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Original Article

Spatio-Temporal Analysis of Cropping Patterns in Satara District (Maharashtra) Using Remote Sensing and GIS

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Abstract

This study investigates the spatio-temporal dynamics of cropping patterns in Satara District, Maharashtra, over a 23-year period (2001–2024) using multi-temporal Landsat satellite imagery and NDVI based analysis within a GIS framework. Satellite data from Landsat 5, 8 and 9 were utilized to derive NDVI values, enabling the classification and monitoring of agricultural land use changes. The results reveal a significant shift towards high input, high yield crops such as sugarcane, wheat and rice, with their spatial coverage increasing from 41 per cent in 2001 to 56 per cent in 2024. In parallel, traditional rain-fed crops like pulses, jowar and bajra showed a marked decline, indicating reduced crop diversity and a transition toward water intensive agriculture. Vegetation cover improved up to 2014 but stabilized thereafter, while a reduction in water bodies and barren lands reflects intensified land use and growing hydrological stress. The analysis was conducted using ArcGIS software for efficient temporal processing and validation was performed using socio-economic abstracts of Satara district and satellite cross-referencing. The findings highlight the dual trajectory of agricultural intensification and ecological degradation, underscoring the need for integrated land and water management policies to ensure long-term sustainability, climate resilience and food security in semi-arid landscapes.

Keywords: *Cropping Patterns, GIS, Remote Sensing, NDVI*

Introduction

Cropping patterns are a fundamental component of agricultural land use, shaped by a complex interaction of environmental factors, socio-economic conditions, technological advancements and policy interventions. In India, where agriculture is the primary livelihood for a significant proportion of the population, analysing spatial and temporal variations in cropping practices is essential for achieving food security, sustainable natural resource management, and climate resilience (ICAR, 2020). Traditional approaches to monitoring cropping patterns, such as field surveys and statistical reports, often lack the spatial detail and temporal consistency required for dynamic assessments. In contrast, the integration of remote sensing and geographic information system technologies has emerged as an effective methodology to capture agricultural dynamics across large and ecologically diverse landscapes. These technologies enable consistent monitoring with improved spatial resolution and time-series analysis capabilities (Begue et al., 2018; Manjunath et al., 2015). Vegetation indices such as the Normalized Difference Vegetation Index (NDVI), derived from multi-temporal satellite imagery, have been widely used to objectively monitor vegetation health, cropping intensity and land use change. Numerous studies have validated the effectiveness of NDVI in agricultural monitoring. For example, Singh et al. (2011) used IRS-P6 AWiFS data to map cropping pattern shifts in Uttar Pradesh, highlighting the influence of irrigation and market access on crop decisions. Similarly, Ray et al. (2005) analyzed crop diversification trends in Punjab using remote sensing, linking changes to economic and policy-driven transformations in farming systems. Expanding this approach further, Qiu et al. (2022) developed a high-resolution multi-decadal cropping dataset for China, demonstrating the utility of RS-based vegetation monitoring in supporting long-term agricultural planning. These global and national-scale studies reinforce the value of geospatial technologies in assessing agricultural transitions.

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However, there remains a critical need for region-specific assessments that can capture localized dynamics, particularly in ecologically sensitive and water-stressed environments. In Maharashtra, Bharathkumar and Mohammed-Aslam (2015) used NDVI time-series data to assess drought impacts on vegetation in Ahmednagar district, highlighting a strong correlation between vegetation stress and rainfall variability in semi-arid areas. Regionally, Shinde and Mali Jadhav (2025) conducted a study using NDVI derived from Landsat imagery to assess vegetation health in Satara District. Their research confirmed the applicability of satellite-based NDVI for monitoring crop conditions and land cover changes over time, making it a useful foundation for further investigations into cropping pattern dynamics. In a related context, Shinde and Telore (2025) applied RS-GIS techniques to assess drought risk in the Yerla River Basin, a sub-region of Satara District. Their study mapped drought-prone areas using geospatial datasets and emphasized the urgent need for integrated land and water resource planning to address agricultural vulnerability in semi-arid regions.

