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Analyzing Rainfall Data for Drought Investigation in Gariyaband District, Chhattisgarh: A Research Study

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ABSTRACT

Analyzing drought patterns facilitates crop planning in rainfed regions, enhancing drought prediction capabilities. This study explores the recurrence patterns of drought based on weekly, seasonal, monthly, and yearly rainfall severity using last 10 years of data (2011 to 2020) from Gariyaband, Chhattisgarh. Among the study period, SMW 39 experienced the most severe drought. Over the decade, SMW 35 encountered a maximum of three instances of severe drought, while SMW 24 had up to four instances of moderate drought. Notably, July had no catastrophic drought compared to December, which reached a maximum rate of 90.00%. In July, severe drought occurred at the highest percentage (40.00%). Seasonal analysis revealed that during the monsoon season, 40.00% of the time experienced no drought, 50.00% mild drought, 10.00% severe drought, and 0.00% devastating drought. Similarly, during the kharif season, 50.00% of the time had no drought, 30.00% mild drought, 20% severe drought, and 0% devastating drought. The year 2015 stood out as a severe drought period with a rainfall variance of -25.640%. To ensure irrigation in rainfed areas, implementing significant measures is imperative.

Keywords: Drought analysis, rainfed areas, recurrence patterns, severity, Gariyaband, Chhattisgarh, climatic seasonal analysis, monsoon season, kharif season, irrigation, rainfall variance.

I. INTRODUCTION

Rainfall stands as the primary water source crucial for agricultural practices, significantly influencing crop selection, farming methods, and overall agricultural productivity. [5] It is a hydrological phenomenon characterized by its random occurrence, varying both spatially and temporally. [6] Understanding the annual rainfall distribution in a specific region is vital for effective crop planning, estimating irrigation needs, and implementing soil and water conservation measures in rainfed agriculture systems. [7] The distribution and quantity of rainfall directly impact plant growth and development in rainfed areas. Droughts, which are recurring climatic events, vary in severity, duration, and geographical location, posing significant challenges to ecosystems and human societies. Recognized as one of the most severe natural disasters, drought exacerbates over time due to prolonged periods of insufficient rainfall.[8] Consequently, comprehending drought patterns, severity, frequency, and distribution is essential for proactive planning and decision-making. By identifying appropriate drought indicators and establishing early warning systems, policymakers and farmers can mitigate the adverse effects of drought.[9] Various drought indices have been developed over the years to monitor drought conditions, utilizing rainfall data alongside other relevant factors.[10-11] In the Gariyaband plain of Chhattisgarh, a study aims to analyze patterns of drought recurrence based on 16 years of rainfall data from 2011 to 2020.[12-14]

II. METHODOLOGY

In January 1st, 2012, the district of Gariyaband was established, comprising five administrative blocks known as tehsils (refer to Fig. 1). Its geographic boundaries span from latitudes N 20°57'46"

ISSN PRINT 2319 1775 Online 2320 7876
Research Paper Journal Volume 11, Iss 10, 2022

to 20°17'36" and longitudes E 82°53'05" to 81°53'05". Positioned at an elevation of 340.00 meters above mean sea level, the district shares its borders with Raipur to the north, Dhamtari to the west, and the state of Odisha to the east. As of year 2014, the total area of the district is 582,286.00 hectares. [4-6]

