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AGRICULTURAL TRANSFORMATION USING GIS AND SATELLITE IMAGE DATA IN NANDURBAR DISTRICT, MAHARASHTRA

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Abstract

This study investigates land use and land cover (LULC) changes and agricultural transformation in Nandurbar District, Maharashtra, India, between 2015 and 2025 using Geographic Information System (GIS) and remote sensing techniques. The analysis reveals significant shifts in land use patterns, with agricultural land expanding by 10.24% at the expense of barren land (-9.52%) and forest cover. Improved irrigation infrastructure has driven this transformation, particularly in regions like Shahada and Nandurbar talukas, which exhibit higher agricultural productivity. Conversely, rain-fed areas such as Akkalkuwa and Dhadgaon face productivity challenges due to degraded soil quality and limited irrigation. Normalized Difference Vegetation Index (NDVI) analysis indicates a positive trend in vegetation health, with moderate to dense vegetation increasing by 22.39% and 7.48%, respectively, while barren land decreased by 26.57%. The study highlights the role of GIS and remote sensing in monitoring agricultural changes and underscores the need for sustainable water management, crop diversification, and policy interventions to address regional disparities and ensure long-term agricultural resilience.

Keywords: Agricultural transformation, GIS, Remote Sensing, LULC, NDVI.

Introduction

Agriculture is the backbone of rural economies, particularly in regions like Nandurbar District, Maharashtra, where it serves as the primary livelihood for a majority of the population. However, rapid population growth, climate change, and resource constraints have necessitated the adoption of advanced technologies to optimize agricultural practices. Geospatial technologies, such as Geographic Information Systems (GIS) and remote sensing, have emerged as powerful tools for monitoring and managing agricultural landscapes. These technologies enable the analysis of land use patterns, vegetation health, and the impact of policy interventions, providing a comprehensive understanding of agricultural dynamics (Verma et al., 2020).

Land Use and Land Cover (LULC) analysis is essential for understanding agricultural expansion, land degradation, and changes in cropping patterns. Studies by Singh and Sharma (2019) have demonstrated the effectiveness of satellite imagery in tracking cropping patterns and soil moisture variations, contributing to sustainable land management practices. Additionally, vegetation indices such as the Normalized Difference Vegetation Index (NDVI) and Soil-Adjusted Vegetation Index (SAVI) are widely used to assess vegetation health, which directly influences agricultural productivity (Patel et al., 2021).

GIS has also proven valuable in evaluating soil and water resources. Gupta et al. (2018) demonstrated that integrating GIS with hydrological models helps identify water-stressed areas, optimizing irrigation strategies. Spatial analysis of groundwater recharge potential zones has further enhanced water resource management, particularly in semi-arid regions (Mishra & Rao, 2022). These tools enable the identification of critical areas for water conservation, promoting agricultural sustainability.

The socio-economic impacts of agricultural land use changes are significant. Shifts in land use, driven by market demands and policy interventions, directly affect rural livelihoods. Kumar and Mehta (2020) highlighted how these changes influence socio-economic conditions in rural areas. Bhattacharya et al. (2023) explored the role of geospatial technology in precision farming, demonstrating that real-time monitoring can improve productivity and sustainability.

This study utilizes GIS and satellite image data to analyse agricultural transformation in Nandurbar District. By incorporating LULC analysis, NDVI, and other remote sensing techniques, the research aims to provide a comprehensive framework for assessing the impacts of agricultural transformation. The findings will offer insights into the effectiveness of modern technologies in agricultural management and inform policies aimed at ensuring sustainable development and improving agricultural productivity in the region.

Objectives

1. To analyse agricultural transformation in Nandurbar District using GIS and satellite imagery to detect LULC changes over time and understand the spatial dynamics of agricultural practices.
2. To evaluate agricultural productivity and vegetation health through satellite-derived vegetation indices such as NDVI and assess their correlation with crop growth and overall agricultural output.