Satara District's unique agro-ecological location as the humid Western Ghats and the semi-arid Deccan Plateau makes it particularly suitable for studying cropping pattern dynamics. This transitional zone is characterized by spatial heterogeneity in rainfall, soil types and elevation, which influence land use decisions. Over the past two decades, the district has undergone significant agricultural transformation due to increased irrigation availability, market-oriented farming practices and changing rainfall patterns. These changes have led to a marked shift from traditional, rain-fed crops such as jowar, bajra and pulses to high-input, commercial crops such as sugarcane, wheat and rice. These shifts raise critical concerns regarding groundwater depletion, biodiversity loss and the sustainability of farming systems. (Tilekar, 2024; Agawane & Jadhav, 2023) Despite these developments, limited efforts have been made to conduct a comprehensive geospatial assessment of cropping pattern transitions in Satara. This study aims to address this research gap by employing RS-GIS tools to assess land use changes over a 23-year period (2001–2024). Using multi-date Landsat imagery and NDVI analysis processed through ArcGIS software, the study classifies cropping categories, quantifies spatio-temporal transitions and evaluates ecological implications of agricultural intensification. Validation through field surveys and secondary datasets enhances the reliability of the findings. Ultimately, the review highlights a growing consensus that geospatial technologies are indispensable for monitoring cropping pattern changes, especially in the context of climate variability and resource constraints. The present study builds on this foundation to offer insights for policy interventions that promote sustainable agriculture, effective land use planning and long-term ecological resilience in Satara District.

Objective:

To study the spatio-temporal transformation of cropping patterns in Satara District

Study Area:

Satara District is geographically situated in the south west region of Maharashtra, in peninsular India, occupying a transitional zone between the Western Ghats (Sahyadri Hills) and the Deccan Plateau. The district extends between 17°05′N to 18°11′N latitudes and 73°33′E to 74°54′E longitudes, forming part of the upper Krishna River basin. Bordered by Pune District to the north, Solapur to the east, Sangali to the south and Ratnagiri to the west location of Satara provide a unique ecological interface that combines coastal influences with continental climatic regimes.

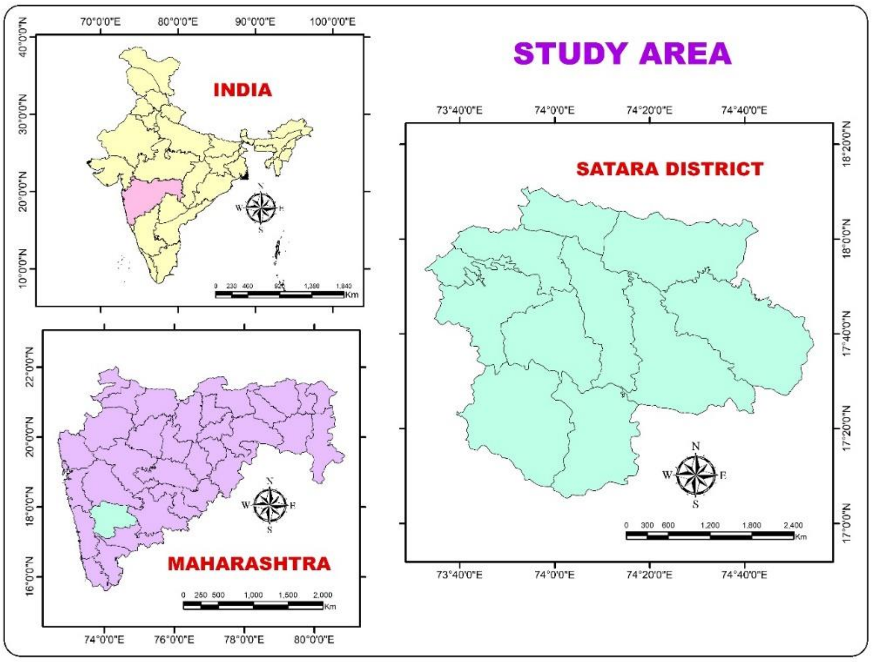

Figure 1: Location map of Satara District

The district lies on the windward side of the Western Ghats, where moist air from the sea is forced to rise by the mountains. As the air rises, it cools and condenses to form clouds, resulting in heavy rainfall due to orographic precipitation. Covering an approximate area of 10,480 km², Satara exhibits complex physiographic characteristics, including rugged mountain ranges, forested slopes, deeply incised river valleys and fertile alluvial plains. The western part is dominated by the Western