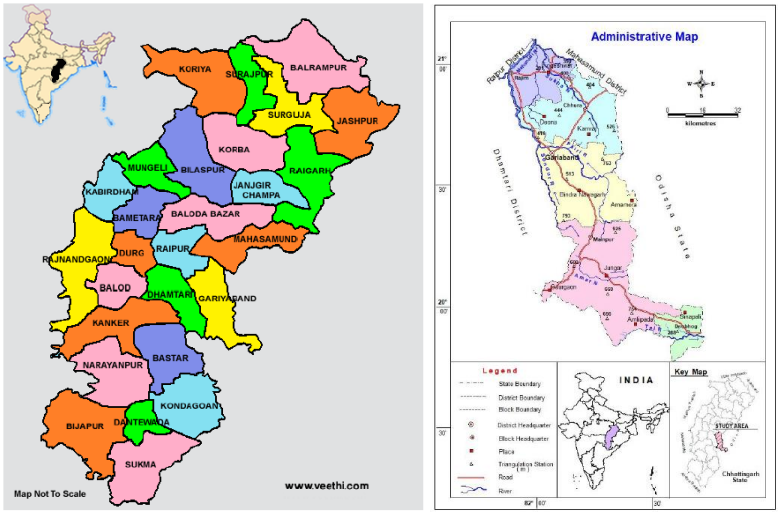

Figure 1: - Map of Gariyaband district

The daily rainfall data for the study area was obtained from the Tehsil office situated in Gariyaband. Rain gauges, including both recording and non-recording devices, placed in close proximity were utilized for collecting 24-hour rainfall measurements. The dataset covers the most recent decade, spanning from 2011 to 2020, encompassing daily rainfall records. These daily values were aggregated to derive weekly, monthly, seasonal, and annual rainfall statistics, following the guidelines provided by the IMD. Sinha et al. (2017) conducted a study on rainfall trends in the region.[10]

Drought Analysis

Meteorological drought severity is commonly determined based on the extent of dryness relative to a typical or average level of precipitation. According to IMD criteria, a meteorological drought occurs when seasonal rainfall drops below 75.00% of the long-term average for a specific area. Additionally, a drought is classified as "moderate" if the precipitation deficit ranges between 25.00% and 50.00% of the total rainfall, and as "severe" if it exceeds 50.00% of the total rainfall (Pandey & Associates, 2014). IMD employs a straightforward methodology to assess drought severity by calculating the percentage deviation between actual rainfall (P_{rain}) and the long-term mean rainfall (P_{mean}), resulting in the percentage deviation (Di).[12-14]

$$Di = [(P_{rain} - P_{mean}) / P_{mean}] \times 100 \quad (1)$$

Table 1 displays the % departure of rainfall and the category of drought evaluation.

Table 1. Cataloguing of drought

S. No.	Class Drought category	Condition
1.	No Drought	Di>0.0
2.	Mild Drought	0.0>Di<-25.0
3.	Severe Drought	-25.0>Di> -50.0
4.	Disastrous Drought	Di< -50.0

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, Iss 10, 2022

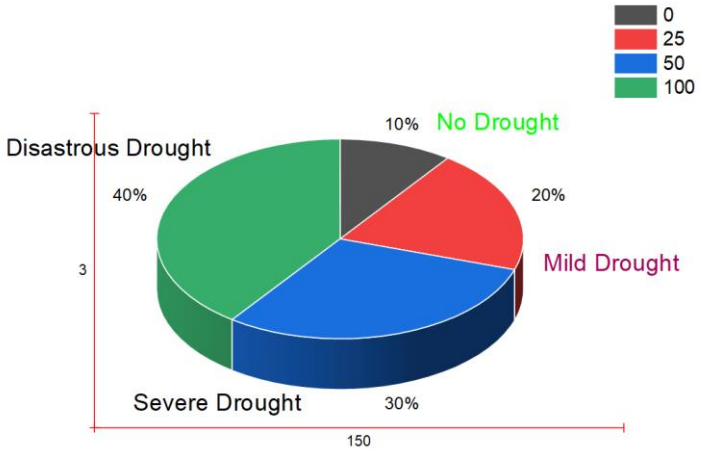

Figure 1-1 Water Availability Analysis and Cataloguing of drought

III. RESULTS AND DISCUSSION

Rainfall data from Gariyaband, Chhattisgarh, spanning the period of the last decade (2011-2024), underwent analysis to discern patterns of drought recurrence at weekly, seasonal, monthly, and yearly intervals based on severity. The outcomes of this analysis are elaborated upon in the subsequent sections.

Weekly Drought Analysis

Forecasting of weekly drought occurrences was conducted utilizing the percentage deviation equation, with the results depicted in Table 2 and Figure 2. This predictive analysis aids in optimizing agricultural practices such as crop selection, determination of sowing dates, irrigation scheduling, and judicious utilization of rainfall in rainfed regions. Notably, the weeks leading up to the monsoon season were the focal point of the weekly drought study, spanning from the 24th to the 39th week. Among these, SMW 39 experienced the most significant drought impact, followed by SMW 26, 29, and 31. Throughout the ten-year duration of the study, only three instances of severe drought were recorded in SMW 35, while SMW 24 encountered four instances of moderate drought. Additionally, SMW 26, 27, 28, 32, 34, 36, and 38 did not report any drought conditions. This investigation underscores substantial fluctuations in quantitative measures, indicative of the region's erratic rainfall patterns.

