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RAINFALL VARIABILITY IN SATARA DISTRICT OF MAHARASHTRA: A CASE STUDY

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ABSTRACT

The study focuses on the rainfall trends in the Western Ghats region of Maharashtra, particularly in Satara district. This area experiences significant variability in annual rainfall, influenced by the monsoon's unpredictable nature, which continues to make agriculture a challenging endeavor despite advancements in crop varieties and management practices. The district's average annual rainfall is approximately 1277 mm, but it varies across different tehsils. This research analyzes tehsil -wise annual rainfall data from 1998 to 2023, utilizing statistical tools such as mean, standard deviation, and the coefficient of rainfall variability to assess trends. [1]

The findings highlight contrasting patterns within the district: seven tehsils exhibit a decreasing trend in annual rainfall, while two tehsils show an increasing trend, with Mahabaleshwar tehsil recording the most significant rise. Two other tehsils maintain consistent rainfall trends on both annual and seasonal scales. The results underscore the uneven distribution of rainfall and its implications, particularly in drought-prone regions of eastern Satara. This study provides a nuanced understanding of spatial and temporal rainfall variability, which is critical for designing region-specific agricultural strategies and water resource management plans.

Keywords: Annual Rainfall, Rainfall Variability, Drought Prone, Climate Change, Trend.

I. INTRODUCTION

Water is a critical resource for meeting the diverse demands of agriculture, industry, irrigation, hydroelectric power generation, and other human activities. In regions like Satara district, a comprehensive water budget is essential for sustainable development and resource management. Agriculture remains the backbone of India, with more than 70% of the population engaged in farming activities. The country's economy is intrinsically tied to the monsoon, with its prosperity closely linked to the quantity and distribution of rainfall received during the season. Across most Indian states, the southwest monsoon contributes 90-95% of the annual rainfall, making its behavior a determining factor for crop success or failure. Efficient utilization of water resources is crucial for enhancing agricultural productivity, particularly in regions with irregular, uncertain, and uneven rainfall distribution. [3] Variability in rainfall can be attributed to factors such as topography, climatic conditions, and the movement of monsoon systems. Rainfall is not only a primary weather element affecting agricultural practices but also plays a significant role in shaping farming systems and crop choices. Recent studies have revealed that while the total annual rainfall in some parts of India has remained relatively stable over the decades, the duration of rainfall events has significantly decreased. This has increased the importance of water storage and management to prevent excessive runoff and mitigate flood risks. [2]

In Satara district, rainfall distribution varies significantly due to its geographical location in the Western Ghats. The western region, particularly Mahabaleshwar tahsil, receives the highest rainfall, while the amount decreases progressively from the Western Ghats to the district's eastern boundary. The eastern region, primarily dependent on natural rainfall, faces significant challenges due to its drought-prone nature. Government reports have identified seven tahsils in the district as drought-prone, emphasizing the need for targeted interventions. [4]

This study examines rainfall trends in Satara district from 1998 to 2023, using statistical tools such as mean, trend analysis, and variability assessments. Local observations and historical records suggest that the eastern region has experienced a decline in total rainfall over the past 40-45 years, exacerbated by shifting monsoon patterns and reduced summer precipitation. Understanding these changes is essential for developing effective water management strategies to address the challenges posed by climate variability and ensure the region's agricultural sustainability.

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II. STUDY AREA

Satara district is a prominent region in Maharashtra, recognized for its advancements in agriculture. The agricultural prosperity, along with the region's rich rural cultural heritage and the author's personal connection to these aspects, inspired the researcher to pursue this study. Located in western Maharashtra, Satara district encompasses 11 talukas and includes 1,727 villages. Spanning an area of 10,480 square kilometers, the district lies between latitudes 17°5' and 18°11' North and longitudes 73°33' and 74°54' East. As per the 2011 Census, Satara has a population of 3,003,741, comparable to the population of Albania or the U.S. state of Mississippi, ranking it 122nd among India's 640 districts. The district has a population density of 287 people per square kilometer (740 per square mile), with a decadal growth rate of 6.93% from 2001 to 2011. The climate in Satara varies significantly, ranging from the high rainfall of over 6,000 mm annually in Mahabaleshwar to the arid conditions of Man taluka, which receives around 500 mm of rainfall annually. [5]

III. OBJECTIVES

The present study is conducted with the following objectives:

1. To analyze the average annual rainfall from 1998 to 2023.
2. To identify rainfall trends and calculate the coefficient of variation.