Ghats, with elevations exceeding 1,200 meters in certain areas, while the eastern portion gradually descends into semi-arid basaltic terrain typical of the Deccan Plateau. These geomorphological variations support a wide range of land uses, from intensive irrigated agriculture in valley bottoms to forestry and horticulture in upland and sloping regions. The district's varied elevation and slope also impact soil formation, moisture retention and vegetation distribution. Administratively, the district is divided into **11 tehsils**, with **Satara city** serving as the district headquarters. Satara has rivers that flow all year and some that flow only in certain seasons. The main rivers are Krishna, Koyna and Venna. These rivers give water for farming, drinking, and making electricity at the Koyna Dam. The area gets rain in two main seasons. The west side, near the hills, gets a lot of rain (more than 3000 mm), but the east side gets much less (less than 600 mm). This spatial heterogeneity in climate and topography renders the district an important site for research in **land use dynamics, cropping pattern shifts, hydrological modelling and climate adaptation strategies.**

Data and Methodology:

The NDVI analysis uses Landsat data from 2001 (Landsat 5), 2014 (Landsat 8), and 2024 (Landsat 9), all covering WRS-2 Path 146/147 and Row 48. While Landsat 5 used Band 3 (Red) and Band 4 (NIR), Landsat 8 and 9 use Band 4 (Red) and Band 5 (NIR), allowing consistent multi-temporal vegetation assessment (Table 1).

Table 1: Acquisition of Landsat Data

Year	Sensor	Collection	WRS-2 Path	WRS-2 Row	Green Band	NIR Band
2001	Landsat-5 TM	C02 T1 L2 (SR)	146/147	48	SR_B3	SR_B4
2014	Landsat-8 OLI	C02 T1 L2 (SR)	146/147	48	SR_B4	SR_B5
2024	Landsat-9 OLI-2	C02 T1 L2 (SR)	146/147	48	SR_B4	SR_B5

Source: Compiled by authors

Figure 2: Flow chart of Methodology

The NDVI was calculated using Landsat satellite images from the years 2001, 2014, and 2024. This was done by using the Red and Near-Infrared (NIR) bands to study the health and density of vegetation. By comparing NDVI values over these years, changes in cropping patterns were observed, showing how farming practices have changed over time. The formula for NDVI is:

NDVI = (NIR - Red) / (NIR + Red)

Table 2: Specification of sensors of Landsat series

Satellite	Sensor	Red band	NIR band
Landsat 5	Thematic Mapper	Band 3 (0.63-0.69 mm)	Band 4 (0.76-0.90 mm)
Landsat 8	Thermal Infrared	Band 4 (0.636-0.673 mm)	Band 5 (0.851-0.879 mm)
Landsat 9	Thermal Infrared	Band 4(0.64-0.67 mm)	Band 5(0.85-0.88 mm)

Source: Compiled through USGS Earth Explorer Handbook

Result and Discussion:

A comparative spatial and temporal analysis of cropping patterns in Satara District for the years 2001, 2014 and 2024, revealing notable land use transformations. A key observation is the steady increase in land under high-input, high-yield crops such as wheat, rice, maize and sugarcane, rising from 41per cent in 2001 to 56 per cent in 2024. This trend reflects agricultural intensification driven by improved irrigation, mechanization and hybrid seed adoption, indicating a shift toward agro-industrial farming systems influenced by market demand and government incentives promoting food security and rural income.