Study Area

Nandurbar District, located in northern Maharashtra, is characterized by undulating terrain. Agriculture is the primary livelihood source for the majority of the population. The district experiences seasonal rainfall patterns, which significantly influence the cropping calendar and agricultural productivity. Major crops include cotton, sorghum, pulses, and millet, which are well-suited to the region's climate and soil conditions.Over the years, the district has witnessed significant agricultural transformations, driven by improvements in irrigation practices, soil conservation measures, and government interventions. The introduction of irrigation systems and soil management techniques has led to shifts in cropping patterns and crop diversification. Government initiatives have aimed to enhance agricultural productivity and resilience to climate variability.The reliance on rain-fed agriculture and the dynamics of agricultural transformation underscore the importance of sustainable land management strategies to improve food security, water conservation, and overall agricultural productivity. This study focuses on analysing these transformations using

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GIS and satellite imagery to understand long-term trends and their impacts on the region's agricultural landscape.

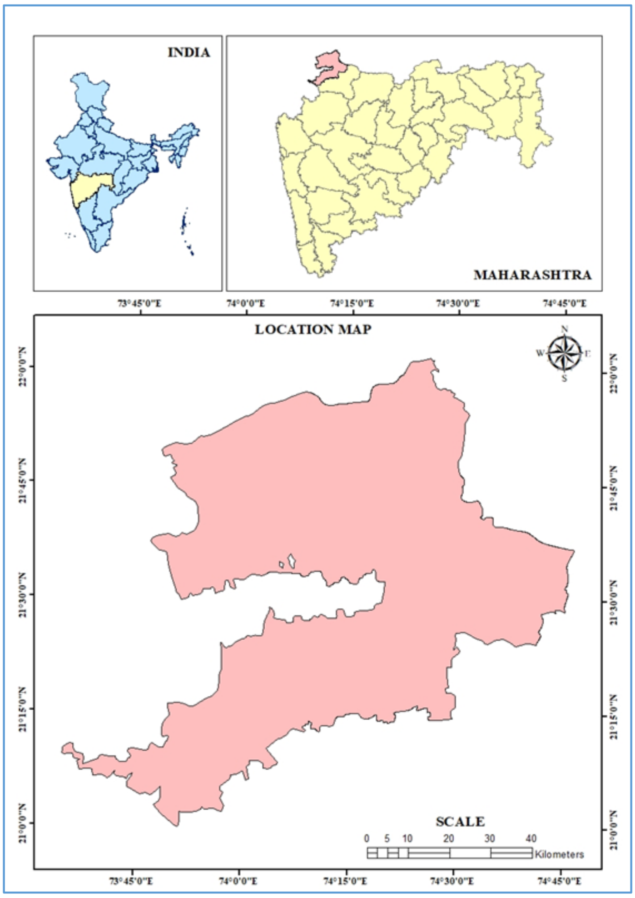

Fig. No. 1 Location Map

Methodology

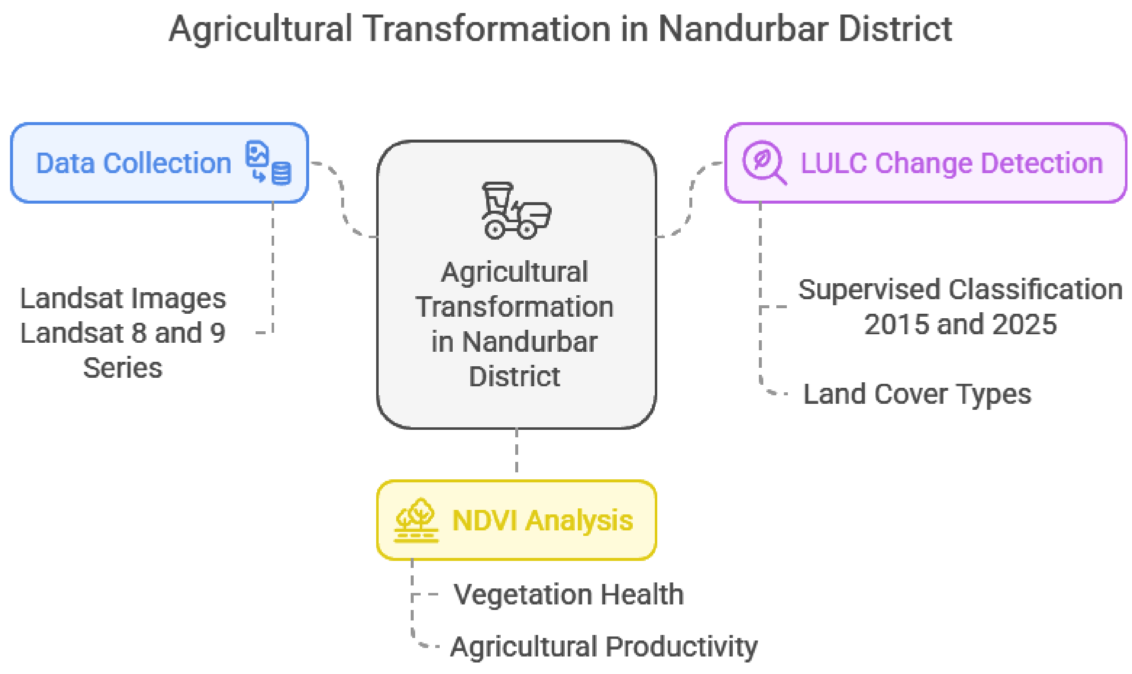

Fig. No. 2Research Methodology

The study employs a GIS-based approach, integrating satellite image data, remote sensing techniques, topographical maps, and agricultural statistics. The methodology involves the following steps:

1. **Data Collection:** Satellite images from Landsat 8 and 9 were acquired for multiple years (2015 and 2025) to facilitate LULC change detection. NDVI was calculated using the near-infrared (NIR) and red bands of the satellite imagery to assess vegetation health and agricultural productivity.
2. **LULC Change Detection:** Supervised classification techniques were used to categorize land cover into classes such as agricultural land, forest, water bodies, and urban areas. Change detection analysis quantified land cover changes over the study period.
3. **NDVI Analysis:** NDVI was computed for each satellite image to assess vegetation health. The formula used is: **NDVI = (NIR+R) / (NIR−R)**

NDVI values range from -1 to +1, with higher values indicating healthier vegetation.

Table No. 1. NDVI Values and Vegetation Class.

