InSight Bulletin: A Multidisciplinary Interlink International Research Journal
Peer Reviewed International, Open Access Journal.
ISSN : 3065-7857 / Website: https://ibrj.us / Volume-2, Issue-7 / July - 2025

Original Article

Assessment of Rainfall Intensity and Rainy Days Distribution across Talukas in Satara District, Maharashtra

Dr. Arjun G. Ohal[1], Dr. T. P. Shinde[2], Prakash S. Shinde[3]
[1]Associate Professor and Head, Department of Geography, Mahila Mahavidyalay, Karad. M.S
[2]Professor and Head, Department of Geography, Mudhoji College Phaltan .M.S
[3]Research Student, Shivaji University, Kolhapur. M.S

Manuscript ID: IBMIIRJ -2025-020716

Submitted: 10 June 2025

Revised: 27 June 2025

Accepted: 15 July 2025

Published: 31 July 2025

ISSN: 3065-7857

Volume-2

Issue-7

Pp. 74-80

July 2025

Correspondence Address:
Arjun G. Ohal, Associate Professor and Head, Department of Geography, Mahila Mahavidyalay, Karad. M.S.
Email: sprakash.gisrs@gmail.com

OPEN ACCESS

Quick Response Code:

Web. https://ibrj.us

DOI: 10.5281/zenodo.17045930

DOI Link:
https://doi.org/10.5281/zenodo.17045930

Abstract
This study aims to assess the spatiotemporal variability of rainfall intensity and the distribution of rainy days across the talukas of Satara district, Maharashtra, from 2006 to 2023. Using statistical techniques such as Z-score analysis and linear trend estimation, the research evaluates deviations from normal rainfall patterns and identifies drought-prone regions. Taluka-wise data on annual rainfall and the number of rainy days were analyzed to detect trends and anomalies. The findings indicate a declining trend in rainfall and rainy days in eastern talukas like Man, Khatav, and Phaltan, suggesting growing vulnerability to meteorological drought. In contrast, western talukas such as Mahabaleshwar and Jawali showed consistently high rainfall and frequency of rainy days. The spatial disparities observed in rainfall distribution emphasize the need for localized drought mitigation strategies and adaptive water resource planning. The study contributes to a better understanding of regional climatic behavior and supports informed decision-making for sustainable development in semi-arid regions.

Keywords: *Rainfall variability, Rainy days, Satara district, Statistical Analysis.*

Introduction

Rainfall is one of the most critical climatic parameters influencing regional hydrology, agriculture, and water resource management. Its spatial and temporal variability significantly impacts the socio-economic stability of agrarian regions, particularly in semi-arid and drought-prone areas. In Maharashtra, Satara district presents a unique physiographic and climatic setting that ranges from high-rainfall Western Ghats to low-rainfall eastern plains, making it an ideal case for rainfall variability analysis. Understanding the patterns of rainfall intensity and distribution of rainy days across different talukas is essential for effective agricultural planning, drought preparedness, and water resource allocation. The frequent occurrences of erratic rainfall in the region have led to uncertainties in crop planning and have increased the vulnerability of farmers, especially in the eastern talukas. This calls for a comprehensive analysis of rainfall behavior over time. Numerous studies have examined rainfall variability and trends using statistical and geospatial techniques to assess climate behavior and support water resource planning. Ahire et al. (2021) analyzed rainfall trends in the Satara district over two decades, revealing noticeable spatial and temporal variations. Similarly, Dhulgude et al. (2023) employed geospatial tools to map rainfall variability within Satara, demonstrating the value of GIS in visualizing climate data. Chavan et al. (2023) used non-parametric statistical methods in Solapur district, confirming significant annual and seasonal deviations in rainfall, and underlining the robustness of non-parametric approaches in regional hydrological assessments. Arvind et al. (2017) and Muthiah et al. (2024) extended these findings through long-term statistical analyses in other Indian regions, emphasizing the growing trend of integrating statistical rigor with regional datasets to detect climate shifts. Further supporting this body of work, Nandargi (2012) examined the relationship between rainy days and seasonal intensity in the Koyna catchment, establishing foundational links between rainfall patterns and hydrological impacts. Aikh et al. (2023) and Panda et al. (2019) highlighted long-term trends across different climatic zones, reaffirming rainfall variability as a widespread phenomenon influenced by both natural and anthropogenic Factors' Studies by Selvaraj et al.