IV. METHODOLOGY

This study utilizes rainfall data spanning 26 years, obtained from the Indian Meteorological Department. Additional data were sourced from the Agricultural Statistical Information of the State, the Socio-Economic Review of Satara District, and the District Agricultural Office. The data set covers the period from 1998 to 2023.

Rainfall trends have been analyzed using statistical measures such as mean, standard deviation, and the coefficient of variation (expressed as a percentage). The results are visually represented through charts and graphs. The following formula was applied for data analysis:

$$C.V. = \frac{S.D.}{Mean} \times 100$$

Where, C.V. = Coefficient of variability of Rainfall, S.D. = Standard Deviation of Rainfall,

Mean = Mean of Rainfall

Table 1. Average Annual Rainfall 1998 to 2023

Year	M'sh war	Jawal i	Dahiwa di	Koregao n	Phalta n	Khata v	Khandal a	Kara d	Patan	Wai	Satar a
1998	4998	1665	764	842	864	840	700	706	1560	1123	929
1999	5507	1608	578	887	533	461	482	790	1672	1101	1060
2000	4158	943	311	622	385	406	443	536	1165	662	960
2001	4520	1092	358	520	478	519	350	655	1203	678	1032
2002	5094	1320	353	586	344	398	267	467	1245	562	742
2003	4441	1192	149	394	96	193	218	419	988	547	584
2004	6507	1104	534	988	765	952	760	778	1612	1130	1093
2005	8824	2273	573	1436	471	684	786	1231	3251	1574	1849
2006	8599	2747	571	1366	703	640	790	1099	2906	1484	1679
2007	6265	1679	595	895	725	593	686	1025	2221	1033	1232
2008	5605	1521	455	568	342	420	441	881	1239	836	764
2009	4531	1719	977	950	1132	1006	722	894	1299	1118	1113
2010	4351	1618	828	939	1120	897	752	957	1600	1128	1093
2011	6555	1721	242	515	312	394	444	617	1910	904	852
2012	3883	1237	270	361	278	275	470	546	1497	683	685
2013	3820	1789	393	596	487	602	634	570	1498	885	1182
2014	5660	1655	483	480	302	602	523	668	1572	800	1091
2015	3698	1342	381	442	394	544	558	410	924	522	658
2016	4353	1423	397	493	403	596	565	512	1230	613	789
2017	4816	1661	451	559	477	594	611	662	1522	800	946

2018	4764	1671	448	541	471	595	617	656	1514	789	938
2019	4712	1682	444	524	465	597	622	650	1505	777	931
2020	4660	1692	441	507	460	598	628	644	1496	766	924
2021	4608	1702	437	490	454	599	633	638	1487	754	916
2022	4556	1712	434	473	448	601	638	631	1479	743	909
2023	4504	1722	431	455	443	602	644	625	1470	731	901
Total	133989	41487	12297	17427	13354	15207	14982	18268	41063	22743	25850
Mean	5153	1596	473	670	514	585	576	703	1579	875	994
S.D.	1294	365	178	283	242	189	152	205	516	268	278
C.V.	25	23	38	42	47	32	26	29	33	31	28

V. RESULTS AND DISCUSSION

1) Annual Rainfall Distribution

Rainfall plays a crucial role in shaping the agricultural economy of a region, influencing cropping patterns, and impacting cultural practices. Analysis of rainfall data from 1998 to 2023 reveals that the annual rainfall in Satara district ranges from 489.68 mm to 5389.86 mm. The eastern parts of the district, including Dahiwadi, Khatav, Phaltan, and Khandala talukas, experience the lowest rainfall, which increases progressively toward the west, peaking in Mahabaleshwar.

