KHARIF CROP PLANNING BASED ON WATER AVAILABILITY FOR GARIYABAND DISTRICT

M.Tech (Agril.Engg.)

by

Rajendra Kumar Deo

DEPARTMENT OF SOIL AND WATER ENGINEERING

SWAMI VIVEKANAND COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY & RESEARCH STATION,

FACULTY OF AGRICULTURAL ENGINEERING,

INDIRA GANDHI KRISHI VISHWAVIDYALAYA

RAIPUR (CHHATTISGARH)

2022

KHARIF CROP PLANNING BASED ON WATER AVAILABILITY FOR GARIYABAND DISTRICT

Thesis

Submitted to the

Indira Gandhi Krishi Vishwavidyalaya, Raipur

by

Rajendra Kumar Deo

IN PARTIAL FULFILMENT TO THE REQUIRMENT FOR THE DEGREE OF

Master of Technology

in

Agricultural Engineering

(Soil and Water Engineering)

Roll No. 20200820 U.E.Id. No. 20200820

July 2022

CERTIFICATE - I

This is to certify that the thesis entitled **"KHARIF CROP PLANNING BASED ON WATER AVAILABILITY FOR GARIYABAND DISTRICT"** submitted in partial fulfillment of the requirements for the degree of **Master of Technology** in **Agricultural Engineering** of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, is recorded of the bonafide research work carried out by **Rajendra Kumar Deo** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.

No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published / published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by him.

Chairman

Date: 20/07/2022

THESIS APROVED BY THE STUDENT ADVISOY COMMITTEE

Chairman	**(Dr. B. L. Sinha)**	______
Member	**(Dr. Jitendra Sinha)**	______
Member	**(Dr. S. V. Jogdand)**	______
Member	**(Dr. M. K. Pradhan)**	______
Member	**(Dr. M. P. Tripathi)**	______

CERTIFICATE – II

This is to certify that the thesis entitled **"KHARIF CROP PLANNING BASED ON WATER AVAILABILITY FOR GARIYABAND DISTRICT"** submitted by **Rajendra Kumar Deo** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur in partial fulfillment of the requirements for the degree of **Master of Technology in Agricultural Engineering** in the Department of Soil and Water Engineering has been approved by the external examiner and Student's Advisory Committee after oral examination.

Signature of Head of the Department/

Dean (In case of out campii)

(Name: Dr. V.K. Pandey **)**

Date: 20/10/2022

Major Advisor ____________________

Faculty Dean ____________________

Approved /Not approved

Director of Instructions ____________________

Acknowledgement

It is matter of pleasure to glance back and recall the path of traverse during the days of hard work and perseverance. It is still great at this juncture to recall all the faces and spirits in the forms of teachers, friends, near and dear ones. I should consider this work nothing more than incomplete without attending to the task of acknowledging the overwhelming help we received during this Endeavour.

First and foremost, we sincerely extend our profound gratitude to our Major Advisor ***Dr. B. L. Sinha*** *Assistant Professor, Department of Soil and Water Engineering, SV College of Agricultural Engineering and Technology & Research Station, Raipur for his generous help, inspiring guidance, unstained alteration, and constant supervision, timely help during the course of investigation and also in the preparation of the thesis. I have immense pleasure and privilege to be associated with him during the course of our study. I acknowledge all his contribution most gratefully.*

I am highly indebted to member of my Advisory Committee Dr. M. P Tripathi, Professor, Department of Soil and Water Engineering, IGKV, Raipur for providing excellent suggestions by devoting his precious time in the midst of his busy schedule and for kind sympathetic attitude during the whole degree programme.

I have deep regards for members of my advisory committee Dr. Jitendra Sinha, Associate Professor, Department of soil and Water Engineering, Dr. S.V. Jogdand, Assistant Professor, Department of Farm Power and machinery Engineering, Dr. M. K. Pradhan Assistant Professor, Agricultural Statistics for their kind supervision motivations and support by which I was pushed towards hard working and punctuality.

I specially extend my sincere thanks to Er. Parveen Kumar Jamre, Subject Matter Specialist (Soil and Water Engineering), KVK Gariyaband for their unforgettable support and kind help during the research work.

I acknowledge with the sense of responsibility and gratitude to Dr. Girish Chandel, Hon'ble Vice Chancellor, Dr. S. S. Sengar, Direction of Instruction, Dr. V. K. Pandey, Dean of Swami Vivekanand College of Agricultural Engineering and Technology & Research Station, Faculty of Agricultural Engineering, IGKV Raipur, for providing necessary facilities, technical and administrative supports for the conductance of this research work.

I would like to express extended my thanks to Dr. Dhiraj Khalkho, Scientist/ Associate Professor, Dr. P. Katre, Assistant Professor and Dr. Narendra Agrawal, Assistant Professor, Department of Soil and Water Engineering, Swami Vivekanand College of Agricultural Engineering and Technology & Research Station, Faculty of Agricultural Engineering, IGKV Raipur, for their patient guidance and useful critique of this project work.

I express my sincere thanks to my friends Prashant Kumar Soni, Prashant Patle, and my senior Er. Shashikant Verma, who encouraged me in each and every step of my post-graduation and they deserve a more personal note of gratitude

I am obliged to all our class friends, for their friendships and encouragements, without them we cannot complete our research work. We wish to convey our sincere thanks to our family members and for their highest degree of love and constant encouragement. Last but not the least there aren't enough word to express my gratitude to my beloved father, mother, elder brother and sister and all who have been directly or indirectly related for their constant encouragement.

Place: - IGKV, Raipur

Date: - 20/10/2022

Rendra

Rajendra Kumar Deo

ii

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations/ Symbols	Descriptions
%	Percent
Agril. Engg	Agricultural Engineering
C. G.	Chhattisgarh
CV	Coefficient of Variation
DAS	Days After Sowing
Dept.	Department
Engg.	Engineering
et al.	Et alia
FAE	Faculty of Agricultural Engineering
Fig.	Figure
Ha	Hectare
i.e.,	That is
ICAR	Indian Council of Agricultural Research
IGKV	Indira Gandhi Krishi Vishwavidyalaya
IMD	Indian Meteorological Department
Km	Kilo meter

M. Tech.	Master of Technology
MAE	Mean Absolute Error
Max	Maximum
Min	Minimum
Mm	Mili meter
MSE	Mean Square Error
MSL	Mean Sea Level
NARP	National Agriculture Release Program
Rf	Rainfall
RMSE	Root Mean Square Error
S. No.	Serial no.
SD	Standard Deviation
SMW	Standard Meteorological Week
Viz.	Which is
$\geq$	Less than equal to
$\leq$	More than equal to
$<$	Less than
$>$	More than
Σ	Standard Deviation
C_s	Skewness
&	And

THESIS ABSTRACT

a) Title of Thesis	:	Kharif Crop Planning Based on Water Availability for Gariyaband District
b) Full Name of the Student	:	Rajendra Kumar Deo
c) Major Subject	:	Soil and Water Engineering
d) Name and Address of the Major Advisor	:	Dr. B. L. Sinha Assistant Professor, Soil and Water Engineering, SVCAET & RS, FAE, IGKV, Raipur (C.G.)
e) Degree to be Awarded	:	M. Tech (Agricultural Engineering)

Signature of the Student

Signature of Major Advisor

Date: 20/10/2022

Signature of Head of Department

ABSTRACT

The rainfall is the first meteorological index which farmers and environmental scientists ever considered because it is the single most crucial factor that determines the type of crop that will be grown, its success or failure, and the general cropping pattern of the area. Therefore, the study entitled "Kharif Crop planning Based on Water availability for Gariyaband District" deals with the daily rainfall data from five tehsils in the Gariyaband district for a ten-year period (2011 - 2020) were used. To describe the pattern of rainfall over the district, the variability among the various stations were examined on a monthly and weekly basis. Onset and withdrawal of monsoon and probability of rainfall is also examined.

xiii

During *Kharif* season (22-44th SMW) the highest mean weekly rainfall was found to be 142.9 mm (29th SMW) in Chhura, 114.8 mm (32nd SMW) in Deobhog, 148.1mm (35th SMW) in Fingeshwar, 104.6 mm (29th SMW) in Gariyaband and 125 mm (35th SMW) in Mainpur tehsil and lowest mean weekly rainfall was found to be 0 mm (44th SMW) in all over the study area. The CV varies from 244.1 % (42thSMW) to 42.2 % (33thSMW) at Chhura, 298.1% (43thSMW) to 49.6% (25thSMW) at Deobhog, 204.4% (43thSMW) to 46.1% (28thSMW) at Fingeshwar, 289.1% (41thSMW) to 55.5(28thSMW) at Gariyaband and 316.2 (44thSMW) to 55.4 (34thSMW) at Mainpur. The consistency is shown by a higher standard deviation and a lower coefficient of variation. This indicates the consistent and predictable pattern of rainfall over the duration of the weeks. This assessment shows that there are significant variations in quantitative measures, suggesting that the rainfall is highly erratic in all over the study area.

The highest mean monthly rainfall was observed to be 365.7 mm (July) in Chhura, 378.1 mm in Deobhog, 267 mm in Fingeshwar, 300 mm in Gariyaband during August month and 405.8 mm (July) in Mainpur. The monthly CV ranged from 36.9% (August) to 259.9% (December) in Chhura, 33.1% (July) to 316.2% (December) in Deobhog, 35.8% (July) to 227.4% (December) in Fingeshwar, 37.5% (September) to 316.2% (December), 34.4% (September) to 301.5% (February). Further from the analysis, it is also indicated that the value of coefficient of variation, skewness was found to be lowest of in the month of August, in Chhura and Fingeshar, July in Devbhog, September in Gariyaband and Mainpur respectively which signifies less variation in rainfall distribution and has a consistent and uniform rainfall pattern during this period.

While analyzing the average number of rainy days per year ranged from 52 in Chhura and Fingeshwar to 60 in Mainpur. Similar to this, Fingeshwar experienced 45 days of rain on average during the *Kharif* season whereas Mainpur experienced 51 days. The onset and withdrawal of the rainy season, as well as their probability, were calculated. To have precise information of dry spells, the weekly dry and wet spell probabilities were developed using Markov chain analysis. Based on the length of the rainy season and the dry spell, crop planning recommendations were made.

Based on weekly dry and wet spell analysis, in-situ moisture conservation measures and prospective water harvesting periods were proposed. Various plotting position functions were used to calculate the weekly predicted rainfall at probability levels of 50, 60, 70, 75, 80, and 90 percent A good fit was obtained for the *Kharif* season periods with the California plotting-position function using error statistics.

It was found that, in the weeks coinciding with nursery and reproductive stages of paddy crop were having good rainfall and sufficient rainfall all throughout critical crop stage (31-35th SMW) of maize crop. The probability of dry weeks (P_D) occurring was reported for the 22,40,42, and 44th SMW at Chhura; 4 weeks (41-44th SMW) at Deobhog; and 21,41, and 44th SMW was observed for the remaining tehsils, namely Fingeshwaer, Gariyaband, and Mainpur. The beginning of the effective monsoon was also observed to fall between June 18 and June 24 in all five tehsils, whereas the date of the probable departure of the effective monsoon was June 39 SMW (17 -23 September).

सारांश

शीर्षक	:	गरियाबंद जिले के लिए पानी की उपलब्धता के आधार पर खरीफ फसल की योजना
छात्र का पूरा नाम	:	राजेन्द्र कुमार देव
प्रमुख विषय	:	मृदा एवं जल अभियांत्रिकी
प्रमुख सलाहकार का नाम और पता	:	डॉ. बी. एल. सिन्हा सहायक प्राध्यापक, मृदा और जल अभियांत्रिकी, एस.वी.सीएईटी और आरएस, एफएई, इं.गा.कृ.वि.वि., रायपुर (छ.ग.)
प्रदान की जाने वाली उपाधि	:	कृषि अभियांत्रिकी मे स्नातकोत्तर

छात्र का हस्ताक्षर

प्रमुख सलाहकार का हस्ताक्षर

दिनांकः 20/10/2022

विभागाध्यक्ष का हस्ताक्षर

सारांश

वर्षा, मौसम विज्ञान का एक सूचकांक है, जिसे किसानों और पर्यावरण वैज्ञानिकों द्वारा सबसे पहले माना जाता है, क्योंकि यह सबसे महत्वपूर्ण कारक है जो बोई जाने वाली फसल के प्रकार, उसकी सफलता या विफलता और किसी क्षेत्र के सामान्य फसल प्रणार्ली को निर्धारित करता है। इसलिए, ''गरियाबंद जिले के लिए पानी की उपलब्धता के आधार पर खरीफ फसल की योजना'' नामक अध्ययन में गरियाबंद जिले के पांच तहसीलों से दस साल की अवधि (2011 – 2020) की दैनिक वर्षा के आंकड़ों का उपयोग किया गया, जिले में वर्षा चक्र की स्थिति का वर्णन करने के लिए मासिक और साप्ताहिक आधार पर विभिन्न तहसीलों में वर्षा की भिन्नता की जांच की गई, साथ ही साथ मानसून की शुरुआत और वापसी एवं वर्षा के संभावनाओ की भी जांच की गई है।

खरीफ मौसम (22–44 SMW) के दौरान सबसे अधिक औसत साप्ताहिक वर्षा 142.9 मिमी (29 SMW) छूरा में, 114.8 मिमी (32 SMW) देवभोग में, 148.1 मिमी (35 SMW)

xvi

फिंगेश्वर में, 104.6 मिमी (29 SMW), गरियाबंद में और मैनपुर तहसील में 125 मिमी (35 SMW) दर्ज की गई और पूरे अध्ययन क्षेत्र में न्यूनतम औसत साप्ताहिक वर्षा 0 मिमी (44 वां SMW) पाई गई। विभिन्नता का गुणांक 244.1% (42 SMW) से 42.2% (33 SMW) छूरा में, 298.1% (43 SMW) से 49.6% (25 SMW) देवभोग में, 204.4% (43 SMW) से 46.1% (28 SMW) फिंगेश्वर में, 289.1% (41 SMW), गरियाबंद में 289.1% (41 SMW) से 55.5% (28 SMW) और मैनपुर में 316.2% (44 SMW) से 55.4% (34 SMW) तक पाया गया, इस आकलन से पता चलता है कि पूरे अध्ययन क्षेत्र में मानक विचलन और विभिन्नता गुणांक आंकडो अत्यधिक भिन्नता है, जो कि क्षेत्र मे वर्षा के अत्यधिक अनिश्चितता को दर्शाता है।

सबसे अधिक औसत मासिक वर्षा छुरा में 365.7 मिमी (जुलाई), देवभोग में 378.1 मिमी, फिंगेश्वर में 267 मिमी, गरियाबंद में 300 मिमी और मैनपुर में 405.8 मिमी (जुलाई) दर्ज की गई, मासिक विभिन्नता गुणांक 36.9% (अगस्त) से 259.9% (दिसंबर) छूरा में, 33.1% (जुलाई) से 316.2% (दिसंबर) देवभोग में, 35.8% (जुलाई) से 227.4% (दिसंबर) फिंगेश्वर में, 37.5% (सितंबर) से 316.2% (दिसंबर), 34.4% (सितंबर) से 301.5% (फरवरी) के बीच पाया गया। इसके अलावा यह भी संकेत मिलते है, कि विभिन्नता गुणांक और विषमता का मूल्य छुरा और फिंगेशर मे अगस्त के महीने मे, देवभोग में जुलाई को, गरियाबंद और मैनपुर में सितंबर में सबसे कम पाया गया जो कि कम भिन्नता का प्रतीक है, इस अवधि के दौरान वर्षा का वितरण एक समान रहता है।

वर्षा के दिनों की औसत संख्या का विश्लेषण करते समय पाया गया कि छुरा और फिंगेश्वर में 52 से लेकर मैनपुर में 60 दिन तक प्रति वर्ष वर्षा होती है। इसी तरह, खरीफ मौसम के दौरान फिंगेश्वर में औसतन 45 दिनों तक बारिश हुई जबकि मैनपुर में 51 दिनों तक वर्षा का अनुभव हुआ। वर्षा ऋतु की शुरुआत और वापसी, साथ ही उनकी संभावना की गणना की गई। शुष्क काल की सटीक जानकारी प्राप्त करने के लिए, मार्कोव श्रृंखला विश्लेषण का उपयोग करके साप्ताहिक शुष्क और आर्द्र सप्ताह की संभावनाओं को विकसित किया गया। वर्षा ऋतु की अवधि और शुष्क अवधि के आधार पर फसल नियोजन की सिफारिशें की गईं। साप्ताहिक शुष्क और आर्द्र वर्तनी विश्लेषण के आधार पर, यथा स्थान मे नमी संरक्षण उपायों और संभावित जल संचयन अवधियों का प्रस्ताव दिया गया। 50, 60, 70, 75, 80, और 90 प्रतिशत के संभाव्यता स्तरों पर साप्ताहिक पूर्वानुमानित वर्षा की गणना के लिए विभिन्न प्लॉटिंग स्थिति कार्यों का उपयोग किया गया।

यह पाया गया कि धान की फसल की नर्सरी और प्रजनन चरणों और मक्का की फसल के महत्वपूर्ण चरण (31–35 SMW) के साथ आने वाले हफ्तों के दौरान अच्छी और पर्याप्त वर्षा होती रहती है। शुष्क सप्ताह होने की संभावना छुरा के लिए 22, 40, 42, और 44 SMW में सूचित की गई, देवभोग में 4 सप्ताह (41–44 SMW) और शेष तहसीलों अर्थात् फिंगेश्वर, गरियाबंद और मैनपुर के लिए 21,41, और 44 SMW को माना गया। सभी पांच तहसीलों में 18 जून से 24 जून के बीच प्रभावी मानसून की शुरुआत भी देखी गई, जबकि मानसून के संभावित प्रस्थान की तिथि 39 SMW (17–23 सितंबर) अनुमानित की गई।

CHAPTER I

INTRODUCTION

Rainfall is one of the most important hydrologic events that affects numerous agricultural and non-agricultural enterprises. Rainfall is affected not just by time, but also by geography and height in space. Total rainfall and its distribution throughout the course of the year are incredibly valuable and crucial for improved crop planning and designing irrigation strategies for a given area.

Chhattisgarh is a state in India that covers from 80˚15′ to 84˚24′ East longitudes and 17˚46′ to 24˚5′ North latitude. It covers a total area of 13.51 million hectares. It has three agro-climatic zones: the Chhattisgarh plains, the Bastar plateau, and the Northern hill zone, with 74%, 97%, and 95% of the land being rainfed. Chhattisgarh's climate is classified as subtropical. The average annual rainfall is 1200-1400 mm and is obtained in 65 rainy days, with the south-west monsoon contributing 85% of the rainfall from June to September and the remaining 15% from the north-east summer and winter seasons (Anonymous, 2019). Monsoon season begins around June 15th on the southernmost part of the Bastar plateau and lasts until June 25th across the entire region. It is fully withdrawn from the entire state till the end of September. As a result, rice has long been farmed throughout the state to feed the indigenous population. Despite ample rains, seasonal droughts, particularly during critical crop growth stages in September and October, are a common problem in rainfed farming throughout the state. Droughts are caused by unpredictable rainfall distribution, which results in unstable crop yields.

Approximately 70% of the state's agricultural area is rainfed, and rice is the state's main crop. One method of mitigating the impact of decreased rainfall is to provide an appropriate supply of water through irrigation. This necessitates knowledge of rainfall patterns and variations in order to determine the additional water requirements of diverse crops. In this region, terminal drought is a common element of the rice crop. In addition, because 80 percent of this region is rainfed, crop activities are hampered by intermittent dry spells. Thus, the success of the rice harvest is dependent not only on monsoonal rainfall but also on October rainfall caused by cyclonic activity in the Bay of Bengal.

Several new innovative approaches for increasing crop productivity have been developed. However, because it is mostly dependent on monsoon rains, it confronts significant challenges in the form of natural calamities. Looking at agricultural production in good and bad monsoon years reveals this trend. As a result, analysing a region's yearly, seasonal, and monthly rainfall is beneficial for developing a proper cropping system, cropping pattern, and water collecting structure. Average monthly, seasonal, and annual rainfall are beneficial in establishing a general picture of a region, but weekly rainfall data analysis gives more useful and precise data for rainfall-based crop planning.

The study of rainfall patterns is crucial for every region's agricultural planning. For optimal rainwater management at many levels and purposes, such as land and crop management and crop planning in any location, accurate rainfall analysis is required. In order to maintain a reasonable crop yield in a rainfed environment, rainfed crops and management strategies must be planned in accordance with the region's rainfall pattern. Rainfall studies, particularly the research of its variability, provide more information for rainfed crop planning.

In light of the foregoing, the current study was designed to identify monsoon interferences in the study area in terms of probable dates of onset and withdrawal of effective monsoon. It was also attempted to assess the probability of rainfall availability and crop planning.

OBJECTIVES

1. To analyse rainfall data and workout the rainfall variability for Gariyaband district.
2. To estimate rainfall using different plotting position functions.
3. To suggest suitable crop plan based on water availability for *Kharif* season.

CHAPTER II

REVIEW OF LITERATURE

Planning for crops, subsequent crop output, and other planning have long placed a high value on quantifying the unpredictability of climatic elements. Rainfall has the most aspects of all climatic elements. In general, annual rainfall or the magnitude of its variation from normal is used as the primary independent variable in various analyses. The distribution of rainfall, rather than its total amount, is what is more significant. Therefore, it is helpful to know in advance when the effective monsoon will start and how likely it is that a dry spell will occur throughout the growing season. Such prior knowledge assists in determining planting patterns as well as planning complete plans for proper and efficient rainwater management in order to improve crop output per unit of available water.

The review of the literature is presented to emphasize the relevant studies conducted by numerous writers for various other locations.

2.1 Rainfall Analysis

Gare *et al.* (2000) examined daily rainfall data collected at the Agricultural Research Station Gadhinglaj in Maharashtra from 1969 to 1996. Data for annual, seasonal, monthly, weekly, and weekly probability of rainfall were all analysed. The average annual rainfall was 931.1 mm, with 75% falling between June and September (southwest monsoon) and 14% falling between October and November (northeast monsoon). During the 28th to 32nd SMW (CV 73 to 98%) and 39th SMW (CV 68%) of the *Kharif* and rabi seasons, respectively, there was comparatively less variance in the weekly rainfall. According to initial estimations, rain might be expected with a likelihood of more than 75% from MW 28 to 31 in the *Kharif* season and MW 39 in the rabi season. Conditional probabilities (W/D) exceeding 80% in MW 29 showed the suitability of the 29th MW for dry sowing

Krishnamurthy and Shukla (2000) investigated the intra-seasonal and interannual variability of rainfall across India and discovered that the geographical patterns of the rainfall anomalies over India vary significantly on both a daily and seasonal time scale.

Osborn *et al*. (2000) applied the "amount quantile" method to perform over 30-year period for each site and for each month, all daily rainfall amounts were ranked, then sorted into ten equal "amount quantiles." Each quantile from the 30-year data set contains 10% of the total rainfall amount, with the first quantile containing the 10% of total rainfall associated with the least intense events (wet day daily totals), and the 10th quantile, the most intense events. The changing contribution of the "30-year 10th decile" rainfall events to total annual rainfall can thus be determined.

Hundal and Kaur (2002) looked at climatic variability in several parts of Punjab state, both annually and seasonally. For Amritsar (1970–1988), Patiala (1970–1988), Ludhiana (1970–1999), and Bathinda (1970–1999), historical daily meteorological data were used to study the rainfall variations (1977-98). It was discovered that rainfall at all sites varied greatly throughout the year and during specific seasons, as indicated by the significant standard deviation and coefficient of variations for both types of rainfall. Rainfall increased overall by roughly 120 mm at Amritsar, 150 mm at Ludhiana, 150 mm at Patiala, and 140 mm at Batinda, according to the five-yearly moving average trends in rainfall.

Singh *et al.* (2005) examined daily rainfall data from the Agromet observatory Sabour near Bhagalpur, Bihar, from 1972 to 1999. The information was examined for yearly, seasonal, monthly, and weekly timeframes. Between the 19th to the 41st, the 24th to the 40th, and the 26th to the 39th standard meteorological weeks, respectively, the probabilities of 10, 20 and 40 mm of rainfall each week exceeded 60%. A total of 1185.3 mm of rain fell on average each year, with the *Kharif*, summer, and rabi seasons receiving 954.0, 105.2, and 126.2 mm of that total. Rainfall totals ranged from 7.5 mm in December to 320.5 mm in July. The 22nd to 41st weeks saw almost 87 percent of the entire year's rainfall.

Ali *et al.* (2007) examined daily rainfall data from Kota district in south-eastern Rajasthan for 48 years (1956-2003) to determine the south-west monsoon features for rainfed crop planning. The monsoon's typical arrival date was 2 July (± 15 days ago). The projected dates for the early and late onset of the monsoon were

17-June and 17-July, respectively. The usual monsoon departure was recorded on September 14 (±14 days). Monsoon withdrawal was predicted to begin on August 31st and end on September 28th, respectively. Rainfall averages 741 mm per year and 675 mm per season (June to September). Average length of monsoon season (LMS) was found to be 73 days with standard deviation of 21 days. The rainfall pattern in the Kota region was observed to be highly erratic with average annual and seasonal (June to September) rainfall of 741 and 675 mm, respectively.

Vaidya *et al.* (2008) did a study on rainfall probability analysis for crop planning in Gujarat state. To investigate rainfall features, the beginning and end of the monsoon season, as well as the length of time with guaranteed rainfall, the daily rainfall data from several Gujarati districts were analysed. They concluded that as rainfall decreased, the coefficient of variation increased. 23–26 SMW marked the beginning of monsoon rains, and 38–42 SMW marks their exit.

Kothari *et al.* (2009) examined data on the intervening essential dry spell and the availability of extra water for rainwater management in crop planning. Conventionally, probabilities of dry spells are calculated for various standard climatic weeks without taking the start of the monsoon in any given year into account, and data for the period of crop growth is presumptively based on the typical week of the start of the monsoon. This strategy has been contrasted with a logical strategy known as the "Onset of monsoon approach," which arranges the weekly rainfall data by using the monsoon's onset as a datum for each year. For this investigation, 45 years' worth of weekly rainfall data from the Rajasthani state's Bhilwara district were employed. There is a significant discrepancy between the initial and conditional probabilities. Although there is a significant difference between the two ways in terms of the initial and conditional probabilities of intervening dry spells, the new strategy has been deemed to be more logical than the old approach. As a result, it has been accepted for the district's tehsil-level examination of dry spells and the presence of surplus water.

Sinha (2012) evaluated monthly and yearly rainfall data for 39 years (1971-2010) for Raipur, Bilaspur, Ambikapur, and Jagdalpur districts and discovered that the mean annual rainfall for the four districts was 1172.6, 1183.4, 1383.4, and 1418.4 mm, respectively. When the coefficient of variation for the average annual rainfall was analyzed, Bilaspur (18.7%) had the lowest value, followed by Jagdalpur (20.7%), Raipur (22.4%), and Ambikapur (23.4%). (24.1 percent). Over various districts of Chhattisgarh, the monsoon typically begins between SMW 24 and SMW 25. When the rainfall distribution was examined, it was discovered that it was better in Jagdalpur than in Ambikapur, Raipur, and Bilaspur.

Manikandan *et al.* (2013) employed weekly analysis of daily rainfall data from Coimbatore for 30 years (1981-2010) to evaluate the variability and probability level of occurrence. The research found that the standard weeks from the 40th to the 45th had rainfall amounts of more than 25 mm with a 50% probability, with 14.6 mm falling in the 41st week. The eight-week period from the 39th to the 46th standard week saw a 50% chance of receiving 25 mm of weekly rainfall. Regardless of the anticipated amount of rainfall, the weekly rainfall analysis' CV showed .

Jajoria *et al.* (2014) identified the cropping pattern of a region and the appropriate crop to be grown through the use of a rainfall index, The current study therefore focuses on the Udaipur District of Rajasthan, India's rainfall characteristics. To investigate the variability and frequency of daily rainfall over the last 39 years (1973–2011), the data were evaluated. The region's mean annual rainfall was 630.20 millimetres, with the greatest amounts (1,145 mm) falling in 1973 and1983, respectively. Accordingly, the contributions from the winter, summer/pre-monsoon, monsoon, and post-monsoon seasons were 1.08, 3.17, 89.89, and 5.86 percent. Rainfall in June, July, August, and September is more useful in determining whether a crop is suitable for growing during that time in order to produce a crop that will be profitable.