How to cite this article:
Ohal, A. G., & Shinde, T. P. (2025). Assessment of Rainfall Intensity and Rainy Days Distribution across Talukas in Satara District, Maharashtra. Insight Bulletin: A Multidisciplinary Interlink International Research Journal, 2(7), 74–80. https://doi.org/10.5281/zenodo.17045930

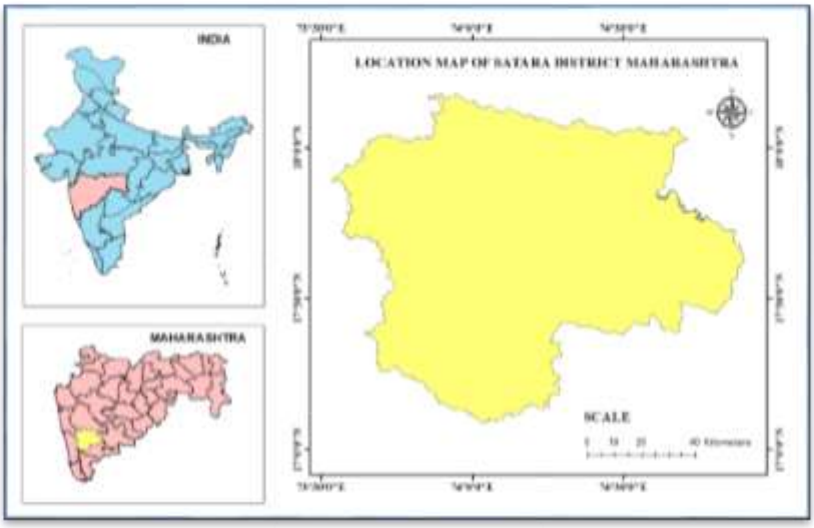
(2024) and the Research Gate publications (2025) on drought risk and spatial rainfall distribution in Satara underscore the importance of combining statistical and spatial analysis for better climate adaptation strategies. Collectively, these studies demonstrate a comprehensive, evolving methodology in rainfall trend analysis, providing a framework for localized climate assessments using statistical and GIS-based approaches. This study focuses on the statistical assessment of rainfall intensity and rainy day distribution across the eleven talukas of Satara district. By employing statistical techniques such as mean, standard deviation, coefficient of variation, and trend analysis, the research aims to uncover spatial disparities and temporal changes in rainfall characteristics. These insights will help identify talukas with high variability and drought susceptibility, thereby guiding localized adaptation and mitigation strategies. The application of statistical methods in rainfall studies enhances the reliability of climate interpretations and supports data-driven decision-making. The outcomes of this research are expected to contribute significantly to regional climate assessment, water management policies, and sustainable agricultural development in Satara district.

Objective:

To assess the rainfall intensity and rainy days using statistical tools.

Study Area:

Figure 1: Location map of Satara District (Maharashtra).