Table 2. Weekly drought occurrence during the period of 2011-2024

SMW	No Drought		Mild Drought		Severe Drought		Disastrous Drought	
	No. of Weeks	Occurrence (%)	No. of Weeks	Occurrence (%)	No. of Weeks	Occurrence (%)	No. of Weeks	Occurrence (%)
24	3.00	30.01	4.00	40.01	2.00	20.00	1.00	10.00
25	3.00	30.08	3.00	30.05	2.00	20.00	2.00	20.00
26	5.00	50.07	0.00	0.00	0.00	0.00	5.00	50.00
27	5.00	50.03	0.00	0.00	1.00	10.00	4.00	40.00
28	5.00	50.04	1.00	10.06	1.00	10.00	3.00	30.00
29	4.00	40.02	0.00	0.00	1.00	10.00	5.00	50.00
30	3.00	30.05	2.00	20.02	1.00	10.00	4.00	40.00
31	4.00	40.06	0.00	0.00	1.00	10.00	5.00	50.00

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, Iss 10, 2022

32	5.00	50.04	2.00	20.03	2.00	20.00	1.00	10.00
33	3.00	30.06	2.00	20.04	2.00	20.00	3.00	30.00
34	5.00	50.08	1.00	10.08	0.00	0.00	4.00	40.00
35	3.00	30.04	1.00	10.06	3.00	30.00	3.00	30.00
36	5.00	50.02	1.00	10.04	0.00	0.00	4.00	40.00
37	4.00	40.06	1.00	10.06	2.00	20.00	3.00	30.00
38	5.00	50.05	1.00	10.07	0.00	0.00	4.00	40.00
39	4.00	40.02	0.00	0.00	0.00	0.00	6.00	60.00