Bhuarya *et al.* (2015) investigated the significance of rainfall and rainy days in Chhattisgarh, India, in determining the cropping pattern of a region in general and the type of crop to be produced, as well as its success or failure. In addition to describing the rainfall's spatial distribution, they also described its seasonal and yearly variations in the several districts of the state of Chhattisgarh. The findings showed that the state's mean annual rainfall is 1167 mm (± 147mm), of which the winter, summer, southwest, and post-monsoon period each contribute 20, 30, 1050, and 67 mm, respectively. The district of Kabirdham in the Chhattisgarh Plain Agro-Climatic Zone (ACZ) has the lowest annual (885 mm) and southwest monsoon period, while Surajpur, which is located in the Northern Hills ACZ, receives the maximum annual rainfall (1411 mm) and south-west monsoon season (1311 mm) (778 mm). With rice being grown in 80% of the cultivated land and low rainfall and high inter-annual variability in certain districts, such as Kabirdham, Durg, Bemetara, Mungeli, and Rajnandgaon, there is a substantial chance of crop failure should the southwest monsoon rainfall fail. Conserved water can then be used for low-water-demand crops like pulses and oil seeds during rabi season as well as for life-saving irrigation during dry spells in the *Kharif* season.

Chaudhary *et al.* (2015) explored the use of rainfall data for strategic crop planning in a rainfed rice-based cropping system in Chhattisgarh. There are a wide range of different weather patterns in this area. In the state, three primary agro-climatic zones have been identified: the northern hill area, the Bastar plateau ACZ, and the Chhattisgarh lowlands zone. Here, rainfall data for a few typical districts has been analysed, and conclusions about the cultivation of rice as the main crop have been produced. Based on observation, it has been discovered that the annual rainfall decreases from east to west. From 1300 to 1600 mm of rain fall falls annually in the state's eastern region. This includes the districts of Mahasamund, Raipur, Janjgir, Korba, Raigarh, Jashpur, and Surguja. When the CV for yearly rainfall was examined, it was discovered that Bilaspur had the lowest, followed by Jagdalpur, Raipur, and Ambikapur. Similar calculations have been made for reliable rainfall quantity and timing. The development of farm tanks and OFRs can help to store excess water and maximise its usage for subsequent crops as well as for irrigation of the rice crop, which is vital to the crop's survival.

Mahilange (2018) analysed that the highest mean annual rainfall was recorded in Bastar (1222.0 mm) followed by Bijapur (1181.1 mm), and Sukma (1176.8 mm). While the lowest mean annual rainfall (1125.2 mm) was recorded in Kondgaon followed by Dantewada (1140.5 mm). The highest CV of annual rainfall was found at Narayanpur 8.6% followed by Bastar 7.6% and lowest CV for the annual rainfall was found in Bijapur 5.7% followed by Sukma 5.9%. The highest mean annual rainy days of 74 were recorded in Kondagaon and Bijapur followed by Bastar, 71 days and Sukma, 70 days. While the lowest mean annual rainy days recorded in Dantewada district 56 days followed by Narayanpur 59 days. The highest CV of annual rainy days was recorded in district Kondagaon i.e., 15.1% followed by Bijapur 14.6%. While the lowest CV were found in district Narayanpur 12.2% followed by Sukma 12.3%. There are 32 interesting results obtained from the analysis that through CV of annual rainfall of Bijapur is found to be lowest but rainy day is comparatively on the higher side. This indicates that is possibility of increasing cropping intensity in that district. When as the highest CV of annual rainfall was observed in narayanpur district with lowest CV value 12.2%of rainy days. The overall CV value of all six districts were in comparatively less indicates there is possibility of indicates cropping intensity and increasing production and productivity of different crops throughout the Bastar plateau zone. The analysis of wet spell, concluded that maximum probability of occurrence of wet spell was ranged from 70-79%, during 29-32 SMW in the most of tehsils & districts and conditional probability (wet after wet) occurs during 29-31 SMW, between 80-100%.

Xalxo (2021) investigated rainfall data for the 18 Chhattisgarh ancestral districts of Baster, Bilaspur, Dantewada, Dhamtari, Durg, Janjgir- Champa, Jaspurnagar, Kanker, Korba, Koriya, Kawardha, Mahasamund, Raigarh, Raipur, Rajnandgaon, Surguja, Bijapur, and Narayanpur during the 37 years (C.G). Following analysis, it was discovered that Chhattisgarh's mean annual rainfall was approximately 1188mm. The Baster district had the greatest average annual rainfall of 1484mm. Study shows that Chhattisgarh's plain region receives less rainfall on average, averaging between 970 and 1281 millimetres, compared to the Baster plateau zone and the northern hill zone.

2.2 Markov Chain Analysis

Gore (2001) used a Markov-Chain model to calculate the probability of rainy and dry spells over districts in all subdivisions of the country from five homogeneous regions and hilly areas, utilising daily rainfall data from 1901 to 1990 for all stations in the subdivisions. In making decisions for agricultural operations, it is claimed that climatological analysis presented as probabilities can be highly helpful.

Singh *et al*. (2004) made a dry spell analysis for Bathinda, Punjab using the Markov chain approach. The initial and conditional probabilities were computed.

The probability of occurrence of dry spell was >92% from the first standard meteorological week (SMW) to the 22nd SMW, except for the 4th, 7th and 8th SMW (during which the probability was 77, 73 and 85%, respectively). Starting from the 23rd SMW, the probability of dry spells decreased and reached the lowest value (38%) during the 27th SMW, then increased to 100% from the 44th to 55th SMW. The probability of the occurrence of wet spells was maximum (62%) during the 27th SMW (July).

Srivastava *et al.* (2004) introduced the probability concept in order to illustrate the significance of dry and wet spells for planning weather-sensitive agricultural activities. Four selected stations representing various agroclimatic zones in Uttar Pradesh, India, had their weekly rainfall data fitted with a Markov chain model. In the *Kharif* season, initial and conditional probabilities of dry and wet spells of various lengths occurring at these stations were estimated, and their probabilities were computed.

Gill and Kingra (2008) using a Markov chain technique, calculated the initial and conditional probabilities of rainfall for Ludhiana. Data about Ludhiana's weekly rainfall were collected from 1970 to 2004. From SMW (Standard Meteorological Week) 26 to34, the probability of a wet spell occurring was 50% or higher, while the probability of a dry spell occurring was less than 50%. During the rest of the year, the probability of a dry spell occurrence was greater than 50% and approached 100% for a few weeks, but the probability of a wet spell occurrence was less than 35% from SMW 1-25 and 37-52 and was also found to be 0 for a few weeks.

Subash *et al.* (2009) investigated rice-wheat planning rainfall probability for dry and wet spells. The Markov chain model was used to determine the initial and conditional probabilities of a dry or wet week, as well as the likelihood of successive dry or wet periods lasting two or three weeks, for a set of stations. Different crop management techniques and remedies are given based on the rainfall pattern and distribution to explore maximum rainfall received during the season to optimise production and decrease the existing gap between potential and actual production.

Garg and Singh (2010) used a three-state Markov chain approach to establish an analytical procedure for assessing the independence of rainfall behaviour. This statistical analysis of Rainfall pattern in Mandya District analytical approach was used for daily rainfall data collected over a 42-year period (1961-2002) from the Pantnagar, India-based IMD-approved meteorological observatory. For the analysis of daily and weekly rainfall data, the entire year was separated into three distinct periods: pre-monsoon (Jan. 1–May31), monsoon (June 1–Sept.30), and post-monsoon (Oct. 1–Dec. 31). A day/week was considered dry if the amount of precipitation fell below 2.5mm/17.5mm, and wet if it fell between (2.5mm to 5mm)/17.5mm to 35mm, respectively. If the amount of precipitation fell beyond these thresholds, the day/week was considered rainy.

Piyadasa and Sonnadara (2010) conducted a study to use Markov models at the three chosen weather stations where long-term data records were available to estimate the daily rainfall climatology of Sri Lanka. Daily rainfall could be predicted with an accuracy of ~ 72±4 % using both the first and second order Markov models. Predicting wet days during the wet season was significantly more accurate than during the dry season, while predicting dry days during the dry season was significantly more accurate than during the wet season. Standard probability distributions along with transition probabilities based on the first order Markov model were used to anticipate the average number of rainy periods per month and the average length of a wet spell per month. The deviation of the simulated values from the observed values was lower than the statistical variations which indicate that the model is suitable for simulating wet and dry spells in Sri Lanka.

Soomro and Talpur (2011) used the Markov chain model to assess the likelihood of receiving a series of wet and dry days, which is necessary for many real-world applications including agricultural yield design and prediction. The intensity of the rainfall is largely determined by the local climate conditions. Utilizing historical data from 1987 to 2006 for the meteorological station in Karachi, this model is used to forecast long-term weather conditions.

Hossain and Anam (2012) conducted research on seasonal fluctuations in rainfall in Bangladesh. To simulate the daily occurrence of rainfall, stochastic rainfall models took into account the frequency of rainy days and the amount of rainfall in various regions. The relationship between the current rainfall and the rainfall from the previous two time periods was shown using logistic regression in conjunction with the Markov chain of various order. A dry-wet spell's dependence on the occurrence of rain in the research area's rainy season, which runs from April to September, was demonstrated to exist. This was demonstrated by comparing wet days from the prior two time periods to dry days from those same periods. 26 years' worth of daily rainfall data were gathered from the meteorological agency for examination. The findings indicate that rainfall follows a second order. Both Markov chains and logistic regression indicate that it is more likely for Dhaka station rainfall to be dry followed by dry than wet followed by wet, and that the model can successfully handle a variety of applications involving rainfall.

Admasu *et al.* (2014) used the Markov chain probability model in order to describe the long-term frequency behaviour of wet and dry weather periods throughout the primary rainy season at Dhera, (Central rift valley region of Ethiopia). The study employed 24-year (1984-2010) rainfall data, with weekly rainfall data serving as the standard, to investigate the likelihood of dry and rainy weeks. The primary rainy season begins in the 26th week (25th June – 1st July) and lasts until the 40th week (1st-7th October). This illustrates the potential major rainy season duration of 105 days. For the research site during the wet season, the coefficients of variation for the beginning and withdrawal week were 69.4 and 99.2%, respectively. On weeks 26 and 28, when the threshold limits are 10 millimetres per week and 20 millimetres per week, respectively, the chance of initial and conditional probability occurrences is greater than 50%. They demonstrated that for short-duration crops, supplemental irrigation and moisture conservation practises must be implemented between the 38th and 40th weeks, and supplementary irrigation is clearly required after the 40th week. Additionally, between the 28th and 33rd weeks, it is necessary to practise capturing runoff water for supplemental irrigation and building steps to prevent soil erosion.

Dabral *et al.* (2014) stated that crop planning and agricultural operations require knowledge of the sequence of dry and wet periods. The current study was conducted with the goals of predicting dry and wet spell analysis using a Markov chain model and also determining the precise timing of monsoon onset and termination at the study region for North Lakhimpur (Assam), India, utilising weekly rainfall data collected over a 24-year period. The findings showed that week’s 1 through 14 as well as weeks 41 through 52 have increased probabilities of dry weeks occurring. The probability that a dry week will occur in these weeks' ranges from 41.67 % to 100 %. As there are 50 percent to 95.83 percent odds of two consecutive dry weeks occurring, the first to fourth week and the 43rd to 52nd week of the year stay under stress on average. According to the analysis, North Lakhimpur has its first monsoon season beginning in week 23 (4–10 June). It is best to begin wet land preparation for producing short-duration rice varieties during the 25th week (18 June to 24 June). As of week 14, the pre-monsoon season officially begins (2nd April to 8th April). Summer maize can be sown (rainfed) as early as week 14. The start of wet land preparation for long-duration rice varieties is best done in week 15 (9 April to 15 April).

Kar *et al.* (2014) examined the weekly rainfall in Kandhamal district from 1965 to 2010 for crop planning and determining the likelihood of dry and wet periods. In the Kandhamal district, which is in the East-coast hill region's agro-climatic zone, this will serve as the benchmark for crop planning and sustainable agricultural management. A Markov chain model was used to calculate the likelihood of dry or rainy weeks as well as the forward and backward accumulation of rainwater adequate for crop production. This research can be used to identify several cropping systems, including intercropping and sequence cropping, that are appropriate for that time period.

Ramdurg *et al.* (2015) using a weekly analysis to study the variability and probability level of occurrence by. 39th SMW saw the highest mean weekly precipitation (42.5 mm). The CV was less than 15% during SMWs22–33,35, and37–42, indicating that the amount of precipitation remained constant over those weeks. The crop may be advised for dry land during SMWs 22 to33,35, and 37 to 42 because the rainfall was more regular during these times than it was during SMWs 18 to21, which also occurred under the south west monsoon period. The analysis found that greater than 20 mm of rainfall might be anticipated with 50% probability during the 38th to 40th SMW, providing a clue for rainwater harvesting.

Vanitha and Ravi (2017) investigated spell distribution using the Markov chain model. It was decided that a week would be the best amount of time for this objective. In this study, the probabilities of occurrence of a wet week (P_W), a dry week (P_D), a wet week preceded by a wet week (P_{WW}), a dry week preceded by a dry week (P_{DD}), and two and three consecutive wet and dry weeks (P_{2W}, P_{2D}, P_{3W}, and P_{3D}) at a threshold rainfall limit of 20 mm/week are estimated. Daily rainfall data for Kumulur, Trichy district, Tamil Nadu, was converted to weekly period for 30 years from 1986 to 2015. A Markov chain model was used to calculate the likelihood of dry or rainy weeks as well as the forward and backward accumulation of rainwater adequate for crop production. This analysis can help determine the best cropping practises, including as intercropping and sequence cropping, for that time period.

Behera and Subudhi (2018) conducted a dry and wet-spell analysis of Odisha and discovered that water stress reduced yield by 50%. Using a weekly rainfall-based Markov Chain model, daily rainfall data for 25 years (1992–2016) were collected, with a dry week being defined as less than 20 mm of precipitation and a wet week being defined as 20 mm or more. Weekly rainfall data for 25 years (1992-2016) showed that the monsoon begins in earnest on June 11 and lasts until the 38th SMW (17 23 September). Consequently, crop planning can be adjusted accordingly.

Ray *et al.* (2018) employed a Markov chain probability model to 20 years (1997 to 2016) of weekly rainfall data in Mayurbhanj to determine the likelihood that dry and wet spells would occur there. With a total duration of 20 weeks, the monsoon season begins on the 24th SMW (11th–17th June) and lasts until the 43rd SMW (22nd–28th October) (140 days). Initial, conditional, and successive dry and wet week probabilities indicated that the odds of a week becoming wet are highest between the 24th and the 40th week. Because irrigation is guaranteed throughout this time, agricultural operations like planting and sowing can be accomplished successfully.

2.3 Probability Analysis

Rao *et al.* (1988) using daily rainfall data for Anantapur, Nandyal, and Lam from 1969 to 1984, calculated the likelihood of obtaining sufficient rainfall for effective crop establishment. The consequences for agricultural production were examined, and the probabilities of getting a minimum of 50, 75, or 100 mm of rainfall per month at each location were computed at various levels of likelihood.

Rajeevan (2001) assessed the state, issues, and potential outcomes of long-range Indian summer monsoon forecasts. Indicating that chaotic internal dynamics may ultimately limit the predictability of the Indian monsoon, it is discovered that the prediction of Indian monsoon variability is sensitive to the beginning conditions.

Shabri (2002) ranked eight plotting position methods based on their performance in estimating annual maximum flood flows at 31 stations of peninsular Malaysia. The methods were ranked according to values of RMSE and MAE on a scale 1 to 8 with “1” being the best method. He reported that he Weibull method was the best performing one compared to the other method considered in the study.

Adeboye and Alatise (2007) fitted the normal distribution to the peak flow discharge of two rivers in Nigeria using seven probability plotting positions *i.e.,* Hazen, Weibull, Blom, Cunnane, California, Grington and Chegodajev plotting position method. They concluded that the Weibull’s method is suitable for fitting the normal distribution.

Makkonn (2008) compared the return period of the largest value in a sample of 21 annual extreme values as determined by commonly used plotting position formulae namely, Weibull’s, Beard, Grington, Hazen and numerical method proposed by Harris. He reported the percentage error in estimation of the event was zero for Weibull method while all other methods overestimated the return period of the largest annual extreme event, that is, underestimated to risk of occurrence.

Pali *et al*. (2014). They collected daily rainfall information for 20 years (1994–2013) from the Durg, Dhamdha, and Patan Tehsils in Chhattisgarh's Durg district. They examined the data and discovered that the mean annual rainfall for the three study Tehsils was 1067.9, 908.7, and 1088.8 mm, respectively, and that 98 percent of the total annual rainfall occurred during the monsoon season alone. Out of the 20 years, at Durg, Dhamdha, and Patan Tehsils, respectively,20,11, and 25% of the years were observed as excess rainfall years,25,23, and 28% as normal rainfall years, and the remaining55,66, and 50% as deficit rainfall years. It suggests that Dhamdha Tehsil is dealing with a bigger deficiency in rainfall than other Tehsils. At a 75 percent likelihood level, the seasonal rainfall quantities in the Durg, Dhamdha, and Patan Tehsils were determined to be 743, 730, and 881 mm, respectively.

Singh *et al.* (2016) analysed rainfall data which provides a better opportunity for estimating the minimum assured rainfall to aid in crop planning. Based on 13 years of data from Shivri, Lucknow, and Uttar Pradesh (2000-2012), an attempt was made to examine rainfall distribution patterns, i.e., weekly, seasonal, and yearly rainfall. Using the Blom plotting tool, expected weekly, monthly, seasonal, and yearly rainfall values at various probability levels were calculated. Based on a 13-year annual average, the research shows that the measured rainfall was 829.35 mm, emerging from an average of 40.7 wet days. At a 75 percent chance level, there will be 636.5 mm of yearly precipitation. Similarly, at a 75 percent chance level, the maximum weekly rainfall of 42.0 mm was forecast for the 37th week, followed by 38.6 mm for the 27th standard week, and the lowest rainfall of 0.0 mm for the 40th week. In contrast, a review of monthly rainfall at 70, 75, and 80% likelihood levels reveals that July, August, and September are the three most important wet months, with possibilities of receiving 100 to 150 mm per month. At a 70% probability level, seasonal rainfall is projected to be 600 mm during the *Kharif* cropping season, compared to 12.6 mm during the Rabi and 4.2 mm during the Zaid cropping seasons.

Murugappam (2017) using rainfall data, the performance of nine plotting position formulae namely, Hazen, California, Weibull, Beard, Chegodayev, Blom, Gringorten, Cunnance and Adamowski, in estimating magnitudes of annual and seasonal rainfall with higher return periods (or lesser probability of exceedance) at Puducherry in Union Territory of Puducherry, it has been assessed using the error statistics such as Mean Square Error (MSE), Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) and Agreement Index (AI).The plotting-position formulae are assigned ranks based on the mentioned error statistics and the Agreement Index. The mean ranking for a plotting-position method is computed as the average of all the rankings assigned to that method in terms of the seven statistics namely, MSE, RMSE, MAE, minimum AI, maximum AI, mean AI and standard deviation of AI. The method which yields the minimum mean ranking is assigned an overall ranking “1”. They found out that the error statistics were found to be consistently the least for Weibull method in estimation of rainfall magnitude with different probability of exceedance, while California method found to be consistently high.

Sinha *et al.* (2018) investigated the rainfall probability for crop planning in the Raipur region of Chhattisgarh state and discovered that at 75% probability level, the highest rainfall 25.83 mm was obtained by the 33rd week and the lowest rainfall 7.41 mm was received by the 39th week. Rabi season received the lowest rainfall at 70% likelihood, 13.61mm, which contributed 1.15% of the normal annual rainfall; *Kharif* season received the most rainfall at this probability level, 315.79 mm, which contributed 26.81% of the average annual rainfall. Despite the need for more irrigation for *Kharif* crops, there is at least a 70% chance that there will be enough rainfall to support the growth of high-value fruit crops.

Raju *et al.* (2021) studied the weekly probability analysis of rainfall using statistical methods to forecast the lowest assured rainfall that aids in crop planning and management. Weekly rainfall data from the Regional Agricultural Research Station in Anakapalle was studied using an incomplete gamma probability model from 1990 to 2019. The results suggested that the reliable amount of rainfall will be more than 15.0 mm from the 23rd to the 44th SMW (4th June to 4th November). It gives the length of the growth season taking a 50% chance of rain into account. In spite of the amount of rainfall expected, a study of the coefficient of variation of weekly rainfall showed that reliable rainfall would occur during the time period.

2.4 Crop Planning

Mujumder *et al.* (2005) investigated rainfall patterns for crop planning in two West Bengal agroclimatic zones with rainfed rice agriculture. They determined that the short duration rice variety is good for cultivation in the red and laterite zones of West Bengal, so that water requirements may be satisfied during key stages of growth, and the medium/long duration rice variety is appropriate for cultivation in the old alluvial zone of West Bengal, with the crop to be sown in the third week of June.

Singh (2005) examined the 29-year (1972-2000) daily rainfall data at the Bihar Agriculture College, Sabour (Bihar). Additionally, Markov chain probabilities

(>=20mm of rain each week) were calculated. The data showed that the mean sowing rainfall began around June 20th. From the 26th to the 34th standard meteorological week in *Kharif*, there were greater than 70% initial probability of receiving 20 mm. Additionally, the results showed that crops including rabi maize, oil seeds, and pulses benefited more from rainfall during the rabi season.

Singh *et al.* (2005), conducted the rainfall in the Bhilwara region for the purpose of crop planning. To ascertain the start, end, length, variability, and dry spell periods in Bhilwara, the daily rainfall data from 1960 to 2001 were analysed. The length of the rainy season varied from 5 to 27 weeks, and it was advised that off-season and primary tillage operations might begin at the 24th week while crop planting could begin at the 27th week.

Kumar *et al.* (2007) studied weekly rainfall data from Saharanpur for 45 years (1985-1999) for crop planning and management to determine the irrigation period required for the crops. The findings indicated that the sowing of *Kharif* crops, including maize, fodder crops, pulses, and oilseeds in Saharanpur's rain-fed region, may begin in the 22nd and 23rd week since rain is anticipated in the weeks after the sowing, and the first and second cultural activities could be performed in the 26th and 29th week. Designing a water harvesting structure with a 5-year recurrence frequency and providing irrigation infrastructure is the only way to plan for rabi crops.

Manorama *et al.* (2007) conducted research on rainfall analysis for the Nilgiris (Tamil Nadu). At various probability levels, weekly, monthly, seasonal, and annual studies were conducted. He proposed starting crops of potatoes, cabbage, carrots, etc. in the third week of April and planting a second crop in a rotation of these vegetables at the end of August.

Reddy *et al.* (2007) investigated the influence of rainfall on agriculture in Andhra Pradesh's north Telangana region. Results showed that, compared to the preceding 20 years, rainfall fell over the last 20 years in all districts. In September compared to the preceding 20 years, there was less consistent rainfall. However, there was an increase in consistent rainfall in October in all the districts, allowing for the timely sowing of rabi crops in the area's black cotton soils.

Goswami *et al.* (2008) evaluated long-term rainfall data, in order to calculate projected weekly rainfall at different probability levels for the Sali rice season in the Jaintia Hill district, A Sali rice crop calendar for the district has been created based on anticipated rainfall at the 50% and 75% likelihood level and the amount of water needed. It was proposed that the 22 and 24 MW was optimum for sowing or transplanting

Kothari *et al.* (2008) investigated a method for crop planning in rainfed locations using rainfall analysis. The 20-year (1985-2004) period covered by the data was covered by the weekly meteorological records kept at the Dry Land Farming Research Station in Bhilwara. They offered two methods, "Meteorological" and "Onset of monsoon," which were used to crop selection and cropping systems in various years to maximise yields per unit of precipitation.

Kumar (2008) studied characterization and probability of rainfall for crop planning in ChotaNagpur plateau. They collected 50 years data (1965- 2005) for study. Variability found maximum (139%) in N-E monsoon and minimum (45.2%) in SW monsoon. Frequent droughts affected *Kharif* crops. Probability of getting 50 mm rainfall was noticed during MW 26 to MW 38.

Maniyar *et al.* (2008) investigated crop and cropping patterns in the Marathwada region of Maharashtra state based on rainfall. The rainfall statistics at the Tehsil level for 28 years were examined. The length of the growth season ranged from 17 to 21 MW. Their recommendations for crops and cropping systems included long-duration crops like cotton and red gramme, short to medium-duration crops like green gramme, black gramme, soybean, sorghum, rabi-sorghum, safflower, and Bengal gramme, and rain-fed crops like sorghum, rabi-sorghum, and rabi-sorghum.

Mokashi *et al.* (2008) investigated rain and its probability-based forecast for Solapur, India, using 30 years of rainfall data from the Dry Farming Research Station in Solapur (1974-2003). In accordance with the preliminary wet probability data, >20 mm of precipitation was recorded in MW 24 (11–17 June), and 57% of the data indicate that the rainy season for *Kharif* crops has begun. During this time, sowing *Kharif* crops such as pearl millet, sunflower, and pigeon pea is suggested. In late July and early August, when the monsoon arrives late, the midseason corrective crop like sunflower is advised as a backup crop. However, MW 39 (24-30 September) with 75% confidence implies the best chance of rain during the Rabi season. The Rabi crops, such as winter sorghum, safflower, and gramme, are advised during this month to retain soil moisture.

Patel *et al.* (2008) examined the seasonal and annual variation in rainfall in Chhattisgarh, central India. Using historical daily data spanning 30 years, the variability analysis was conducted (1951-1980). They came to the conclusion that crop diversification was necessary for the agriculture of the northern highland Bastar plateau, some districts in the Chhattisgarh plains zone, and some districts.

Ahmed *et al.* (2009) conduct research on rainfall-based crop planning in Assam's Barak valley zone. In Karimganj, Assam, the daily rainfall data were analysed for 47 years (1960–2006). The total mean annual rainfall was 4073.5 mm, which was distributed as 2613.6 mm, 1134.8 mm, and 330.3 mm in the *Kharif* (June–September), summer (March–May), and rabi (October–February) seasons, respectively. Between the 18th and 37th weeks, the probability of 60- and 100-mm rainfall per week exceeds 70%. It is advised to complete the transplanting of ahu rice by the first week of April in flood-free upland and medium land locations, and the second crop of rice may be transplanted beginning in the 31st week. Sowing of toria/potato/vegetables may begin in uplands areas as early as the 43rd week. In locations where a second crop of rice is not possible owing to flooding, ahu rice should be followed by potato/toria/vegetables, etc., beginning in the 43rd week.

Bhargava *et al.* (2010) investigated rainfall variability and probability pattern for crop planning in the Roorkee region (Uttarakhand), India. Daily rainfall data from the Agrometeorological Observatory, Department of WRD&M, IIT, Roorkee, was studied for the chance and variability of evolving a rainfall-based farming system with the least risk. The annual, seasonal, monthly, and weekly mean rainfall, standard deviation, and coefficient of variation were calculated. August was the wettest month, coming in second with 272.4 mm, they discovered (271.4 mm). The least rainy (6.0 mm) contributing month was November. From the second week of June, they advised sowing the *Kharif* crop. In the Roorkee region, the month of July is considered appropriate for rice crop transplanting.

Jat *et al.* (2010) examined the daily rainfall data for Udaipur, Rajasthan, for 81 years (1921-2001). According to the weekly rainfall probability analysis, 10 mm of Monsoon rainfall is projected to fall with a 50% chance on the 24th SMW in the Udaipur region, when seedbed preparation and maize sowing can begin. Between 25% and 50% of the time, it rains on average. As of the 40th week onward, there is a very low likelihood of receiving the minimum promised weekly rainfall. Thus, a maize variety with a brief growing season might be used for *Kharif*.

Chand *et al.* (2011) conducted research on the study of rainfall for crop planning in the Jhansi district of Uttar Pradesh's Bundelkhand region. The 34 years (1975–2008) of rainfall data from Jhansi in the Bundelkhand agroclimatic zone of U.P. were studied to determine the weekly, monthly, seasonal, and annual probabilities at various levels of rainfall for effective crop planning. They discovered that August (286.0 mm) and April (3.1 mm) are the months with the highest and lowest rainfall, respectively. They also proposed that *Kharif* season crops and varieties be chosen with the growing time to reduce moisture stress, as well as in-situ moisture conservation methods such as mulching, use of anti-transparent, weed management, and enough plant stands to mitigate the effect of dry spell during important crop growth stages.