Satara district, located in the western part of Maharashtra, India (Figure 1), spans approximately 10,480 km² and lies between latitudes 17°00'N to 18°15'N and longitudes 73°30'E to 75°00'E. Administratively, it comprises eleven talukas and four revenue divisions, including 1,721 revenue villages. The district's physiography is diverse, encompassing the Sahyadri Mountain ranges, undulating plateaus, and eastern plains, making it well-suited for spatial hydrological and drought-related studies. The region experiences a tropical monsoon climate, with the majority of rainfall concentrated between June and September. Rainfall distribution is highly variable—western regions like Mahabaleshwar receive over 6,000 mm annually due to orographic influence, whereas eastern talukas such as Khandala, Phaltan, Khatav, and Man receive less than 500 mm, leading to recurrent drought conditions. These eastern zones are officially classified as drought-prone. Agriculture in Satara is heavily dependent on rainfall and surface water sources such as tanks, lakes, and reservoirs. However, the spatial dynamics of these waterbodies remain under-monitored. Given these conditions, the district provides a suitable case for geospatial drought assessment.

Data and Methodology:

Rainfall and Rainy Days Data:

The present study utilized daily rainfall and rainy days records obtained from the Maharain Portal and District Statistical Abstract and the Satara District Collectorate. The analysis covers from year 2006 to 2023. Two primary parameters were examined: annual rainfall measured in millimeters and the number of rainy days, defined as days with rainfall equal to or exceeding 1 mm. For data processing and visualization, Microsoft Excel was used for tabulation, while Python libraries such as Seaborn and Matplotlib were employed to generate heatmaps. Additionally, basic statistical tools were applied to calculate the mean, variance, and coefficient of variation to assess temporal variability in rainfall patterns.

Methodology:

Rainfall and rainy days data (2006–2023) for 11 talukas of Satara district were obtained from the Maharain Portal, Government of Maharashtra. This dataset was used to conduct a statistical analysis aimed at identifying temporal trends, variability, and spatial disparities in rainfall patterns. Both total rainfall (in mm) and the number of rainy days were examined across talukas. Heat map visualizations were employed to illustrate the intensity and frequency of rainfall events over time. The observed fluctuations and declining trends helped in identifying drought-prone areas and periods of climatic stress. The statistical methods applied in this analysis are outlined in Table 1.

S. N.	Statistical Tool	Mathematical Expression	Inventor
1	Total	$\Sigma X = X1 + X2 \ldots n$	Fundamental arithmetic
2	Mean	$\bar{X} = \Sigma X / n$	Adrien-Marie Legendre (17th century)
3	Median	$\text{Median} = X_{(n+1)}/2$	Gustav Theodor Fechner, 1850s
4	Maximum and Minimum	$\text{Max} = \max(X_1, X_2, \ldots, X_n)$ $\text{Min} = \min(X_1, X_2, \ldots, X_n)$	-
5	Range	$\text{Range} = \text{Max} - \text{Min}$	-
6	Standard Deviation	$\sigma = \sqrt{[\Sigma (X_i - \bar{X})^2 / n]}$	Karl Pearson, 1894
7	Coefficient of Variation	$CV = (\sigma / \bar{X}) \times 100$	Karl Pearson, 1896
8	Z-Score	$Z = (X - \bar{X}) / \sigma$	Karl Pearson (early 1900s)
9	Linear Trend	$m = [n\Sigma XY - \Sigma X\Sigma Y] / [n\Sigma X^2 - (\Sigma X)^2]$	Francis Galton (1886); Carl F. Gauss (early 1800s)
10	Correlation Coefficient	$r = [n\Sigma XY - \Sigma X\Sigma Y] / \sqrt{[(n\Sigma X^2 - (\Sigma X)^2)(n\Sigma Y^2 - (\Sigma Y)^2)]}$	Karl Pearson, 1896
11	Coefficient of Determination	$R^2 = 1 - [\Sigma(\hat{Y} - Y)^2 / \Sigma(Y - \bar{Y})^2]$	Karl Pearson (1909)

Table 1: Statistical Formulas for Analysis of Rainfall and Rainy Days.