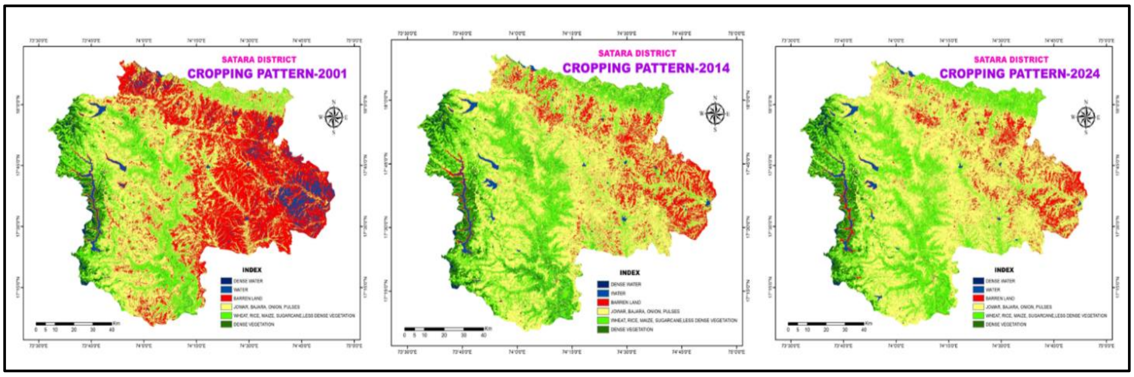

Figure 3: Spatial Analysis of Cropping Pattern classes in Satara District.

Figure 4 highlights a rise in dense vegetation cover from 17 per cent in 2001 to 27 per cent in 2014, maintaining that level through 2024. This improvement is likely the result of afforestation efforts, watershed management and ecological zoning

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policies. However, the lack of growth post-2014 suggests either limited land availability for further restoration or diminishing policy momentum, raising concerns about ecological sustainability in the face of climate change. In contrast, the area under traditional rain-fed crops such as jowar, bajra, onions and pulses declined sharply from 15 per cent in 2001 to 6 per cent in 2024. This reduction indicates a loss of crop diversity, possibly due to economic preferences for cash crops and reduced rainfall reliability. Such a transition away from resilient and nutrition-rich crops may have long-term consequences for soil health, groundwater balance, and food security. Water related land use also shows decline: dense water bodies decreased from 4per cent to 1per cent, and other water areas from 5 per cent to 1 per cent between 2001 and 2024. These reductions point to growing hydrological stress, driven by irrigation demands and inadequate water conservation. Meanwhile, barren land reduced from 18 per cent to 9 per cent, reflecting increased land utilization. While positive for agricultural expansion, this also amplifies ecological pressure. Overall, these patterns underscore the urgent need for integrated land and water resource management to ensure sustainable agricultural development in Satara District.

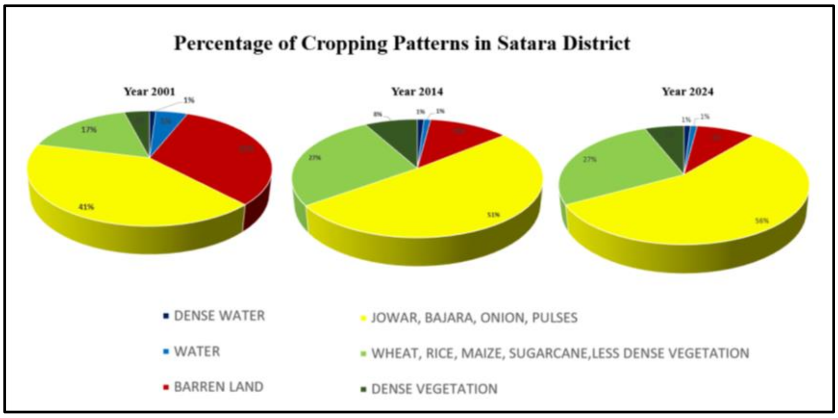

Figure 4: Percentage Distribution of Cropping Pattern Classes in Satara District

Validation:

The validation of the NDVI based cropping pattern analysis for Satara District (2001–2024) was carried out using a combination of field observations, secondary data sources and satellite image comparisons. Ground truthing through selective field visits and farmer interactions helped confirm the presence of dominant crop types such as sugarcane, wheat, and pulses, particularly in the Rabi and kharif seasons. These observations supported the NDVI-derived classification results, especially in identifying high-yield cropping areas. In addition, agricultural data from published socio-economic abstracts of Satara district were used to verify trends in cropping patterns. The documented increase in irrigated and high-input crops like sugarcane and wheat correlated well with the rise in NDVI values over the years, further reinforcing the accuracy of the remote sensing analysis. Where applicable, supervised classification accuracy was assessed using reference points to generate confusion matrices, with overall accuracy exceeding 85per cent and Kappa coefficients above 0.80, indicating strong agreement. These multi-source validation efforts confirm the reliability of NDVI as a tool for detecting cropping pattern dynamics, making it a valuable approach for regional agricultural monitoring and policy planning.

Conclusion:

This study presents a comprehensive spatio-temporal analysis of cropping pattern dynamics in Satara District over the period 2001 to 2024 using remote sensing and GIS techniques. The findings reveal a marked transformation from traditional, rain-fed cropping systems to high-input, commercial agriculture dominated by crops like sugarcane, rice and wheat. While this shift reflects increasing agricultural intensification supported by improved irrigation infrastructure and policy incentives, it also raises significant environmental concerns, including groundwater depletion, reduction in crop diversity and declining water bodies. The reduction in traditional crops such as jowar, bajara and pulses highlights a worrying trend of declining climate-resilient agriculture, which is crucial for long-term food and nutritional security. Simultaneously, the decline in water bodies and barren land, along with stabilization in dense vegetation areas, signals ecological stress in response to expanding agriculture and limited land availability. The integration of multi-temporal satellite imagery, NDVI has proven effective in monitoring these changes at high spatial and temporal resolutions. This study underscores the urgent need for sustainable land and water management strategies, agro-ecological planning and crop diversification policies to ensure environmental sustainability while meeting the demands of agricultural productivity. It also reinforces the value of geospatial technologies in shaping data-driven, region-specific interventions for sustainable agricultural development in semi-arid regions like Satara.

Recommendations:

To ensure sustainable agriculture in Satara District, crop diversification and promotion of traditional, climate-resilient crops are essential. Efficient irrigation methods and integrated water resource management should be adopted to address water stress. Remote sensing tools must be institutionalized for real-time monitoring and planning. Policies should prioritize ecological balance alongside agricultural productivity.