Bhadoria *et al.* (2013) conducted research on crop planning and rainfall probability analysis for the Madhya Pradesh region of Chambal. To determine the long-term averages of annual, seasonal, monthly, and weekly rainfall as well as its temporal variability, 29 years' worth of daily rainfall data (1981–2009) collected at RVSKVV, Zonal Agricultural Research Station Morena, were analysed. A coefficient of variation of 27.1% showed that the yearly rainfall was largely constant over time. August had the biggest rainfall contribution (33.4 percent) during the wet season, followed by July (28.9 per cent). They found that there is plenty of opportunity for rain water gathering from July to September, which can be used for crop saving irrigation as well as pre-sowing irrigation for succeeding Rabi crops, which are often sown on residual soil moisture.

Manikandani *et al.* (2014) examined Coimbatore's daily rainfall data for 30 years (1981-2010) in order to conduct a weekly analysis of variability and the likelihood that an event will occur. The research found that, over an eight-week period, from the 39th to the 46th standard week, there was a 50% chance of seeing 25 mm of weekly rainfall. During the growing season, which lasts from the 39th to the 46th standard weeks, sorghum and short-duration pulses that tolerate drought can be grown.

Pali *et al.* (2016) examined daily rainfall data from Durg, Dhamdha, and Patan Tehsils in Chhattisgarh's Durg district from 1994 to 2013. It was possible to predict and assess the ET requirements of the rice crop at various growth stages by using rainfall and evaporation data to determine weekly and seasonal mean rainfall, expected rainwater availability at particular probability levels, and so on. In comparison to ET demands during the nursery stage of the rice crop, the projected rainwater received with a 75% likelihood is less. The anticipated weekly rainfall totals at the seedling and vegetative phases are reassuringly in excess of ET demand. As a result, this extra rainwater needs to be collected on the farm itself so that it can be recycled during the reproductive stage's dry season.

Vanitha and Ravikumar (2017) used 24-hour daily rainfall data (1986-2015) from Kumulur, Trichy, Tamil Nadu, to study weekly rainfall analysis for crop planning using Markov's chain models. The findings showed that from the 38th to 52nd SMW there is a greater than 10% chance of 2 consecutive wet weeks occurring, and that greater than 10% chance of 3 consecutive wet weeks occurring during the 46th to 51st SMW. In locations where a dry spell is prevalent, crop planning requires more information about the likelihood of exceeding a given quantity of rainfall during a crop growth period or in a month. The vital growing stage of the crop should not coincide with two or three straight dry spells, as this will lower production. For numerous agricultural operations including seed bed preparation, sowing, irrigation scheduling, intercultural operation, and harvesting, a dry and wet spell is necessary to plan the timing.

Pradhan *et al.* (2018) used for weekly analysis to study the rainfall distribution and the probability of occurrence. The CV was less than 20 per cent from 10th to 22nd standard week, indicated that the rainfall is consistent during this period. The above rainfall analysis showed that the crops could be recommended under rainfed condition between 22nd to 35th standard weeks as the rainfall is more consistent during this period as compared to 36th to 52nd and 10th to 21st standard weeks for summer ploughing, which fall under Southwest monsoon. The moisture requirement of crops could be met from 26th to 38th standard week as these weeks has the probability of 50 per cent for getting 20 mm of weekly rainfall. The analysis revealed that the drought-resistant finger millet, Kodo millet, Niger, horse gram and drought escaping little millet can be grown. Maize may be grown with supplemental irrigation of one or two to get the best yield out of available soil moisture as rainfed farming. Drought resistant short duration pulses and oilseeds can be grown within the growing period from 39th to 46th standard weeks.

CHAPTER III

MATERIALS AND METHODS

This chapter goes through all of the information needed for the study as well as the method used to achieve the desired results. The research area and its various facts have been explained sequentially in this chapter to understand the many activities conducted and processes followed, as well as the sequential procedure adopted for designing and managing strategies for sustainable agricultural output under rainfed conditions.

3.1 Location and Extent of Study Area

3.1.1 Location

Gariyaband district is located in the rich plains of Chhattisgarh. This district, which encompasses 5 tahsils (Gariyaband, Fingeshwar, Chhura, Mainpur, and Deobhog), is located between latitudes N 20˚57'46" and 20˚17'36" and longitudes E 82˚53'05"and 81˚53'05". The district is located in the agroclimatic zones of Zone-7 Eastern plateau and hills (Planning Commission, 2013), the Chhattisgarh plains zone (NARP, 2013), and the agro ecological subregion (ICAR) of Chhattisgarh/Mahanadi Basin (Agro eco region (J3(Cd/Cm)5).

This district experiences the start of the South-West monsoon on the 25th Standard Meteorological Week, with an average of 48 rainy days and 1035.0 mm of rainfall. The North -West monsoon has an average of 4 rainy days and 73.9 mm of rainfall, for a total average annual rainfall of 1197.1 mm in an average of 55 rainy days. The tehsil selected for the study purpose are presented in Fig. 3.1 and the geographical locations of the stations are presented in Table 3.1.

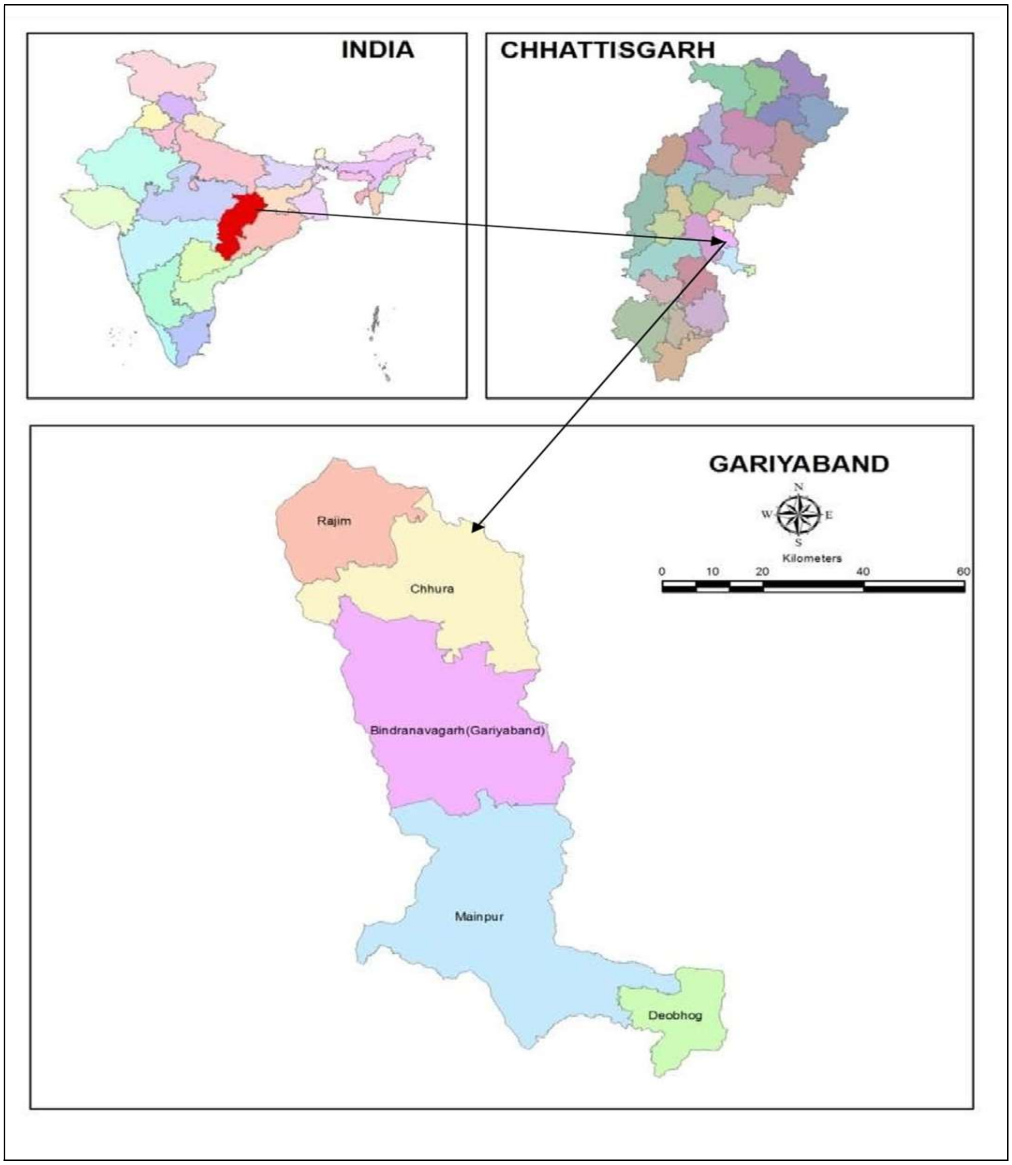

Figure 3.1: Location of Study Area

3.1.2 Land use pattern and agricultural characteristics

Total geographical area of Gariyaband district is 582286 ha and total gross cropped area in Gariyaband district (in the year 2020-21) was estimated to be 157872 ha and net cropped area in the district comes to about 136110 ha. *Kharif* area of the district was 136103 ha. The information of land use and other agricultural characteristics are presented in Table 3.2

Table 3.1: Profile of Gariyaband district

District Profile	
Location	N 20˚57'46" and 20˚17'36" E 82˚53'05" and 81˚53'05"
Total No. of Tehsils	05
Geographical area	582286.1 ha
Forest Cover	293580.1 ha
Area under Agriculture use	219500 ha
Net sown area	1425900 ha
Gross cropped area	219500 ha
Net irrigated area	Season 76400 ha Rabi Season 36000 ha
Net Rainfed area	90216 ha

Table 3.2: Agricultural characteristics of Gariyaband district (2020-21)

Tehsil	Geographical area (ha)	Gross cropped area (ha)	Net cropped area (ha)	*Kharif* season		
				Area sown (ha)	Irrigated area (ha)	Rainfed area (ha)
Chhura	129114.7	29698	26820	26813	10173	16640
Deobhog	47473.2	23754	23050	23050	908	22142
Fingeshwar	62284.5	42389	12081	30308	28104	2204
Gaiyaband	153758.4	24862	20620	20620	4798	15822
Mainpur	189655.3	37169	35312	35312	1556	33756
Total	582286.1	157872	136110	136103	45539	90564

3.1.3 Water resource

There are 85 canals which provide irrigation water to 23683 ha area of crops. There are 12104 tube wells in the district out of which about 39% of it in Fingeshwar Tehsil. The information of water resource and area irrigated by different resources are summarized in Table 3.3

Table 3.3: Area irrigated by different sources in Gariyaband district (2020-21)

Particular		Tehsil				
		Chhura	Deobhog	Fingeshwar	Gariyaband	Mainpur
Canal	Number of sources	26	17	6	17	19
	Irrigated Area (ha.)	6052	306	15910	996	419
Pond	Number of sources	130	25	104	205	53
	Irrigated Area (ha.)	115	35	105	37	65
Open Well	Number of sources	1549	8	24	20	28
	Irrigated Area (ha.)	214	7	0	5	7
Tube Wells	Number of sources	2517	215	4780	3303	1289
	Irrigated Area (ha.)	3258	410	11459	3610	1034

3.2 Data Acquisition

The Gariyaband District Collectorate was where much of the information for the Gariyaband district was acquired. The Department of Land Records in the District of Gariyaband provided daily rainfall statistics for the ten-year period (2011-2020), and other crucial data were also gathered from other sources and used in this study.

The Standard Meteorological Weeks table was used to transform the daily rainfall data into weekly data. This standard table split the complete year of 365 days into 52 Standard Meteorological Weeks, of which the weeks relevant to the *Kharif* season were studied, i.e., the 23rd to the 39th week (June to September).

3.3 Methodology

The development of an appropriate crop planning and water resource plan was considered to be a potential solution based on the literature researched and challenges encountered in and around the study area. This might be a strategy to avoid terminal droughts at crucial growth phases and encourage optimal agricultural production. This was done by looking at rainfall using a variety of different parameters.

3.3.1 Statistical analysis

Various parameters can be utilized to determine the statistical behavior of any hydrological series. To examine the variability of any hydrologic series, the mean, standard deviation, coefficient of variation, and skewness coefficient are typically used. All of these parameters were frequently employed to describe rainfall variability in the current study. The rainfall at each location was statistically evaluated on a weekly and monthly basis.

3.3.1.1 Mean

The mean is a statistic that measures central tendency. It is calculated by dividing the sum of the specified variables by the number of observations in the data collection. It is the most widely used phrase for figuring out the data set's mean. The equation 3.1 was used to calculate mean.

$$MEAN\ (\bar{X}) = \frac{\sum_{i=1}^{N} X_i}{N} \qquad \text{………. (3.1)}$$

Where,

$\bar{X}$ = Mean

X_i = Variables

N = No. of Variables

3.3.1.2 Standard Deviation

The standard deviation is calculated as the square root of the mean of the squares of deviations of the rainfall value from the arithmetic mean of all such rainfall. It is an indicator of variability and is frequently referred to as scatter or dispersion around the mean value. It's provided via the formula in equation 3.2.

$$SD(\sigma) = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})} \qquad \ldots\ldots (3.2)$$

Where,

σ = Standard Deviation

X_i = Variables

$\bar{X}$ = Mean

N = No. of Variables

3.3.1.3 Coefficient of Variation

The coefficient of variation seems to make evaluating the variability of rainfall sample (CV %). The CV is derived by dividing the standard deviation by the rainfall mean. As a percentage, it shows how the amount of rainfall can vary.

The reliability of rainfall on a percentage basis is demonstrated by this measurement. The CV threshold levels for any interpretation are 25, 50, 100, 150, and 250 percent for yearly, seasonal, monthly, weekly, and daily rainfall, respectively (Manorama *et al.*, 2007; Swetha, 2014).

$$CV = \left(\frac{\sigma}{\bar{X}}\right) X\ 100 \qquad \ldots.. (3.3)$$

Where,

CV = Coefficient of Variation

σ = Standard Deviation

$\bar{X}$ = Mean

3.3.1.4 Skewness

Skewness is the antithesis of symmetry, and its presence indicates that a particular series is not symmetrical. The skewness parameter indicates whether the data distribution is symmetrical or asymmetrical around an average. Asymmetry can be skewed either positively or negatively. When a series is favorably skewed, the mean comes before the median; when it is negatively skewed, the mode comes before the median. More skewness is present with higher numbers.

$$C_s = \frac{N(N-2)}{N-1}\sum_{i=1}^{N}\left(\frac{X_i - \bar{X}}{\sigma}\right)^3 \qquad \text{..... (3.4)}$$

Where,

C_s = Skewness

σ = Standard Deviation

X_i = Variables

$\bar{X}$ = Mean

N = No. of Variables

Along with statistical characteristics, the maximum and minimum values of the series were displayed. The maximum and minimum values of a series represent the highest and lowest variables in the series.

3.3.2 Analysis of rainy days

The average number of rainy days on annual and monthly basis was analysed. If the rainfall data is equal to or more than 2.5 mm/day, then it was considered as rainy days as per Indian Meteorological Department (IMD, Pune) guidelines (Dixit *et al.*, 2005; Seetharam 2005; Swetha 2014).

3.3.3 Analysis of Monsoon Characteristics

Crop planning can benefit greatly from knowing the likely weeks of an effective monsoon's onset and withdrawal. Daily rainfall data from the Department of Land Records, District - Gariyaband, were transformed onto weekly basis in order to estimate the arrival of the monsoon season. The study examined data for all five tehsils Chhura, Deobhog, Fingeshwar, Gariyaband, and Mainpur from 2011 through 2020.

Using the forward and backward accumulation methods proposed by Morris and Zandestra (1979), the start and end of the rainy season were calculated from weekly rainfall data. This approach accumulated weekly rainfall via forward accumulation (20+21+...+52 weeks) until a particular amount of rainfall was accumulated. The commencement of the growing season for dry sown crops and land preparation has been fixed at 75 mm of accumulated rainfall (Babu and Lakshminarayana, 1997; Panigrahi and Panda, 2002; Swetha, 2014).

By accumulating rainfall data in backward (52+51+50+...+30 weeks), it was possible to determine the end of the rainy season. In order to allow for field ploughing after crop harvest, it was decided to postpone until the end of the rainy season when there had been 20 mm of precipitation accumulated (Babu and Lakshminarayana, 1997). The post-monsoon season was not taken into consideration when the rainy season was withdrawn, hence in the current study, backward accumulation of rainfall is investigated beginning at the 47th SMW rather than the 52nd SMW. The rank number was assigned to the precise weeks that denoted the start and conclusion of the rainy season. For each time interval, the probability of a specific amount of precipitation was determined. The percent probability (P) of each rank was then calculated using Weibull's algorithm (equation 3.5) (Dash and Senapati, 1992).

$$P = \frac{m}{N+1} \qquad \text{….. (3.5)}$$

Where,

P = Probability

m = rank

N = No. of years.

3.3.4 Markov Chain Analysis

The rainfall patterns have a direct impact on whether crops grow successfully or fail miserably, especially in rainfed environments. A simple criterion related to sequential events, such as dry and wet spells, was used to analyses rainfall data and collect specific information needed for crop planning and agricultural operations. A rainy week after another wet week, or a dry week following a wet or dry week, are examples of sequential events whose probabilities should be calculated during the growth season of crops. This is the foundation for the rainfall analysis utilizing the Markov-Chain technique.

A weekly rainfall of 20 mm is sufficient for all crop growth phases. As a result, a given week might be characterized as being dry if it receives less than 20 mm of precipitation, and vice versa (Pandharinath, 1991). Each week was classified as dry or wet based on this criterion and the corresponding probabilities were determined. The following were the estimated parameters for the analysis.

3.3.4.1 Initial Probabilities

According to the Markov probability model, the initial probability is the probability that a specific week of the year would be dry or wet under the premise that the weather from the preceding week (dry or wet) will not be taken into account. The initial probability of a week being dry or wet is described by equation 3.6 and 3.7 respectively

$$P_W = \frac{F_W}{n} \qquad \text{….. (3.6)}$$

$$P_D = \frac{F_D}{n} \quad \text{..... (3.7)}$$

Where,

P_W = Probability of week being wet

P_D = Probability of week being dry

F_W = Frequency of wet week

F_D =Frequency of dry week

n = Numbers of years of data

3.3.4.2 Conditional Probabilities

The probability that a specific week of the year will be dry or wet is known as a conditional probability, which is based on the premise that the weather from the preceding week whether dry or wet will be taken into account. It shows the probability that the weather will vary from one week to the next. The conditional probability is given by equation 3.8 to 3.11.

$$P_{WW} = \frac{F_{WW}}{F_W} \quad \text{..... (3.8)}$$

$$P_{DD} = \frac{F_{DD}}{F_D} \quad \text{..... (3.9)}$$

$$P_{WD} = 1 - P_{DD} \quad \text{..... (3.10)}$$

$$P_{DW} = 1 - P_{WW} \quad \text{.... (3.11)}$$

Where,

P_{WW} = Probability of occurrence of wet week preceded by wet week

P_{DD} = Probability of occurrence of dry week preceded by dry week

P_{WD} = Probability of occurrence of wet week preceded by dry week

P_{DW} = Probability of occurrence of dry week preceded by wet week

F_{DD} = Frequency of occurrence of dry week preceded by dry week

F_{WW} = Frequency of occurrence of wet week preceded by wet week

3.3.4.3 Consecutive Probabilities

The probability of consecutive wet weeks at any station conveys a sense of alternate dry weeks and the probability of continuous rainy spells. Similar measurements were carried for three and four consecutive wet and dry weeks, respectively, to offer an understanding of the necessity of in-situ moisture conservation measures and water harvesting strategies to be employed for dry land ecosystems.

The series of dry weeks indicates that additional irrigations and moisture conservation techniques are required. The availability of excessive runoff water for rainwater harvesting and the need to implement appropriate soil erosion control measures are shown by multiple wet periods (Reddy *et al.*, 2008). sequential probabilities provided by equation 3.12 to 3.17 respectively

$$P(2W) = P_{Ww1} \times P_{WWw2} \quad .... (3.12)$$

$$P(2D) = P_{Dw1} \times P_{DDw2} \quad .... (3.13)$$

$$P(3W) = P_{Ww1} \times P_{WWw2} \times P_{WWw3} \quad .... (3.14)$$

$$P(3D) = P_{Dw1} \times P_{DDw2} \times P_{DDw3} \quad .... (3.15)$$

$$P(4W) = P_{Ww1} \times P_{WWw2} \times P_{WWw3} \times P_{WWw4} \quad .... (3.16)$$

$$P(4D) = P_{Dw1} \times P_{DDw2} \times P_{DDw3} \times P_{DDw4} \quad .... (3.17)$$

Where,

P(2D) = Probability of 2 consecutive week dry starting with week.

P(2W) = Probability of 2 consecutive week wet starting with week.

P(3D) = Probability of 3 consecutive week dry starting with week.

P(3W) = Probability of 3 consecutive week wet starting with week.

P(4D) = Probability of 4 consecutive week dry starting with week.

P(4W) = Probability of 4 consecutive week wet starting with week.

P_{Dw1} = Probability of the week being dry (first week)

P_{DDw2} = Probability of second week being dry, given the preceding week dry.

P_{DDw3} = Probability of third week being dry, given the preceding week dry.

P_{DDw4} = Probability of fourth week being dry, given the preceding week dry.

P_{Ww1} = Probability of the week being wet (first week)

P_{WWw2} = Probability of second week being wet, given the preceding week wet.

P_{WWw3} = Probability of third week being wet, given the preceding week wet.

P_{WWw4} = Probability of fourth week being wet, given the preceding week wet.

3.3.5 Probability analysis

Probability and frequency of rainfall data facilitates us to determine the expected rainfall with various chance of occurrence

3.3.5.1 Probability analysis

Probability plotting position are used for the graphical demonstration of maximum hydrologic series and serve as estimates of probability of exceedance of those series. Probability plots provide a n parametric means of forming an estimate of the data's probability distribution by drawing a line by hand or by programmed means through the plotted points. Because these striking characteristics, the graphical approach has been preferred by many engineers and hydrologists.

In the past about 100 years, a number of plotting-position methods related numerical method have been proposed for analysis of extreme events. Many plotting

– position formula is available; all of this formula can be expressed in general form by equation 3.18

$$P = \frac{m - a}{N + b} \quad .... (3.18)$$

Where,

a and b are constant

N = number of years

m = rank

Some of the formula which have been use in this study are as

Weibull's Plotting – Position Function

This is most commonly used formula among all other plotting – position formula (Murugappan, 2017). The value of constant a and b are 0 and 1 respectively in equation 3.19

$$P = \frac{m}{N + 1} \quad .... (3.19)$$

Where,

P = Probability

m = rank

N = No. of years.

Gringorten Plotting Position Function

In this Gringorten plotting position formula (1963) the value of constant a and b are 0.44, 0.12 respectively. It is given using equation 3.20

$$P = \frac{m - 0.44}{N + 0.12} \quad .... (3.20)$$

Where,

P = Probability

m = rank

N = No. of years.

California Plotting Position Function

In this California (1923) plotting position formula the value of constant a and b are 1 and 0 respectively. This plotting position formula is given using equation 3.21

$$P = \frac{m}{N} \quad .... (3.21)$$

Where,

P = Probability

m = rank

N = No. of years.

Return Period

The return period is reciprocal of probability of exceedance. This is expressed as in equation 3.22

$$T = \frac{1}{P} \quad .... (3.22)$$

Where,

P = Probability

T = Time period

3.3.5.2 Error Statistics

The term 'Error" denotes the difference between observed rainfall data and estimated rainfall data of that particular week or month. A plotting-position formula should be unbiased and should have the smallest mean square error (MSE) among all estimates (Cunnane, 1978). So, the error statistic such as Mean Square Error (MSE), Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) which were determined using equation 3.23, 3.24 and 3.25 respectively:

$$MSE = \sum_{i=1}^{N} \frac{1}{N} \left(R_{p\,i} - R_i \right) \quad \text{.... (3.23)}$$

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{1}{N} \left(R_{p\,i} - R_i \right)} \quad \text{.... (3.24)}$$

$$MAE = \sum_{i=1}^{N} \frac{1}{N} \left(\left| R_{p\,i} - R_i \right| \right) \quad \text{.... (3.25)}$$

Where,

MSE = Mean Square Error

RMSE = Root Mean Square Error

MAE = Mean Square Error

N = Number of years

$R_{p\,i}$ = Probable rainfall for i^{th} week

R_i = Actual rainfall for i^{th} week

CHAPTER IV

RESULT AND DISCUSSION

The research was carried out in order to plan *Kharif* crops depending on the water availability for Gariyaband. Daily rainfall data over a 10-year period (2011–2020) was collected and used in this study.

An attempt has been made to evaluate rainfall patterns on a monthly and weekly basis. The average annual rainy days were calculated in order to determine the number of rainy days and the frequency of rainfall events throughout the year. The average onset and withdrawal date and length of the rainy season were examined. The initial, conditional, and successive dry and wet spell probability were estimated using the Markov chain analysis approach.

With the use of several plotting position functions, the projected weekly rainfall at various probability values over a variety of stations was calculated. Based on the rainfall study, a variety of corrective actions were recommended for *Kharif* season crops in order to ensure sustainable agricultural output.

4.1 Analysis of Rainfall Variability

For every farmer, choosing on a crop planning scheme and irrigation schedule depends greatly on the amount of rainfall and its distribution pattern. In order to save soil and plan irrigation and flood control, engineers may utilise the predicted quantity of rainfall. For the purposes mentioned above, daily data for a period of ten years were gathered and analysed to provide the following estimates of monthly and weekly rainfall.

The rainfall variability of Gariyaband district, tehsil wise rainfall data was calculated using statistical metrics such as mean, standard deviation, and coefficient of variation.

4.1.1 Monthly Rainfall Variability

All five of the tehsils of the Gaiyaband district are located in the agricultural climate zone of the Chhattisgarh plains. Table 4.1 to 4.5 displays the variance in monthly rainfall for all tehsils. The offered statistical variables include mean, maximum, minimum, CV, and skewness.

Similar analyses for monthly rainfall were carried out by various researcher (Patil and Patil, 1991; Pimpale *et al.,* 2001; Nath and Deka, 2002; Singh *et al.,* 2002; Dastidar *et al.,* 2010; Bemal *et al.,* 2012 and Xalxo, 2021) and observed variations in monthly rainfall.

4..1.1.1 Chhura Tehsil

Table 4.1 shows that at Chhura, the maximum mean monthly rainfall was recorded in July (365.7 mm), followed by August (328.10 mm), September (286.43 mm), June (192.19 mm), and October (37.27 mm). Similarly, July had the highest maximum monthly rainfall (788.1 mm) and November had the lowest maximum monthly rainfall (0 mm). The monthly CV ranged from 36.9% in August to 259.9% in December. The CV from June to August was well within the threshold level (<100%), indicating consistent rainfall around the average monthly rainfall in Chhura tehsil as shown Figure 4.1. The skewness ranged from 0.4 (June, August) to 1.9 (April), while all other months in the Chhura tehsil had positive skewness.

Further from the analysis, it is also indicated that the value of coefficient of variation and skewness were found to be lowest of 36.9 % and 0.4, respectively, in the month of August which signifies less variation in rainfall distribution of the Chhura and has a consistent and uniform rainfall pattern.