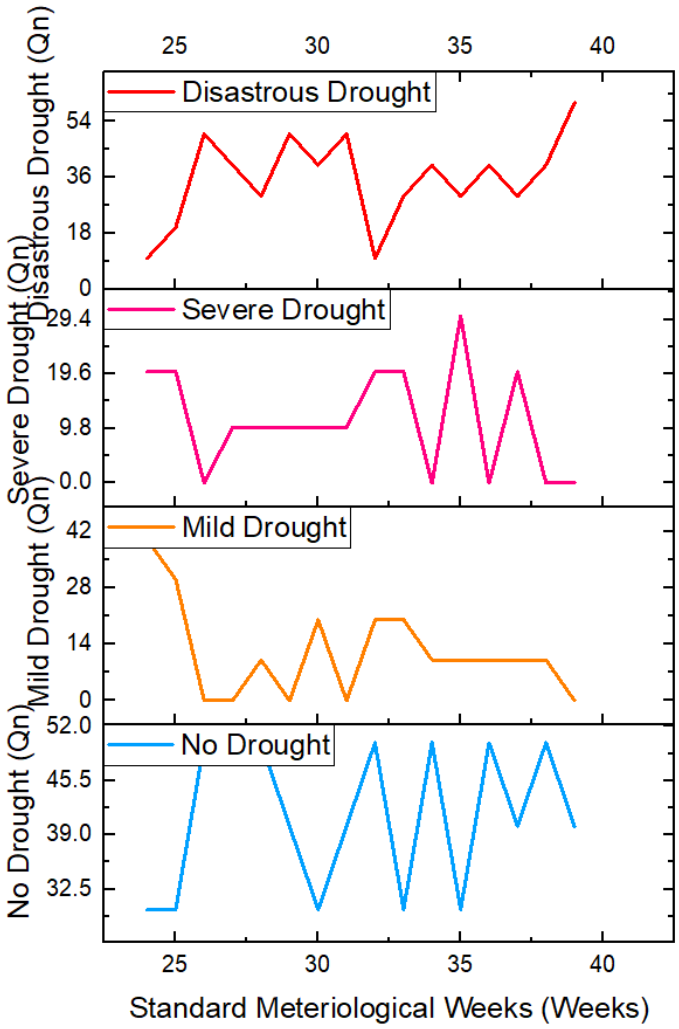

Figure 2: - Occurrence of Weekly Drought

Monthly Drought Analysis

Monthly Drought Analysis

The distribution of monthly drought occurrences, categorized into no drought, moderate drought, severe drought, and catastrophic drought, along with the average monthly rainfall and the frequency of drought incidents over a decade, is presented in Table 3. Figure 3 illustrates the severity of moderate droughts, constituting 20.00%, 30.00%, 20.00%, and 10.00% in June, July, August, and September, respectively, during the monsoon season. This depiction underscores the severity of drought conditions in the Gariyaband region. Notably, December exhibited the highest proportion of catastrophic drought (90.00%), while July recorded none. Furthermore, July witnessed the highest percentage (40.00%) of days with severe drought conditions.

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, Iss 10, 2022

Table 3. Monthly drought occurrence during the period of 2000-2024

Month	No Drought		Mild Drought		Severe Drought		Disastrous Drought	
	No. of Month	Occurrence (%)	No. of Month	Occurrence (%)	No. of Month	Occurrence (%)	No. of Month	Occurrence (%)
Jan	1	10.302	0	0.492	2	20.180	7	70.735
Feb	2	20.078	0	0.183	0	0.709	8	80.095
Mar	3	30.960	0	0.496	0	0.494	7	70.828
Apr	2	20.323	1	10.168	1	10.617	6	60.635
May	3	30.512	0	0.629	1	10.635	6	60.622
Jun	5	50.924	2	20.897	2	20.498	1	10.177
Jul	3	30.407	3	30.394	4	40.116	0	0.677
Aug	6	60.560	2	20.413	0	0.395	2	20.701
Sept	6	60.646	1	10.645	2	20.474	1	10.906
Oct	6	60.722	0	0.855	1	10.698	3	30.905
Nov	0	10.458	10	0.815	0	0.577	0	90.660
Dec	1	0.898	0	100.295	0	0.879	9	0.325

During July and August, the majority of runoff from the rainy season is observed, but by employing in-situ or ex-situ water harvesting techniques, this water can be stored and utilized for crop production during the kharif, rabi, and zaid seasons. Moreover, it can serve as crucial irrigation water, especially during the one or two weeks of prolonged dry spells within the monsoon season, which can negatively impact the kharif crops in the area.

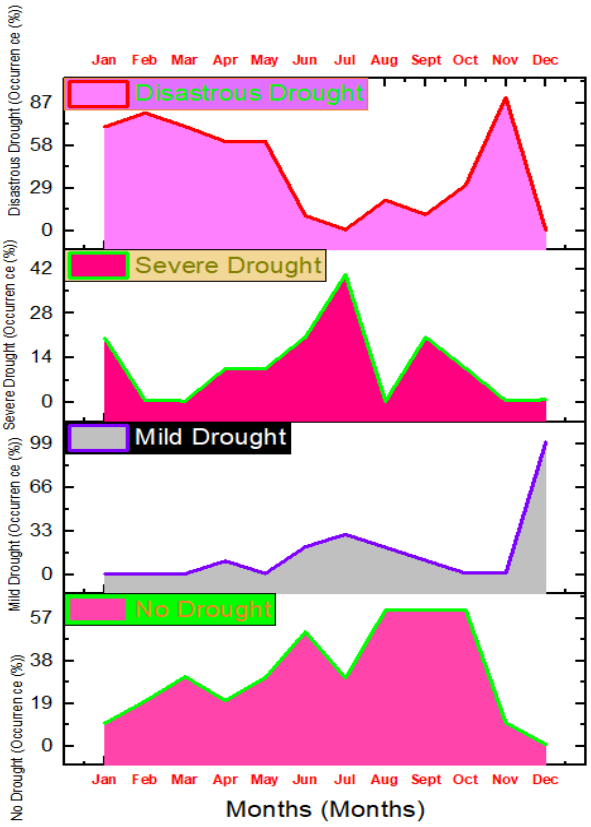

Figure 3: - Occurrence of Monthly Drought

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, Iss 10, 2022

Seasonal Drought Analysis

The mean seasonal rainfall data reveals that 75% of the total annual precipitation occurs during the monsoon season. Illustrated in Figure 4, during the monsoon period, there were no instances of disastrous drought, 40% occurrences of moderate drought, 10% of severe drought, and 50% of no drought conditions, as outlined in Table 4. This underscores the potential benefits of capturing surface runoff during the monsoon season and effectively utilizing stored rainwater in the subsequent winter and summer seasons. Furthermore, during the summer and pre-monsoon period, there was a likelihood of 30% for moderate drought, 10% for severe drought, 0% for disastrous drought, and 60% for no drought. However, up to 70% of the winter season was characterized by drought conditions. Consequently, the distribution of rainfall exhibits unpredictability and inequality.

