrigation)	30 (Hoeing, mulching, protective irrigation)
1st Plant protection spray (Bud initiation stage- 5% NSKE)	35-45	31-32	31-32	31-32
Tipping	45	32	32	32
Hoeing & Weeding 2nd	45-50	32	32	32
Flowering stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-70**	**34-35**	**34-35***	**34-35***
2nd protection spray (50% flowering)	60-70	35	35	35
50% flowering (multi -nutrient spray)	65-75	35	35	35
Pod filling stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**110**	**41**	41 (Irrigate with excess stored water)	41 (Irrigate with excess stored water)
3rd Plant protection spray	110	41	41	41
Maturity/Harvesting	130-140	44-45	44-45	44-45
Varieties: Early duration- ICPL 87 (120-130 days), Phule Rajeshwari (140-150 days). Medium duration - BDN 711 (150-160 days), Vipula (150-170 days) Long duration - BSMR 853 (160-170 days), PKV Tara (170-180 days)				
Seed rate: 3-4kg/ha, Spacing: Short duration (ICPL 87) - 45×10 cm Medium duration - 60×20 cm, 90×20 cm			Diseases: Fusarium wilt, Sterility mossaic Pest: Tur pod fly	
Fertilizer dose: 25:50:50 Kg NPK/ha			Suitable for Inter cropping with Bajara (1:2) and sunflower (1:2)	

Table 4.44: Contingency Crop Management and Planning of Sunflower crop in *kharif* season

Crop- Sunflower					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Madha	**Malshiras**	**Mangalwedha**
Land preparation & ploughing	2-3 Weeks before sowing	23-24	23-24	23-24	24-25
Sowing (*kharif*)	01 July - 15 July	27	27	27	28
Fertilizer application (Half N:full P:full K)	At the time of sowing	27	27	27	28
Pre emergence spraying	1-2	27	27	27	29
Germination	2-10	28	28	28	29
Thinning and gap filling	15-20	30	30	30	31
1st Plant protection spray	15	29	29	29	30
Hoeing & Weeding 1st	15-20	30	30	30	31
Seedling leaf plant development stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**10-35**	**29-32**	29-32 (Hoeing, org. residue, mulching)	29-32 (Hoeing, org. residue, mulching)	30-33 (Hoeing, org. residue, mulching)
2nd Plant protection spray	30	31	31	31	32
Growing a bud (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**35-45**	**32-34**	32-34 (Hoeing, mulching)	32-34 (Hoeing, mulching)	33-35 (Hoeing, mulching)
Head formation stage	43-45	34	34	34	35
3rd Plant protection spray	45	34	34	34	35
Flowering (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**50-60**	**35-36**	35-36 (foliar spray of urea, protective irrigation)	35-36 (foliar spray of urea, protective irrigation)	36-37 (foliar spray of urea, protective irrigation)
Borax spray (at flowering initiation)	50	35	35	35	36
Grain Filling stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**70-80**	**37-39**	37-39 (protective irrigation)	37-39 (protective irrigation)	**38-40***
Harvesting	85-90	40	40	40	41
Varities: Early duration - Phule Bhaskar (80-85 days), Modern (80-85 days), Bhanu (85-90). Hybrid - KBSH 1(85-90 days), Phule Raviraj (90-95 days)					
Spacing: 45×30 cm, 60×30 cm	Seed rate: 10-12 kg/ha		Fertilizer dose: 50:25:00 kh NPK/ha		
Pest: Capitulum borer,Tobacco caterpillar	Diseases: Alternaria leaf blight, Verticillium wilt, Powdery mildew				