Results and Discussion:

Mahabaleshwar

Mahabaleshwar recorded the highest total rainfall (85,091.20 mm) and rainy days (2040) from 1994–2023, with a mean annual rainfall of 4727.29 mm and mean rainy days of 113.33. The standard deviation of rainfall (1481.26 mm) and CV (31.33%) suggest moderate variability in rainfall, while rainy days remained more stable (CV = 10.91%). The maximum rainfall recorded was 8295.8 mm, and the minimum was 2553.8 mm, indicating a wide range of 5742 mm. Despite this, the correlation between rainfall and rainy days is negligible (0.01), implying that heavy rainfall is often confined to fewer, intense events. This aligns with the heat map, which shows persistently high rainfall and rainy days, affirming its role as a climatic high zone in the basin. The trend indicates a stable and humid microclimate, acting as a key recharge zone. Despite slight fluctuations, no significant decline is observed, confirming its hydrological importance.

Figure 2: Heat Map of Rainy Days

Figure 3: Heat Map of Rainfall

Wai

Wai received total rainfall of 30,883.50 mm and 1210 rainy days, with mean values of 1715.75 mm rainfall and 93.28 rainy days annually. Rainfall varied moderately (CV = 23.54%), while rainy days were also somewhat variable (CV = 17.38%). The maximum rainfall recorded was 2744.80 mm, and the minimum was 1118.50 mm, with a range of 1626.3 mm. The correlation (0.33) shows a moderate relationship between the two variables. Heat map data indicates that Wai remained moderately wet, with occasional dips in rainfall during drought years such as 2012 and 2015. The trend reflects moderate rainfall reliability, with some declining episodes during 2012, 2015, and 2018, consistent with regional droughts. Rainfall intensity per day appears to have slightly increased, indicating shorter-duration but high-intensity events in recent years.

Khandala

Khandala experienced 29,537.10 mm of rainfall and 890 rainy days, averaging 1640.95 mm rainfall and 90.22 rainy days/year. The rainfall CV (28.78%) and rainy days CV (16.17%) reflect moderate inter-annual variability. The rainfall ranged from 826.10 mm to 2738.20 mm, with a standard deviation of 472.28 mm. The correlation (0.42) shows a relatively strong relationship, supported by heat map patterns that depict both wet and dry spells, with severe drops in 2012 and 2018. The decreasing trend in rainy days and erratic rainfall pattern, particularly post-2010, indicates increasing climatic variability, making agriculture more vulnerable. The taluka remains in a moderate drought risk category.

Phaltan

Phaltan had total rainfall of 18,518.00 mm and 762 rainy days, with mean values of 1028.78 mm rainfall and 79.94 rainy days. Rainfall variability was moderate (CV = 29.52%), while rainy days showed slightly higher variability (CV = 20.90%). The range of rainfall was 1247.50 mm, with a maximum of 1829.60 mm and a minimum of 582.10 mm. A moderate correlation (0.28) was observed. Heat maps frequently showed yellow to orange shades, confirming its classification as a drought-prone zone with short and scattered rainfall spells. The heatmap shows frequent dry years, particularly from 2012 to 2019. Annual rainfall is low and concentrated in fewer days, suggesting reduced groundwater recharge potential and high agricultural stress.

Man

Man received 16,154.10 mm of rainfall and 813 rainy days, with mean annual values of 897.45 mm rainfall and 67.22 rainy days. The rainfall CV (31.73%) and rainy days CV (23.70%) show high variability. Rainfall ranged between 402.70 mm and 1473.90 mm, indicating frequent dry years. The correlation (0.39) suggests moderate rainfall predictability based on rainy days. Heat maps confirm repeated drought events, particularly in 2012, 2015, and 2022, making it one of the most vulnerable talukas. Man taluka exhibits high drought vulnerability. The trend shows severe declines in both rainfall and number of rainy days, especially in 2012, 2015, 2018, and 2022, all identified as major drought years in Maharashtra. The situation signals long-term hydrological stress.

