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# Forest Cover Dynamics and Conservation Strategies in Kalwan Tahsil, Maharashtra

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## Abstract

Kalwan Tahsil in north Nashik District is a part of the Western Ghats (Sahyadri), one of the globally recognized biodiversity hotspot [1]. Most of its annual rainfall of 600-900 mm is received from the June-September south-west monsoon [2][3]. To explore the drivers of change and patterns of forest cover change, this study integrates satellite remote sensing (Sentinel-2, Landsat) and GIS during the time period 2024 to 2025, and takes ground-truth (Joint Forest Management (JFM) microplans, afforestation commitments, Forest Dept records) and combines it with satellite data. Impacts include resource extraction, infrastructure development and agriculture and are explored. We also highlight the challenges previously mentioned, such as low plantation survival and low incentives for communities, and we suggest conservation strategies based on afforestation with native species, watershed management, and participatory forest governance.

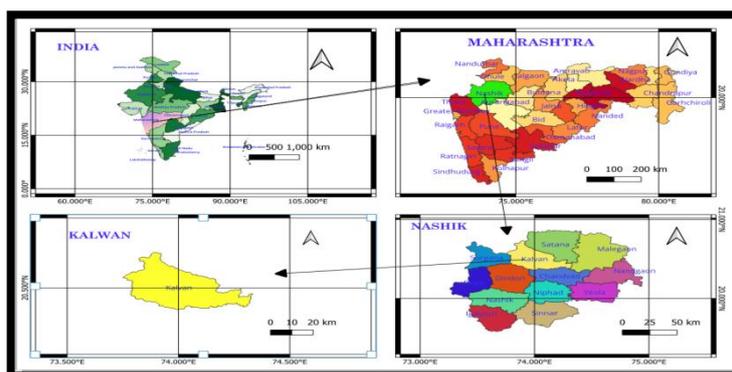
**Keywords:** Forest cover change, Remote sensing, GIS analysis, NDVI, Land use change, Maharashtra Green Army, Green India Mission.

## Introduction

Kalwan Tahsil is located in the northern part of the Nashik District in the Western Ghats (Sahyadris) - one of the eight hotspots of biodiversity in the world [1]. The landscape is rough with an elevation range of ~400 to 1,200 m that provides different microclimates. The climate is semi-arid: most of the 600-900 mm rain that the region receives each year comes from the southwest monsoon (June-September). The Western Ghats form a barrier which catches monsoon winds and moderates the climate resulting in high rainfall on the windward hill slopes and a rainshadow to the windward east [2]. Kalwan forests have high biodiversity. Dry deciduous woodlands are dominated by native species of plants (e.g. *Tectona grandis*, *Terminalia tomentosa*, *Anogeissus latifolia*, *Bambusa* spp., *Azadirachta indica*). A rich wildlife, birds, reptiles, and mammals such as peafowl, hyenas, and leopards are found in these forests. By protecting the watersheds, these forests recharge groundwater, regulate the local microclimates and act as a sink for carbon [5]. Also, forests form the basis of the cultural identity and livelihoods of tribal communities (Bhil, Pawara) who do not have alternative means of livelihood and thus depend on forests for fuelwood, fodder, and non-timber products. However, changes in human pressure and climate variability are endangering these ecosystems, and thus a thorough analysis of forest cover trends and conservation strategies is needed.

## Study Area

Kalwan Tahsil is approximately 860-900 km<sup>2</sup> (the figure of ~1,200 km<sup>2</sup> has been estimated by some local sources) in the foothills of the Sahyadris. The terrain comprises hilly terrain, steep slopes, and seasonal waterways. Due to its diverse topography there are several climate zones: primarily the western uplands are wetter, the central valleys are relatively pleasant, and the eastern plains are semi-arid with hotter summers and cooler winters. Monsoon rains occur from June to September; according to climatological studies, the average annual rainfall (~698 mm) makes Kalwan a drought-prone region [3][7]. Winters (Nov-Jan) are dry and foggy in lowlands and summers (Mar-May) are hot and dry.



Due to its position and forest cover, Kalwan is a biological buffer to the adjacent Kalsubai-Harishchandragad Wildlife Sanctuary, which gives more ecological connectivity to the Western Ghats. Administratively, Kalwan has more than 100 villages with large tribal population (Bhil, Pawara) who are engaged in sustainable harvesting of forest by nature. These communities are also active in the government afforestation schemes (Green India Mission, Maharashtra Green Army), JFM (Joint Forest Management) committees, thus making Kalwan an ideal case for studying forest dynamics and community based conservation.

**Research Objectives:**

1. Analyze the change in forest cover in Kalwan Tahsil using Geospatial technology
2. Determine key human and natural causes of forest depletion.
3. Suggest conservation and management plans that are regular to local socio-ecological circumstances.