Table 4.44 cont…

Crop- Sunflower				
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**	
			Pandharpur	**South Soalpur**
Land preparation & ploughing	2-3 Weeks before sowing	23-24	23-24	23-24
Sowing (*kharif*)	01July - 15 July	27	27	27
Fertilizer application Half N:full P:full K)	At the time of sowing	27	27	27
Pre emergence spraying	1-2	27	27	27
Germination	2-10	28	28	28
Thinning and gap filling	15-20	30	30	30
1st Plant protection spray	15	29	29	29
Hoeing & Weeding 1st	15-20	30	30	30
Seedling leaf plant development stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**10-35**	**29-32**	29-32 (Hoeing, org. residue, mulching)	29-32 (Hoeing, org. residue, mulching)
2nd Plant protection spray	30	31	31	31
Growing a bud(Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**35-45**	**32-34**	32-34 (Hoeing, mulching, protective irrigation)	32-34 (Hoeing, mulching, protective irrigation)
Head formation stage	43-45	34	34	34
3rd Plant protection spray	45	34	34	34
Flowering (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**50-60**	**35-36**	35-36 (foliar spray of urea, protective irrigation)	35-36 (foliar spray of urea, protective irrigation)
Borax spray (at flowering initiation)	50	35	35	35
Grain Filling stage(Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**70-80**	**37-39**	37-39 (protective irrigation)	37-39 (protective irrigation)
Harvesting	85-90	40	40	40
Varities: Early duration - Phule Bhaskar (80-85 days), Modern (80-85 days), Bhanu (85-90). Hybrid - KBSH 1(85-90 days), Phule Raviraj (90-95 days)				
Spacing: 45×30 cm, 60×30 cm	Seed rate: 10-12 kg/ha		Fertilizer dose: 50:25:00 kh NPK/ha	
Pest: Capitulum borer,Tobacco caterpillar	Diseases: Alternaria leaf blight, Verticillium wilt, Powdery mildew			

Table 4.45: Contingency Crop Management and Planning of Rabi Sorghum crop in *rabi* season

Crop- Rabi Sorghum					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Akkalkot	**Barshi**	**Karmala**
Ploughing& land preparation	In Summer	22-23	22-23	22-23	22-23
In situ moisture conservation practices viz., Compartmental bunds (3.6×3.6m,6×2m,10×10m)	45 days before sowing	31-32	31-32	31-32	31-32
Sowing (with seed cum fert seed drill)	15 Sep - 15 Oct	37-42	38	38	38
Fertilizer application (Half N:full P:full K)	At sowing	38	38	38	38
Pre emergence spraying	1-2	38	38	38	38
Emergence of seedling	3-14	39	38-40	38-40	38-40
Plant protection spray 1st	10	39	39	39	39
Hoeing & Weeding 1st	21	41	41	41	41
fertilizer application (Half N)	30	43	43	43	43
Growing Point Differentiation (GPD) stage (Protective irrigation-If Probability of P(D) and	**30-40**	**43-44**	43-44 (Hoeing, org. Straw, mulching)	43-44 (Hoeing, org. Straw, mulching)	43-44 (Hoeing, org. Straw, mulching)
Plant protection spray 2nd	30	43	43	43	43
Hoeing & Weeding 2nd	35	43	43	43	43
Booting stage	**40-45**	**44-45**	45-46 (Hoeing, protective irrigation)	45-46 (Hoeing, protective irrigation)	45-46 (Hoeing, protective irrigation)
Hoeing 3rd	56	46	46	46	46
2% Potassium spray	55	46	46	46	46
Panicle initiation	58-60	47	47	47	47
Flowering	**70-75**	**48-49**	48-49 (protective irrigation)	48-49 (protective irrigation)	48-49 (protective irrigation)
Grain filling stage	**90-95**	**51**	51 (protective irrigation)	51 (protective irrigation)	51 (protective irrigation)
Maturity/Harvesting	110-130	02	02	02	02
Drying	120-140	03-04	03-04	03-04	03-04
Varieties: 1)Medium soil - Phule Suchitra, Maldandi 35-1, Parbhani Moti 2) Heavy soil- Phule Vasudha, Phule Yashoda, Phule Revati, CSH 15					
Spacing: 45×15 cm (1.48 lakh Plant population) Seed rate: 10-12 kg/ha			Fertilizer dose: 40:20:00, 60:30:00 kg NPK/ha		
Diseases: Head smut, Grain smut, Leaf rust, Downy mildew Pest: Sorghum shoot fly, Stem borer, Midge fly			Suitable for Inter cropping with Pearl millet and Safflower (4:2 or 6:3)		