Table 4. Seasonally and yearly drought occurrence during the period of 2011-2024

Season	No Drought		Mild Drought		Severe Drought		Disastrous Drought	
	No. of Month	Occurrence (%)	No. of Month	Occurrence (%)	No. of Month	Occurrence (%)	No. of Month	Occurrence (%)
Climatic Season								
Winter	3.00	30.00	0.00	0.00	0.00	0.00	7.00	70.00
Pre-monsoon	3.00	30.00	1.00	10.00	0.00	0.00	6.00	60.00
Monsoon	4.00	40.00	5.00	50.00	1.00	10.00	0.00	0.00
Post-monsoon	6.00	60.00	0.00	0.00	2.00	20.00	2.00	20.00
Cropping Season								
Rabi	4.00	40.00	0.00	0.00	0.00	0.00	6.00	60.00
Kharif	5.00	50.00	3.00	30.00	2.00	20.00	0.00	0.00
Zaid	5.00	50.00	3.00	30.00	1.00	10.00	1.00	10.00
Yearly								
Annual	3.00	30.00	6.00	60.00	1.00	10.00	0.00	0.00

Harvest Period

A seasonal analysis of rainfall distribution to evaluate drought conditions indicated that 75% of the total annual rainfall occurred during the kharif season. As depicted in Figure 5, during the kharif season, there were 50% instances of no drought, 30% of moderate drought, 20% of severe drought, and 0% of catastrophic drought. The kharif season's abundant rainfall offers an opportunity to collect surplus water for essential irrigation during dry spells, particularly during critical crop growth stages. Table 4 outlines the frequency of drought occurrences during the zaid season, with no drought, moderate drought, severe drought, and catastrophic drought listed in order. Forty percent of the rabi season experienced no drought, while sixty percent faced catastrophic drought, highlighting the irregular pattern of dry spells in the region.

ISSN PRINT 2319 1775 Online 2320 7876
Research Paper Journal Volume 11, Iss 10, 2022