NDVI Range	Vegetation Class	Description
-1.0 to 0.0	Water Bodies	Lakes, rivers, and water surfaces with no vegetation.
0.0 to 0.2	Barren Land/Soil	Bare soil, rocks, and non-vegetated surfaces.
0.2 to 0.4	Sparse Vegetation	Degraded vegetation, fallow lands, dry grasslands.
0.4 to 0.6	Moderate	Healthy crops, shrubs, and semi-dense vegetation.

	Vegetation	
0.6 to 0.8	Dense Vegetation	Well-growing crops, dense agricultural fields, and forests.
0.8 to 1.0	Very Dense Vegetation	Thick, well-irrigated vegetation, mature forests.

Results and Discussion

1. LULC Analysis: LULC analysis indicates that agricultural land has expanded in response to improved irrigation infrastructure, whereas forest and barren lands have declined. The spatial analysis based on satellite image data suggests that agricultural transformation is more significant in regions with better irrigation facilities, while rain-fed areas continue to face productivity challenges. The findings emphasize the role of GIS and satellite data in monitoring agricultural changes and formulating policies for sustainable development.

The analysis revealed significant shifts in land use patterns in Nandurbar District between 2015 and 2025. Agricultural land expanded significantly, primarily at the expense of forest cover and barren land. This transformation reflects a shift toward more intensive agricultural practices, driven by increasing demand for food and livelihood security. The results indicate a [See Table 2] increase in agricultural land over the decade, underscoring the district's growing reliance on agriculture.

Table No. 2. Land use / Land Cover Analysis percentage (2015 and 2025)

Sr.No.	LU/LC Class	Area % (2015)	Area % (2025)	% Change
1	Barren Land	49.44	39.91	-9.52
2	Agriculture	37.29	47.54	10.24
3	Water	0.66	1.42	0.75
4	Settlement	9.37	10.02	0.66
5	Other	3.24	1.11	-2.13
Total		100.00	100.00	0.00

The analysis of land use/land cover (LU/LC) changes reveals significant shifts in land utilization over time. A notable decline of 9.52% in barren land suggests increased land development, likely due to agricultural expansion or urbanization. Correspondingly, agricultural land has expanded by 10.24%, indicating a transformation of previously uncultivated areas into farmland, possibly driven by increased agricultural activities and improved irrigation. Additionally, water bodies have shown a slight increase of 0.75%, which may be attributed to better water conservation measures or seasonal variations.