Table 4.45 cont…

Crop- Rabi Sorghum					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Madha	**Malshiras**	**Mangalwedha**
Ploughing& land preparation	In Summer	22-23	22-23	22-23	22-23
in situ moisture conservation practices viz., Compartmental bunds	45 days before sowing	31-32	31-32	31-32	31-32
Sowing (with seed cum fert seed drill)	15 Sep - 15 Oct	37-42	38	38	37
Fertilizer application (Half N:full P:full K)	At sowing	38	38	38	37
Pre emergence spraying	1-2	38	38	38	37
Emergence of seedling	3-14	39	38-40	38-40	38-39
Plant protection spray 1st	10	39	39	39	38
Hoeing & Weeding 1st	21	41	41	41	40
fertilizer application (Half N)	30	43	43	43	42
Growing Point Differentiation (GPD) stage	**30-40**	**43-44**	43-44 (Hoeing, org. Straw, mulching)	43-44 (Hoeing, org. Straw, mulching)	42-43 (Hoeing, org. Straw, mulching)
Plant protection spray 2nd	30	43	43	43	42
Hoeing & Weeding 2nd	35	43	43	43	42
Booting stage	**40-45**	**44-45**	45-46 (protective irrigation)	45-46 (protective irrigation)	44-45 (protective irrigation)
Hoeing 3rd	56	46	46	46	45
2% Potassium spray	55	46	46	46	45
Panicle initiation	58-60	47	47	47	46
Flowering	**70-75**	**48-49**	48-49 (protective irrigation)	48-49 (protective irrigation)	47-48 (Protective irrigation)
Grain filling stage	**90-95**	**51**	51 (protective irrigation)	51 (protective irrigation)	50 (protective irrigation)
Maturity/Harvesting	110-130	02	02	02	01
Drying	120-140	03-04	03-04	03-04	02-03
Varieties: 1)Medium soil - Phule Suchitra, Maldandi 35-1, Parbhani Moti 2) Heavy soil- Phule Vasudha, Phule Yashoda, Phule Revati, CSH 15					
Spacing: 45×15 cm (1.48 lakh Plant population) Seed rate: 10-12 kg/ha			Fertilizer dose: 40:20:00, 60:30:00 kg NPK/ha		
Diseases: Head smut, Grain smut, Leaf rust, Downy mildew Pest: Sorghum shoot fly, Stem borer, Midge fly			Suitable for Inter cropping with Pearl millet and Safflower (4:2 or 6:3)		

Table 4.45 cont…

Crop- Rabi Sorghum					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Mohol	**Pandharpur**	**Sangola**
Ploughing& land preparation	In Summer	22-23	22-23	22-23	22-23
in situ moisture conservation practices viz., Compartmental bunds (3.6×3.6m, 6×2m, 10×10m)	45 days before sowing	31-32	31-32	31-32	31-32
Sowing (with seed cum fert seed drill)	15 Sep - 15 Oct	37-42	38	38	37
Fertilizer application (Half N:full P:full K)	At sowing	38	38	38	37
Pre emergence spraying	1-2	38	38	38	37
Emergence of seedling	3-14	39	38-40	38-40	38-39
Plant protection spray 1st	10	39	39	39	38
Hoeing & Weeding 1st	21	41	41	41	40
fertilizer application (Half N)	30	43	43	43	42
Growing Point Differentiation (GPD)	**30-40**	**43-44**	43-44 (Hoeing, org. Straw, mulching)	43-44 (Hoeing, org. Straw, mulching)	42-43 (Hoeing, org. Straw, mulching)
Plant protection spray 2nd	30	43	43	43	42
Hoeing & Weeding 2nd	35	43	43	43	42
Booting stage	**40-45**	**44-45**	45-46 (protective irrigation)	45-46 (protective irrigation)	44-45 (protective irrigation)
Hoeing 3rd	56	46	46	46	45
2% Potassium spray	55	46	46	46	45
Panicle initiation	58-60	47	47	47	46
Flowering	**70-75**	**48-49**	48-49 (protective irrigation)	48-49 (protective irrigation)	47-48 (protective irrigation)
Grain filling stage	**90-95**	**51**	51 (protective irrigation)	51 (protective irrigation)	50 (protective irrigation)
Maturity/Harvesting	110-130	02	02	02	01
Drying	120-140	03-04	03-04	03-04	02-03
Varieties: 1)Medium soil - Phule Suchitra, Maldandi 35-1, Parbhani Moti 2) Heavy soil- Phule Vasudha, Phule Yashoda, Phule Revati, CSH 15					
Spacing: 45×15 cm (1.48 lakh Plant population) Seed rate: 10-12 kg/ha			Fertilizer dose: 40:20:00, 60:30:00 kg NPK/ha		
Diseases: Head smut, Grain smut, Leaf rust, Downy mildew Pest: Sorghum shoot fly, Stem borer, Midge fly			Suitable for Inter cropping with Pearl millet and Safflower (4:2 or 6:3)		