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

References:
1. *Agawane, R., & Jadhav, S. (2023).* Agricultural transformation and sustainability challenges in Western Maharashtra. *Journal of Rural Studies, 38(3), 112–128.*
2. *Begue, Agnes, Damien Arvor, Beatriz Bellon, Julie Betbeder, Diego De Abelleyra, Rodrigo P. D. Ferraz, Valentine Lebourgeois, Camille Lelong, Margareth Simões, and Santiago R. Verón. (2018).* Remote Sensing and Cropping Practices: A Review. *Remote Sensing, 10(1), 99. https://doi.org/10.3390/rs10010099*
3. *Bharathkumar, L., & Mohammed-Aslam, M. A. (2015).* Crop Pattern Mapping of Tumkur Taluk Using NDVI Technique: A Remote Sensing and GIS Approach. *Aquatic Procedia, 4, 1397–1404. https://doi.org/10.1016/j.aqpro.2015.02.181*
4. *Directorate of Economics and Statistics, Maharashtra. (2001).* District Socio-Economic Abstract: Satara. *Government of Maharashtra. Retrieved from https://mahades.maharashtra.gov.in*
5. *Directorate of Economics and Statistics, Maharashtra. (2014).* District Socio-Economic Abstract – Satara. *Government of Maharashtra. Retrieved from https://mahades.maharashtra.gov.in*
6. *Directorate of Economics and Statistics, Maharashtra. (2024).* District Socio-Economic Abstract: Satara District. *Government of Maharashtra. Retrieved from https://mahades.maharashtra.gov.in*
7. ***Indian Council of Agricultural Research** (2020).* Annual Report 2019–20. *New Delhi: ICAR. Retrieved from https://icar.org.in*
8. *Pawar, G. A. (2022).* Mapping and assessment of changing vegetation cover in Pune Division (Maharashtra). *Akshar Wangmay: International Research Journal (UGC-CARE Listed), Special Issue–V (Volume I), 162–165. ISSN: 2229-4929.*
9. *Pawar, G. A. (2022).* The relationship between rainfall and vegetation in the Pune Division (Maharashtra). *International Journal of Advanced and Applied Research, 9(5), 756–759. ISSN: 2347-7075.*
10. *Pawar, G. A. (2023).* Mapping and assessment of vegetation cover in the Banganga Basin (Maharashtra). *Education and Society (UGC-CARE Listed), Special Issue–I (Volume III). ISSN: 2278-6864.*
11. *Manjunath, K. R., More, R. S., Jain, N. K., Panigrahy, S., & Parihar, J. S. (2015).* Mapping of Rice-Cropping Pattern and Cultural Type Using Remote-Sensing and Ancillary Data: A Case Study for South and Southeast Asian Countries. *International Journal of Remote Sensing, 36(24), 6008–6030. https://doi.org/10.1080/01431161.2015.1110259*
12. *Qiu, B., Hu, X., Chen, C., Tang, Z., Yang, P., Zhu, X., Yan, C., & Jian, Z. (2022).* Maps of Cropping Patterns in China during 2015–2021. *Scientific Data, 9(1), 479. https://doi.org/10.1038/s41597-022-01589-8*
13. *Rahman, Md., & Saha, S. (2009).* Spatial Dynamics of Cropland and Cropping Pattern Change Analysis Using Landsat TM and IRS P6 LISS III Satellite Images with GIS. *Geo-Spatial Information Science, 12(2), 123–134. https://doi.org/10.1007/s11806-009-0249-2*
14. *Ray, S. S., Sood, A., Das, G., Panigrahy, S., Sharma, P. K., & Parihar, J. S. (2005).* Use of GIS and Remote Sensing for Crop Diversification — A Case Study for Punjab State. *Journal of the Indian Society of Remote Sensing, 33(2), 181–188. https://doi.org/10.1007/BF02990034*
15. *Shinde, P. S., & Mali Jadhav, V. H. (2025).* Assessment of vegetation health using NDVI derived from Landsat images: A case study of Satara District, Maharashtra. *International Journal of Advance and Applied Research, 6(6), [Jan–Feb Issue]. https://doi.org/10.5281/zenodo.15063630*
16. *Shinde, P. S., & Telore, N. V. (2025).* Drought risk assessment in the Yerla River Basin of India using remote sensing and GIS methods. *Disaster Advances, 18(4), April. https://doi.org/10.25303/184da03003630*
17. *Singh, N. J., Kudrat, M., Jain, K., & Pandey, K. (2011).* Cropping Pattern of Uttar Pradesh Using IRS-P6 (AWiFS) Data. *International Journal of Remote Sensing, 32(16), 4511–4526. https://doi.org/10.1080/01431161.2010.489061*
18. *Sonia, Ghosh, T., Gacem, A., Alsufyani, T., Alam, M., Yadav, K., Amanullah, M., & Cabral-Pinto, M. (2022).* Geospatial Evaluation of Cropping Pattern and Cropping Intensity Using Multi Temporal Harmonized Product of Sentinel-2 Dataset on Google Earth Engine. *Applied Sciences, 12(24), 12583. https://doi.org/10.3390/app122412583*
19. *Sood, A., Choudhury, B. U., Ray, S. S., Jalota, S. K., Sharma, P. K., & Panigrahy, S. (2009).* Impact of Cropping Pattern Changes on the Exploitation of Water Resources: A Remote Sensing and GIS Approach. *Journal of the Indian Society of Remote Sensing, 37(3), 483–491. https://doi.org/10.1007/s12524-009-0033-7*
20. *Tilekar, P. (2024).* Cropping pattern dynamics and agro-ecological transition in Satara District. *Satara Research Journal, 12(1), 45–58.*