Furthermore, settlements have grown by 0.66%, reflecting ongoing urban expansion and infrastructure development. On the other hand, land classified under "Other" has decreased by 2.13%, which may indicate the conversion of mixed or wasteland areas into more productive uses such as agriculture or settlements. Overall, the trend highlights a shift towards intensified land use, emphasizing agricultural dominance and urban growth, with potential socio-economic and environmental implications that warrant further investigation.

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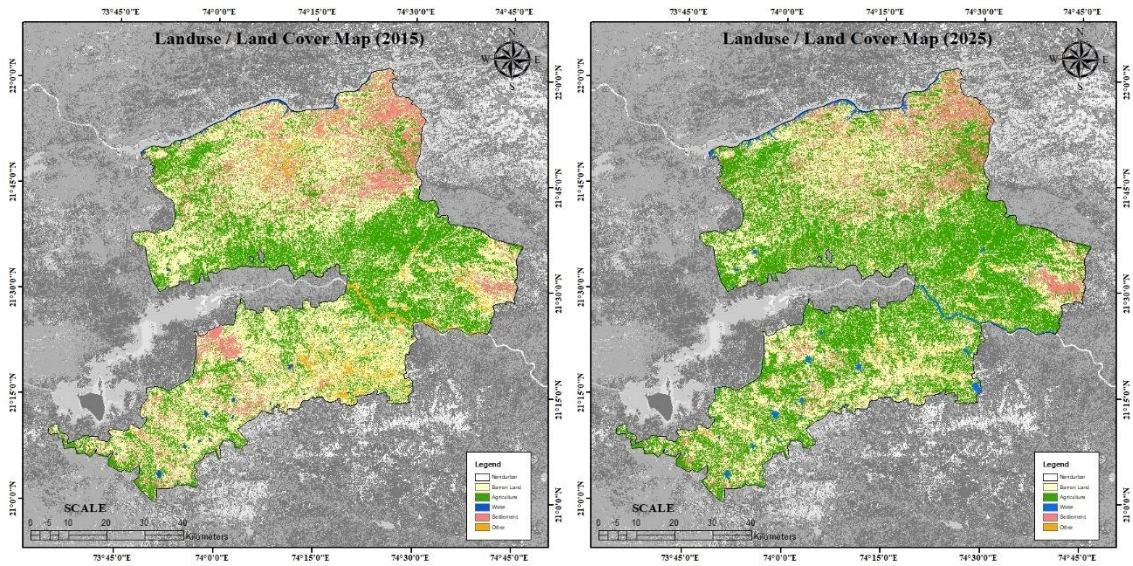

Fig. No. 3 Land use / Land Cover Map (2015 and 2025)