Table 4.45 cont…

Crop- Rabi Sorghum				
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**	
			North Solapur	**South Solapur**
Ploughing& land preparation	In Summer	22-23	22-23	22-23
in situ moisture conservation practices viz., Compartmental bunds (3.6×3.6m, 6×2m, 10×10m)	45 days before sowing	31-32	31-32	31-32
Sowing (with seed cum fert seed drill)	15 Sep - 15 Oct	37-42	38	38
Fertilizer application (Half N:full P:full K)	At sowing	38	38	38
Pre emergence spraying	1-2	38	38	38
Emergence of seedling	3-14	39	38-40	38-40
Plant protection spray 1st	10	39	39	39
Hoeing & Weeding 1st	21	41	41	41
fertilizer application (Half N)	30	43	43	43
Growing Point Differentiation (GPD) stage	**30-40**	**43-44**	43-44 (Hoeing, residue covering, Protective irrigation)	43-44 (Hoeing, residue covering, Protective irrigation)
Plant protection spray 2nd	30	43	43	43
Hoeing & Weeding 2nd	35	43	43	43
Booting stage	**40-45**	**44-45**	45-46 (Protective irrigation)	45-46 (protective irrigation)
Hoeing 3rd	56	46	46	46
2% Potassium spray	55	46	46	46
Panicle initiation	58-60	47	47	47
Flowering	**70-75**	**48-49**	48-49 (Protective irrigation)	48-49 (Protective irrigation)
Grain filling stage	**90-95**	**51**	51 (Protective irrigation)	51 (Protective irrigation)
Maturity/Harvesting	110-130	02	02	02
Drying	120-140	03-04	03-04	03-04
Varieties: 1)Medium soil - Phule Suchitra, Maldandi 35-1, Parbhani Moti 2) Heavy soil- Phule Vasudha, Phule Yashoda, Phule Revati, CSH 15, PKV Kranti				
Spacing: 45×15 cm (1.48 lakh Plant population) Seed rate: 10-12 kg/ha			Fertilizer dose: 40:20:00, 60:30:00 kg NPK/ha	
Diseases: Head smut, Grain smut, Leaf rust, Downy mildew Pest: Sorghum shoot fly, Stem borer, Midge fly			Suitable for Inter cropping with Pearl millet and Safflower (4:2 or 6:3)	

Table 4.46: Contingency Crop Management and Planning of Chickpea (Gram) crop in *rabi* season

Crop- Chickpea					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Akkalkot	**Barshi**	**Karmala**
Land preparation & ploughing	2nd Fortnight of September	38-39	37	37	37
Sowing	Last week of Sep to 1st week of Oct	39-40	40	40	40
Fertilizer application	At the time of sowing	39	40	40	40
Thinning and gap filling	10	41	41	41	41
Hoeing & Weeding 1st	25-30	43-44	43-44	43-44	43-44
Flowering stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**40-50**	**45-47**	45-47 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)	45-46 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)	45-47 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)
Hoeing & Weeding 2nd	60	48	48	48	45-47
fertilizer application (2% ureaay in case of stress)	70	50	50	50	50
Pod development stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-65**	**48-49**	48-49 (Protective irrigation with harvested NE rain water)	48-49 (Protective irrigation with harvested NE rain water)	48-49 (Protective irrigation with harvested NE rain water)
Maturity and Harvesting	90-110	52-01	52-01	52-01	52-01
Varieties: Phule Vijay (85-90 days), Phule Digvijay (90-95 days), Phule Vishal (110-115 days), PKV-2, PKV-4					
Spacing: 30×10 cm Seed rate: 100 kg/ha			Pest: Gram pod borer, Gram cut worm		
Fertizer dose: 25:50:30 Kg NPK/ha			Diseases: Fusarium wilt, Ascochyta blight, Dry root rot		

Table 4.46 cont…

Crop- Chickpea					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Madha	**Malshiras**	**Mangalwedha**
Land preparation & ploughing	2nd Fortnight of September	38-39	37	37	37
Sowing	Last week of Sep to 1st week of Oct	39-40	40	40	39
Fertilizer application	At the time of sowing	39	40	40	39
Thinning and gap filling	10	41	41	41	40
Hoeing & Weeding 1st	25-30	43-44	43-44	43-44	42-43
Flowering stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**40-50**	**45-47**	45-47 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)	45-46 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)	44-46 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)
Hoeing & Weeding 2nd	60	48	48	48	47
fertilizer application (2% ureaay in case of stress)	70	50	50	50	49
Pod development stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-65**	**48-49**	48-49 (Protective irrigation with harvested NE rain water)	48-49 (Protective irrigation with harvested NE rain water)	47-48 (Protective irrigation with harvested NE rain water)
Maturity and Harvesting	90-110	52-01	52-01	52-01	51-52
Varieties: Phule Vijay (85-90 days), Phule Digvijay (90-95 days), Phule Vishal (110-115 days), PKV-2, PKV-4					
Spacing: 30×10 cm Seed rate: 100 kg/ha			Pest: Gram pod borer, Gram cut worm Diseases: Fusarium wilt, Ascochyta blight, Dry root rot		
Fertizer dose: 25:50:30 Kg NPK/ha					