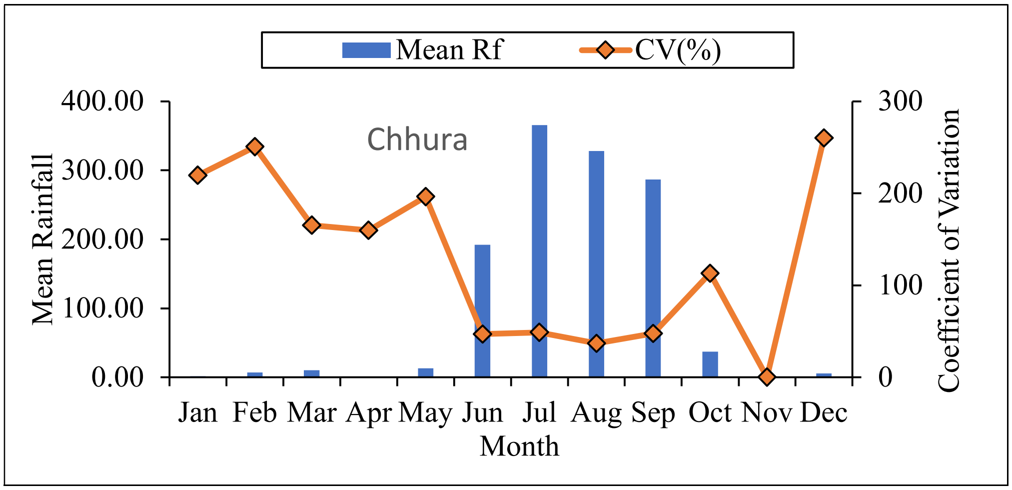

Figure 4. 1 : Variation in mean monthly rainfall of Chhura

Table 4.1: Monthly rainfall parameters over Chhura Tehsil

Month	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
January	1.4	10.1	0	3.2	219.3	1.4
February	7.2	61.1	0	18.1	250.6	1.2
March	10.3	49.9	0	16.9	165.3	1.8
April	0.7	3.3	0	1.2	159.5	1.9
May	13.1	66.9	0	25.7	196.4	1.5
June	192.2	338.4	24.6	90.0	46.8	0.4
July	365.5	788.1	130.3	179.1	49.0	0.7
August	328.1	502.4	159.3	121.0	36.9	0.4
September	286.4	605.3	125.3	136.5	47.6	1.0
October	37.2	129	0	42.0	112.8	1.5
November	0.0	0	0	0.0	-	-
December	5.6	48.7	0	14.5	259.9	1.2

4..1.1.2 Deobhog Tehsil

According to Table 4.2, the maximum mean monthly rainfall at Deobhog was observed in August (378.1 mm), followed by July (302.2 mm), September (286.3 mm), June (227.6 mm), and October (57.9 mm). Similarly, August had the most maximum monthly rainfall (764.3 mm) while November had the lowest (0 mm). From 33.1% in July to 316.2% in December, the monthly CV varied. The CV for the months of June through September was far below the threshold level (100%), showing steady rainfall in the Deobhog tehsil around the average monthly rainfall depicted in Figure 4.2. All other months in the Deobhog tehsil showed positive skewness except for July (-0.6), where the skewness ranged from -0.6 (July) to 1.8 (May).

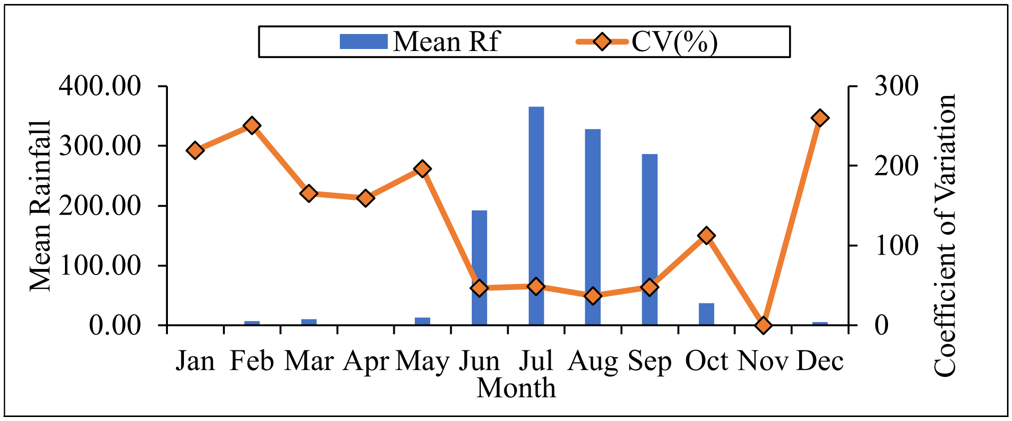

Figure 4. 2 : Variation in mean monthly rainfall of Deobhog

Table 4.2: Monthly rainfall parameters over Deobhog Tehsil

Month	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
January	14.0	114.8	0	36.2	258.4	1.2
February	1.3	10	0	3.2	240.7	1.2
March	10.2	62.8	0	20.0	196.5	1.5
April	19.5	95	0	30.3	155.4	1.4
May	26.9	115	0	39.4	146.4	1.8
June	227.6	515	92.6	126.5	55.6	0.8
July	302.2	393.5	64.5	100.2	33.1	-0.6
August	378.1	764.3	167	185.6	49.1	0.2
September	286.3	490	131	106.8	37.3	0.2
October	57.9	172	0	62.9	108.6	0.9
November	0.0	0	0	0.0	0.0	0.0
December	8.0	80.4	0	25.4	316.2	0.9

4.1.1.3 Fingeshwar Tehsil

Table 4.3 reveals that at Fingeshwar, the highest mean monthly rainfall was observed in September (267.3 mm), with the following months coming in second through fourth: (161.9 mm). Similarly, July had the most maximum monthly rainfall (471.6 mm), while November had the lowest (0 mm). From 35.8 percent in July to 227.4 percent in December, the monthly CV varied. The CV from June to October was well below the threshold level (100%), showing regular rainfall in the Fingeshwar tehsil at levels close to the average monthly rainfall. In the Fingeshwar tehsil, the skewness ranged from 0.3 (August) to 1.8 (April), while all other months exhibited positive skewness.

Table 4.3: Monthly Rainfall parameters over Fingeshwar Tehsil

Month	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
January	4.5	28	0	9.0	200.2	1.5
February	9.0	67.2	0	20.9	232.0	1.3
March	48.3	277.1	0	90.8	188.2	1.4
April	5.3	21	0	8.7	163.3	1.8
May	11.6	53.8	0	22.4	192.9	1.6
June	161.9	332.8	88	90.2	55.7	1.1
July	257.4	471.6	136	92.1	35.8	0.8
August	267.0	463.2	110	122.5	45.9	0.3
September	267.3	590	81	162.6	60.8	0.8
October	37.8	109	0	37.6	99.5	0.6
November	0.0	0	0	0.0	-	-
December	4.4	39	0	12.2	277.4	1.1

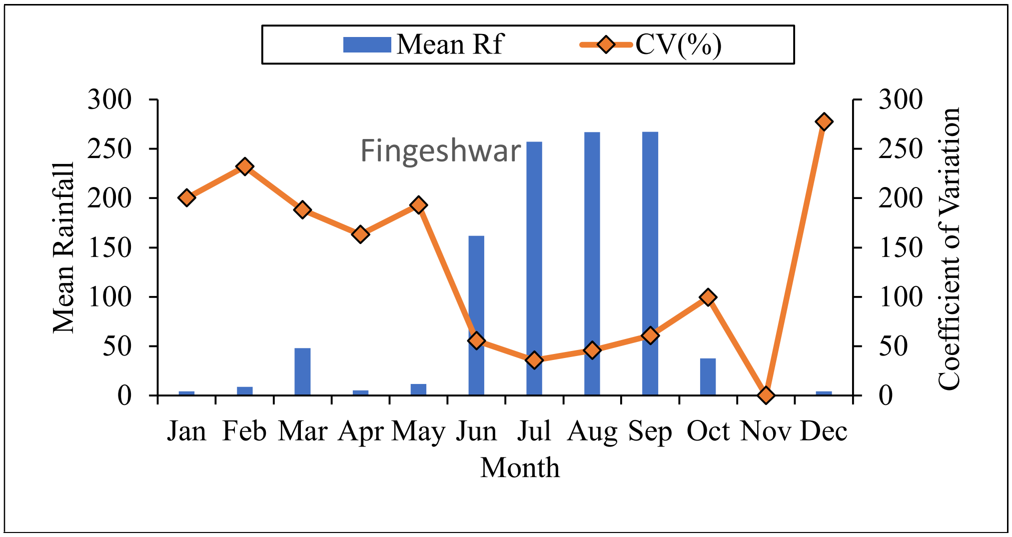

Figure 4. 3 : Variation in mean monthly rainfall of Fingeshwar

4.1.1.4 Gariyaband Teshsil

According to Table 4.4, at Gariyaband, the month with the meanest monthly rainfall was August (300 mm), followed by July (299.1 mm), and September (139.3 mm) (219.7 mm), The lowest maximum monthly rainfall was in November (0 mm), and August had the highest maximum monthly rainfall (596.1 mm). The monthly CV varied from 37.5 percent in September to 316.2 percent in December. The CV in Gariyaband Tehsil from June to October was considerably below the threshold level (100%), indicating steady rainfall at or near the average monthly rainfall. In the Gariyaband tehsil, the skewness ranged from -0.7 (October) to 1.6 (March).

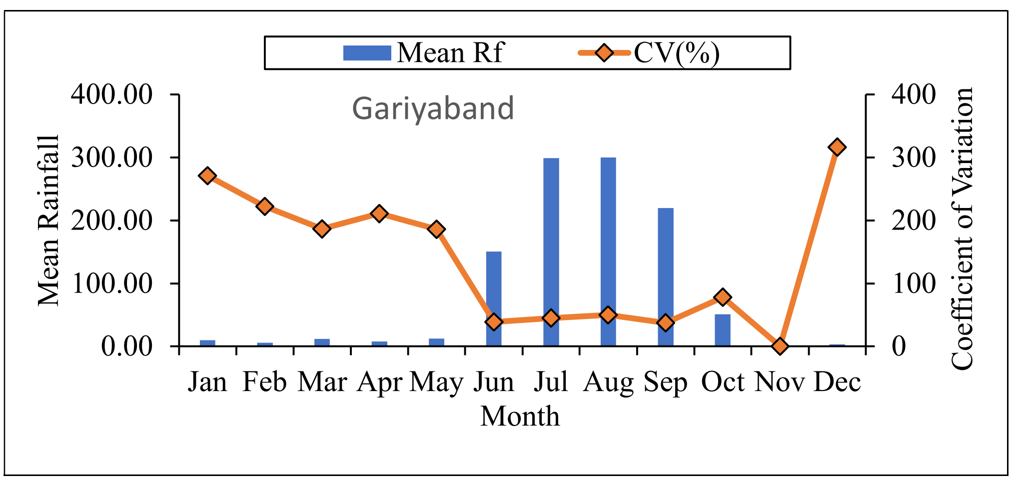

Figure 4. 4 : Variation in mean monthly rainfall of Gariyaband

Table 4.4: Monthly rainfall parameters over Gariyaband Tehsil

Month	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
January	9.7	83.8	0	26.2	271.1	1.1
February	5.7	37	0	12.7	222.2	1.3
March	11.5	66	0	21.3	186.3	1.6
April	7.6	51.3	0	16.1	210.7	1.4
May	11.9	71.2	0	22.1	185.8	1.3
June	150.5	241.5	40	58.5	38.9	0.2
July	299.1	559.6	176	134.8	45.1	1.0
August	300.0	596.1	157.6	149.1	49.7	1.1
September	219.7	378	91.4	82.4	37.5	-0.2
October	50.6	97.2	0	39.5	77.9	-0.7
November	0.0	0	0	0.0	-	-
December	3.0	29.6	0	9.4	316.2	0.9

4.1.1.5 Mainpur Tehsil

Table 4.5 reveals that at Mainpur, the highest mean monthly rainfall was recorded in July (405.8 mm), with the following months coming in second through fourth: June (232.4 mm), August (378.2 mm), September (305.4 mm), and October (74.7 mm). Similar to that July had the highest maximum monthly rainfall (891.1 mm) and November had the lowest maximum monthly rainfall (0 mm). In September, the monthly CV was 34.4%; in February, it was 315.15%. The CV from June to October was well below the threshold (100%), indicating steady rainfall in the Mainpur tehsil at or near the normal monthly amount. The Mainpur tehsil experienced positive skewness in all other months, whereas the skewness ranged from 0.2 (August) to 1.7 (April).

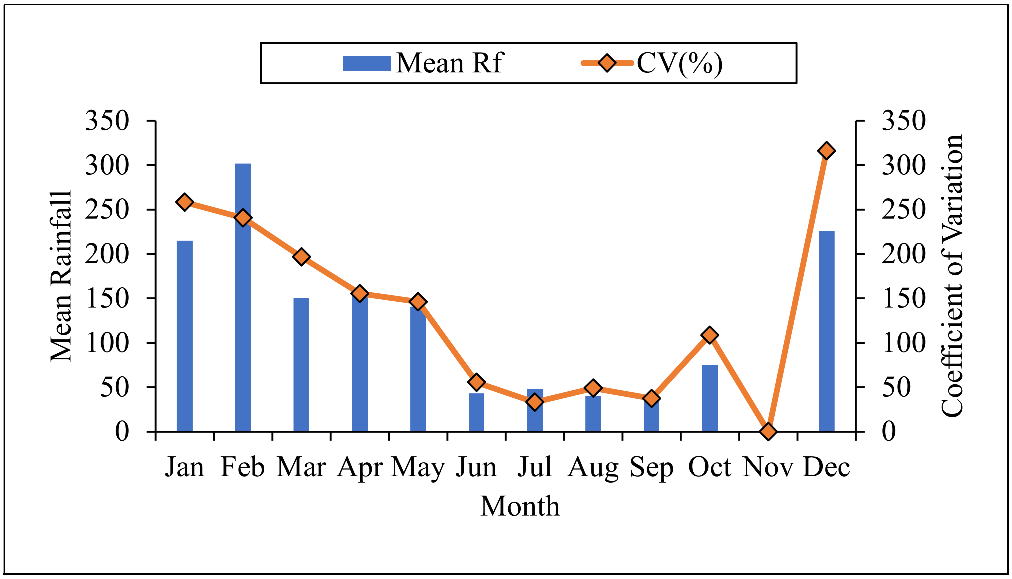

Figure 4. 5 : Variation in mean monthly rainfall of Mainpur

Table 4.5: Monthly rainfall parameters over Mainpur Tehsil

Month	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
January	1.1	7	0	2.4	214.9	1.4
February	5.2	49.3	0	15.5	301.5	1.0
March	8.3	39	0	12.5	150.8	1.4
April	10.8	40	0	16.5	152.8	1.7
May	21.9	87.4	0	30.8	140.7	1.6
June	232.4	386.9	94.4	99.9	43.0	0.7
July	405.8	891.1	212.2	193.6	47.7	0.9
August	378.2	689.5	144.4	151.7	40.1	0.2
September	305.4	509.3	188.2	105.2	34.4	0.5
October	74.7	168.4	5.2	55.8	74.7	0.3
November	0.0	0	0	0.0	-	-
December	7.7	51.6	0	17.3	226.1	1.3

4.1.2 Weekly Rainfall Variability

Weekly rainfall data for the *Kharif* season (22-44th SMW) were evaluated to determine the mean, maximum, minimum, SD, CV, and skewness. Although CV indicates the variation in rainfall around on its mean, the appropriateness of the measure is determined by the use to which it is put. Weather information is needed for a shorter time span in current agriculture. Annual rainfall usually reflects similarities in certain climatic patterns, which may be useful for identifying agro–climatic homogeneous zones, but it does not even provide insight into the erratic behaviour of rainfall during the growing season, especially during the various phonological periods of crop growth. Even the use of monthly rainfall data has significant flaws. Thus, the weekly characteristics of rainfall was taken into account in this study. Table 4.6–4.10 lists the different weekly rainfall metrics.

During *Kharif* season (22-44th SMW) the highest mean weekly rainfall (Table 4.1-4.5) was found to be 142.9 mm (29th SMW) followed by 114.9 mm (35th SMW) in Chhura tehsil, 114.8 mm (32th SMW) followed by 110.9 mm (29th SMW) in Deobhog tehsil and 148.1 mm (35th SMW) followed by 81.1 mm (29th SMW) in Fingeshwar tehsil, 104.6 mm (29th SMW) followed by 101.7 mm (35th SMW) in Gariyaband tehsil 138.6 mm (29th SMW) followed by 125 mm (35th SMW) on Mainpur tehsil. The highest maximum rainfall was found to be 335.5 mm (35th SMW), 330.5 mm (32th SMW), 265.5mm (31th SMW), 240.5mm (35th SMW) and 336 mm (35th SMW) in Chhura, Fingeshwar, Deobhog, Gariyaband and Mainpur tehsil respectively. Also, the lowest maximum rainfall found was 0 mm (44thSMW), 35.6 mm (41thSMW), 0 mm (44thSMW), 0 mm (44thSMW) and 5.2 mm (44thSMW), in in Chhura, Fingeshwar, Deobhog, Gariyaband and Mainpur tehsil respectively.

The CV within threshold limits (<150%) for weekly rainfall gives us an idea about high dependable rainfall around the mean during particular weeks (Swetha, 2011). During *Kharif* season (22-44th SMW) for weekly rainfall, the CV varies from 244.1 % (42thSMW) to 42.2 % (33thSMW) at Chhura, 298.1% (43thSMW) to 49.6% (25thSMW) at Deobhog, 204.4% (43thSMW) to 46.1% (28thSMW) at Fingeshwar, 289.1% (41thSMW) to 55.5(28thSMW) at Gariyaband and 316.2 (44thSMW) to 55.4 (34thSMW) at Mainpur. The CV was observed to be within the threshold limits (<

150%) during most of the weeks over various tehsil excepts 40th - 43th SMW (3 weeks) at Chhura; 22th, 39th, 42th 43th (4 weeks) at Deobhog; 22th, 37th, 40th - 43th SMW (6 weeks) at Fingehswar; 22th, 42th, 43th SMW (3 weeks) at Gariyaband; 22th, 42th - 44th SMW (4 weeks) at Mainpur respectively. Except for the 33rd and 38th SMW at Chhura, the 23rd and 25th SMW at Deobhog, the 28th and 38th SMW at Fingeshwar and Gariyaband, and the 30th SMW at Mainpur. Tables 4.1-4.5 give a comprehensive examination of the various statistical measures throughout the *Kharif* season (22-44th SMW).

Consistency is shown by a higher standard deviation and a lower coefficient of variation. This indicates the consistent and predictable pattern of rainfall over the duration of the weeks. This assessment shows that there are significant variations in quantitative measures, suggesting that the rainfall is highly erratic in all over the study area.

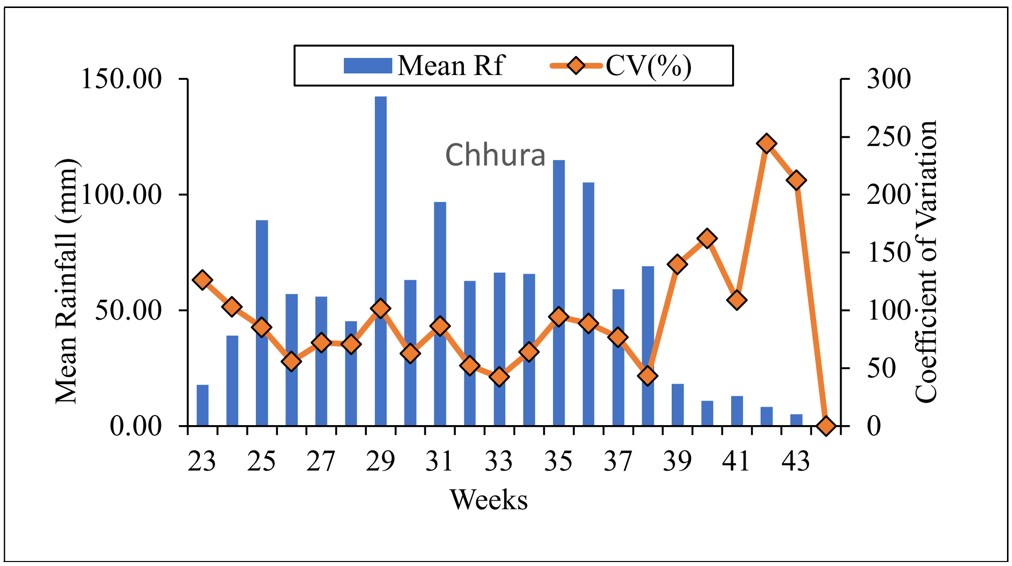

Figure 4. 6 : Variation in mean weekly rainfall of Chhura

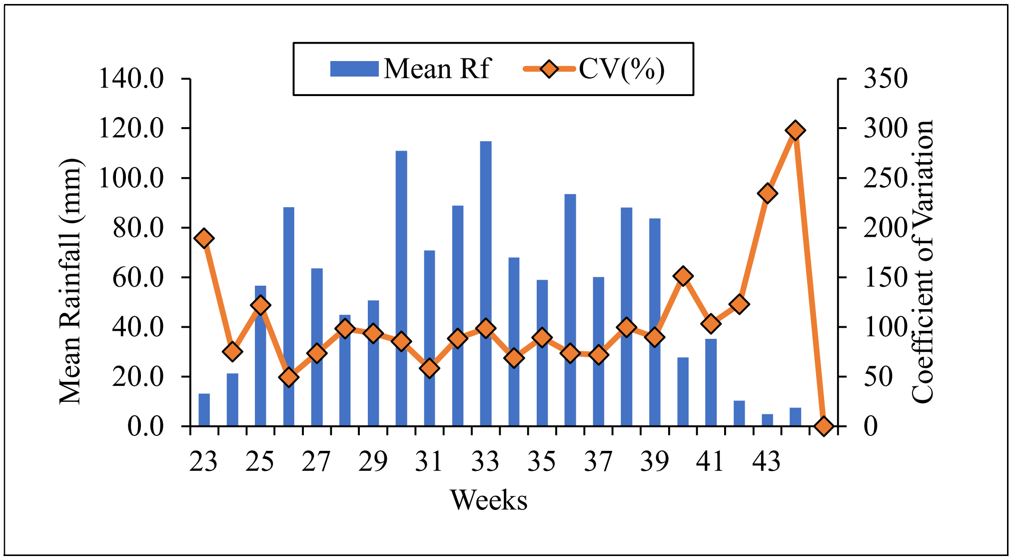

Figure 4. 7 : Variation in mean weekly rainfall of Deobhog

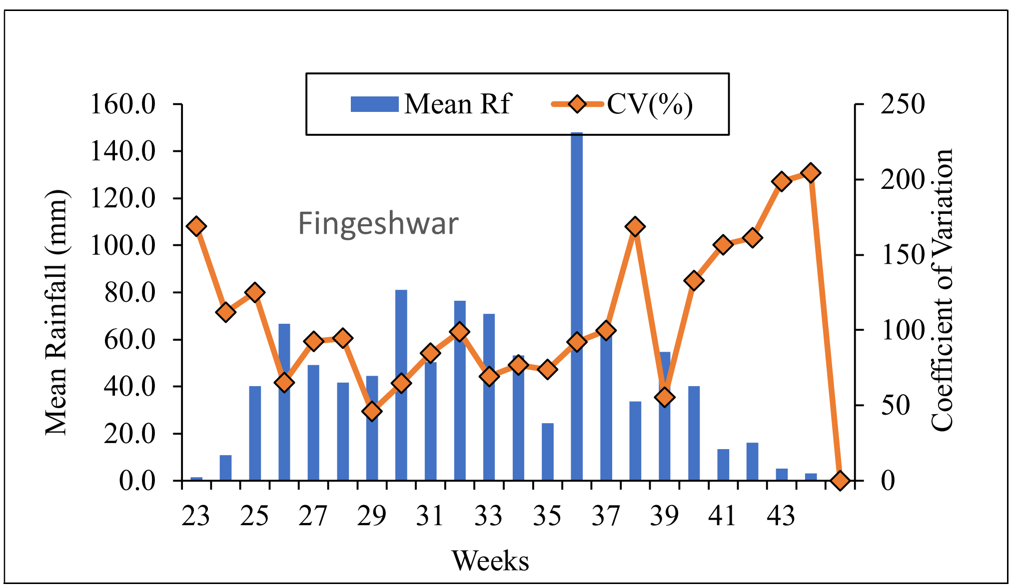

Figure 4. 8 : Variation in mean weekly rainfall of Fingeshwar

Table 4.6: Weekly Rainfall Parameters over Chhura

SMW	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
22	9.9	31.2	0	11.3	114.0	1.5
23	17.8	62.2	0	22.5	126.2	1.6
24	39.2	145	0	40.3	102.9	1.1
25	89.0	224.2	0	76.0	85.4	1.2
26	57.0	117.9	0	31.8	55.8	0.0
27	56.0	155.7	10.2	40.2	71.9	0.6
28	45.4	101	1	32.0	70.6	0.6
29	142.4	523	32.9	144.6	101.5	1.2
30	63.2	144.8	13.9	39.5	62.6	1.0
31	96.9	255.9	5.2	84.0	86.6	0.7
32	62.8	126.5	29.7	32.8	52.3	0.9
33	66.3	103.4	18.2	28.0	42.2	-0.6
34	65.7	141.2	10.5	42.0	63.8	1.3
35	114.9	335.5	6.4	108.6	94.5	1.1
36	105.2	302.6	2.5	93.3	88.6	0.2
37	59.1	153.6	0	45.3	76.6	0.0
38	69.2	110.7	16.4	30.1	43.5	-0.3
39	18.2	62.2	0	25.4	139.9	1.8
40	10.9	58.4	0	17.7	162.2	1.7
41	13.0	43.5	0	14.1	108.9	1.2
42	8.3	68.4	0	20.2	244.2	1.2
43	5.1	33.5	0	10.8	212.5	1.4
44	0.0	0	0	0.0	0.0	0.0

Table 4.7: Weekly rainfall parameters over Deobhog Tehsil

SMW	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
22	13.2	76.5	0	25.1	189.5	1.6
23	21.3	47.4	0	16.1	75.3	-0.3
24	56.6	244.5	0	69.0	121.8	0.8
25	88.3	156.8	30	43.8	49.6	-0.2
26	63.6	122.1	7	46.8	73.7	0.3
27	44.9	132.3	0	44.2	98.4	0.7
28	50.7	156.3	0	47.5	93.7	1.0
29	110.9	277	5.2	94.8	85.5	1.1
30	70.9	137.1	21.8	41.4	58.5	0.3
31	88.8	266	3.8	78.6	88.5	0.2
32	114.8	330.5	17	113.4	98.8	1.1
33	68.1	148.9	3	46.8	68.8	0.1
34	59.0	173.1	8	52.7	89.5	1.0
35	93.5	227.8	14	69.0	73.7	0.9
36	60.2	123.3	4.2	43.2	71.8	0.6
37	88.2	276.3	0	87.9	99.7	0.4
38	83.8	227.5	11.9	75.2	89.8	0.8
39	27.8	117.5	0	42.1	151.3	1.6
40	35.1	89.9	0	36.2	103.2	0.5
41	10.4	35.6	0	12.7	122.9	1.2
42	4.9	36.7	0	11.5	234.6	1.3
43	7.6	76.5	0	22.5	298.1	1.0
44	0.0	47.4	0	0.0	-	-

Table 4.8: Weekly rainfall parameters over Fingeshwar tehsil

SMW	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
22	1.5	7.2	0	2.5	168.9	1.8
23	10.8	32	0	12.0	111.9	0.9
24	40.2	171.2	0	50.2	124.9	1.1
25	66.7	140.2	15.2	43.4	65.1	0.4
26	49.1	126.8	0	45.4	92.4	1.0
27	41.7	131.2	0	39.4	94.4	1.0
28	44.5	69	8	20.5	46.1	-0.8
29	81.1	150	14	52.3	64.5	0.5
30	50.4	154	8	42.6	84.5	0.8
31	76.5	265.5	12.4	75.5	98.8	1.1
32	71.0	156	14	49.1	69.1	1.0
33	53.2	129.6	11	40.9	76.8	0.8
34	24.5	52.8	0	18.1	73.8	0.8
35	148.1	475	28	136.3	92.0	1.1
36	65.9	209.6	0	65.6	99.6	0.7
37	33.7	178.8	0	56.8	168.7	1.3
38	54.7	103.8	8	30.3	55.3	-0.4
39	40.2	168.6	0	53.4	132.7	1.1
40	13.4	53.2	0	21.0	156.6	1.9
41	16.1	79	0	26.0	161.3	1.6
42	5.1	29.2	0	10.2	198.6	1.5
43	3.1	20	0	6.4	204.4	1.5
44	0.0	0	0	0.0	-	-