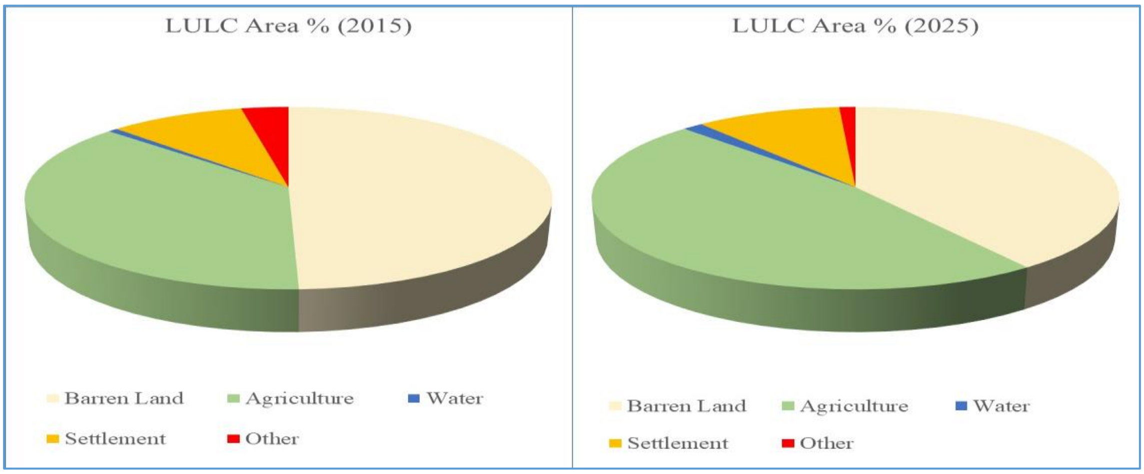

Fig. No. 4Land use / Land Cover Area (2015 and 2025)

2. NDVI Analysis: Table No. 3 presents the land cover changes based on NDVI classification between 2015 and 2025. A significant shift in vegetation cover is observed, indicating an overall improvement in vegetation health and land productivity.

Table No. 3. NDVI Analysis Percentage (2015 and 2025)

Sr. No.	NDVI Range	Vegetation Class	Area % (2015)	Area % (2025)	% Change
1	-1.0 to 0.0	Water Bodies	0.62	0.86	0.24
2	0.0 to 0.2	Barren Land/Soil	27.91	1.34	-26.57
3	0.2 to 0.4	Sparse Vegetation	52.37	48.18	-4.19
4	0.4 to 0.6	Moderate Vegetation	16.61	39.00	22.39
5	0.6 to 0.8	Dense Vegetation	2.40	9.88	7.48
6	0.8 to 1.0	Very Dense Vegetation	0.09	0.73	0.65

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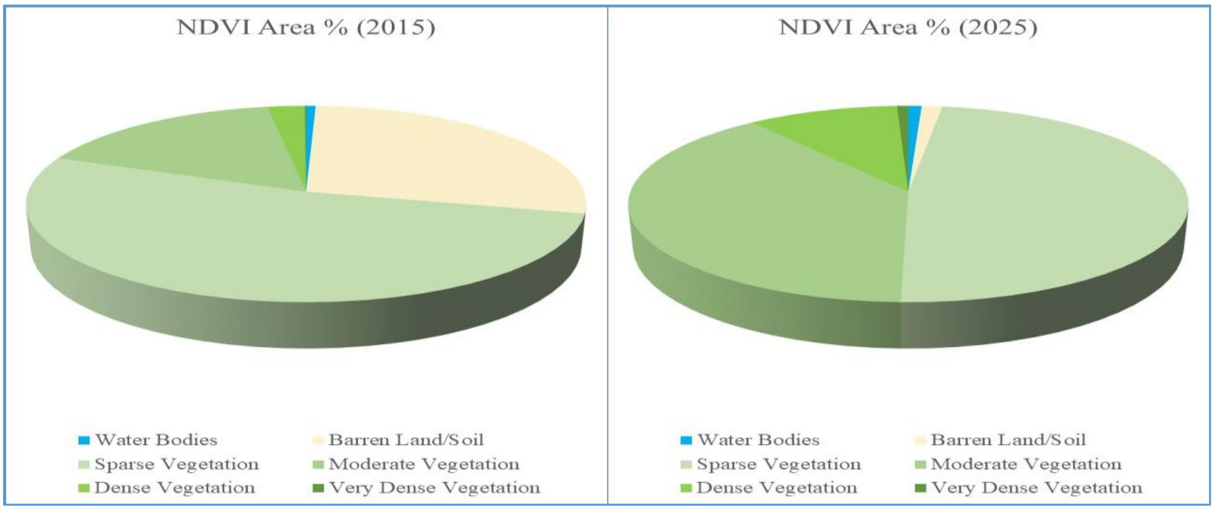

Fig. No. 5NDVI Area (2015 and 2025)

The **Barren Land/Soil category (0.0 to 0.2 NDVI)** has drastically decreased by **-26.57%**, suggesting extensive land rehabilitation, afforestation, or increased agricultural activities. This reduction is complemented by a substantial increase in **Moderate Vegetation (0.4 to 0.6 NDVI)**, which has expanded by **22.39%**, indicating improved vegetation health, possibly due to better irrigation, afforestation, or sustainable land use practices. Similarly, **Dense Vegetation (0.6 to 0.8 NDVI)** has increased by **7.48%**, and **Very Dense Vegetation (0.8 to 1.0 NDVI)** has grown by **0.65%**, reinforcing the trend of increasing green cover.