Table 4.46 cont…

Crop- Chickpea					
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**		
			Mohol	**Pandharpur**	**Sangola**
Land preparation & ploughing	2nd Fortnight of September	38-39	37	37	37
Sowing	Last week of Sep to 1st week of Oct	39-40	40	40	39
Fertilizer application	At the time of sowing	39	40	40	39
Thinning and gap filling	10	41	41	41	40
Hoeing & Weeding 1st	25-30	43-44	43-44	43-44	42-43
Flowering stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**40-50**	**45-47**	45-47 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)	45-46 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)	44-46 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)
Hoeing & Weeding 2nd	60	48	48	48	47
fertilizer application (2% ureaay in case of stress)	70	50	50	50	49
Pod development stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-65**	**48-49**	48-49 (Protective irrigation with harvested NE rain water)	48-49 (Protective irrigation with harvested NE rain water)	47-48 (Protective irrigation with harvested NE rain water)
Maturity and Harvesting	90-110	52-01	52-01	52-01	51-52
Varieties: Phule Vijay (85-90 days), Phule Digvijay (90-95 days), Phule Vishal (110-115 days), PKV-2, PKV-4					
Spacing: 30×10 cm Seed rate: 100 kg/ha			Pest: Gram pod borer, Gram cut worm Diseases: Fusarium wilt, Ascochyta blight, Dry root rot		
Fertizer dose: 25:50:30 Kg NPK/ha					

Table 4.46 cont…

Crop- Chickpea				
Package of Practices	**Days After Sowing (DAS)**	**MW**	**Tehsils**	
			North Solapur	**South Solapur**
Land preparation & ploughing	2nd Fortnight of September	38-39	37	37
Sowing	Last week of Sep to 1st week of Oct	39-40	40	40
Fertilizer application	At the time of sowing	39	39	39
Thinning and gap filling	10	41	41	41
Hoeing & Weeding 1st	25-30	43-44	43-44	43-44
Flowering stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**40-50**	**45-47**	45-47 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)	45-46 (Hoeing, mulching, foliar spray of KNO_3, protective irrigation)
Hoeing & Weeding 2nd	60	48	48	48
fertilizer application (2% urea in case of stress)	70	50	50	50
Pod development stage (Protective irrigation-If Probability of P(D) and P(D/D) more than 50%)	**60-65**	**48-49**	48-49 (Protective irrigation with harvested NE rain water)	48-49 (Protective irrigation with harvested NE rain water)
Maturity and Harvesting	90-110	52-01	52-01	52-01
Varieties: Phule Vijay (85-90 days), Phule Digvijay (90-95 days), Phule Vishal (110-115 days), PKV-2, PKV-4				
Spacing: 30×10 cm	Seed rate: 100 kg/ha		Pest: Gram pod borer, Gram cut worm Diseases: Fusarium wilt, Ascochyta blight, Dry root rot	
Fertizer dose: 25:50:30 Kg NPK/ha				

{* indicates that MW week coincides with critical growth stage of crop but station has sufficient moisture for that week as probability of wet is more during this week}

5. SUMMARY AND CONCLUSIONS

5.1. Summary

The present study entitled 'Assessment of Drought in the Solapur district using Standardized Precipitation Index (SPI)' is undertaken to determine annual drought, extreme events and variation through Standardized Precipitation Index (SPI) and Precipitation Deciles (PD). Determination of Onset and withdrawal of monsoon using forward and backward accumulation method, dry and wet weeks probabilities by using Markov chain model for suggesting Tehsilwise crop planning and management based on rainfall analysis. The summary of results obtained by analyzing long term daily rainfall data of different Tehsils in Solapur district are given below.