Table 4.9: Weekly rainfall parameters over Gariyaband Tehsil

SMW	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
22	9.3	51.3	0	16.4	176.6	1.7
23	16.0	57.5	0	19.8	123.6	1.2
24	36.5	96	0	26.0	71.3	1.0
25	69.1	184.4	4.6	56.7	82.1	0.7
26	30.8	64.8	7.1	22.5	73.3	0.9
27	37.6	86.4	4.4	28.7	76.3	0.3
28	57.6	112.8	15.2	32.0	55.5	-0.5
29	104.6	313.8	19	106.4	101.7	1.3
30	65.5	166	26	44.8	68.5	1.0
31	78.6	284.3	2.8	92.4	117.6	1.1
32	78.1	155	22.6	37.4	47.9	0.0
33	50.9	133.8	13.2	37.6	73.8	1.1
34	35.6	69	1.6	25.0	70.3	0.2
35	101.7	240.5	38	75.7	74.4	1.6
36	70.9	198	0	64.7	91.2	0.1
37	48.6	123	0	38.7	79.7	0.9
38	64.8	127.2	2.6	40.0	61.7	-0.2
39	16.4	61.2	0	22.6	137.4	1.9
40	28.2	76.8	0	30.9	109.5	0.9
41	12.1	36.2	0	14.4	118.6	1.5
42	7.0	64.2	0	20.2	289.1	1.0
43	3.3	22.6	0	7.3	223.2	1.3
44	0.0	0	0	0.0	-	-

Table 4.10: Weekly rainfall parameters over Mainpur Tehsil

SMW	Mean (mm)	Max (mm)	Min (mm)	SD (mm)	CV (%)	Skewness
22	12.9	64.3	0	24.1	187.3	1.6
23	21.7	82.2	0	24.1	111.2	0.6
24	58.4	205.4	0	60.8	104.3	0.4
25	83.8	234.1	4.3	71.9	85.9	0.4
26	74.3	166.9	20.4	44.8	60.3	0.6
27	50.8	145.2	2.4	42.9	84.5	0.5
28	83.7	183.3	6.1	52.6	62.8	0.1
29	138.6	417	32	129.6	93.5	1.2
30	79.3	178.6	8.6	54.7	69.0	-0.3
31	125.0	312.2	6.8	110.5	88.4	0.4
32	55.5	181.8	6	49.4	89.0	0.6
33	82.6	186.9	21	49.2	59.6	1.1
34	67.7	142	12.2	37.5	55.4	-0.2
35	110.1	281	27.3	85.7	77.8	1.3
36	106.2	321.5	11.1	94.2	88.7	0.9
37	50.7	138.3	0	41.5	81.9	1.0
38	113.7	336	0	99.3	87.3	0.7
39	16.5	36.4	0	16.2	98.3	0.3
40	28.0	67.2	0	26.7	95.2	0.6
41	31.5	108.9	0	32.1	101.7	0.8
42	8.1	40	0	14.1	173.3	1.7
43	6.5	31.4	0	10.8	165.8	1.8
44	0.5	5.2	0	1.6	316.2	1.6

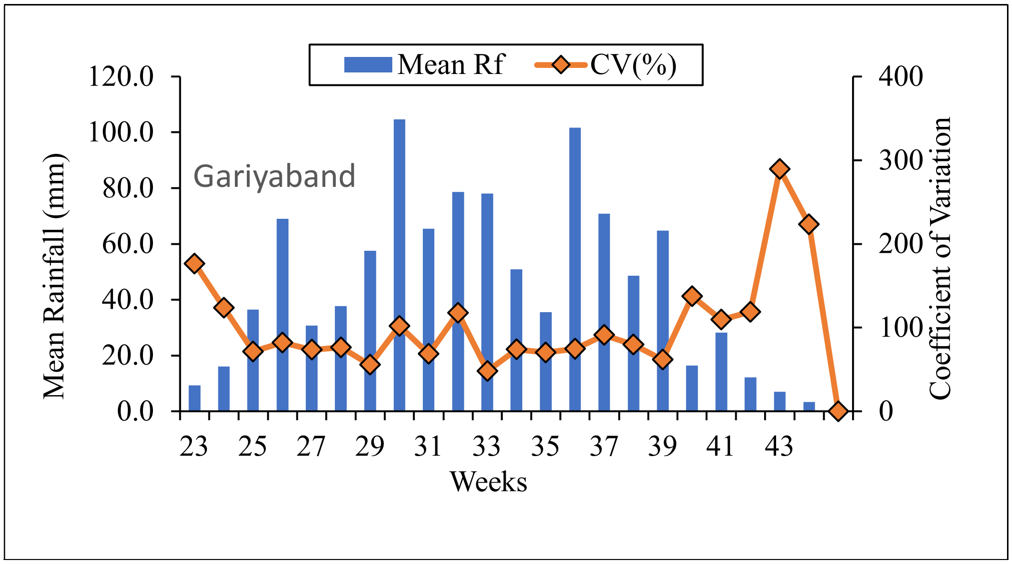

Figure 4. 9 : Variation in mean weekly rainfall of Gariyaband

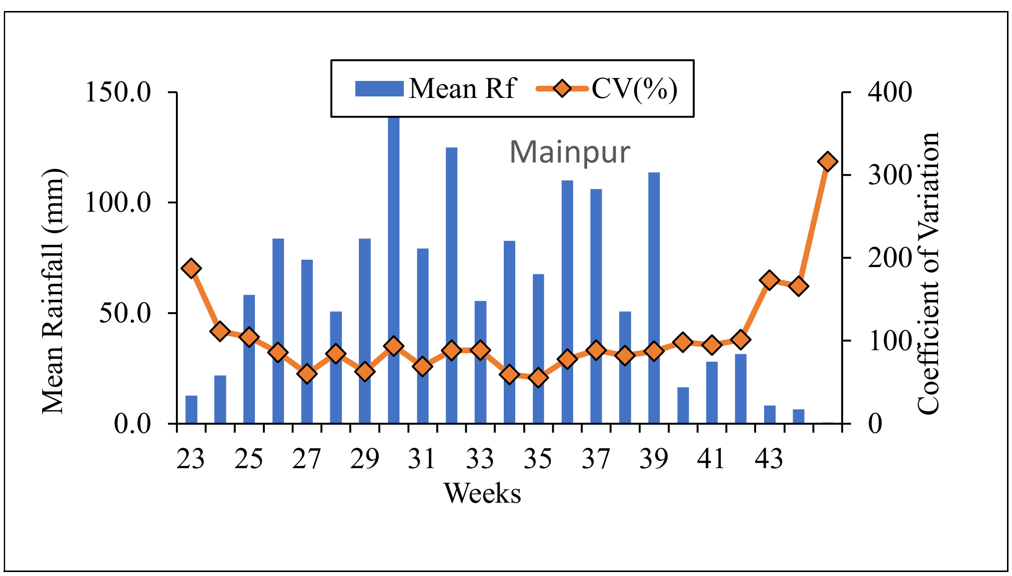

Figure 4. 10 : Variation in mean weekly rainfall of Mainpur

4.2 Analysis of Rainy Days

Considering 10 years (2011-2020) rainfall data the annual rainy days were worked out over various Tehsils of Gariyaband district. The rainfall ≥2.5 mm was considered as rainy days as per IMD protocol. After calculating the average annual rainy days, the results of average annual rainy days were presented as a whole number of rainy days by considering the decimal value above ≥ 0.5 towards its next higher number, similarly a value with < 0.5 was considered towards its lower value number.

The average annual rainy days (Table 4.11) varied from 52 days at Chhura and Fingeshwar to 60 days at Mainpur. Similarly, the average rainy days during *Kharif* season (Table 4.12) varied from 45days at Fingeshwar to 51 days at Mainpur

Similar, analysis of rainy days was carried out by De and De, 2003; Singh *et al.,* 2003; Dixit *et al.,* 2005; Barman *et al.,* 2012 for various stations and found differences in number of rainy days over different regions

Table 4.11: Average annual rainy days of Gariyaband district

Years	Tehsil				
	Chhura	Deobhog	Fingeshwar	Gariyaband	Mainpur
2011	44	43	49	71	55
2012	52	50	40	49	49
2013	64	54	65	63	69
2014	47	52	48	46	58
2015	48	48	45	39	55
2016	60	61	66	69	60
2017	42	54	52	51	59
2018	46	50	50	44	55
2019	63	62	48	62	64
2020	58	76	60	58	79
Mean	**52**	**55**	**52**	**55**	**60**

Table 4.12: Average rainy days in Gariyaband district during *Kharif* season

Years	Tehsil				
	Chhura	Deobhog	Fingeshwar	Gariyaband	Mainpur
2011	44	43	48	69	53
2012	51	47	37	48	47
2013	57	47	54	53	61
2014	44	49	45	44	50
2015	42	42	43	38	44
2016	56	53	55	55	51
2017	34	46	42	40	51
2018	43	41	38	41	46
2019	45	52	43	52	49
2020	50	47	48	40	56
Mean	**47**	**47**	**45**	**48**	**51**

4.3 Characteristics of Rainy Season

The Morris and Zandstra (1979) technique of forward and backward accumulation of weekly rainfall data is used to calculate the onset, withdrawal of the rainy season.

Similar analysis of onset and withdrawal of monsoon for different region over India have been evaluated may many scientists (Dash and Senapati, 1992; Babu and Lakshminarayan, 1997; Dixit, 2005; Ali, 2007; Mandel 2013) and result reveled an early onset of monsoon (south-west monsoon) in south-western part of India followed by central and north-western parts of India. Similarly, withdrawal of monsoon was late at southern and southern-eastern parts of India

4.3.1 Onset of Rainy season

At the beginning of the rainy season, there should be enough rain to prepare the field and plant it with crops. The start of the rainy season is considered to have occurred when precipitation hits 75 mm following the 20th SMW. The Standard

Meteorological Week during which the corresponding year's rainy season began is depicted in the table. The Table 4.13 shows that the rainy season begins on the 25th, SMW in all Tehsils, with the biggest delay occurring on the 29th, 31st, 29th, 31st, and 28th SMW in Chhura, Deobhog, Fingeshwar, Gariyaband, and Mainpur tehsils, respectively.

Table 4.13: Probability (%) of onset of Monsoon

SMW	Probability (%) of onset of monsoon											
	20	21	22	23	24	25	26	27	28	29	30	31
Chhura	0.0	0.0	0.7	6.6	21.6	47.0	27.1	29.4	21.1	57.7	33.0	49.5
Deobhog	1.2	5.7	1.5	41.7	19.2	54.1	34.6	27.3	52.8	24.0	61.0	57.6
Fingeshwar	7.3	-	-	2.2	32.9	44.8	35.9	30.7	18.8	53.8	35.7	50.7
Gariyaband	1.0	-	4.3	8.9	20.9	47.2	15.3	23.3	36.3	59.1	44.3	51.3
Mainpur	-	-	9.8	13.4	42.5	53.8	49.6	100.0	55.3	66.8	52.5	65.2
SMW	Probability (%) of onset of monsoon											
	32	33	34	35	36	37	8	39	40	41	42	43
Chhura	31.6	31.4	9.2	53.4	51.8	32.1	35.4	7.6	2.8	1.9	2.4	0.2
Deobhog	24.7	41.8	42.5	32.3	57.9	39.7	23.3	13.1	0.8	0.2	2.9	0.0
Fingeshwar	47.8	36.8	9.5	68.5	46.2	32.2	33.2	34.2	8.4	12.9	0.6	0.0
Gariyaband	52.6	34.6	19.1	61.8	48.3	33.8	43.0	10.8	19.9	3.8	4.0	0.1
Mainpur	40.2	54.8	44.7	63.7	60.5	35.8	62.7	5.2	17.5	22.5	2.8	1.1

4.3.2 Withdrawal of Rainy season

According to Morris and Zandstra (1979), the withdrawal of the rainy season is based on the 20 mm of rainfall that was accumulated retroactively from the 46th SMW. This information is shown in a table that shows when the rainy season ends in various years. The table shows that the withdrawal of rainy season is in the 38th, 38th, 39th, and 38th SMW in Chhura, Deobhog, Fingeshwar, Gariyaband, and Mainpur tehsils, respectively, while the latest withdrawal of rainy season is in the 43rd SMW for all tehsils in Gariyaband district.

The percentage probabilities for withdrawal of rainy season during different standard meteorological weeks are presented in Table 4.14

Table 4.14: Probability of Withdrawal of Monsoon

SMW	Probability (%) of Withdrawal of monsoon										
	35	36	37	38	39	40	41	42	43	44	45
Chhura	76.5	78.7	76.1	148.2	39.0	28.1	29.0	24.9	13.5	-	-
Deobhog	85.3	91.9	68.9	63.6	42.1	20.6	15.2	31.3	-	-	-
Fingeshwar	86.7	75.0	58.6	101.2	62.6	41.4	45.8	19.8	9.1	-	-
Gariyaband	95.1	78.9	76.7	97.9	45.6	58.9	36.3	30.9	11.2	-	-
Mainpur	92.6	84.8	76.7	86.3	43.8	60.0	62.0	30.0	23.5	-	-

4.4 Markov Chain Analysis

The assessment of dry and wet spells can be used as a tool to identify time periods of inadequate water availability during the periods of crop growth. When water shortages coincide with important growth stages, other solutions can be developed. As an outcome, the chances of dry and wet spells occurring during crop growth season, along with conditional probabilities that take sequential events into account, provide the vital information on erratic rainfall characteristics required for various agricultural operations.

Numerous scientists conducted similar weekly evaluations of dry and wet spells for various parts of the nation (Pandharinath, 1991; Dash and Senapati, 1992; 289, Singh and Bhandari, 1998; Khichar *et al.*, 2000; Sharma *et al.*, 2003; Sharma and Kumar, 2003; Singh *et al.*, 2004; Jat *et al.*, 2005; Reddy *et al.*, 2008; Subhash *et al.*

4.4.1 Initial and conditional probabilities of dry and wet spells

In Tables 4.15 to 4.19, the initial and conditional probabilities of rainfall during the 22 to 44 standard meteorological weeks of all the tehsils in the Gariyaband district were estimated. There is a correlation between the initial and conditional dry and wet probability.

$P_D + P_W = 100\ \%$;

$P_{DD} + P_{WD} = 100\ \%$

and $P_{WW} + P_{DW} = 100\ \%$, respectively.

The main focus was given to the results of *Kharif* season only since it is very important factor for production.

4.4.2 Probability of dry and wet spells for consecutive weeks

Tables 4.20 to 4.24 analyse and summarise the successive dry and rainy spells. The findings suggest that during the *Kharif* season, the occurrence of 2 successive dry weeks was observed in the SMWs for 22–23, 41–44 at Chhura, 22, 41, 43–44 at Deobhog, 22–24, 39, 42–44 at Fingeshwar, 22–23, 39, 41–44 at Gariyaband, and 22–23, 44 SMW at Mainpur.

Assessments of three and four consecutive dry weeks as well as analyses for 2, 3, and 4 consecutive wet weeks during distinct SMW at multiple probability levels have also been compiled and are shown in Tables 4.20 to 4.24.

Table 4.15: Initial and conditional probabilities over Chhura

SMW	Initial Probability		Conditional Probability			
	P_W	P_D	P_{WW}	P_{DW}	P_{DD}	P_{WD}
22	20.0	80.0	50.0	50.0	100.0	0.0
23	30.0	70.0	0.0	100.0	71.4	28.6
24	50.0	50.0	20.0	80.0	60.0	40.0
25	80.0	20.0	62.5	37.5	100.0	0.0
26	90.0	10.0	88.9	11.1	100.0	0.0
27	80.0	20.0	87.5	12.5	0.0	100.0
28	80.0	20.0	75.0	25.0	0.0	100.0
29	100.0	0.0	80.0	20.0	0.0	0.0
30	90.0	10.0	100.0	0.0	0.0	100.0
31	80.0	20.0	100.0	0.0	50.0	50.0
32	100.0	0.0	80.0	20.0	0.0	0.0
33	90.0	10.0	100.0	0.0	0.0	100.0
34	90.0	10.0	88.9	11.1	0.0	100.0
35	80.0	20.0	87.5	12.5	0.0	100.0
36	70.0	30.0	85.7	14.3	33.3	66.7
37	70.0	30.0	71.4	28.6	33.3	66.7
38	90.0	10.0	66.7	33.3	0.0	100.0
39	30.0	70.0	66.7	33.3	0.0	100.0
40	20.0	80.0	50.0	50.0	75.0	25.0
41	30.0	70.0	33.3	66.7	85.7	14.3
42	10.0	90.0	100.0	0.0	77.8	22.2
43	10.0	90.0	100.0	0.0	100.0	0.0
44	0.0	100.0	0.0	0.0	90.0	10.0

Table 4.16: Initial and conditional probabilities over Deobhog

SMW	Initial		Conditional			
	P_W	P_D	P_{WW}	P_{DW}	P_{DD}	P_{WD}
22	30.0	70.0	33.3	66.7	85.7	14.3
23	50.0	50.0	20.0	80.0	60.0	40.0
24	80.0	20.0	50.0	50.0	50.0	50.0
25	100.0	0.0	80.0	20.0	0.0	0.0
26	80.0	20.0	100.0	0.0	0.0	100.0
27	60.0	40.0	83.3	16.7	25.0	75.0
28	80.0	20.0	62.5	37.5	50.0	50.0
29	90.0	10.0	77.8	22.2	0.0	100.0
30	100.0	0.0	90.0	10.0	0.0	0.0
31	80.0	20.0	100.0	0.0	0.0	100.0
32	80.0	20.0	100.0	0.0	100.0	0.0
33	90.0	10.0	77.8	22.2	0.0	100.0
34	70.0	30.0	85.7	14.3	0.0	100.0
35	90.0	10.0	77.8	22.2	100.0	0.0
36	80.0	20.0	87.5	12.5	0.0	100.0
37	70.0	30.0	71.4	28.6	0.0	100.0
38	90.0	10.0	66.7	33.3	0.0	100.0
39	30.0	70.0	100.0	0.0	14.3	85.7
40	60.0	40.0	50.0	50.0	100.0	0.0
41	20.0	80.0	50.0	50.0	37.5	62.5
42	10.0	90.0	100.0	0.0	88.9	11.1
43	10.0	90.0	0.0	100.0	88.9	11.1
44	0.0	100.0	0.0	0.0	90.0	10.0

Table 4.17: Initial and conditional probabilities over Fingeshwar

SMW	Initial		Conditional			
	P_W	P_D	P_{WW}	P_{DW}	P_{DD}	P_{WD}
22	0.0	100.0	0.0	0.0	100.0	0.0
23	30.0	70.0	0.0	100.0	100.0	0.0
24	50.0	50.0	40.0	60.0	80.0	20.0
25	90.0	10.0	55.6	44.4	100.0	0.0
26	70.0	30.0	85.7	14.3	0.0	100.0
27	70.0	30.0	71.4	28.6	33.3	66.7
28	80.0	20.0	62.5	37.5	0.0	100.0
29	90.0	10.0	77.8	22.2	0.0	100.0
30	80.0	20.0	87.5	12.5	0.0	100.0
31	90.0	10.0	88.9	11.1	100.0	0.0
32	90.0	10.0	88.9	11.1	0.0	100.0
33	70.0	30.0	85.7	14.3	0.0	100.0
34	50.0	50.0	100.0	0.0	60.0	40.0
35	100.0	0.0	50.0	50.0	0.0	0.0
36	70.0	30.0	100.0	0.0	0.0	100.0
37	30.0	70.0	0.0	100.0	0.0	100.0
38	80.0	20.0	37.5	62.5	100.0	0.0
39	50.0	50.0	60.0	40.0	0.0	100.0
40	30.0	70.0	66.7	33.3	57.1	42.9
41	20.0	80.0	0.0	100.0	62.5	37.5
42	10.0	90.0	0.0	100.0	77.8	22.2
43	10.0	90.0	0.0	100.0	88.9	11.1
44	0.0	100.0	0.0	0.0	90.0	10.0

Table 4.18: Initial and conditional probabilities over Gariyaband

SMW	Initial (%)		Conditional (%)			
	P_W	P_D	P_{WW}	P_{DW}	P_{DD}	P_{WD}
22	20.0	80.0	0.0	100.0	100.0	0.0
23	30.0	70.0	0.0	100.0	71.4	28.6
24	80.0	20.0	25.0	75.0	50.0	50.0
25	80.0	20.0	75.0	25.0	0.0	100.0
26	50.0	50.0	80.0	20.0	20.0	80.0
27	60.0	40.0	33.3	66.7	25.0	75.0
28	90.0	10.0	55.6	44.4	0.0	100.0
29	80.0	20.0	100.0	0.0	50.0	50.0
30	100.0	0.0	80.0	20.0	0.0	0.0
31	60.0	40.0	100.0	0.0	0.0	100.0
32	100.0	0.0	60.0	40.0	0.0	0.0
33	90.0	10.0	100.0	0.0	0.0	100.0
34	60.0	40.0	100.0	0.0	25.0	75.0
35	100.0	0.0	60.0	40.0	0.0	0.0
36	70.0	30.0	100.0	0.0	0.0	100.0
37	80.0	20.0	62.5	37.5	0.0	100.0
38	90.0	10.0	88.9	11.1	100.0	0.0
39	40.0	60.0	75.0	25.0	0.0	100.0
40	50.0	50.0	40.0	60.0	60.0	40.0
41	30.0	70.0	66.7	33.3	57.1	42.9
42	10.0	90.0	0.0	100.0	66.7	33.3
43	10.0	90.0	0.0	100.0	88.9	11.1
44	0.0	100.0	0.0	0.0	90.0	10.0

Table 4.19: Initial and conditional probabilities over Mainpur

SMW	Initial (%)		Conditional (%)			
	P_W	P_D	P_{WW}	P_{DW}	P_{DD}	P_{WD}
22	20.0	80.0	0.0	100.0	100.0	0.0
23	40.0	60.0	25.0	75.0	83.3	16.7
24	70.0	30.0	57.1	42.9	100.0	0.0
25	70.0	30.0	71.4	28.6	33.3	66.7
26	100.0	0.0	70.0	30.0	0.0	0.0
27	80.0	20.0	100.0	0.0	0.0	100.0
28	80.0	20.0	75.0	25.0	0.0	100.0
29	100.0	0.0	80.0	20.0	0.0	0.0
30	80.0	20.0	100.0	0.0	0.0	100.0
31	80.0	20.0	75.0	25.0	0.0	100.0
32	80.0	20.0	75.0	25.0	0.0	100.0
33	100.0	0.0	80.0	20.0	0.0	0.0
34	90.0	10.0	100.0	0.0	0.0	100.0
35	100.0	0.0	90.0	10.0	0.0	0.0
36	90.0	10.0	100.0	0.0	0.0	100.0
37	80.0	20.0	87.5	12.5	0.0	100.0
38	90.0	10.0	77.8	22.2	0.0	100.0
39	40.0	60.0	75.0	25.0	0.0	100.0
40	50.0	50.0	60.0	40.0	80.0	20.0
41	60.0	40.0	50.0	50.0	50.0	50.0
42	20.0	80.0	100.0	0.0	50.0	50.0
43	10.0	90.0	0.0	100.0	77.8	22.2
44	0	100	0	0	90	10

Table 4.20: Consecutive Dry and Wet Weeks probabilities over Chhura

SMW	Consecutive (%)					
	P2D	P3D	P4D	P2W	P3W	P4W
22	80.0	72.0	72.0	0.0	0.0	0.0
23	70.0	70.0	63.0	15.0	0.0	0.0
24	35.7	35.7	35.7	0.0	0.0	0.0
25	12.0	8.6	8.6	16.0	0.0	0.0
26	10.0	6.0	4.3	56.3	11.3	0.0
27	20.0	20.0	12.0	71.1	44.4	8.9
28	0.0	0.0	0.0	70.0	62.2	38.9
29	0.0	0.0	0.0	75.0	65.6	58.3
30	0.0	0.0	0.0	72.0	54.0	47.3
31	0.0	0.0	0.0	80.0	64.0	48.0
32	0.0	0.0	0.0	100.0	100.0	80.0
33	0.0	0.0	0.0	72.0	72.0	72.0
34	0.0	0.0	0.0	90.0	72.0	72.0
35	0.0	0.0	0.0	71.1	71.1	56.9
36	0.0	0.0	0.0	61.3	54.4	54.4
37	10.0	0.0	0.0	60.0	52.5	46.7
38	3.3	1.1	0.0	64.3	55.1	48.2
39	0.0	0.0	0.0	20.0	14.3	12.2
40	0.0	0.0	0.0	13.3	8.9	6.3
41	52.5	0.0	0.0	15.0	10.0	6.7
42	77.1	57.9	0.0	3.3	1.7	1.1
43	70.0	60.0	45.0	10.0	3.3	1.7
44	100.0	77.8	66.7	0.0	0.0	0.0

Table 4.21: Consecutive Dry and Wet Weeks probabilities over Deobhog

SMW	Consecutive (%)					
	P2D	P3D	P4D	P2W	P3W	P4W
22	70.0	70.0	56.0	0.0	0.0	0.0
23	42.9	42.9	42.9	16.7	0.0	0.0
24	12.0	10.3	10.3	16.0	5.3	0.0
25	0.0	0.0	0.0	50.0	10.0	3.3
26	0.0	0.0	0.0	64.0	32.0	6.4
27	0.0	0.0	0.0	60.0	48.0	24.0
28	5.0	0.0	0.0	66.7	66.7	53.3
29	5.0	1.3	0.0	56.3	46.9	46.9
30	0.0	0.0	0.0	77.8	48.6	40.5
31	0.0	0.0	0.0	72.0	56.0	35.0
32	0.0	0.0	0.0	80.0	72.0	56.0
33	10.0	0.0	0.0	90.0	90.0	81.0
34	0.0	0.0	0.0	54.4	54.4	54.4
35	0.0	0.0	0.0	77.1	60.0	60.0
36	20.0	0.0	0.0	62.2	53.3	41.5
37	0.0	0.0	0.0	61.3	47.6	40.8
38	0.0	0.0	0.0	64.3	56.3	43.8
39	0.0	0.0	0.0	20.0	14.3	12.5
40	5.7	0.0	0.0	60.0	40.0	28.6
41	80.0	11.4	0.0	10.0	10.0	6.7
42	33.8	33.8	4.8	5.0	2.5	2.5
43	80.0	30.0	30.0	10.0	5.0	2.5
44	88.9	79.0	29.6	0.0	0.0	0.0

Table 4.22: Consecutive Dry and Wet Weeks probabilities over Fingeshwar

SMW	Consecutive (%)					
	P2D	P3D	P4D	P2W	P3W	P4W
22	80.0	80.0	80.0	0.0	0.0	0.0
23	70.0	56.0	56.0	0.0	0.0	0.0
24	50.0	50.0	40.0	0.0	0.0	0.0
25	8.0	8.0	8.0	36.0	0.0	0.0
26	30.0	24.0	24.0	38.9	15.6	0.0
27	0.0	0.0	0.0	60.0	33.3	13.3
28	6.7	0.0	0.0	57.1	49.0	27.2
29	0.0	0.0	0.0	56.3	40.2	34.4
30	0.0	0.0	0.0	62.2	38.9	27.8
31	0.0	0.0	0.0	78.8	61.3	38.3
32	10.0	0.0	0.0	80.0	70.0	54.4
33	0.0	0.0	0.0	62.2	55.3	48.4
34	0.0	0.0	0.0	42.9	38.1	33.9
35	0.0	0.0	0.0	100.0	85.7	76.2
36	0.0	0.0	0.0	35.0	35.0	30.0
37	0.0	0.0	0.0	30.0	15.0	15.0
38	0.0	0.0	0.0	0.0	0.0	0.0
39	50.0	0.0	0.0	18.8	0.0	0.0
40	0.0	0.0	0.0	18.0	6.8	0.0
41	45.7	0.0	0.0	13.3	8.0	3.0
42	56.3	32.1	0.0	0.0	0.0	0.0
43	70.0	43.8	25.0	0.0	0.0	0.0
44	88.9	69.1	43.2	0.0	0.0	0.0

Table 4.23: Consecutive Dry and Wet Weeks probabilities over Gariyaband

SMW	Consecutive (%)					
	P2D	P3D	P4D	P2W	P3W	P4W
22	72.0	72.0	72.0	0.0	0.0	0.0
23	70.0	63.0	63.0	0.0	0.0	0.0
24	14.3	14.3	12.9	0.0	0.0	0.0
25	10.0	7.1	7.1	20.0	0.0	0.0
26	0.0	0.0	0.0	37.5	9.4	0.0
27	8.0	0.0	0.0	48.0	36.0	9.0
28	2.5	0.5	0.0	30.0	24.0	18.0
29	0.0	0.0	0.0	44.4	14.8	11.9
30	0.0	0.0	0.0	100.0	55.6	18.5
31	0.0	0.0	0.0	48.0	48.0	26.7
32	0.0	0.0	0.0	100.0	80.0	80.0
33	0.0	0.0	0.0	54.0	54.0	43.2
34	0.0	0.0	0.0	60.0	36.0	36.0
35	0.0	0.0	0.0	100.0	100.0	60.0
36	0.0	0.0	0.0	42.0	42.0	42.0
37	0.0	0.0	0.0	80.0	48.0	48.0
38	0.0	0.0	0.0	56.3	56.3	33.8
39	60.0	0.0	0.0	35.6	22.2	22.2
40	0.0	0.0	0.0	37.5	33.3	20.8
41	42.0	0.0	0.0	12.0	9.0	8.0
42	51.4	30.9	0.0	6.7	2.7	2.0
43	60.0	34.3	20.6	0.0	0.0	0.0
44	88.9	59.3	33.9	0.0	0.0	0.0

Table 4.24: Consecutive Dry and Wet Weeks probabilities over Mainpur

SMW	Consecutive (%)					
	P2D	P3D	P4D	P2W	P3W	P4W
22	80.0	64.0	64.0	0.0	0.0	0.0
23	60.0	60.0	48.0	0.0	0.0	0.0
24	25.0	25.0	25.0	17.5	0.0	0.0
25	30.0	25.0	25.0	40.0	10.0	0.0
26	0.0	0.0	0.0	71.4	40.8	10.2
27	0.0	0.0	0.0	56.0	40.0	22.9
28	0.0	0.0	0.0	80.0	56.0	40.0
29	0.0	0.0	0.0	75.0	75.0	52.5
30	0.0	0.0	0.0	64.0	48.0	48.0
31	0.0	0.0	0.0	80.0	64.0	48.0
32	0.0	0.0	0.0	60.0	60.0	48.0
33	0.0	0.0	0.0	75.0	56.3	56.3
34	0.0	0.0	0.0	72.0	54.0	40.5
35	0.0	0.0	0.0	100.0	80.0	60.0
36	0.0	0.0	0.0	81.0	81.0	64.8
37	0.0	0.0	0.0	80.0	72.0	72.0
38	0.0	0.0	0.0	78.8	78.8	70.9
39	0.0	0.0	0.0	31.1	27.2	27.2
40	0.0	0.0	0.0	37.5	29.2	25.5
41	32.0	0.0	0.0	36.0	27.0	21.0
42	40.0	32.0	0.0	10.0	6.0	4.5
43	45.0	22.5	18.0	10.0	5.0	3.0
44	77.8	0	38.9	0	19.4	0

4.5 Planning of Soil and Water Conservation

Potential rainwater harvesting weeks were estimated by taking four parameters into account: consecutive wet weeks, specified conditions, and another parameter of mean weekly rainfall greater than or equal to 20 mm. Each condition that satisfied the reference five parameters was allocated one weightage factor. In order to qualify as a viable week for rainwater harvesting, a week has to reach four weightages or more. The results are shown in Table 4.25. They showed that the potential weeks for rainwater harvesting at Chhura were found to be 26-39 SMW; 25-38 SMW in Deobhog; 26-37 SMW in Fingeshwar; 26-40 SMW in Gariyaband and 26-41 SMW in Mainpur Tehsil, respectively.