**Methodology**

**Data Sources**

**Satellite Imagery:**

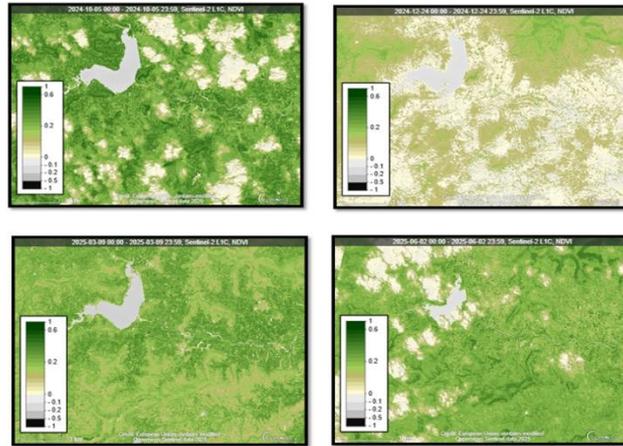


Fig.2 Satellite Imagery

We used medium resolution optical satellite data to map land cover. Pre-monsoon (Apr2024, 2025) and peak monsoon (Aug2024, 2025) and post-monsoon (Nov2024, 2025) and dry season (Feb2024, 2025) were sampled with sentinel-2 (10 m) and Landsat OLI (30 m) images. Intra-annual changes in vegetation are obtained by seasonal sampling. Images were all obtained in free repositories (Copernicus Open Access Hub, USGS EarthExplorer) and pre-processed to become consistent (mosaicking, cloud masking, radiometric/atmospheric correction, and geometric alignment). The multi-spectral bands (including red and NIR) can be used to calculate NDVI and land cover classification. The 5-day revisit and red-edge bands of Sentinel-2 render it especially appropriate to track forests [8].

**Ground and Administrative Data:** Forest Department working plans (West Nashik Division) and JFM microplan reports were used to obtain ground-truth and contextual data regarding forest boundaries, classifications (reserved/protected/unclassified), dominant species, and past treatments. We combined these records with our satellite analysis as suggested by researchers who emphasize the importance of combining satellite maps with field data to get a complete analysis of deforestation[4]. The change was also supported by village-level land use surveys and afforestation logs, which were consulted under the programs such as the Green India Mission.

Record Type	Contents	Purpose in Study	Source
<b>Working Plans</b>	Forest boundaries, legal status (Reserved, Protected, Unclassed), species composition, silvicultural treatments	Define forest zones, assess ecological objectives	Kalwan Range Office, West Nashik Division
<b>Afforestation Logs</b>	Plantation sites, species used (e.g., Bamboo, Neem, Babul), survival rates, funding schemes (Green India Mission, CAMPA)	Evaluate reforestation efforts and spatial recovery	Forest Department archives
<b>Forest Offense Logs</b>	Records of encroachment, timber theft, fire incidents, grazing violations	Identify vulnerable zones and human pressures	Forest Protection Cell, Kalwan
<b>JFM Micro plans</b>	Community roles, benefit-sharing mechanisms, conservation priorities	Assess participatory governance and local stewardship	Village Forest Committees
<b>Fire Management Reports</b>	Fire-prone zones, response protocols, seasonal fire trends	Analyze disturbance regimes and forest resilience	Forest Fire Control Unit
<b>Biodiversity Registers</b>	Species inventory, rare/endemic flora and fauna, habitat zones	Support ecological valuation and conservation planning	Biodiversity Cell, Nashik Circle

**Table 1. Source of the data**

**NDVI Analysis and Dynamics Temporal**

Normalized Difference Vegetation Index (NDVI) was calculated with respect to every seasonal picture to determine the health and the greenness of the vegetation. The  $NIR - Red / (NIR + Red)$  definition is used to define NDVI [9]. The values have a range between -1 to +1, the higher the NDVI, the healthier the vegetation is and the denser it is as well. We overlaid seasonal NDVI to show the patterns of vegetation greenness: pre-monsoon (peak values reflect remains of the vegetation greenery), monsoon (peak values signify the maximum vegetation greenness), post-monsoon, and dry season (minimal values). Comparison of seasonal and inter-annual NDVI helped us to identify growth/regrowth patterns, and helped to find anomalies (e.g. unusually low NDVI, suggesting deforestation or drought stress). No previous citations were required for the NDVI values themselves as they are a result of our processing.