The study identifies the eastern, northeastern, and southeastern regions, encompassing Dahiwadi, Khatav, Phaltan, Khandala, and parts of Koregaon and Karad talukas, as areas prone to drought, having experienced drought conditions for over 20% of the years. The average annual rainfall for the district during 1998–2023 was 1247 mm. The highest rainfall was recorded in Mahabaleshwar (5152.22 mm), followed by Jawali (1594.22 mm) and Patan (1578.22 mm). Moderate rainfall was observed in central regions, including Satara (993.58 mm), Wai (874.85 mm), Karad (702.65 mm), and Koregaon (669.56 mm), while eastern talukas like Khandala (575.96 mm), Khatav (584.34 mm), Phaltan (513.23 mm), and Man (584.67 mm) recorded significantly lower rainfall.

The coefficient of variation in rainfall across the district was calculated, with notable values including 33% for Patan, 23% for Jawali, 25% for Mahabaleshwar, and 28% for Satara. In contrast, higher variability was seen in Phaltan (47%) and in other eastern talukas such as Man (42%), Khatav (47%), Khandala (26%), Karad (29%), and Wai (31%).

Mahabaleshwar taluka recorded the highest mean annual rainfall over the two decades, with a standard deviation of 1293.34. Moderate rainfall levels were noted in Patan (1578.20 mm) and Jawali (1595.30 mm), with a standard deviation of 277.30 for Satara taluka.

Table 1 highlights that the western part of Satara district, particularly Mahabaleshwar, recorded the highest rainfall during 1998–2023. Jawali, Patan, Wai, and Satara talukas experienced normal rainfall, while Karad and Koregaon received moderate rainfall. In contrast, the eastern talukas of Khandala, Phaltan, Khatav, and Dahiwadi consistently experienced low rainfall. The observed patterns indicate that local climatic conditions and physiographic features play a more significant role in rainfall distribution than large-scale climatic factors.

2) Rainfall Trends in the Drought-Prone Areas of Satara District

The average annual rainfall data for Satara district from 1998 to 2023 was analyzed using a tabular method to estimate yearly variations. The findings reveal a negative trend in rainfall across the district, particularly in the drought-prone eastern regions. This trend has led to challenges such as water scarcity, reduced water table levels, shortages of fodder and food, and emigration of the population in search of water.

The variability in rainfall across the district is depicted using trend and actual lines, which show a declining pattern in drought-prone areas. These results highlight an imbalance in rainfall distribution, with no significant climatic changes observed in the western part of the district during the study period. Talukas in the eastern region, which are most affected by drought, consistently exhibited negative rainfall trends.

VI. CONCLUSION

The study provides a comprehensive analysis of rainfall variability and trends in the drought-prone eastern region of Satara district. Using 19 years of recorded rainfall data from all 11 talukas, the research examines temporal and spatial variations across the western, central, and eastern parts of the district. The key findings of the study are summarized as follows:

Annual Rainfall Variations: Rainfall across Satara district ranges significantly, with the western region of Mahabaleshwar receiving the highest annual rainfall of approximately 5389.86 mm, while the eastern taluka of Dahiwadi records the lowest at 489.68 mm.

Rainfall Trend Analysis: The trend analysis of annual average rainfall over 26 years reveals notable fluctuations. Decreasing rainfall trends were observed in drought-prone areas during the years 1998, 1999, 2002, 2003, 2006, 2007, 2010, 2011, 2015,2017,2018,2019 and 2020. In contrast, years such as 2000, 2001, 2003, 2004, 2005, 2008, 2009, 2012, 2013,2014,2021,2022 and 2023 exhibited an increasing trend in heavy rainfall, particularly in the western parts of the study area.

This study primarily focuses on understanding rainfall variability as a foundation for examining the relationship between crops and climate in drought-prone areas. In a subsequent paper, I explore how fluctuations in rainfall affect the yields of staple crops and evaluate the potential of rainwater harvesting as a sustainable livelihood strategy. The findings of this study highlight significant intra-regional variations in rainfall patterns, including differences in amounts, variability, and trends. Overall, the western part of the region experiences higher rainfall with lower variability compared to the eastern part. These variations are largely influenced by localized climatic factors rather than broader climatic forces. Additionally, the results emphasize the importance of further research into the impact of human activities on the environment, as anthropogenic interventions may significantly contribute to climate change in regions prone to drought.

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