The long term daily rainfall data of 59 years of Akkalkot, Barshi, Karmala, Madha, Malshiras, Mangalwedha, Mohol, Pandharpur and Sangola and 22 years of North and South Solapur tehsil were used to compute annual and monthly rainfall and rainy days of eleven tehsils of Solapur district. The statistical parameters *viz.,* mean, standard deviation, coefficient of variation, meteorological drought, initial, conditional and consecutive probabilities of dry and wet week were estimated from the Weather Cock software developed by CRIDA, Hyderabad. In this study meteorological drought was analysed by using Standardized Precipitation Index (SPI) by SPI_SL_6.exe software. DrinC (Drought Indices Calculator) is a software package used for the calculation of drought indices like precipitation deciles. The onset and withdrawal of rainy season was computed from mean weekly rainfall data by forward and backward accumulation methods as per the procedure suggested by Babu and Lakshminarayana (1997). The initial, conditional and consecutive probability of dry and wet week at threshold limit 20 mm of rainfall during the crop growth period (23 to 41 MW) is calculated using 'Weather Cock' software.

5.1.1 Rainfall analysis

The Solapur district is having 603 mm mean average annual rainfall. It was varied from 107 mm at Malshiras with 49.1 per cent variation to 1343.5 mm at Malshiras with 49.1 per cent variation. The average annual rainfall of Solapur district was received in 37 mean rainy days with the highest (71) rainy days during 1998 at Mohol tehsil with 26.3 per cent variation and the lowest (11) rainy days during 1972 at Madha tehsil with 26.0 per cent variation.

According to study, it is observed that September month contributes highest amount of mean rainfall 160.8 mm with 69.9 per cent variation followed by August, June. The September month contributes the highest amount of mean rainy days (8 days) with 48.5 per cent variation followed by August, July.

5.1.2 Standardized Precipitation Index (SPI)

Meteorological drought for various tehsil of Solapur district is assessed for 12 month's timescales (SPI 12). The negative value of SPI indicated drought (dry) condition and positive value indicated wet condition.

For Akkalkot tehsil out of 59 years 10, 40 and 9 years observed at wet, near normal and dry or extreme drought condition respectively. Similarly, For Barshi tehsil out of 40 years 7, 44 and 8 years observed at wet, near normal and dry or extreme drought condition respectively. For Karmala tehsil out of 59 years 9, 40 and 10 years observed at wet, near normal and dry or extreme drought condition respectively. For Madha tehsil out of 59 years 8, 43 and 8 years observed at wet, near normal and dry or extreme drought condition respectively. For Malshiras tehsil out of 59 years 98, 42 and 8 years observed at wet, near normal and dry or extreme drought condition respectively.

For Mangalwedha tehsil out of 59 years 7, 42 and 10 years observed at wet, near normal and dry or extreme drought condition respectively. For Mohol tehsil out of 59 years 7, 42 and 10 years observed at wet, near normal and dry or extreme drought condition respectively. For North Solapur tehsil out of 22 years 3, 17 and 2 years observed at wet, near normal and dry or extreme drought condition respectively. For Pandharpur tehsil out of 59 years 10, 40 and 9 years observed at wet, near normal and dry or extreme drought condition respectively. For Sangola city tehsil out of 59 years 9, 40 and 10 years observed at wet, near normal and dry or extreme drought condition respectively and for South Solapur tehsil out of 22 years 4, 18 and 4 years observed at wet, near normal and dry or extreme drought condition respectively.

Considering the trend and frequency of drought in decades it is observed that in decade the two or three wet years happen, two or three dry years happens and four or five normal years happens. But it was observed that in Akkalkot, Pandharpur and Sangola tehsils during the last two decade period the frequency of drought increased severely. In all other tehsils of Solapur district, the 2001-2010 decade showed near normal condition for maximum times with one or two moderately dry condition year and/or one extreme year. The recent decade showed frequent rise number of drought years for all stations. This indicated that that a SPI value becomes more negative with increase in time scales in recent times.

5.1.3 Precipitation deciles (PD)

In Akkalkot, Barshi, Karmala, Madha, Malshiras, Mangalwedha, Mohol, Pandharpur and Sangola tehsils 24 drought events were observed out of 59 years. Whereas, in the North & South Solapur tehsils 09 drought events were observed out of 22 years.

In case of Pandharpur and Sangola tehsils, it was observed that the frequency of the drought event was increased during the last three decades as compared to previous decades. Whereas in Akkalkot and Malshiras tehsils the frequency of the drought event was increased in

the last two decade as compared to previous decades. In all other tehsils of Solapur district frequency of drought events was increased in recent decade which may become very severe in the upcoming decade. As severity of drought is more in recent decade, more efforts are needed for *in situ* moisture conservation.

5.1.4 Onset and withdrawal of monsoon season

From the analysis of weekly rainfall data, it was observed that the mean week of onset of monsoon was 25 standard meteorological week (MW) (*i.e.,* 18 June – 24 June) for all tehsils of Solapur district except Mangalwedha tehsil where mean onset was 26 standard meteorological week (MW) (*i.e.,* 25 June – 01 July).