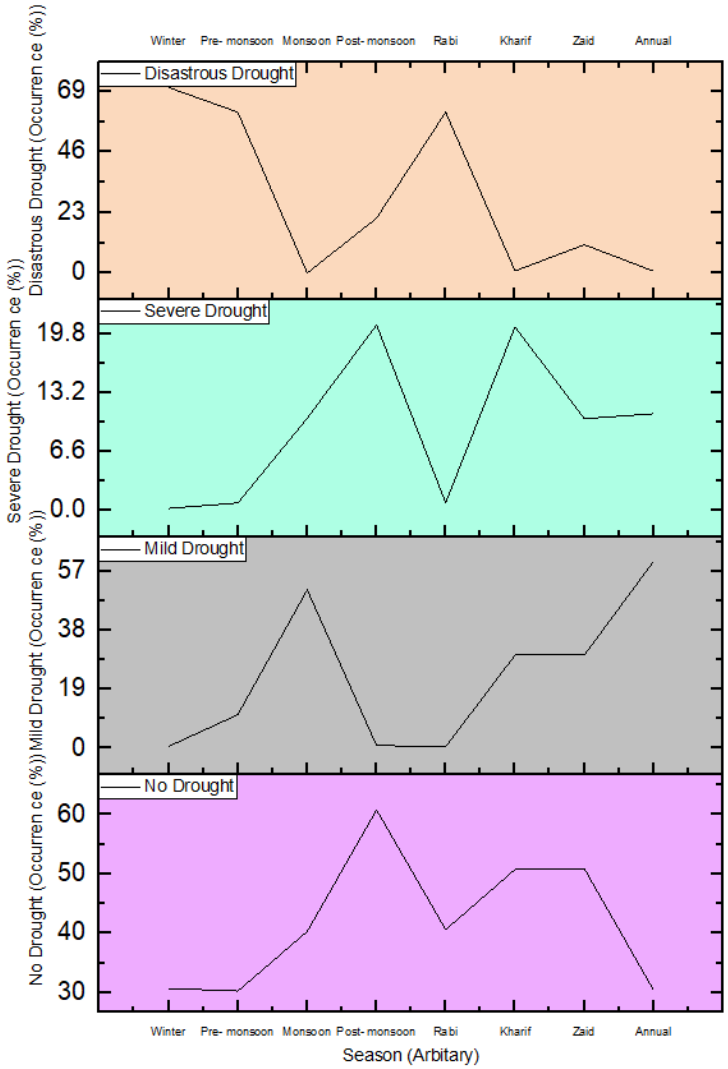

Figure 4: - Yearly Percentage Deviation of Rainfall , Occurrence of drought in Climatic Season and Occurrence of drought in Cropping Season

Yearly or Annual

Based on data collected over a decade (2011-2024), the average annual precipitation in the Gariyaband region is approximately 1069.23 mm. The plot depicted in Figure 6 illustrates the fluctuating nature of rainfall over the ten-year period, showcasing its erratic and variable patterns. A climatic drought is recognized when there is a 0 to 25% reduction in rainfall. Notably, there were no instances of catastrophic drought throughout the study period. Instead, the occurrences of no drought, moderate drought, and severe drought conditions were 30%, 60%, and 10%, respectively. The year 2015 experienced an extreme drought, with a rainfall variance of -25.64%. Any year with rainfall deviating between 0 to -25% is considered a minor drought year. Accordingly, six out of the ten years (2011, 2013, 2014, 2017, 2018, and 2019) could be classified as mild drought years. Among these, 2011 had the least severe drought, with a rainfall variation of -0.58%. Additionally, seven of the years (2011, 2013, 2014, 2015, 2017, 2018, and 2019) were categorized as drought years, with persistent droughts occurring from 2013 to 2015 and from 2017 to 2019. Conversely, years without drought exhibited a percentage variation in rainfall greater than zero, indicating that droughts typically occur outside the monsoon season and are prevalent in the Gariyaband region.

ISSN PRINT 2319 1775 Online 2320 7876
 Journal Volume 11, Iss 10, 2022

IV. CONCLUSION

The analysis of a decade-long dataset for the Gariyaband region in the Chhattisgarh plain has shed light on the recurring nature of droughts in the area, offering insights into their occurrence and severity. SMW 39 emerged as the period with the most significant drought impact, followed by SMW 26, 29, and 31. Throughout the ten-year study period, SMW 35 experienced a maximum of three severe droughts, while SMW 24 encountered up to four moderate droughts. Monsoon months, particularly July, August, September, and June, witnessed mild droughts ranging from 10% to 30%, highlighting the severity of drought in the region. Conversely, December recorded the highest catastrophic drought at 90%, whereas July reported no such instances. Notably, July also witnessed the highest proportion of severe drought conditions at 40%.

A seasonal analysis revealed that during the monsoon season, 40% of the time was drought-free, with 50% experiencing mild droughts and 10% facing severe droughts, while disastrous droughts were absent. Conversely, the summer and pre-monsoon seasons saw 30%, 10%, 0%, and 60% of the time with no drought, mild drought, severe drought, and disastrous drought conditions, respectively. Additionally, a significant portion (70%) of the winter season was affected by drought.

Considering the cropping season, the kharif season exhibited 50% of the time with no drought, 30% with moderate droughts, 20% with severe droughts, and none with catastrophic droughts. Notably, 2015 stood out as a year of extreme drought, marked by a rainfall deviation of -25.64%. The analysis also revealed that six out of the ten years experienced mild droughts, with 2011 being the least severe. Conversely, seven years were characterized by drought, with prolonged drought periods observed from 2013 to 2015 and 2017 to 2019.

Given these findings, it is imperative to implement effective water harvesting techniques in the region to capture excess runoff during the monsoon season. This stored water can then be utilized for supplemental irrigation during the drier summer and post-monsoon periods, ensuring crop preservation. Furthermore, the insights gained from this study can inform the development of optimal cropping patterns and scheduling of agricultural activities in the area.

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