Table 4.25: Consecutives wet spell probabilities for rainwater harvesting

Station		Chhura	Deobhog	Fingeshwar	Gariyaband	Mainpur
Wet week probabilities	P_W SMW ≥40%	24-38	23-38 40	24-36, 38-39	24-40	23-41
	P(2W) SMW ≥20%	26-39	25-40	25-37	25-40	25-41
	P(3W) SMW ≥10%	26, 39.41	25-41	26-37	27-40	26-41
	P(4W) SMW ≥5%	24-41	26-41	27-37	27-41	26-41
Mean weekly rainfall SMW ≥20 .mm		24-38	23-40	24-39	24-40	23-41
Potential week for water harvesting		**26-39**	**25-38**	**26-37**	**26-40**	**26-41**

The consecutive dry periods indicate that additional irrigation and moisture conservation methods are required. With reference to water availability during crop growth phases, the dry spell analysis can be used as a technique to identify periods of deficit (Table 4.35). Table 4.26 shows the data for the risk of occurrence of dry weeks (P_D) during the *Kharif* season (23-44th SMW) at probability limits of 25%, 26-50%, 51-75%, and >75% for various tehsils in the Gariyaband area. It revealed that even during the *Kharif* season, the possibility of dry weeks (P_D) occurring was recorded during the22,40,42, and 44th SMW at Chhura; 4 weeks (41-44th SMW) at Deobhog; and21,41, and 44th SMW was observed for the remaining tehsil, i.e., Fingeshwaer, Gariyaband, and Mainpur.

Similar findings were observed for the conditional probability of dry week preceded by dry week (P_{DD}) during the 22, 25, 26, 41, and 44th SMW at Chhura, 22, 31, 35, 40, 42, and 44th SMW at Deobhog, 22-25, 31, 38, 42, and 44th SMW at Fingeshwar, 22, 38, 43, and 44 SMW at Gariyaband and 22-24, 40, 43, and 44, SMW at Mainpur Tehsil. The in-situ moisture conservation measures which may be adapted during dry spells of more than 50% probability level presented in Table 4.26.

Table 4.26: Weeks with different probabilities of occurrence of dry week during Kharif season over different Tehsil of Gariyaband district

Tehsils	**Dry week (<20 mm per week) occurring at different probability level during *Kharif* season**			
	<25%	**26-50%**	**51-75%**	**>75%**
Chuura	25, 35, 38	24, 26-37	23, 39, 41	22, 40, 42-44
Deobhog	24-26, 28-33, 35-36, 38	23, 27, 34, 37, 40	22,39	41-44
Fingshwar	25, 28-32, 35, 38	24, 26-27,33-34, 36, 39	23, 37, 40	22, 41-44
Gariyaband	24-25, 28-30, 32--33, 35, 37-38.	26-27, 31, 34, 36, 40	23, 39, 41	22, 42-44
Mainpur	26-38	24-25,40-41	23,3	22,42-44

4.6 Probability Analysis of Weekly Rainfall

Tables 4.29 to 4.33 give the results of the analysis of rainfall data from the last 10 years and the weekly chance of occurrence. This forecast assists in maximising the selection of crops, the timing of their sowing and irrigation, and the effective use of precipitation in order to achieve maximum yield. We focused on the monsoon season weeks while estimating weekly rainfall probabilities (23rd to 42nd SMW). The chance of weekly rainfall is calculated for all Tehsils in the Griyaband district using three distinct plotting-position functions: Weibull's method, Gringorten's method, and California's method at probability levels of 50%, 60%, 70%, 75%, 80%, and 90%.

Using error statistics, evaluate how well each plotting-position function performs for each Tehsil separately (Murugappan, 2017). This evaluation technique helps in determining the ranking of each plotting - position function in calculating weekly rainfall magnitudes for each Tehsil of Gariyaband, as shown in Table 4.27-Table 4.28 reveals that California's plotting-position function is rated as the highest overall for all five Tehsils of Gariyaband.

In Fig., a visual representation of the expected rainfall value at a 70 to 90 percent likelihood level is shown. The 90 percent probability was shown to have received the least amount of rainfall, while the 70 percent probability is shown to be on top and is followed by a curve of rising probabilities. The maximum rainfall at 75% probability level was 48.2 mm (33 SMW), followed by 44.8 mm (29 SMW) at Chhura Tehsil, 60.3 mm (25 SMW), followed by 46.9 mm (29 SMW) at Deobhog Tehsil, 47.8 mm (35 SMW), followed by 47.6 mm (29 SMW) at Fingeshwar Tehsil, 52.9 mm (32 SMW), followed by 51.3 mm (35 SMW) (31 SMW). Lowest rainfall of 0 mm was recorded in the following areas: Chhura (40-42 SMW), Deobhog (42 SMW), Fingeshwar (37,40-42 SMW), Gariyaband (42 SMW), and Mainpur Tehsil (42 SMW).

Table 4.27: Error statistics in estimation of Kharif season rainfall for different plotting - position function

Plotting Position	Tehsils of Gariyaband district														
	Chhura			Deobhog			Fingeshwar			Gariyaband			Mainpur		
	MSE	RMSE	MAE	MSE	RMSE	MAE	MSE	RMSE	MAE	MSE	RMSE	MAE	MSE	RMSE	MAE
Weibulls	24.0	4.9	0.7	19.6	4.4	0.6	18.5	4.3	0.7	15.1	3.9	0.7	37.0	6.1	0.8
Gringorten	19.9	4.5	0.7	18.7	4.3	0.6	13.6	3.7	0.6	11.3	3.4	0.6	24.9	5.0	0.6
California	16.8	4.1	0.6	15.8	4.0	0.6	12.6	3.5	0.6	10.4	3.2	0.6	21.4	4.6	0.6

Table 4.28: Ranking of plotting - position functions in estimation of magnitude of Kharif season rainfall with different probability of rainfall

Plotting Position	Tehsils of Gariyaband district														
	Chhura			Deobhog			Fingeshwar			Gariyaband			Mainpur		
	MSE	RMSE	MAE	MSE	RMSE	MAE	MSE	RMSE	MAE	MSE	RMSE	MAE	MSE	RMSE	MAE
Weibulls	3	3	3	3	3	1	3	3	3	3	3	3	3	3	3
Gringorten	2	2	2	2	2	3	2	2	1	2	2	2	2	2	2
California	1	1	1	1	1	2	1	1	2	1	1	1	1	1	1

Table 4.29: Prediction of weekly rainfall at different levels at Chhura

SMW	Weibull's						Gringorten's						California					
	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%
23	0.0	0.0	0.0	1.2	6.1	11.8	0.0	0.0	0.4	2.2	6.4	11.2	0.0	0.0	2.1	4.2	9.0	14.7
24	0.0	2.1	5.7	9.6	18.2	28.3	0.0	4.5	7.6	11.0	18.4	27.2	1.1	7.6	11.2	15.1	23.7	33.8
25	6.2	18.7	25.5	32.8	49.1	68.4	14.1	24.6	30.4	36.6	50.4	66.8	16.3	28.8	35.6	42.9	59.2	78.5
26	23.3	28.4	31.2	34.1	40.8	48.6	26.5	30.8	33.2	35.7	41.3	48.	27.7	33.2	36.1	39.3	46.4	54.8
27	11.8	18.5	22.1	26.	34.7	45.	15.4	21.1	24.2	27.6	35.1	43.9	17.2	23.8	27.5	31.4	40.1	50.4
28	10.6	15.9	18.7	21.8	28.6	36.7	14.1	18.5	20.9	23.5	29.3	36.1	14.9	20.1	23.	26.	32.9	41.
29	0.0	9.9	22.8	36.5	67.3	103.7	23.5	33.6	39.2	45.1	58.4	74.1	26.6	38.4	44.8	51.7	67.2	85.4
30	21.4	27.7	31.1	34.8	43.	52.8	24.9	30.3	33.3	36.4	43.5	51.8	26.5	32.8	36.2	39.9	48.1	57.9
31	4.2	18.2	25.8	34.	52.3	73.9	12.9	24.8	31.3	38.2	53.7	72.	15.5	29.5	37.1	45.3	63.6	85.2
32	26.7	32.2	35.1	38.3	45.4	53.8	30.0.	34.6	37.2	39.9	45.9	53.1	31.1	36.6	39.5	42.7	49.8	58.2
33	41.2	45.0	47.0	49.3	54.2	60.1	41.3	44.9	46.8	48.9	53.5	58.9	41.7	45.9	48.2	50.7	56.2	62.8
34	19.8	26.7	30.5	34.6	43.6	54.3	24.3	30.1	33.3	36.8	44.4	53.5	25.4	32.3	36.1	40.2	49.2	59.9
35	0.0	13.1	23.	33.6	57.2	85.2	5.6	21.	29.5	38.5	58.7	82.6	9.5	27.6	37.5	48.1	71.8	99.7
36	2.3	17.8	26.3	35.4	55.7	79.7	11.4	24.7	31.9	39.7	57.0	77.5	14.9	30.4	38.9	47.9	68.2	92.2
37	9.4	16.9	21.	25.3	35.1	46.7	13.9	20.0.3	23.8	27.5	35.8	45.7	15.4	22.9	27.	31.4	41.2	52.8
38	39.2	43.7	46.2	48.8	54.7	61.7	42.4	46.2	48.3	50.0.5	55.4	61.2	42.8	47.3	49.8	52.5	58.4	65.4
39	0.0	0.0	0.0	0.4	5.5	11.7	0.0	0.0	0.0	1.5	5.9	11.1	0.0	0.0	1.2	3.6	8.7	14.9
40	0.0	0.0	0.0	0.0	1.9	6.3	0.0	0.0	0.0	0.0	2.0	5.8	0.0	0.0	0.0	0.5	4.2	8.6
41	0.0	0.0	1.0	2.3	5.4	9.1	0.0	0.7	1.8	3.0	5.6	8.7	0.0	1.6	2.9	4.3	7.3	11.
42	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	1.7	6.0

Table 4.30: Prediction of weekly rainfall at different level at Deobhog

SMW	Weibull's						Gringorten's						California					
	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%
23	5.1	7.5	8.9	10.3	13.5	17.3	6.7	8.8	9.9	11.1	13.8	17.0	7.0	9.5	10.8	12.3	15.5	19.3
24	0.0	1.9	7.2	12.9	25.6	40.6	0.0	4.7	9.4	14.4	25.6	38.7	0.1	9.8	15.1	20.0.8	33.5	48.5
25	44.9	51.4	55.0	58.8	67.4	77.5	49.3	54.8	57.8	61.1	68.2	76.7	50.2	56.7	60.3	64.1	72.7	82.8
26	17.8	24.7	28.5	32.5	41.5	52.2	22.8	28.6	31.7	35.1	42.6	51.5	23.4	30.3	34.1	38.1	47.1	57.8
27	14.3	21.3	25.2	29.3	38.5	49.4	8.4	14.3	17.6	21.1	29.	38.3	3.9	10.9	14.8	18.9	28.1	39.
28	12.9	20.4	24.6	29.0	38.8	50.5	4.8	11.2	14.8	18.6	27.1	37.1	6.4	14.	18.1	22.5	32.4	44.1
29	11.7	26.6	34.8	43.5	63.1	86.2	11.7	26.6	34.8	43.5	63.1	86.2	23.7	38.7	46.9	55.6	75.2	98.3
30	28.8	35.1	38.6	42.3	50.6	60.4	21.1	33.8	40.7	48.1	64.7	84.3	33.9	40.3	43.7	47.4	55.7	65.5
31	15.3	27.6	34.4	41.7	57.8	76.9	33.	38.3	41.3	44.4	51.4	59.7	16.8	29.2	35.9	43.2	59.3	78.5
32	2.6	19.5	28.7	38.7	60.8	86.9	12.	26.5	34.5	43.	62.	84.4	16.3	33.2	42.4	52.3	74.5	100.6
33	19.2	26.5	30.6	34.9	44.5	55.9	23.9	30.1	33.6	37.2	45.3	55.	25.1	32.5	36.5	40.8	50.5	61.9
34	2.9	11.4	16.0	20.9	32.	45.1	5.2	12.4	16.4	20.6	30.0.	41.2	5.3	13.8	18.4	23.3	34.4	47.4
35	20.8	31.8	37.8	44.2	58.5	75.5	27.5	36.8	41.9	47.3	59.5	74.	29.7	40.6	46.6	53.0	67.4	84.3
36	15.9	22.6	26.2	30.1	38.9	49.2	20.5	26.1	29.2	32.4	39.7	48.4	21.3	28.	31.6	35.5	44.2	54.6
37	0.0	9.3	16.9	25.1	43.4	65.1	3.4	15.3	21.9	28.9	44.5	63.0	6.6	20.6	28.2	36.4	54.7	76.4
38	15.4	27.1	33.6	40.5	55.9	74.1	12.6	22.6	28.1	34.	47.2	62.7	15.2	27.	33.4	40.3	55.7	73.9
39	26.6	33.1	36.6	40.4	48.9	58.9	0.0	0.0	0.0	0.3	7.5	16.2	0.0	0.0	0.2	3.9	12.4	22.4
40	0.0	3.8	6.8	10.0.1	17.4	26.	1.9	6.6	9.2	11.9	18.1	25.3	2.7	8.3	11.3	14.6	21.9	30.0.5
41	6.4	8.4	9.5	10.0.7	13.3	16.4	4.8	6.5	7.4	8.4	10.0.7	13.3	0.0	.7	1.8	3.	5.6	8.7
42	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	2.	0.0	0.0	0.0	0.0	1.2	3.6

Table 4.31: Prediction of weekly rainfall at different level at Fingeshwar

SMW	Weibull's						Gringorten's						California					
	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%
23	0.0	0.1	1.1	2.2	4.7	7.6	0.0	1.0	1.8	2.8	4.9	7.4	0.0	1.6	2.6	3.8	6.3	9.2
24	0.0	0.0	1.6	6.2	16.2	27.8	0.0	0.1	3.6	7.6	16.3	26.4	0.0	3.7	7.7	12.4	22.3	33.9
25	21.6	28.4	32.	36.1	45.1	55.5	26.	31.8	34.8	38.3	45.9	54.6	27.	33.9	37.5	41.6	50.6	61.
26	1.7	8.9	12.7	17.1	26.4	37.3	6.3	12.5	15.7	19.4	27.4	36.7	8.2	15.4	19.1	23.5	32.9	43.8
27	10.8	17.1	20.4	24.2	32.4	42.0	3.7	9.1	11.9	15.2	22.3	30.0.5	5.3	11.6	14.9	18.7	26.9	36.5
28	25.6	28.4	29.9	31.7	35.4	39.8	27.7	30.1	31.3	32.8	35.9	39.5	32.2	40.1	44.2	49.	59.3	71.2
29	0.0	0.0	0.0	1.3	11.5	23.5	34.9	41.4	44.9	48.9	57.4	67.4	35.6	43.5	47.6	52.4	62.6	74.5
30	6.2	12.9	16.4	20.5	29.3	39.4	9.6	15.4	18.4	22.	29.6	38.4	11.6	18.3	21.8	25.9	34.6	44.8
31	0.0	11.2	17.3	24.4	39.6	57.4	5.2	15.3	20.6	26.8	40.0.	55.4	8.9	20.6	26.6	33.8	49.	66.7
32	19.9	27.6	31.7	36.4	46.5	58.3	24.7	31.3	34.7	38.7	47.3	57.3	26.1	33.9	37.9	42.6	52.8	64.5
33	10.2	16.7	20.1	24.1	32.6	42.5	14.1	19.6	22.5	25.8	33.	41.3	15.4	21.9	25.3	29.3	37.9	47.8
34	6.0	8.8	10.3	12.0	15.7	19.9	7.7	10.0.	11.3	12.7	15.8	19.4	8.2	11.0	12.5	14.2	17.9	22.2
35	5.7	27.3	38.6	51.7	80.0.	112.7	16.8	35.4	45.2	56.6	80.9	10.92	15.0	36.6	47.8	61.0	89.2	122.0
36	0.0	7.1	12.6	19.	32.7	48.7	2.5	11.5	16.2	21.7	33.5	47.1	5.0	15.5	21.	27.4	41.2	57.1
37	0.0	0.0	0.0	0.0	7.5	20.4	0.0	0.0	0.0	0.0	6.9	18.2	0.0	0.0	0.0	2.5	13.6	26.6
38	24.6	29.2	31.5	34.3	40.3	47.2	27.6	31.5	33.5	35.8	40.8	46.7	28.3	32.8	35.2	38.	43.9	50.9
39	0.0	0.0	0.0	2.7	13.7	26.5	23.7	31.	34.8	39.2	48.7	59.7	0.0	0.0	4.3	9.5	20.4	33.2
40	0.0	0.0	0.0	0.0	3.3	8.2	10.0.7	13.4	14.9	16.5	20.0.1	24.3	0.0	0.0	0.0	1.7	5.9	10.8
41	0.0	0.0	0.0	0.0	3.5	9.5	0.0	0.0	0.0	0.0	3.6	8.9	0.0	0.0	0.0	1.4	6.7	12.8
42	0.0	0.0	0.0	0.0	0.0.4	2.7	0.0	0.0	0.0	0.0	0.5	2.4	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.32: Prediction of weekly rainfall at different level at Gariyaband

SMW	Weibull's						Gringorten's						California					
	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%
23	0.0	0.0	0.1	1.9	6.0	10..8	0.0	0.0	1.1	2.7	6.3	10.4	0.0	0.9	2.5	4.5	8.6	13.4
24	9.8	13.8	16.0	18.4	23.6	29.9	11.9	15.4	17.2	19.3	23.9	29.2	13.0	17.0	19.2	21.6	27.0	33.1
25	9.2	18.2	23.2	28.5	40.3	54.2	14.4	22.2	26.3	31.0	41.1	52.9	16.4	25.5	30.3	35.8	47.7	61.5
26	8.1	11.5	13.4	15.4	19.8	25.1	10.4	13.3	14.8	16.5	20.0.3	24.7	10.8	14.2	16.0	18.2	22.6	27.9
27	7.8	12.3	14.8	17.4	23.3	30.2	10.7	14.5	16.5	18.9	23.9	29.7	11.4	15.9	18.3	21.1	27.0	33.8
28	24.9	29.9	32.6	35.4	41.9	49.5	28.1	32.3	34.5	37.0	42.5	48.9	28.9	33.8	36.4	39.5	45.9	53.5
29	0.0	11.6	20.6	30.3	51.9	77.4	12.7	36.4	48.8	63.3	94.4	130.4	8.3	24.9	33.6	43.8	65.5	90.8
30	18.6	25.6	29.5	33.7	42.9	53.8	22.4	28.5	31.7	35.4	43.4	52.7	24.2	31.4	35.1	39.4	48.7	59.6
31	0.0	0.0	3.9	12.5	31.7	54.4	0.0	1.9	8.5	16.3	32.9	52.2	0.0	7.8	15.5	24.5	43.8	66.3
32	39.2	45.1	48.3	51.7	59.4	68.5	42.6	47.7	50.3	53.4	60.0	67.6	43.9	49.8	52.9	56.5	64.2	73.2
33	11.4	17.3	20.6	24.1	31.9	41.1	14.6	19.8	22.5	25.6	32.4	40.2	16.2	22.2	25.3	29.0	36.8	45.9
34	0.0	0.0	1.8	4.0	8.9	14.7	13.3	16.5	18.1	20.1	24.2	29.0	13.7	17.5	19.4	21.7	26.7	32.4
35	24.0	35.7	42.1	49.0.	64.3	82.4	30.9	41.0	46.2	52.3	65.5	80.7	33.4	45.2	51.3	58.5	73.9	91.9
36	2.7	12.9	18.6	24.6	38.0	53.9	6.6	15.4	20.0	25.4	36.9	50.3	10.9	21.3	26.7	33.0	46.5	62.2
37	7.7	13.8	17.2	20.8	28.9	38.4	11.3	16.6	19.4	22.6	29.5	37.6	12.6	18.8	22.1	25.8	34.0.0	43.4
38	24.1	30.2	33.6	37.2	45.2	54.7	28.2	33.4	36.1	39.3	46.1	54.0	29.0	35.2	38.4	42.2	50.3	59.6
39	0.0	0.0	0.0	0.7	5.3	10.7	0.0	0.0	0.0	1.7	5.6	10.2	0.0	0.0	1.4	3.6	8.2	13.5
40	0.0	2.0.	4.6	7.3	13.4	20.6	0.0.4	4.4	6.4	8.8	14.0	20.0	1.1	5.8	8.2	11.1	17.2	24.3
41	6.6	8.9	10.0.1	11.4	14.3	17.8	4.6	6.5	7.5	8.7	11.1	14.0	4.8	7.1	8.2	9.6	12.5	16.0
42	0.0	0.0	0.0	0.0	0.0	2.9	1.5	3.9	5.2	6.6	9.8	13.5	0.0	0.0	0.0	0.0	1.1	4.9

Table 4.33: Prediction of weekly rainfall at different level at Mainpur

SMW	Weibull's						Gringorten's						California					
	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%	90%	80%	75%	70%	60%	50%
23	0.0	0.8	2.7	5.0	9.9	15.6	0.0	2.1	3.8	5.8	10.0	15.0	0.0	3.8	5.7	8.0	12.9	18.6
24	0.0	6.2	11.1	16.8	29.0	43.1	1.7	9.8	14.0	18.9	29.4	41.6	4.4	13.7	18.6	24.3	36.4	50.6
25	8.3	19.7	25.7	32.7	47.6	65.0	14.8	24.6	29.7	35.7	48.5	63.4	17.4	28.9	34.9	41.9	56.8	74.2
26	27.2	34.3	38.1	42.4	51.7	62.6	31.4	37.5	40.7	44.4	52.3	61.6	32.9	40.1	43.8	48.1	57.5	68.3
27	6.0	12.8	16.4	20.5	29.4	39.7	9.8	15.6	18.6	22.2	29.8	38.7	11.5	18.3	21.8	26.0	34.8	45.1
28	29.5	37.7	42.0	47.0	57.8	70.3	34.6	41.6	45.2	49.5	58.6	69.2	36.1	44.3	48.6	53.6	64.4	76.9
29	3.9	24.4	35.0	47.5	74.2	105.2	15.3	32.8	41.9	52.6	75.5	102.0	15.6	36.0	46.7	59.1	85.8	116.8
30	22.9	31.5	35.9	41.1	52.3	65.3	28.2	35.5	39.3	43.7	53.2	64.2	29.8	38.3	42.8	48.0	59.2	72.1
31	9.4	26.9	36.0	46.7	69.7	96.3	5.5	20.3	28.0	37.1	56.4	78.9	23.4	41.0	50.1	60.8	83.7	110.3
32	5.9	13.4	17.3	21.9	31.7	43.2	2.1	8.6	12.0	16.0	24.6	34.5	11.9	19.4	23.4	28.0	37.8	49.2
33	30.7	38.5	42.6	47.5	57.7	69.7	35.2	41.9	45.4	49.5	58.3	68.6	37.0	44.9	49.0	53.8	64.1	76.0
34	29.0	34.9	38.0	41.5	49.2	58.1	32.6	37.5	40.2	43.2	49.7	57.3	33.7	39.6	42.7	46.2	53.9	62.8
35	20.7	34.2	41.3	49.6	67.3	87.9	28.4	40.0	46.0	53.1	68.3	85.9	31.6	45.1	52.2	60.5	78.2	98.8
36	6.4	21.5	29.4	38.6	58.2	81.1	15.1	28.0	34.8	42.7	59.6	79.2	7.5	22.6	30.5	39.7	59.3	82.2
37	6.7	13.4	16.9	20.9	29.6	39.8	10.6	16.3	19.3	22.7	30.2	38.8	12.1	18.7	22.2	26.3	35.0	45.1
38	8.6	24.5	32.8	42.6	63.4	87.6	17.3	31.0	38.2	46.5	64.4	85.2	6.7	22.6	31.0	40.7	61.5	85.7
39	0.8	3.1	4.4	5.8	9.0	12.6	2.5	4.5	5.5	6.7	9.3	12.3	1.5	3.9	5.2	6.6	9.7	13.4
40	0.8	4.9	7.1	9.6	15.0	21.3	3.6	7.1	8.9	11.0	15.5	20.8	4.1	8.3	10.4	12.9	18.3	24.6
41	0.0	3.5	6.1	9.2	15.7	23.3	1.1	5.4	7.6	10.3	15.9	22.5	2.5	7.5	10.1	13.2	19.7	27.4
42	0.0	0.0	0.0	0.0	1.4	4.6	0.0	0.0	0.0	0.0	1.4	4.3	0.0	0.0	0.0	0.3	3.1	6.3