The mean week of withdrawal of monsoon was observed to be 45 MW (*i.e.,* 5 November – 11 November) for Akkalkot, Barshi, Karmala, Madha, Malshiras, Pandharpur and Sangola tehsils. Whereas it was observed to be 43, 44, 46 and 48 for South Solapur, North Solapur, Mohol and Mangalwedha tehsils respectively.

The mean length of rainy season was found to be 20 weeks (140 days) for Akkalkot, Barshi, Karmala, Madha, Malshiras, Pandharpur and sangola tehsils which include rainfall of both south west and north east monsoon. Maximum mean length of rainy season was observed at Mangalwedha *i.e.,* 22 weeks (154 days) and at Mohol *i.e.,* 21 weeks (147 days). Minimum length of rainy season was observed at South Solapur *i.e.,* 18 weeks (126 days) and North Solapur *i.e.,* 19 weeks (133 days). Based on the onset and withdrawal of rainy season various operations can be performed on the field.

5.1.5 Markov-chain initial, conditional and consecutive probabilities of dry and wet weeks

Akkalkot tehsil has more probability of at least 20 mm rainfall in 30, 31, 37, 38, 39 MWs. For Barshi tehsil, there are chances of water harvesting in from 24, 36-39 MWs. In case of Karmala tehsil in 38, 39 MW have more probability of getting at least 20 mm rainfall than remaining weeks. For Madha tehsil, 38, 39, 40 MWs have assured at least 50 per cent probability of getting at least 20 mm rainfall. In Malshiras tehsil 23, 38 and 39 MWs have chances of rain water harvesting. For Mangalwedha tehsil minimum 50 per cent probability of at least 20 mm rainfall is obtained in case of 38 and 39 MW. Mohol tehsil has more chances of water harvesting in 38, 39, 40 MWs. In North Solapur tehsil in 23, 34, 35, 37, 38 and 40 MWs water can be harvested. In case of Pandharpur tehsi, probability of getting at least 20 mm rainfall is observed in 38, 39 and 40 MWs. Sangola tehsil has more chances of water harvesting in 23, 37, 38, 39 and 40 MWs and South Solapur tehsil has more probability of at least 20 mm rainfall in 23, 30, 31, 34, 35, 36, 37, 38, 39, 40 MWs.

5.1.6 Contingency crop planning

Based on mean rainfall, Standardized Precipitation Index (SPI), Precipitation Deciles (PD), onset and withdrawal of rainy season, initial and conditional probability at different critical growth stages of selected *kharif* crops (Pearl millet, Pigeon Pea and Sunflower) and *rabi* crops (Rabi sorghum and Chickpea) tehsil wise contingency measures *viz.,* MW for sowing, protective irrigation and hoeing operation were given. Harvested rainwater can be judiciously utilised for supplementary irrigation of crops at critical growth stages for sustainable crop production. *In-situ* moisture conservation measures such as on farm contour bunding, compartmental bunding, ridges and furrows, tied ridges and *ex-situ* water harvesting measures such as farm pond, tube well recharging, can be necessarily carried out before the commencement of monsoon in the study area. Moisture conservation practices like hoeing, harrowing after effective rainfall, contour cultivation, vegetative barriers, broad bed furrows, and organic, residue or vertical mulching etc. and judicious utilization of water harvested for protective and supplemental irrigation through pressurized irrigation system *i.e*. drip and sprinkler irrigation, will assure availability of moisture in the soil and sustainable crop production.

5.2 Conclusions

The following conclusions were drawn based on the results of study at various tehsils as follows,

1. The mean annual rainfall of tSolapur district is 603 mm. It was varied from 107 mm at Malshiras with 49.1 per cent variation to 1343.5 mm at Malshiras with 49.1 per cent variation. The average annual rainfall of Solapur district was received in 37 mean rainy days with the highest (71) rainy days during 1998 at Mohol tehsil with 26.3 per cent variation and the lowest (11) rainy days during 1972 at Madha tehsil with 26.0 per cent variation.

   In Solapur district,maximum monthly rainfall was observed in September month, contributes highest amount of mean rainfall 160.8 mm with 69.9 per cent variation followed by August, June. The average mean annual rainy days of Solapur district was 37 days in which September month contributes the highest mean rainy days (8 days) with 48.5 per cent variation followed by August, July.