Figure 4: Rainy Days trend analysis

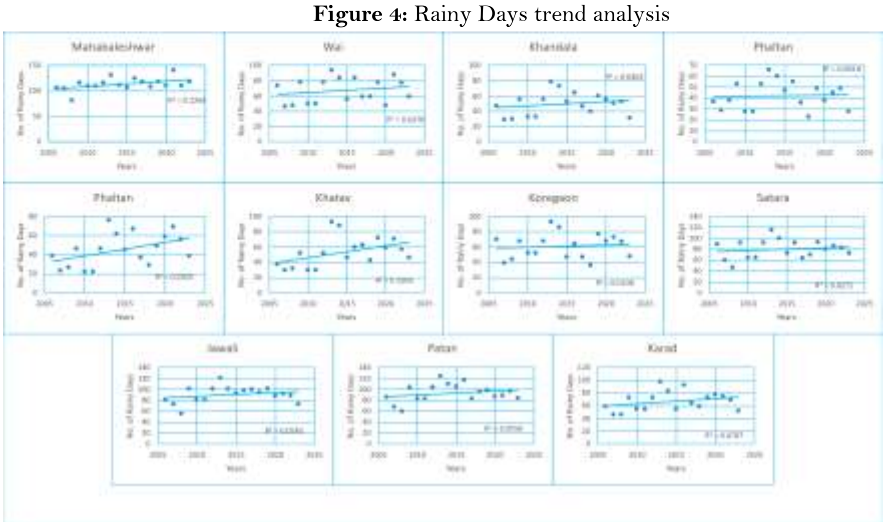
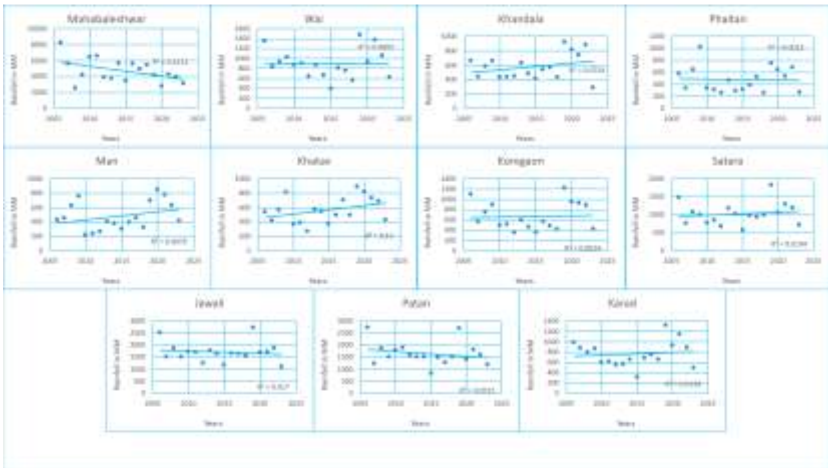


Figure 5: Rainfall trend analysis



Khatav

Khatav experienced 13,755.70 mm rainfall and 962 rainy days, with mean values of 764.21 mm and 67.06 rainy days. The rainfall CV was 31.89%, and rainy days CV was 22.53%, indicating considerable inter-annual variation. Rainfall varied between 317.40 mm and 1317.70 mm, and the correlation (0.47) was the highest among all talukas, reflecting a consistent dependency of rainfall on rainy days. Heat map data matches this trend, with distinct drought phases in 2009, 2012, and 2018. Khatav indicate slightly better conditions than Man and Phaltan, yet still reflect low rainfall totals. There is a noticeable downward trend, with more frequent dry spells and decreasing rainy days, raising concerns for agriculture and water storage planning.

Koregaon

Koregaon recorded 12,011.80 mm rainfall and 1099 rainy days, with mean annual values of 667.32 mm and 61.06 rainy days. Rainfall variability was high (CV = 39.90%), and rainy days also showed significant variation (CV = 26.48%). Rainfall ranged from 360.60 mm to 1217.50 mm, with a correlation of 0.42. These values correspond with heat map observations of moderate rainfall, interrupted by severe drought in some years. The trend is variable, with a few good years (e.g., 2010, 2014), but lacking consistent reliability. This taluka sits in a transitional zone, with increasing risk of drought exposure over time.