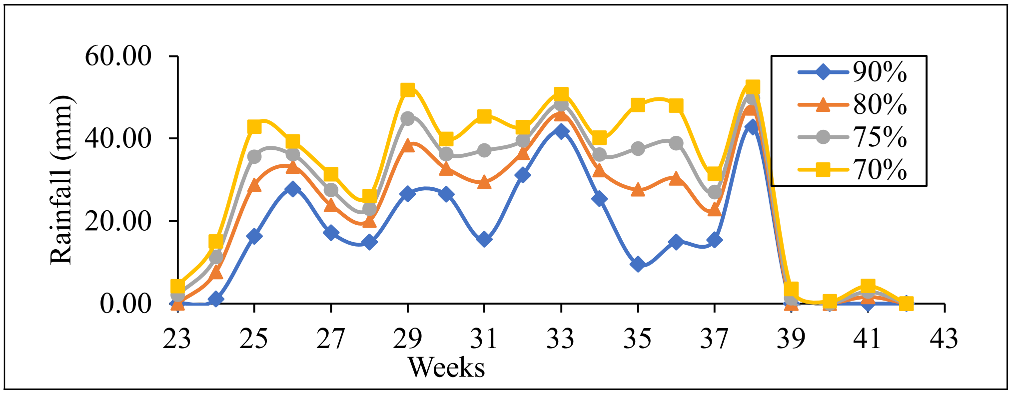

Figure 4. 11: Predicted weekly rainfall at different probability level in Chhura

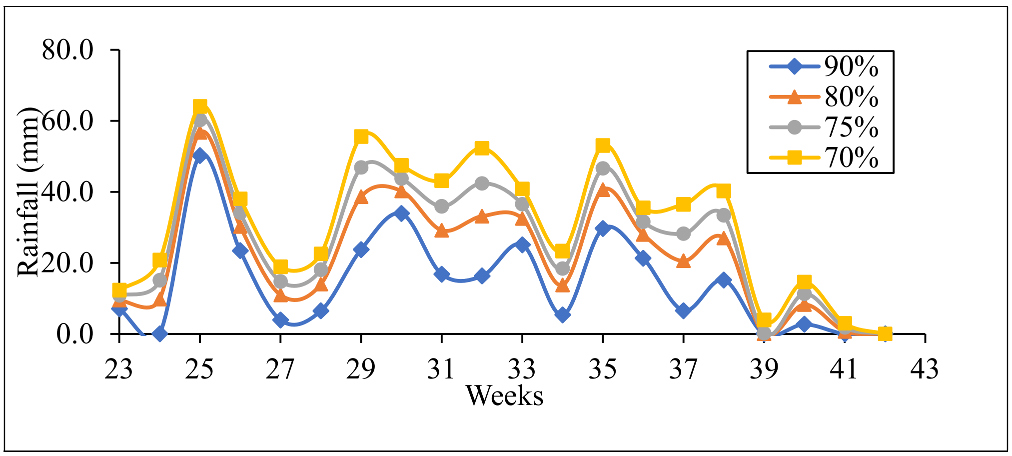

Figure 4. 12: Predicted weekly rainfall at different probability level in Deobhog

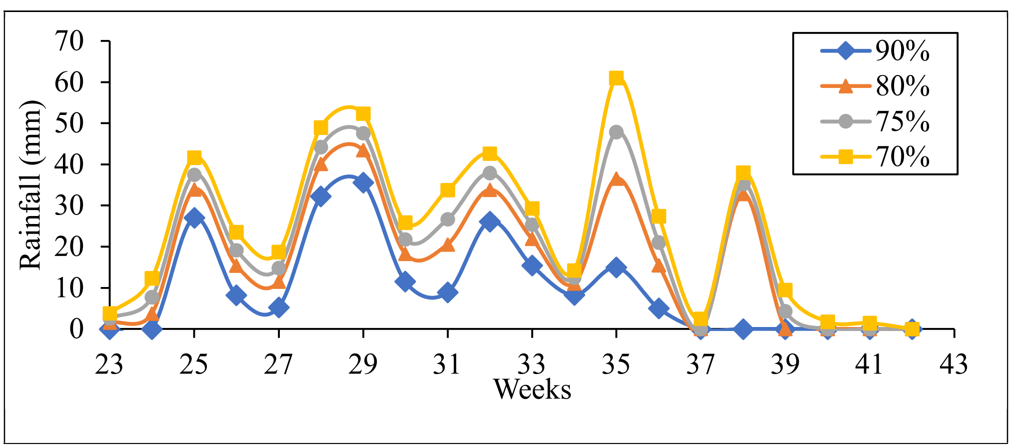

Figure 4. 13: Predicted weekly rainfall at different probability level in Fingeshwar

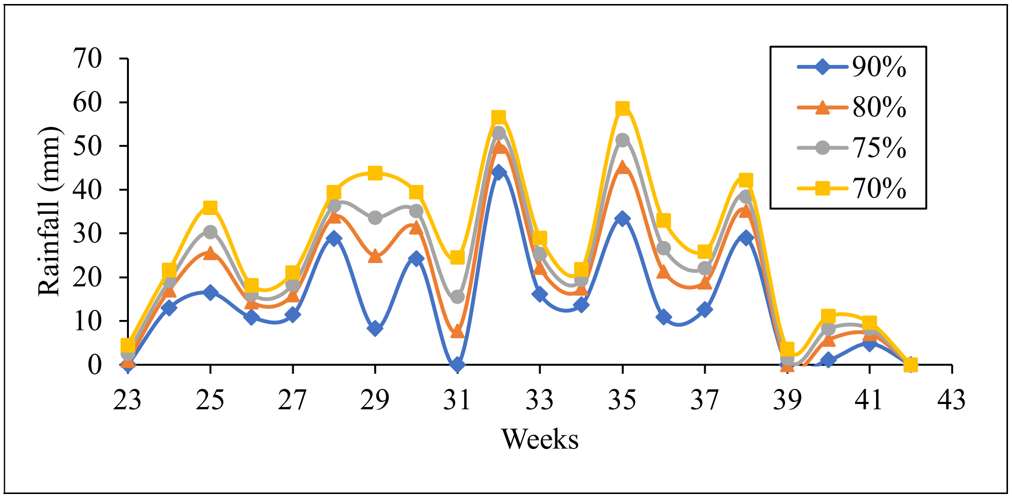

Figure 4. 14: Predicted weekly rainfall at different probability level in Gariyaband

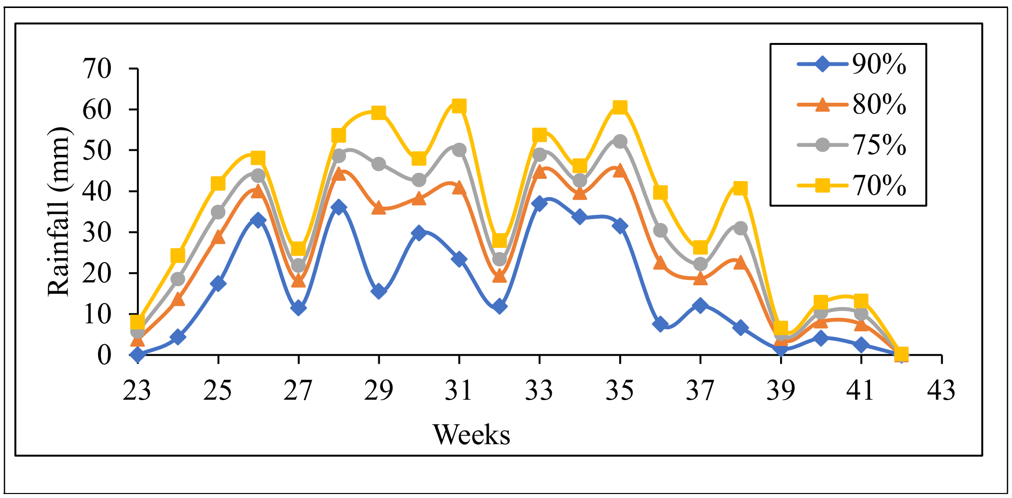

Figure 4. 15: Predicted weekly rainfall at different probability level in Mainpur

4.7 Crop Planning

The availability of rainwater and its distribution over the entire crop growth cycle determine whether rainfed farming is successful or unsuccessful. Although we have no real control over the weather, we may optimize rainfed crop output by modifying crop plans and agronomic techniques in accordance with the likely weather conditions using statistical analytic methods. This management can be done in accordance with the crop growth phases (Table 4.34) (Fig. 4.16,4.18), the crucial stages for water requirement (Table 4.35) (Fig. 4.17,4.19), as well as the stage-by-stage water requirements of various crops, as shown in Table 4.36-4.37.

Table 4.34: Crop growth stages and growing days for different crop

Crop	Sowing time	Duration (Days)	Growth stages	Time of various growth stage (No. of DAS)
Paddy	3rd week of June – July 1st week	120-135	Seedling	0 – 15
			Vegetative	15 – 45
			Reproductive	46 – 75
			Maturity	76 – 120
Maize	3rd week of June – July 1st week	105-115	Seedling	1 – 14
			Vegetative	40 – 65
			Maturity	66 – 95
			Ripening	96 – 105

Table 4.35: Critical stages of different crops

Crop	Sowing time	Duration (Days)	Critical Growth stages	Time of various growth stage (No. of DAS)
Paddy	3rd week of June – July 1st week	120-135	Initial tillering	30-35
			Panicle Initiation	40-45
			Booting	56-58
			Heading	70-72
			Flowering	75-77
Maize	3rd week of June – July 1st week	105-115	Just prior to tasseling & gain filling	48-60

Table 4.36: Stage wise water requirement of Paddy crop

Stages of growth	Water requirement (mm)	Percentage of total water requirement
Nursery	40	3.22
Main field preparation	200	16.12
Vegetative	458	37
Reproductive	417	33.66
Maturity	125	10

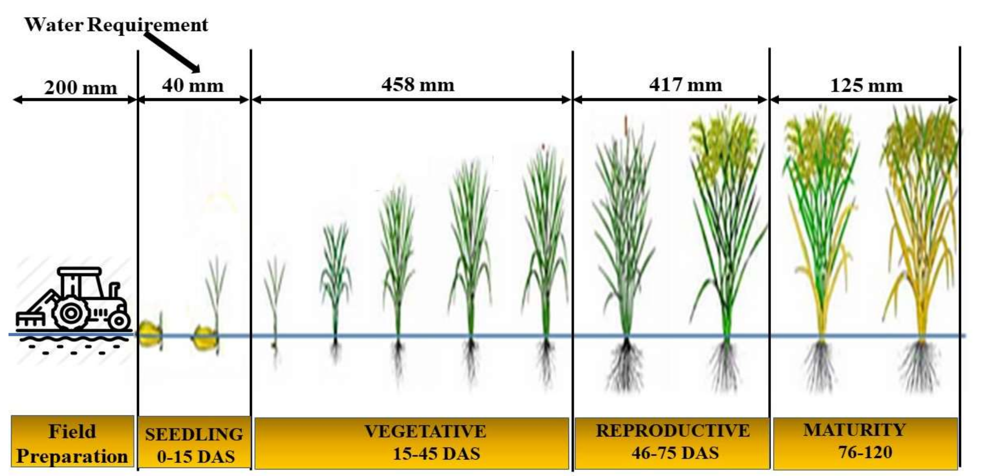

Figure 4. 16: Paddy crop growth stages and water requirement

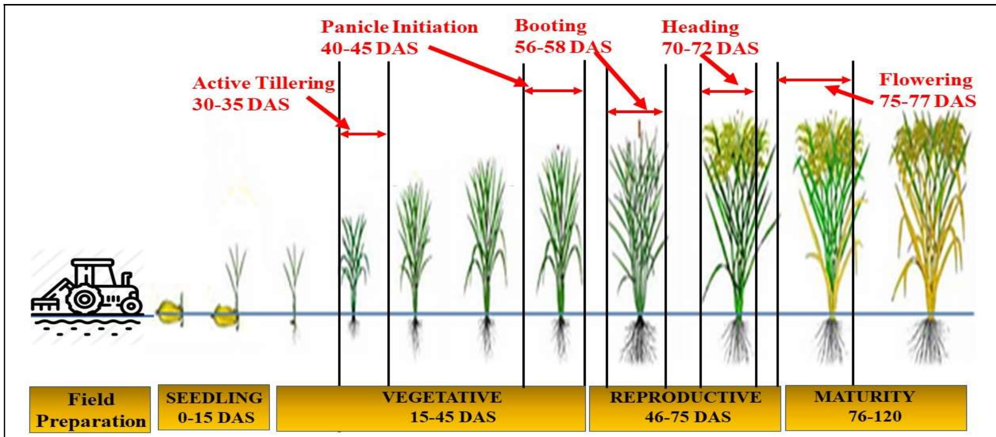

Figure 4. 17: Paddy crop critical growth stages

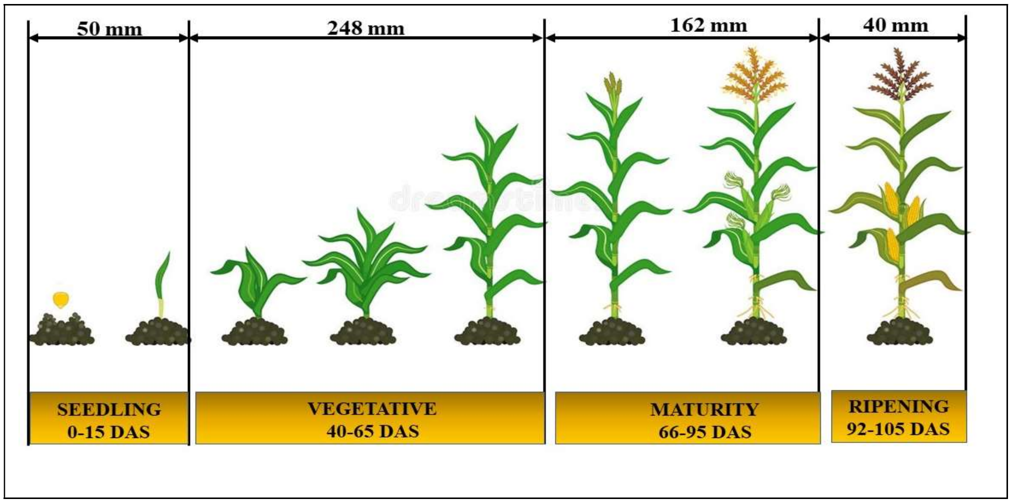

Figure 4. 18: Maize crop growth stages and water requirement

Table 4.37: Stage wise water requirement of Maize crop

Stages of growth	Water requirement (mm)	Percentage of total water requirement
Seedling	50	10
Vegetative	248	49.6
Maturity	162	32.4
Ripening	40	8

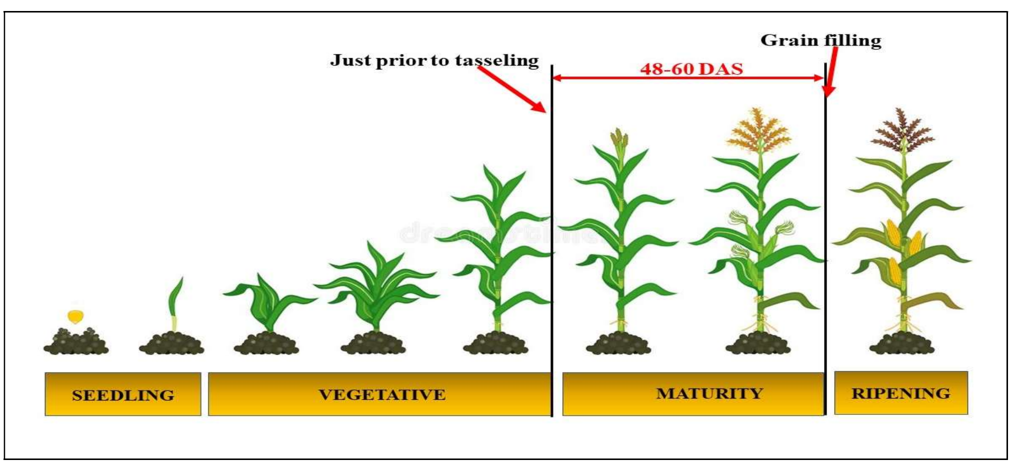

Figure 4. 19: Maize crop critical growth stages

4.7.1 Chhura Tehsil

It is noticeable from Tables 4.13 and 4.14 that the mean dates of the significant monsoon's onset and withdrawal are 18–24 June (25th SMW) and 24–30 September (39th SMW), respectively. Anything that rains before June 18th can be classified as pre-monsoon precipitation. The analysis of rainfall data revealed that there are enough pre-monsoon showers before June 18th. Tillage practices are thus permissible between before and after June 18 and *Kharif* crops can be sown during this time. Further below primary crop strategy for this Tehsil

Paddy Crop

Direct seeded rice and rice nursery of short and medium duration varieties could be sown at this season and transplanted by the 1st – 2nd week of July for a successful crop. At 80 and 70 percent probable levels, total monsoon rain amounts in Chhura ranged from 458 to 618 mm, which might be deemed sufficient for growing rice crops. There seems to be an 80% and 75% chance, respectively, of finding decent rainwater during the seeding and vegetative periods (25th to 34th SMW). Under these conditions, a short duration rice variety of about 100 to 110 days can be easily grown without any adverse effects from a lack of rainfall. If short- or medium-duration rice varieties are cultivated, the leftover moisture after the rice harvested can be used to grow short-duration rabi crops in order to increase yields.

Rainwater with a 75 and 80 percent probability of being available is sufficient in this Tehsil during the transplanting stage (27-28 SMW). There is a high probability of consecutive wet weeks throughout this week. However, the SMW immediately preceding the transplanting period, *i.e.,* the 25-26th SMW, has a higher probability of conditional dry weeks, therefore some assured irrigation facilities should be maintained. The initial wet probability was found to be the highest in the 32nd SMW. The 30-31st and 33rd SMW have the highest conditional wet probability, whereas the 40th to 44th SMW have the highest conditional dry probabilities. It suggests there is a higher probability of a dry week during the maturity phase. For protection of crop in last phases of crop farmer can use stored water.

The critical crop growth stages include active tillering, panicle initiation, booting, heading, and flowering, that fall under the 29th–30th, 31st, 33th, 34th–36th, and 37th–38th SMWs, respectively. During this period, there are 70–100% probabilities of initial and conditional probabilities of weeks being wet.

Maize Crop

Total monsoon rain amounts in Chhura range from 458 to 618 mm at 80 and 70 percent probability levels, which may be deemed sufficient for cultivating maize crops. Rainfall is reasonably good throughout the seeding and vegetative periods (25th to 35th SMW) with 80% and 75% likelihood, respectively. Under rainfed conditions, a maize crop with a sowing time of approximately 95 to 105 days can be easily cultivated without suffering any negative effects from a lack of rainfall.

There is sufficient rainfall all throughout critical crop stage (31-35th SMW) and there is a 75-80% probability of an initial and conditional dry week during the 39-42nd SMW, which falls under the ripening stage of the maize crop. During this dry week, plant irrigation should be undertaken to meet the crop's water needs.

4.7.2 Deobhog Tehsil

Tables 4.13 and 4.14 show that the significant monsoon's average commencement and withdrawal dates are 18–24 June (the 25th SMW) and 17–23 September (the 38th SMW), respectively. Anything that rains before June 18th is considered pre-monsoon precipitation. Since there aren't enough pre-monsoon rains before June 18th, rainfall data analysis has shown this. Thus, after June 18 tillage techniques are allowed, and beyond that date, *Kharif* crops may be seeded. Primary crop plan for this Tehsil is further below

Paddy Crop

For a profitable crop, direct seeded rice and rice nursery of short and medium duration kinds could be sown this season and transplanted by the 2nd - 3rd week of July. Total monsoon rainfall amounts at Deobhog were between 444 and 626 mm at 80 and 70 percent likely levels, which may be considered adequate for the development of rice crops. During the sowing and vegetative stages, there seems to be an 80% and a 75% chance, respectively, of discovering good rainwater (26th to 35th SMW). A rice variety with a short growing season of about 100 to 110 days can be grown successfully in these circumstances without suffering any negative consequences from a shortage of rainfall.

In this Tehsil, adequate rainwater is available for transplanting with a likelihood of between 75 and 80 percent (28-29th SMW). This week has a good chance of having several straight wet weeks. The highest conditional dry probabilities are found in the 41st to 44th SMW, whereas the highest conditional wet probabilities are found in the 31st to 32nd and 39th SMW. It implies that there is a greater chance of a dry week during the maturity phase. Farmers may use saved water for crop protection throughout the latter stages of the crop.

Active tillering, panicle initiation, booting, heading, and blooming are the essential crop growth stages, and they correspond to the 30-31st, 32nd, 34th, 35th - 37th, and 38th-39th SMWs, respectively. The initial and conditional odds of weeks being wet throughout this time range from 70 to 100%.

Maize Crop

In Deobhog, the total monsoon rainfall quantities vary from 444 to 626 mm at 70 and 80 percent likelihood levels, which might be considered enough for growing maize crops. Throughout the sowing and vegetative phases (26th to 36th SMW), rainfall is likely to occur at a rate of 80% and 75%, respectively. In rainfed environments, a maize crop with a planting period of roughly 95 to 105 days can be easily grown without experiencing any detrimental consequences from a lack of precipitation.

There is adequate precipitation throughout the important crop stage (32–36th SMW), and the probability of an initial and conditional dry week during the 40–43th SMW, which corresponds to the maize crop's ripening stage, is 80–90%. Therefore, it was advised that maize should be sown early to allow for irrigation measures to be carried out for field preparation and for seedling so that dry periods during the maturity period may be overlooked.

4.7.3 Fingeshwar Tehsil

The mean dates of the substantial monsoon's onset and departure are 18–24 June (25th SMW) and 17–23 September (38th SMW), respectively, as shown in Tables 4.13 and 4.14. Pre-monsoon precipitation includes all precipitation that occurs prior to June 18th. Since there aren't enough pre-monsoon rains before June 18th, rainfall data analysis has shown this. Thus, *Kharif* crops can be sown between now and June 18 if water is available to the land for field preparation and tillage operations are permitted. Listed below is the Tehsil's major crop plan.

Paddy Crop

For a satisfactory crop, short- and medium-duration varieties of direct seeded rice and rice nurseries could be planted now and transferred by the first or second week of July. Total monsoon rainfall at Fingeshwar ranged from 340.4 to 488.7 mm at 80 and 70 percent probabilities, which was only marginally enough to support rice crop growth. During the sowing and vegetative phases, there appears to be an 80% and a 75% likelihood, respectively, of discovering a reasonable amount of rainwater (25th to 34th SMW). A rice variety with a short growing season of 100 to 110 days can be produced successfully under these circumstances without suffering any negative consequences from a shortage of rainfall.

In this Tehsil, during the transplanting stage, rainwater with a 75 to 80% probability of being accessible is sufficient (27-28 SMW). This week has a good chance of having several straight wet weeks. The SMW preceding the transplanting period, i.e., the 25th–26th SMW, has a higher likelihood of conditional dry weeks; as a result, some assured irrigation facilities should be maintained. It was discovered that the 35th SMW had the highest initial wet probability. The highest conditional dry probabilities are found in the 31st, 38th, 42nd to 44th SMW, whereas the highest conditional wet probabilities are found in the 34th and 36th SMW. According to this, there is a greater chance of a dry week throughout the maturity phase. Farmers can use saved water to safeguard crops during the last stages of harvest.

The crucial stages of crop development are active tillering, panicle initiation, booting, heading, and blooming, which are classified as the 29th–30th, 33rd–34th, and 37th–38th SMWs, respectively. Except for heading and flowering, which have a greater likelihood of a dry week than a wet week, there are 70-100 percent initial and conditional probabilities of weeks being wet during this time. In order to avoid this, irrigation should be arranged during this period before crop transplanting.

Maize Crop

At 80 and 70 percent probability levels, Fingeshwar receives 340 to 488.7 mm of total monsoon precipitation, which may be termed enough for growing maize crops. From the 25th to the 35th SMW, there is a good chance of rain during the vegetative and seeding periods (rainfall probability is 80% and 75%, respectively). In rainfed environments, a maize crop with a planting period of roughly 95 to 105 days can be easily grown without experiencing any detrimental consequences from a lack of precipitation.

The important crop stage (31–35th SMW) receives adequate precipitation, while the 39–42nd SMW, which corresponds to the maize crop's ripening stage, has a 50–90% likelihood of an initial and conditional dry week. To meet the crop's water needs during this dry week, plant irrigation should be done.

4.7.4 Gariyaband Tehsil

The mean dates of the substantial monsoon's onset and departure are 18–24 June (25th SMW) and 17–23 September (38th SMW), respectively, as shown in Tables 4.13 and 4.14. Pre-monsoon precipitation includes all precipitation that occurs prior to June 18th. Rainfall data analysis showed that there will be enough pre-monsoon rains by June 18th. As a result, *Kharif* crops may be sown between now and June 18 and tillage operations are permitted. A little further down, the Tehsil's principal crop plan

Paddy Crop

Direct seeded rice and rice nursery of short and medium duration kinds might be sown this season and transplanted by the 1st - 2nd week of July for a successful production. Total monsoon rain amounts in Gariyaband varied from 395 to 529.4 mm at 80 and 70 percent likely levels, which may be considered enough for cultivating rice crops. During the seeding and vegetative periods, there appears to be an 80% and a 75% likelihood, respectively, that precipitation will not be sufficient (25th to 34th SMW).

During the transplanting stage, rainwater with a 75 to 80% chance of being accessible is sufficient in this Tehsil (27-28 SMW). It's possible that this week will end with several consecutive wet weeks. It was discovered that the 30th, 32nd, and 35th SMW had the highest initial wet probability. The highest conditional wet probabilities are found in the 29th, 31st, 33-34th, and 36th SMW, whereas the highest conditional dry probabilities are found in the 41st to 44th SMW. According to this, there is a greater chance of a dry week throughout the maturity phase. Farmers may use saved water to safeguard crops throughout the latter stages of their growth.

Active tillering, panicle initiation, booting, heading, and blooming are among the crucial stages of crop growth that, respectively, come under the 29th through 30th, 31st through 33rd, 34th through 36th, and 37th through 38th SMWs. There are initial and conditional probability of weeks being wet between 70 and 100 percent of the time during this time.

Maize Crop

Gariyaband can receive between 395 and 529.4 millimetres of total monsoon rainfall each year with probabilities of 80 and 70 percent, respectively. Rainfall is reasonable throughout the seeding and vegetative phases (25th to 35th SMW), with 80% and 75% likelihood, respectively. Without experiencing any detrimental impacts from a lack of rainfall, a maize crop with a sowing time of roughly 95 to 105 days can be easily grown in rainfed conditions.

The important crop stage (the 31th to the 35th SMW) has received enough rain, and the 40th to 42nd SMW, which corresponds to the maize crop's ripening stage, has a likelihood of an initial and conditional dry week of 75 to 80 percent. To meet the crop's water needs during this dry week, plant irrigation should be done.

4.7.5 Mainpur Tehsil

The significant monsoon's average commencement and withdrawal dates are 18–24 June (the 25th SMW) and 1–7 October (the 40th SMW), respectively, as shown in Tables 4.13 and 4.14. Pre-monsoon precipitation includes all precipitation that occurs prior to June 18th. Rainfall data analysis showed that there will be enough pre-monsoon rains by June 18th. As a result, *Kharif* crops may be sown between now and June 18 and tillage operations are permitted. Listed below is the Tehsil's major crop plan.

Paddy Crop

Direct seeded rice and rice nursery of short and medium duration kinds might be sown this season and transplanted by the 1st - 2nd week of July for a successful production. Total monsoon rain amounts in Mainpur varied from 497 to 698 mm at 80 and 70% likely levels, which may be considered sufficient for cultivating rice crops. There appears to be an 80% and 75% possibility, respectively, of finding adequate precipitation throughout the sowing and vegetative phases (25th to 34th SMW). A rice variety with a short growing season of 100 to 110 days can be produced successfully under these circumstances without suffering any negative consequences from a shortage of rainfall. If short- or medium-duration rice types are grown, the residual moisture after harvesting can be utilised to plant short-duration rice harvests to boost yields.

Rainwater with a 75-80% chance of being accessible is sufficient in this Tehsil during the transplanting stage (27-28 SMW). This entire week has a chance of being a string of wet weeks. It was discovered that the 26th, 29th, 33rd, and 35th SMW had the highest initial wet probability. The largest conditional wet probabilities are in the 27th, 30th, 34th, and 36th SMW, whereas the highest conditional dry probabilities are in the 40th and 43-44th SMW.

Active tillering, panicle initiation, booting, heading, and blooming are essential crop growth stages that occur during the 29th-30th, 31st-33rd, 34th-36th, and 37th-38th SMWs, respectively. There are initial and conditional odds of weeks being wet of between 75 and 100 percent at this time.