2. Drought analysis using Standardized Precipitation Index (SPI) in selected tehsils of Solapur district at 12 month's timescale scale. It is observed that frequency of droughts in selected Tehsils showed that in each decade the two or three wet years happen, two or three dry years happens and four or five normal years happens. It was observed that the frequency of drought in Akkalkot, Pandharpur and Sangola tehsils during the last two decade was increased. Whereas, recent decade showed frequent rise in number of drought years in all

other tehsils of Solapur district. This indicated that a SPI value becomes more negative with increase in time scales in recent times. This is due to the non-uniform, irregular and erratic pattern of rainfall which may have had adverse impact on the cropping system.

Drought analysis using Precipitation deciles (PD) showed that there were 24 drought events during the period of 1961-2019 for all tehsils of Solapur district except North & South Solapur where 09 drought events were reported during the period of 1998-2019. In Pandharpur and Sangola tehsils, it was observed that the frequency of the drought event was increased in the last three decade as compared to previous decades. Whereas in Akkalkot and Malshiras tehsils the frequency of the drought event was increased in the last two decade as compared to previous decades, so we can follow the prevailing cropping pattern, harvest the excess water that can be used during dry spell and for the assured supply water in *rabi* season. In all other remaining tehsils of Solapur district frequency of drought events was increased in recent decade which may become very severe in the upcoming decade. As severity of drought is more in recent decade, more efforts are needed for *in situ* moisture conservation.

3. From the analysis of weekly rainfall data, the mean week of onset of monsoon was 25 standard meteorological week (MW) (*i.e.,* 18 June – 24 June) for all tehsils except Mangalwedha tehsil where mean onset was 26 standard meteorological week (MW) (*i.e.,* 25 June – 01 July). The mean week of withdrawal of monsoon was observed to be 45 MW (*i.e.,* 5 November – 11 November) for Akkalkot, Barshi, Karmala, Madha, Malshiras, Pandharpur and Sangola tehsils. For South Solapur, North Solapur, Mohol and Mangalwedha tehsils mean week of withdrawal of monsoon was observed in 43, 44, 46 and 48 respectively.

   Based on the onset and withdrawal of monsoon various field operations can be performed.

4. The Markov-chain probability analysis showed that probability of getting more wet weeks is observed during 34 to 40 MW for different Tehsils. This indicated that all tehsils of Solapur district are *rabi* dominated. The dry and wet week initial, conditional and consecutive probabilities are helpful for crop management planning in different Tehsils of Satara district. Thus, chances of rainwater harvesting in wet weeks is more and judicious use of harvested water in dry spells as protective irrigation is beneficial for the sustainable yield.

5. By considering the overall situation of the Standardized Precipitation Index, and Precipitation Deciles, onset and withdrawal of monsoon, initial, conditional and consecutive dry and wet weeks probability at different critical growth stages of selected *kharif* crops (Pearl millet, Pigeon Pea and sunflower) and *rabi* crops (Rabi sorghum and Chickpea)

tehsilwise contingency measures *viz.,* MW for sowing, protective irrigation and hoeing operation, etc. were suggested.

The study useful in understanding the historic patterns and build future scenarios of drought for risk management and climate change adaptation planning. Increased the drought frequency facilitates for better preparedness, coping mechanisms and contingency measures.

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7. APPENDIX- I

Standard Meteorological Weeks

MW	Calendar Month	Date (From-To)	MW	Calendar Month	Date (From-To)
1	January	01-07	27	July	02-08
2	”	08-14	28	”	09-15
3	”	15-21	29	”	16-22
4	”	22-28	30	”	23-29
5	”	29-04	31	”	30-05 Aug.
6	February	05-11 Feb	32	August	06-12
7	”	12-18	33	”	13-19
8	”	19-25	34	”	20-26
9*	”	26-04 March	35	”	27-02
10	March	05-11	36	September	03-09 Sept.
11	”	12-18	37	”	10-16
12	”	19-25	38	”	17-23
13	”	26-01 April	39	”	24-30
14	April	02-08	40	October	01-07
15	”	09-15	41	”	08-14
16	”	16-22	42	”	15-21
17	”	23-29	43	”	22-28
18	”	30-06 May	44	”	29-04
19	May	07-13	45	November	05-11 Nov.
20	”	14-20	46	”	12-18
21	”	21-27	47	”	19-25
22	”	28-03 June	48	”	26-02 Dec.
23	June	04-10	49	December	03-09
24	”	11-17	50	”	10-16
25	”	18-24	51	”	17-23
26	”	25-01 July	52**	”	24-31

*MW No.9 is 8 days in leap year

**MW No. 52 is of 8 days

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