Satara

Satara had 10,424.80 mm rainfall over 1439 rainy days, with a mean of 579.16 mm and 53.44 rainy days/year. Rainfall and rainy days showed high variability (CV = 30.38% and 35.62%, respectively), and the correlation (0.39) indicated a moderate association. Rainfall values fluctuated between 293.60 mm and 920.90 mm. The heat map revealed alternating wet and dry years, with visible drought signatures in 2009, 2012, and 2015. Satara, indicating relatively favorable rainfall conditions. However, signs of erratic monsoon behaviour are more visible after 2015, demanding improved water management.

Jawali

Jawali received 10,163.20 mm rainfall and 1624 rainy days, with mean values of 564.62 mm rainfall and 49.44 rainy days/year. The rainfall variability was 31.34%, and the correlation between rainfall and rainy days was almost negligible (0.02), indicating that rainfall is often unevenly distributed over days. Heat maps revealed generally favourable conditions, although rainfall declined after 2016. Jawali, ranks among the top three talukas in terms of rainfall and rainy days. The trend remains stable, with only minor inter-annual deviations. The region has good potential for runoff harvesting and storage, especially for downstream use.

Patan

Patan had 8713.30 mm rainfall and 1679 rainy days, with mean values of 484.07 mm and 45.17 rainy days/year. It recorded the highest variability in rainfall (CV = 43.72%) and rainy days (CV = 37.60%). Rainfall ranged from 265.90 mm to 1028.40 mm, with a negative correlation (-0.13), showing that more rainy days don't guarantee higher rainfall. Heat maps reinforced this trend with frequent orange shades, especially during drought years. Patan recorded as another high-rainfall taluka, although variability has increased post-2010. While not as wet as Mahabaleshwar or Jawali, Patan retains a positive rainfall profile with good potential for groundwater recharge zones.

Karad

Karad experienced 8677.70 mm of rainfall and 1207 rainy days, with mean rainfall of 482.09 mm and 42.33 rainy days/year. Rainfall variability was high (CV = 40.67%), and rainy days also showed considerable variation (CV = 29.50%). The correlation (0.13) was weak, and the range of rainfall was 625.90 mm, reflecting frequent dry spells. The heat map showed persistent dryness with little relief even during relatively wet years. Karad taluka is in the mid-range category. The trend shows moderate rainfall with declining rainy days, particularly in recent years. The shift toward more intense rainfall in fewer days indicates potential challenges in soil moisture retention and runoff management.