Maize Crop

It may be thought that the total monsoon rainfall quantities, which range from 497 to 698 mm at 80 and 70 percent likelihood levels, are more than enough to cultivate maize crops. From the 25th to the 35th SMW, there is a good chance of rain during the vegetative and seeding periods (rainfall probability is 80% and 75%, respectively). Under rainfed conditions, a maize crop with a sowing time of roughly 95 to 105 days can be easily grown without encountering any problems due to a shortage of rainfall.

There is adequate precipitation throughout the key crop stage (the 31st to 35th SMW), and the 39th to 42nd SMW, which corresponds to the maize crop's ripening stage, has a 40–80% risk of an initial and conditional dry week. Plant irrigation should be done throughout this dry week to meet the crop's water needs

Table 4.38: Proposed crop water management plan

	Tehsils of Gariyaband District					Strategy
	Chhura	Deobhog	Fingeshwar	Gariyaband	Mainpur	
Mean onset of monsoon Mean withdrawal of monsoon	25th SMW (18-24 June) 39th SMW (24-30 September)	25th SMW (18-24 June) 38th SMW (17-23 September)	25th SMW (18-24 June) 38th SMW (17-23 September)	25th SMW (18-24 June) 38th SMW (17-23 September)	25th SMW (18-24 June) 40th SMW (1-7 October)	Between 17 and 24 June, or no later than 26 June, for land preparation, crop sowing, and nursery.
Consecutive wet spells	26 – 39th SMW	25-38th SMW	26 – 37th SMW	26 – 40th SMW	26 – 41th SMW	Rainwater harvesting during wet spells for using during dry spells
Dry spells with >70% probability	22-23th, 39th, 42-44thSMW	22nd, 39th, 41-44thSMW	22-23th, 37th, 42-44thSMW	22-23th, 41-44thSMW	22nd, 42-44thSMW	Some reliable irrigation is required during the nursery and maturity stages of paddy for transplanted conditions and the ripening stage of maize crop. If irrigation isn't accessible for paddy crops, direct sowing could be preferred.

Table 4.39: Proposed crop management crop during critical growth stages

Crop	Critical stages	Tehsils of Gariyaband District					Strategy
		Chhura	Deobhog	Fingeshwar	Gariyaband	Mainpur	
Paddy crop	Active tillering	29-30th SMW	30-31th SMW	29-30th SMW	29-30th SMW	29-30th SMW	A source of irrigation should be ready during the flowering stage because it may have dry spells, even though almost all phases experience consecutive moist weeks.
	Panicle Initiation	31st SMW	32st SMW	31st SMW	31st SMW	31st SMW	
	Booting	33th SMW	33th SMW	33th SMW	33th SMW	33th SMW	
	Heading	34-36th SMW	35-37th SMW	34-36th SMW	34-36th SMW	34-36th SMW	
	Flowering	37-38th SMW	38-39th SMW	37-38th SMW	37-38th SMW	37-38th SMW	
Maize Crop	Just prior to tasseling & gain filling	31-35th SMW	32-36th SMW	31-35th SMW	31-35th SMW	31-35th SMW	During this time, there is sufficient rainfall.

CHAPTER V

SUMMERY AND CONCLUSIONS

5.1 SUMMARY

Accurate knowledge of the characteristics of rainwater is necessary to plan how to use it. The amount and distribution of rainfall have a big influence on how a crop grows and develops because rainfall is the main supply of water for rainfed agriculture. Chhattisgarh state’s primary crop is rice. When compared to the national average, the productivity is quite low (1.34 t/ha). 1200 to 1600 mm of rainfall fall on the state each year, which is quite a bit. But the inequitable rainfall distribution that frequently results in terminal droughts in widely dispersed places forces a large-scale exodus of farmworkers and farmers to other viable areas, where water shortages at critical growth stages are frequently observed.

Gariyaband is located in the Indian subcontinent's temperate region. Beginning in November and lasting until the end of February is the winter. From March to the second week of June, the summer season lasts. The monsoon season begins in the middle of June and lasts through the end of September. Daily rainfall figures for the ten-year period (2011–2020) were provided by the Department of Land Records in the District of Gariyaband, and other significant data were also gathered from other sources and used in this study.

In acknowledgment of the significance of regional rainfall analysis, research was done to examine the rainfall pattern over a number of stations in the Gariyaband district. The current study's acquisition and utilization of daily rainfall data for the ten-year period (2011-2020) was done in order to achieve this. The daily rainfall data were converted into weekly data using the Standard Meteorological Weeks table. This standard table divided the 365-day calendar year into 52 Standard Meteorological Weeks, of which the 23rd to the 39th week, which correspond to the *Kharif* season, were analysed (June to September).

Utilizing a computer programme in Microsoft Excel, the statistical parameters of maximum, minimum, mean, standard deviation, coefficient of variation, skewness, and weekly and monthly rainfall values were determined. The highest and lowest amounts of precipitation in each week and month were taken into account to determine the maximum and minimum values of precipitation.

The monsoon's characteristics, including its expected onset and withdrawal, were predicted using Morris and Zandestra (1979) forward and backward accumulation technique, and the length of the rainy season was computed. Markov Chain analysis was used to determine the initial and conditional probabilities of a single wet or dry week as well as subsequent 2, 3, and 4 weeks being either dry or wet for the *Kharif* season.

Using varying probability values (50,60,70,75,80, and 90%), Weibull's, Gringorten's, and California's plotting-position functions were used to estimate the amount of rainfall during the *Kharif* season. The California technique receives the overall ranking "1" in terms of error statistics after examination of the efficacy of the aforementioned three plotting-position functions taken into account in the study in best estimating the magnitudes of weekly rainfall at Gariyaband district. As a result, it is recommended that the California technique be used to determine the best plotting-position function for the supplied hydrologic data.

A thorough crop planning was recommended for each of the studies based on the aforementioned analyses.

5.2 CONCLUSIONS

The conclusions listed below can be reached based on the observations: -

1. The coefficient of variation of the study area was found to be less than the threshold limits (150%) for most of the weeks across several tehsils, with the exception of the 40th - 43rd SMW (3 weeks) at Chhura; 22nd, 39th, 42th 43rd (4 weeks) at Devbhog; 22nd, 37th, 40th - 43rd SMW (6 weeks) at Fingehswar; and 22nd, 42th, 43rd S Throughout the study area, monsoon commencement was seen to begin at its earliest in the 25th SMW, with the most delay occurring on the 29th–30th SMW. The monsoon season finishes throughout the entirety of the study region between the 38th and 39th SMW. As per analysis of all tehsils' dry spells, the widest range of dry weeks (P_D) during the *Kharif* season

would have been between 5 weeks (Chhura and Fingeshwar) and 4 weeks (>75 percent chance) (Devbhog Gariyaband, Mainpur). It can take anywhere between 9 weeks (Fingeshwar) and 4 weeks for a dry week to occur before another dry week (PDD) (>75 percent) (Gariyaband).

2. At a level of 75 percent probability, 48.2 mm (33 SMW) of precipitation was the largest amount, followed by 44.8 mm (29 SMW) at Chhura Tehsil, 60.3 mm (25 SMW), 46.9 mm (29 SMW) at Devbhog Tehsil, 47.8 mm (35 SMW), followed by 47.6 mm (29 SMW) at Fingeshwar Tehsil, 52.9 mm (32 SMW), and 51.3 mm (31 SMW). Chhura (40-42 SMW), Devbhog (42 SMW), Fingeshwar (37,40-42 SMW), Gariyaband (42 SMW), and Mainpur Tehsil all had the lowest rainfall totals of 0 mm (42 SMW).

3. The nursery, reproductive, and maturity stages of the paddy crop experience severe shortages of rainfall in all five study Tehsils, which leads to drought conditions. As a result, if agriculture is solely dependent on monsoon rainfall, its potential output of paddy crops may not be attainable. If excess rainfall is retrieved, only short-duration paddy types (100-110 days) and medium-duration paddy varieties (120-130 days) should be cultivated under rainfed conditions. When irrigation is accessible at crucial growth phases, long-duration (>130 day) rice types should be grown there.

At the peak of the maize crop's ripening, there is a severe lack of rainfall availability in all five study Tehsils, which causes drought-like circumstances. As a result, if agriculture is solely reliant on monsoon rainfall, prospective maize crop production may not be attainable. For a successful maize crop, extra rainwater that falls during the vegetative stage can be collected in water harvesting structures at fields. The timing of canal operations must be controlled to ensure that farmers receive enough supplemental irrigation water during the ripening stages.

5.3 SUGGESTION FOR FUTURE WORKS

1. All other meteorological parameters can be taken into consideration for crop planning in this area.

2. Studies on conjunctive use planning of rainwater groundwater needs to be made for optimal cropping pattern
3. Optimal cropping patterns need to be investigated under rainfed farming situation.

REFERENCES

Adeboye, O.B., and Alatise, M. O. 2007. Performance of probability distributions and plotting positions in estimating the flood of River Osun at Apoje Sub-basin, Nigeria. Agric. Eng. Int.: CIGR J., 9

Admasu, W., Tadesse, K., Yemenu, F. and Abdulkadir, B. 2014. Markov Chain analysis of dry, wet weeks and statistical analysis of weekly rainfall for agricultural planning at Dhra, Central Rift valley Region of Ethiopia. Academic Journals, 9(29):2205-2213.

Ahmad, L., Parvaze, S., Parvaze, S. and Kanth, H. R. 2017 Reference evapotranspiration and crop water requirement of apple (Malus Pumila) in Kashmir Valley Journal of Agrometeorology 19 (3):262-264

Ahmed, P., Deka, R. L., Baruah, B. P. and Nath, K. K., 2009, Rainfall based crop planning in the Bark vally zone of Assam. *J. Agromet.,* 11(2): 192–195.

Ali, M. H., Islam, A. K. M. R. and Amin. M. G. M., 2007, Trend of rainfall and temperature in different regions of Bangladesh during last five decades. *J. Agromet*., 9: 26–33.

Ali, S., Prasad, S. N. and Sethy, B. K., 2007, Analysis of south–west monsoon for rainfed crop planning in Kota region of Rajasthan. *Indian J. Soil Conserv*., 35: 189–193.

Ani shabri. 2002. “A comparison of plotting position formulas for the Pearson Type III distribution”, Jurnal Teknologi, 36(C) Jun. 2002: 61–74, Universiti Teknologi Malaysia.

Anonymous. 2014, Agriculture Contingency plan for District – Gariyaband, ICAR.

Anonymous. 2019, District irrigation plan Gariaband, Pradhan Mantri Krishi Sichayee Yojna (PMKSY), Department of Agriculture, Cooperation & Farmers welfare, Government of India: 14-15.

Anonymous. 2019, District Survey Report – Gariyaband (Chhattisgarh), Directorate of Geology & Mining, Mineral Resource Department, Government of Chhatitsgarh, 17-18.

Anonymous. 2021, District socio-economic data brochure, District Planning and Statistics, Gariyaband, 3-4B.

Anonymous. 2021, Expert System for Paddy, TNAU, https://agritech.tnau.ac.in/expert_system/paddy/cultivationpractices3.html.

Anonymous. 2021, Maize Crop Information https://www.fao.org/land-water/databases-and-software/crop-information/maize/en/.

Anonymous. 2022, Water Requirement: Maize Crop, https://agritech.tnau.ac.in/agriculture/agri_irrigationmgt_maize.html.

Babu, P. N. and Lakshminarayana. B., 1997, Rainfall analysis of a dry land watershed–Polkepad: A case study. *J. Indian Water Resources Soc*., 17 (3): 34–38.

Barman, D., Saha, A. R., Kundu, D. K. and Mahapatra, B. S., 2012, Rainfall characteristics analysis for jute-based cropping system at Barrackpore, West Bengal, India. *J. Agric. Phys.,* 12(1): 23–28.

Behera, S. and Subudhi, C. R. 2018. Markov Chain Model of Weekly Rainfall Probability and Dry and Wet Spells for Agricultural Planning in Ganjam District of Odisha. International Journal of Pharmacy and Pharmaceutical Research, 12(3):422-433.

Bemal, S., Singh, D. and Singh, S., 2012, Rainfall variability analysis over eastern agroclimatic zone of Haryana. *J. Agromet.,* 14(1): 88–90.

Bhadoria H. S., Singh H. and Singh A. 2013. Rainfall Probability Analysis and Crop Planning for Chambal Region of Madhya Pradesh. International Journal of Agriculture, Environment and Biotechnology. 6 (1): 169.

Bhargava A. K., Singh P. K., Mitra V., Prasad A. and Jayapalan M. 2010. Rainfall Variability and Probability Pattern for Crop Planning of Roorkee Region (Uttarakhand) of India, Mausam. 61 (4): 509-516.

Bhuarya, Shiv Kumar. 2015 Agroclimatic analysis of Chhattisgarh state with respect to sustainable crop production. M.Sc Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur: p 25-26, 30-42.

Chand M., Kumar D., Singh D., Roy N. and Singh D. K. 2011. Analysis of rainfall for crop planning in Jhansi district of Bundelkhand zone of Uttar Pradesh. Indian Journal of Soil Conservation. 39 (1): 20-26.

Chaudharay J.L *et al.* 2015, Analysis of rainfall for strategic crop planning under rainfed rice-based cropping system in CG. Ann. Agri. Res. New Series Vol 3(2): 184-190 (2015).

Cunnane, C. 1978. "Unbiased Plotting Positions- A Review." Journal of Hydrology, 37: 205-222.

Dabral, P. P., Purkayastha, K. and Aram, M. 2014. Dry and wet spell probability by Markov chain model- a case study of North Lakhimpur (Assam), India. International journal Agricultural & Biological Engineering, 7(6): 8-13.

Dash, M. K. and Senapati, P. C., 1992, Forecasting of dry and wet spell at Bhubaneswar for agricultural planning. *Indian J. Soil Conserv*., 20: 75–82.

Dastidar A. G., Ghosh, S. U., De, K. and Ghosh, S. K., 2010, Statistical analysis of monsoon rainfall distribution over West Bengal, India. *Mausam*., 61(4): 487– 498.

De Datta, Surjit K. 1981, Principles and Practices of Rice Production, John Wiley & Sons, New York, p 146-172, 318-332.

De, G. C. and De, P., 2003, Agro–meteorological conditions of Sriniketan, West Bengal. *J. Agromet*., 5: 129–133.

Dixit, A. J., Yadav, S. T. and Kokate, K. D., 2005, The variability of rainfall in Konkan region. *J. Agromet*., 7:322–324.

Dutta, P., and Khan, S. A., 2005. Probability analysis of rainfall for crop planning under rainfed condition. Environment-and-Ecology. 23(2): 342-344.

Folland, C., and Anderson, C. 2002. "Estimating changing extremes using empirical ranking methods." J. Climate, 15, 2954–2960.

Gaikwad, S. D. 2009. Characterization of rainfall of Jalna District. *M.Sc. (Agri) Thesis*. Submitted to M.A.U. Parbhani (India).

Ghadekar, S. R. and Miskin, R. B., 1998, A study on the characterization of monsoon rainfall for sorghum (*Sorghum Vulgare Pers*) and its response to typical rainfall patterns. *Mausam*., 49: 115–120.

Gore, P. G. 2001. Study of dry and wet spells for meteorological subdivisions of India. Meteorological Monograph. Hydrology No. 12/2000, IMD Pune.

Gore, P.G. and Ray, K.C.S., 2002, Drought and aridity over district of Gujarat. *J. Agromet*., 4: 75–85.

Goswami B., Singh O.P., Satapathi K.K., Saikia Uday S. 2008, Rainfall analysis in relation to rice crop for Janita Hills district of Meghalaya. Journal-of-Agrometeorology.10(2): 188-192.

Harris, R. I. 1996. "Gumbel re-visited—A new look at extreme value statistics applied to wind speeds", J. Wind Eng. Ind. Aerodyn., 59, 1–22.

Hundal, S.S. and Kaur Prabhjyot. 2002, Annual and seasonal climatic variability at different location of Punjab state. Journal-of-Agrometeorology. 4(2): 113-125.

Jat M. L., Sammauria R., Balyan J. K. and Sharma R. K. 2010. Crop planning in semi-arid tracts of Udaipur region based on analysis of weekly Rainfall. Indian Journal of Soil Conservation. 38 (2): 69-74.

Jat, M. L., Singh, R. V., Balyan, J. K. and Jain, L. K., 2005a, Dry and wet spells for agricultural planning in Udaipur region. *J. Agromet*., 7: 131–134.

Jat, M. L., Singh, R. V., Balyan, J. K. and Jain, L. K., 2005b, Rainfall analysis for crop planning in Udaipur region. *Indian J. Soil Conserv*., 33(3): 264–266.

Jhajharia, D., Shrivastava, S. K., Tulla, P. S. and Sen, R., 2007, Rainfall analysis for drought proneness at Guwahati. *Indian J. Soil Conserv*. 35: 163–165.

Jordaan, I. (2005). Decisions under Uncertainty. Cambridge University Press, 672 pp.

Kar, S. K., Sahoo, D. P. and Subudhi, C. R. 2014. Weekly rainfall analysis for crop planning using Markov's chain model for Kandhamal District of Odisha, India. International Journal of Engineering Research and Applications, 4(9):139-145.

Khudri, Md. Mohsin *et al.* 2013, Determination of best fit probability distribution for annual extreme precipitation in Bangladesh. European Journal of Scientific research, Vol 103, No 3, June- 2013, pp391-404.

Kothari, A. K., Jain, P. M. and Kumar, V., 2009, Analysis of weekly rainfall data using onset of monsoon approach for micro level crop planning. *Indian J. Soil Conserv*., 37(3): 164–171.

Krishnamurthy, K. N., Gowda, D. M. and Vasanth Kumar, T. 2015. Markov Chain

Kumar, A., Rampal., and Sharma, H.C., 2007. Probability analysis of monsoon rainfall data of Saharanpur for agricultural planning. Indian-Journal-of-Soil-Conservation.35 (2): 122-124.

Kumar, B., Baliarshingh A., Jain S. and Sahu K. 2018. Analysis of rainfall probability for strategic crop planning in Puri district of Odisha. International Journal of Chemical Studies. 6 (4): 01-05.

Kumar, V. 2003, Rainfall characteristics of Shimla district (H.P.). *J. Indian Water Resources Soc*., 23(1): 1–10.

Kumari, Pratibha & Kumari, Reena & Sharma, Babloo. (2021). WATER MANAGEMENT IN RICE FARMING.

Majumder A., Ghosh, A., Pal, S. and Saha, A., 2005, Rainfall pattern and crop planning in two agroclimatic zones of West Bengal under rainfed rice cultivation. *J. Agromet*., 7(1): 44–50.

Makkonen, L. 2006. "Plotting Positions in Extreme Value Analysis", Journal of Appl. Meteorol. and Climatol., 45, 334 – 340.

Mandal, K. G., Padhi, J., Kumar, A., Sahoo, D. K., Majhi, P., Ghosh, S., Mohanty, R. K. and Roychaudhuri, M., 2013, Analyzing rainfall events and soil characteristics for water resources management in a canal irrigated area. *J. Water Resources and Ocean Sci.,* 2(1): 1–8.

Manikandan, M., Thiyagarajan, G., Bhuvaneswari, J. and Prabhakaran, N. 2017. Wet And Dry Spell Analysis for Agricultural Crop Planning Using Markov Chain Probability Model at Bhavanisagar. International Journal Mathematics Computer Applied Research, 1(7):11-22.

Manikandani N, Arthi R. B., Sathyamoorthi K. 2014. Weekly rainfall variability and probability analysis for Coimbatore in respect of crop planning. Mausam. 65 (3): 353-356.

Manorama, K., G. Ravichandran and T. A. Joseph. 2007. Rainfall analysis and crop planning for the Nilgiris. Journal of Agrometeorology, 9: 209-215.

Mokashi D. D., Deshpande A. N., Khadtare S. V. and Jadhav J. D. 2008. Rain: Its Probability Based Forecast at Solapur (India). International Journal of Agricultural Sciences. 4(10): 390.

Murugappan, A., Sivaprakasam, S. and Mohan. S. 2017 Ranking of plotting position formulae in frequency analysis of annual and seasonal rainfall at Puducherry, South India, Global Journal of Engineering Science and Researches, July 2017:67-76

Nath, K. K. and Deka, R. L. 2002, Perturbations of climatic elements of Jorhat, Assam. *J. Agromet*., 4: 87–91.

Pali A. K., Thakur H and Khalkho D. 2016. Rainfall analysis-based rice crop planning in Durg district of Chhattisgarh. Indian Journal of Soil Conservation. 44 (1): 30-36.

Patil, P. P. and patil, M. M., 1991, Relationship between the extreme events and the statistical parameters of rainfall at Dhule, Maharashtra state. *Indian J. Soil Conserv.,* 19(1–2): 75–82.

Pimpale, A. R., Hiwase, S. S. and Paual, P. G., 2001, Probability of rainfall at Akola, Maharastra. *J. Soil and Water Conserv., India,* 45(3–4): 129–132.

Pradhan, A., Nag, S. K., Sao, A. and Mukherjee, S. C. (2018). Distribution of Weekly Rainfall and Probability Analysis for Crop Planning in Bastar Region of Chhattisgarh. Journal of Experimental Agriculture International, 25(2): 1-7.

Prathumchai, K., nagai, M., Tripathi, Nitin K., Sasaki Nophea 2018 Forecasting Transplanted Rice Yield at the Farm Scale Using Moderate-Resolution Satellite Imagery and the AquaCrop Model: A Case Study of a Rice Seed Production Community in Thailand, ISPRS Int. J. Geo-Inf. 2018, 7, 73; doi:10.3390/ijgi7020073.

Ramdurg, H., Reddy, S. V. Krishnamurthy, G. D., Babu, M. B. and Nemichandrappa, M. 2015 Weekly rainfall variability and probability analysis for resource planning at Hadagali, Karnataka. International Journal of Agricultural Engineering, 8(2):255-260.

Ray, M., Biswasi, S., Sahoo, K. C. and Patro, H. 2018. A Markov Chain Approach for Wet and Dry Spell and Probability Analysis, International Journal of Current Microbiology and Applied Science, 6:1005-1013.

Reddy, D. R., Sreenivas, G., Mahadevappa, S. G., Lata, A. M., Rao, S. B. S. N. and Varma., N. R. G. 2007. Rainfall variability and its impact on agriculture in north Telangana regions of Andhra Pradesh. Journal of Agrometeorology. 9: 253-258.

Saha, A. and C. Sarkar. 2005. An assessment of climatic risk involved in growing rainfed rabi crops in different agroclimatic zones of West Bengal. Journal of Agrometeorology.7: 36-43.

Saha, R. and Mishra, V. K., 2005, Probability analysis of rainfall at Meghalaya for crop planning. *Indian J. Soil Conserv*., 33: 86–87.

Seetharam, K., 2005, Statistical study of excess and deficit rainfalls over Jalpaiguri. *Mausam*, 56(2): 485–488.

Sharma, D. and Kumar, V., 2003, Prediction of onset and withdrawal of effective monsoon dates and subsequent dry spells in an arid region of Rajasthan. *Indian J. Soil Conserv*., 31(3): 223–228.

Singh, A. K., Singh, Y. P., Mishra, V. K., Arora, S., Verma, C. L., Verma, N., Verma, H.M. and Srivastav, A. 2016. Probability analysis of rainfall at Shivri for crop planning Journal of Soil and Water Conservation, 15(4): 306-312

Singh, J. P. and Singh, S. S., 2004, Climatological parameters and its variation in Bikramganj, Bihar. *Indian J. Soil Conserv*., 32: 69–71.

Singh, P. K. 2005. Rainfall variability and crop planning in Sabour region of Bihar. Journal of agrometeorology. 7: 284-290.

Singh, P. K., Baxla, A. K. and Singh, S. B. 2007. Rainfall characteristic analysis and crop planning of Sabour region of Bihar, Indian Journal of Soil Conservation, 35(1): 36-39.

Sinha B.L. *et al.* 2018, Rainfall probability analysis for crop planning in Raipur region of CG Plain. Journal of Pharmacognosy & Phytochemistry, 2018; 7(5): 2207-2211.

Sr Bhakar 2008, "Probability analysis of rainfall at Kota". Indian Journal of Agricultural Research.

Stedinger, J. R., Vogel, R. M., and Foufoula, G. E. 1993. "Frequency Analysis of Extreme Events." Handbook of Applied Hydrology. Mc-Graw Hill Book Co., New York, Chapter 18.

Subash N, Sikka A. K. and Haris A. A. 2009. Markov Chain Approach -dry and Wet Spell Rainfall Probabilities for Rice-wheat Planning. Indian Journal of Soil Conservation. 37 (2): 218-224.

Subash, N., Ashok, K. and Haris, A. A., 2008, Markov chain approach – dry and wet spell rainfall probabilities for rice–wheat planning. *Indian J. Soil Conserv*., 3(2): 91–99.

Subash, N., Singh, S. S. and Priya, N., 2012, Rainfall variability and its impact on change of cropping systems in Bihar. *Indian J. Soil Conserv*., 40(1): 33–40.

Subramanya, K. 2008 Engineering Hydrology, 3rd edition, Tata Mc-Graw-Hill Publishing Company Ltd.: 39-43

Swetha, A. N. 2014 Rainfall Analysis over Raichur District for Resource Planning in Agriculture. M.Tech, University of Agricultural Sciences, Raichur: p 32-43.

Talathi, M. S., Patil, B. P., Chavan, S. A., Khadse, R. R., and Zagade, M. V.(2008. Rainfall characteristics, and crop planning with reference to rice in Konkan. Journal-of-Agrometeorology.10(1): 101-103.

Thakur, Hansa 2012 Tehsil-Wise Planning of Crop and Water Resources of Durg District. M.Tech Indira Gandhi Krishi Vishwavidyalaya, Raipur: 38-50

Tiwari, A. K., Sharma, A. K. and Srivasta, M. M. 1992 Probability analysis of rainfall data of Datia district Bundelkhand for crop planning. Journal of Soil and Conservation, 20(3):82-88.

Urkurkar, JS, Nain, AS, Tiwari, A, Mishra, RK, 2007. "Analysis of Cropping System in Chhattisgarh". Tech. Bull. No. IGKV, Pub. -2007/24, IGKV, Raipur.

Vaidya V. B, Karande B. I, Pandey V, Lunagaria M. M and A. M. Shekh. 2008. Rainfall probability analysis for crop planning in Gujarat state. Journal of Agro meteorology. 10 (1): 183-185.

Vanitha, S. and Ravikumar, V. 2017. Weekly Rainfall Analysis for Crop Planning Using Markov's Chain Model for Kumulur. International Journal of Agriculture Sciences, 9(42):4679-4682.

Venkatesh H. 1998. Rainfall studies of Bijapur. A climatic appraisal, Karnataka Journal of Agricultural Sciences. 11 (2): 492-494.

Vergara, B.S. 1991. Rice Plant Growth and Development. In: Luh, B.S. (eds) Rice. Springer, Boston, MA. https://doi.org/10.1007/978-1-4899-3754-4_2.

Vora, V. D., Vekariya, P. D., Patel, J. T., Rakholiya, K. D., Sanepara, D. P. and Sharma, G. R. 2016. Rainfall analysis for crop planning in north saurashtra agro-climatic zone. International Journal of Agricultural Science and Research, 6(5):307-320

Xalxo A.L. 2021, Spatial & Temporal Variability of rainfall Pattern in the parental district of CG. M. Sc Thesis, Indira Gandhi Krishi Vishwavidyalaya, Raipur: 90-95

RESUME

Name	:	Rajendra Kumar Deo
Date of birth;	:	15 June 1998
Present Address	:	Village + Post Dhawalpurdih, Tehsils Gariyaband, District Gariyaband (C.G.) PIN 493888
Phone	:	9407742568
Email	:	Deoputra1998@gamil.com
Permanent Address	:	Village Ratawa, Post Pondagaon, Block Nagri, District Dhamtari (C.G.) PIN 493778

Degree	Year	University/ Institution
High School Certificate Exam	2013	CG Board of Secondary Education, Raipur.
Higher Secondary School Certificate Exam	2015	CG Board of Secondary Education, Raipur.
B. Tech (Agril. Engg.)	2020	IGKV, Raipur
M. Tech (Agril. Engg.)	Pursuing	IGKV, Raipur

Professional Experience:	-
Membership of Professional Societies: (If any)	-
Award/ Recognitions (If any):	• National Youth Parliament Festival 2019 (3rd Position) • ICAR - KRITAGAYA Agtech Hackthon - 2020, (National Level)
Publication (If any):	02

Signature