Meanwhile, **Sparse Vegetation (0.2 to 0.4 NDVI)** has decreased by **-4.19%**, likely due to vegetation growth shifting toward moderate and dense classes. The **Water Bodies (-1.0 to 0.0 NDVI)** have increased slightly by **0.24%**, suggesting improvements in water availability or conservation efforts.

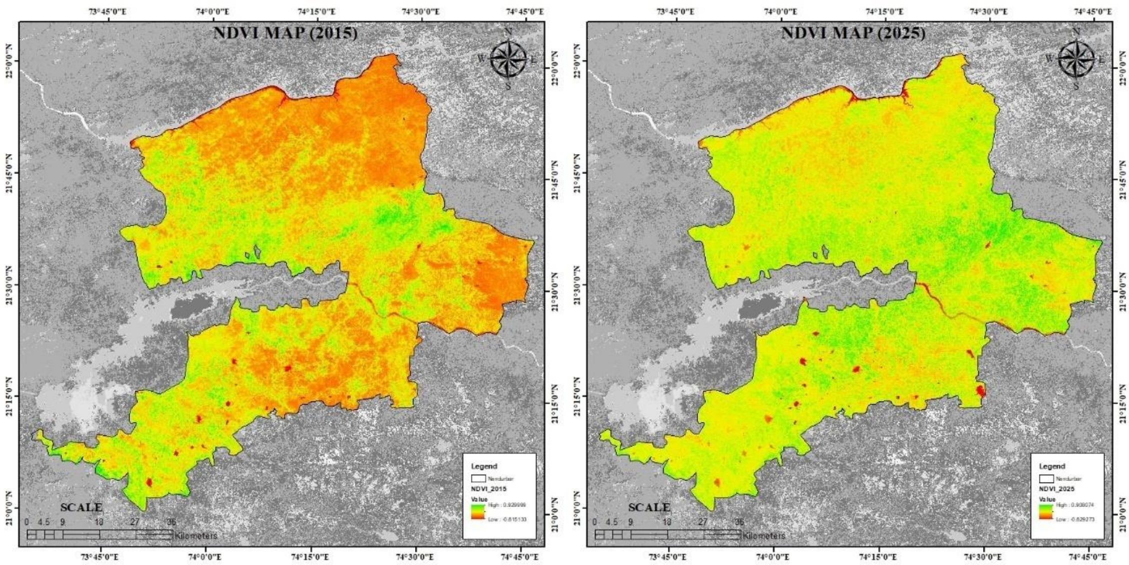

Fig. No. 6NDVI Map (2015 and 2025)

The data suggests a positive shift in vegetation health, with barren land declining and moderate to dense vegetation increasing. These changes may be attributed to afforestation,

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improved agricultural practices, soil conservation measures, and favourable climatic conditions. However, further analysis of land management policies, rainfall patterns, and human interventions is necessary to understand the sustainability of this trend.

3. Validation of Agricultural Transformation Analysis: Nandurbar district, located in the northwestern part of Maharashtra, has witnessed notable agricultural transformation due to changing climatic conditions, evolving irrigation infrastructure, and advancements in remote sensing applications. The district, comprising six talukas—Nandurbar, Akkalkuwa, Taloda, Shahada, Navapur, and Dhadgaon—exhibits spatial variations in agricultural productivity. The integration of Geographic Information System (GIS) and remote sensing techniques has provided valuable insights into land use changes, cropping patterns, and soil moisture variability, aiding in sustainable agricultural planning.