Taluka		**M'shwar**	**Wai**	**Khandala**	**Phaltan**	**Man**	**Khatav**	**Koregaon**	**Satara**	**Jawali**	**Patan**	**Karad**
Rainy Days	**Total**	2040.00	1210.00	890.00	762.00	813.00	962.00	1099.00	1439.00	1624.00	1679.00	1207.00
	Mean	113.33	93.28	90.22	79.94	67.22	67.06	61.06	53.44	49.44	45.17	42.33
	Median	111.50	92.50	92.50	81.50	66.50	66.50	65.50	52.00	52.00	45.50	41.50
	Max	141.00	124.00	121.00	115.00	94.00	98.00	93.00	93.00	79.00	76.00	66.00
	Min	81.00	60.00	56.00	47.00	46.00	46.00	36.00	30.00	29.00	22.00	23.00
	Std Dev	12.37	16.21	14.59	16.71	15.93	15.11	16.17	19.04	14.74	16.98	12.49
	CV (%)	10.91	17.38	16.17	20.90	23.70	22.53	26.48	35.62	29.81	37.60	29.50
	Range	60.00	64.00	65.00	68.00	48.00	52.00	57.00	63.00	50.00	54.00	43.00
Rainfall in MM	**Total**	85091.20	30883.50	29537.10	18518.00	16154.10	13755.70	12011.80	10424.80	10163.20	8713.30	8677.70
	Mean	4727.29	1715.75	1640.95	1028.78	897.45	764.21	667.32	579.16	564.62	484.07	482.09
	Median	4290.60	1691.35	1522.20	1001.35	877.30	721.20	566.55	556.30	548.95	432.30	425.30
	Max	8295.80	2744.80	2738.20	1829.60	1473.90	1317.70	1217.50	920.90	891.60	1028.40	851.70
	Min	2553.80	1118.50	826.10	582.10	402.70	317.40	360.60	293.60	273.40	265.90	225.80
	Std Dev	1481.26	403.87	472.28	303.68	284.80	243.72	266.25	175.92	176.95	211.61	196.09
	CV (%)	31.33	23.54	28.78	29.52	31.73	31.89	39.90	30.38	31.34	43.72	40.67
	Range (mm)	5742.00	1626.30	1912.10	1247.50	1071.20	1000.30	856.90	627.30	618.20	762.50	625.90
Correlation of Rainy days and Rainfall	**Correlation**	0.01	0.33	0.42	0.28	0.39	0.47	0.42	0.39	0.02	-0.13	0.13
	RD Z-Score	0.39	-0.53	-1.29	-1.18	-0.37	-0.40	-0.83	-0.43	-1.21	-0.59	-1.03
	RF Z-Score	-1.11	-0.96	-1.67	-1.04	-0.34	-0.75	-0.94	-1.01	-1.52	-0.96	-1.11
	RD (R^2)	0.2264	0.0378	0.0404	0.0018	0.2025	0.1905	0.0108	0.027	0.055	0.056	0.079
	Rainfall (R^2)	0.2111	0.0005	0.0754	0.0012	0.098	0.13	0.0024	0.0194	0.017	0.0515	0.0134

Table 2: Statistical Analysis of Rainfall and Rainy Days.

Conclusion:

The statistical analysis of rainfall and rainy days data from 2006 to 2023 across the talukas of Satara district reveals significant spatial and temporal variability. Using methods such as Z-score standardization and linear trend analysis, the study identifies fluctuations in rainfall intensity and distribution, highlighting areas that are more prone to drought or erratic monsoon patterns. The Z-score method effectively distinguished years of abnormal rainfall—both below and above normal—while the trend analysis showed a declining rainfall pattern in talukas like Man, Khatav, and Phaltan, suggesting increasing vulnerability to dry spells. Rainy days analysis further indicates that some regions are experiencing reduced rainfall days despite relatively stable annual totals, pointing toward changes in rainfall concentration and intensity. Talukas in the western and hilly regions (like Mahabaleshwar and Jawali) recorded more consistent and higher rainfall compared to the semi-arid eastern talukas. This uneven spatial distribution underscores the need for localized water resource management strategies. The results of this research provide valuable insights for policymakers, planners, and agricultural stakeholders, supporting targeted adaptation and mitigation efforts in response to changing climatic patterns in the Satara district.

Recommendations:

The study recommends prioritizing drought-prone talukas like Man, Khatav, and Phaltan for water conservation measures such as rainwater harvesting and efficient irrigation. Regular monitoring using statistical tools should be adopted for early drought detection. Promotion of drought-resistant crops, sustainable farming, and taluka-specific drought mitigation plans are essential. Additionally, community awareness and capacity-building programs should be implemented to enhance resilience.

Acknowledgment
Nil

Financial Support and Sponsorship
Nil

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References:

1. Ahire, K., Kothawale, R., Hange, P., Jalgaonkar, B., Patil, A., & Shewale, J. (2021). Rainfall trends in the Satara district of Maharashtra over the last two decades. Journal of Natural Resource Conservation and Management, 2, 146–150. https://doi.org/10.51396/ANRCM.2.2.2021.146-150
2. Arvind, G., Kumar, P., Karthi, S., & CR, S. (2017). Statistical analysis of 30 years rainfall data: A case study. IOP Conference Series: Earth and Environmental Science, 80, 012067. https://doi.org/10.1088/1755-1315/80/1/012067
3. Chavan, C. S., Chipade, A., Ghadvir, G., & Deshpande, M. (2023a). Statistical analysis of rainfall data using non-parametric methods of Solapur District, Maharashtra, India. E3S Web of Conferences, 405, 04046. https://doi.org/10.1051/e3sconf/202340504046
4. Chavan, C. S., Chipade, A., Ghadvir, G., & Deshpande, M. (2023b). Statistical analysis of rainfall data using non-parametric methods of Solapur District, Maharashtra, India. E3S Web of Conferences, 405, 04046. https://doi.org/10.1051/e3sconf/202340504046
5. Dhulgude, A., Mali Jadhav, V., & Shinde, P. (2023). Spatial analysis of rainfall data using geospatial technology in Satara District, Maharashtra. Vol. 4, 29–38.
6. Kumbhar, R., Nimbalkar, S. N., Saste, S., Shinde, R., & Matkar, P. S. (2022). Rainfall trend in Satara district of Maharashtra in India. International Journal for Multidisciplinary Research (IJFMR), 4(6), [Article ID: IJFMR22061191]. https://www.ijfmr.com/research-paper.php?id=1191
7. Muthiah, M., Sivarajan, S., Madasamy, N., Natarajan, A., & Ayyavoo, R. (2024). Analyzing rainfall trends using statistical methods across Vaippar Basin, Tamil Nadu, India: A comprehensive study. Sustainability, 16(5), Article 5. https://doi.org/10.3390/su16051957
8. Nandargi, S. (2012). Relationships between rainy days, mean daily intensity, and seasonal rainfall over the Koyna catchment during 1961–2005. The Scientific World Journal. https://onlinelibrary.wiley.com/doi/10.1100/2012/894313
9. Panda, S. N., Dash, S. K., & Behera, B. (2019). Trend analysis of seasonal rainfall and temperature pattern in Kalahandi, Bolangir and Koraput districts of Odisha, India. Atmospheric Science Letters. https://rmets.onlinelibrary.wiley.com/doi/10.1002/asl.932
10. Rahman, P., & Mehnaz, S. (2024). International Journal for Multidisciplinary Research (IJFMR). SSRN. https://doi.org/10.2139/ssrn.5054029
11. Saikh, N. I., Saha, S., Sarkar, D., & Mondal, P. (2023). Rainfall trend and variability analysis of the past 119 (1901–2019) years using statistical techniques: A case study of Kolkata, India. MAUSAM, 74(4), Article 4. https://doi.org/10.54302/mausam.v74i4.5909
12. Selvaraj, B. R., Krishnasamy, S., & Dhason, J. M. I. (2024). Investigation of climate change by analysing the rainfall pattern in Kuzhithuraiyar sub-basin of India using GIS-based spatial analysis. Sustainable Chemistry for Climate Action, 4, 100042. https://doi.org/10.1016/j.scca.2024.100042
13. Sen, Z. (2012). Innovative trend analysis methodology. Journal of Hydrologic Engineering, 17(7), 1042–1046. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000556
14. Singh, R. N., Sah, S., Das, B., Vishnoi, L., & Pathak, H. (2021). Spatio-temporal trends and variability of rainfall in Maharashtra, India: Analysis of 118 years. Theoretical and Applied Climatology, 143, 883–900. https://doi.org/10.1007/s00704-020-03437-3
15. Shinde, P. S., Chaure, R. S., & Banduke, D. K. (2025). Assessment of meteorological drought risk based on rainfall departure across talukas in Satara District, Maharashtra. In S. B. Tilekar et al. (Eds.), Transformative research trends in multidisciplinary contexts (pp. 47–56). JK Publications. https://www.researchgate.net/publication/389503146