1. **Agricultural Productivity Trends:** Agricultural productivity across Nandurbar district varies significantly due to factors such as soil fertility, irrigation facilities, and rainfall patterns. GIS-based land use land cover (LULC) analysis has revealed a shift from traditional rain-fed farming to irrigated agriculture in select areas. Shahada and Nandurbar talukas exhibit higher agricultural productivity, particularly in sugarcane, soybean, and cotton cultivation, due to improved irrigation coverage and fertile alluvial soil. In contrast, Akkalkuwa and Dhadgaontalukas, characterized by hilly terrain and degraded soil quality, show low productivity with dominant crops like jowar, bajra, and pulses. Navapur and Talodatalukas demonstrate moderate productivity, with rice, oilseeds, and pulses being the major crops.
2. **Climate and Soil Influences on Agricultural Transformation:** The district experiences a semi-arid climate with an average annual rainfall of 700-1,200 mm, largely concentrated in the monsoon season. Remote sensing-based NDVI (Normalized Difference Vegetation Index) analysis indicates significant vegetation stress in drought-prone regions, particularly in Akkalkuwa and Dhadgaon. Soil analysis using GIS shows sandy loam and black soil dominance, with high organic matter in irrigated zones but low moisture retention in rain-fed areas. Changes in soil moisture index (SMI) and NDWI (Normalized Difference Water Index) values have been used to monitor water availability trends and their correlation with crop yield variations.
3. **Irrigation and Water Resource Management:** Irrigation coverage varies across talukas, significantly impacting agricultural transformation. Shahada and Nandurbar have the highest irrigation penetration, benefiting from projects like the Upper Tapi Irrigation Scheme and well-based irrigation systems. Conversely, Akkalkuwa and Dhadgaon remain highly dependent on monsoon rainfall, with limited irrigation sources. GIS-based groundwater potential zone mapping indicates depleting water tables in semi-arid regions, necessitating rainwater harvesting and micro-irrigation techniques for sustainable water use.
4. **Policy Interventions and Future Strategies:** Several government schemes, such as the Pradhan Mantri KrishiSinchayeeYojana (PMKSY) and Mahatma Phule Jal Abhiyan, have facilitated watershed development and micro-irrigation adoption. However, policy gaps

exist in market accessibility, crop diversification, and soil conservation practices. GIS-based agricultural risk mapping suggests the need for drought-resistant crop varieties, precision agriculture adoption, and improved storage and processing infrastructure to enhance productivity and resilience.

Discussion

The findings of this study highlight the transformative role of GIS and remote sensing in monitoring agricultural landscapes. LULC and NDVI analyses reveal significant agricultural expansion in Nandurbar District, driven by improved irrigation and food demand, but at the cost of declining forest cover and barren land, raising concerns about deforestation and land degradation. NDVI trends show improved vegetation health, indicating effective land management, yet regional disparities in productivity between irrigated and rain-fed areas persist, necessitating targeted interventions.Policymakers can use these insights to promote sustainable practices, enhance food security, and address climate challenges. Strategies like expanding irrigation, adopting drought-resistant crops, and conserving soil and water can bridge productivity gaps. Integrating socio-economic data with remote sensing can further inform evidence-based decisions.This study emphasizes balancing agricultural growth with environmental sustainability. Future research should focus on long-term land use monitoring, socio-economic impacts, and innovative solutions for sustainable resource management, ensuring a resilient and equitable agricultural system in Nandurbar District.

Conclusion

The findings of this study demonstrate significant land use and agricultural transformation in Nandurbar District between 2015 and 2025. Agricultural land has expanded substantially, driven by improved irrigation infrastructure and increasing food demand, while barren land and forest cover have declined. NDVI analysis reveals improved vegetation health, with moderate and dense vegetation classes showing notable increases, indicating positive impacts of afforestation, irrigation, and sustainable land use practices. However, regional disparities in agricultural productivity persist, with rain-fed areas like Akkalkuwa and Dhadgaon lagging behind irrigated regions such as Shahada and Nandurbar. The integration of GIS and remote sensing has proven invaluable in monitoring these changes and informing policy decisions. To ensure sustainable agricultural development, future strategies should focus on enhancing irrigation coverage, adopting drought-resistant crops, and implementing soil and water conservation measures. Policy interventions must address market accessibility, crop diversification, and infrastructure development to bridge productivity gaps and build resilience against climatic variability. This study underscores the importance of leveraging geospatial technologies for informed decision-making and sustainable land management in semi-arid regions.

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