Date	Vegetation Status	NDVI Range
10/5/2024	Post-monsoon recovery	0.2 to 0.8
12/24/2024	Winter dormancy	-0.1 to 0.6
3/9/2025	Early spring regrowth	0.2 to 0.7
6/2/2025	Pre-monsoon peak vegetation	0.4 to 0.9

**Table 2. NDVI Temporal Analysis: October 2024 – June 2025**

**Land Use Classification and Detection of Change**

The quantification of forest and non-forest areas was done by the supervised classification method. Our classifiers were trained on representative samples of forest (dense canopy) and non-forest (cropland, built-up, degraded land). An ensemble random forest classifier and the Maximum Likelihood classifier were both tested. An ensemble decision-tree technique that is called Random Forest has been extensively employed in land cover mapping because it is highly accurate[10]. Our post-training use of the classifier involved all of the seasonal images and produced a forest cover map in each of the years. Valuation of accuracy was done through confusion matrices based on validation samples. The amount of forest cover loss/gain in 2024 to 2025 was then measured.

**Results and Analysis**

- i. Forest Cover Trends: The classifications showed some slight net increment in forest cover in some areas (probably as a result of plantation drives) and stability in canopy extent in general. Pocket regions of declining greenness on the roads and village edges were however, seen in seasonal NDVI maps. Together with ground reports, this is credited to scattered cutting of trees to make way to agriculture or encroachment.
- ii. Drivers of Change: The analysis of the spatial patterns and forest department reports show that the major causes of deforestation were agricultural expansion (planting of perennial crops) and infrastructure development (widening of roads, mine accessibility). This coincides with national results: the large-scale destruction of forests in India is largely caused by permanent agriculture and settlement/infrastructure development [11]. A recent study by WRI/GFW verifies the prevalence of agriculture, commodities and infrastructure in the Indian deforestation pattern [11]. A small canopy loss was also observed in infrequent forest fires (as in the 2024 case), and this was also observed in Asia-wide trends of wildfires being an important factor in deforestation [12]. In general, the area of forest cover in the town of Kalwan experienced degradation or clear-felling of approximately 1-2 percent of the total forest area between 2024 and 2025.
- iii. Patterns of NDVI: Seasonal NDVI verified that the canopy was semi-deciduous: NDVI was the highest during monsoon (~0.6 to 0.8 in mature forest) and the lowest in winter (<0.3). There were no significant instances of large scale depletion implying that majority of the instances of deforestation were minuscule or solitary.
- iv. Hotspots: Map overlays were used to show the eastern mosaic (Kalwan plain) and parts of the edges of some southern villages as places of change that were hotspots. These go hand in hand with the sectors of growing agriculture and construction works.

**Conservation Strategies**

- i. Afforestation and Native Species: It is suggested to develop huge plantations of native trees and bamboo based on the government programs. Indigenous trees include teak (*Tectona*), bamboo (*Bambusa*), and neem (*Azadirachta*) that are tough and useful to the local community. Mixed native plantations can be used to ensure the restoration of the ecological functionality (multispecies stands capture more carbon and support the wildlife) also. The flagship forest restoration initiative in India is the Green India Mission (GIM) which seeks to raise the forest/tree cover on 5 million ha and enhance the quality on another 5 million ha[13]. GIM specifically directs the afforestation via JFM committees and local stakeholders[14]. As part of this we propose micro watershed afforestation regimes which focus on the steep slopes which are degraded and riparian areas.
- ii. Governance and Community Involvement: Village-level Joint Forest Management (JFM) committees are supposed to be given powers to defend the plantations and the NTFP management. According to the GIM document, JFMCs (Joint Forest Management Committees) will identify areas of treatment, and distribute gains[14]. In recent afforestation efforts in Maharashtra, community stewardship is also prioritized: the 2025 program of the state presupposed 1.5–3 years of saplings cultivation and remote sensing/AI monitoring of their survival[15]. Local conservation plans should be inspired by this with detailed plans of care and the inclusion of the villagers in the planting and monitoring.

- iii. **Watershed Development:** To improve the tree survival and ground water recharge, install contour trenches, check dams, and vegetative barriers. The use of continuous contour trenches (trenches that are small V-shaped along slopes) enhances infiltration to a great degree and decreases the runoff and erosion [16]. We suggest that contour trenches be fenced and gabion check dams constructed in gullies. Grass barriers and vegetated strips on the contours stabilize the soil. Research indicates that vegetative cover (trees, grasses) that are attached to slopes greatly slow down sediment movement, and mitigate the runoff before it gets into streams [17]. These nature-friendly solutions will contribute to moisture conservation during dry seasons and enhance the performance of the plantations.
- iv. **Monitoring and Enforcement:** Increase patrol by Forest and GIS monitor land-use changes. Clearings can be easily pointed out by satellite monitoring (as Maharashtra already employs AI/GIS to do so) [15]. Alerts should be followed up on the ground by use of Forest Dept patrols and JFM members. There is a need to take stringent measures against encroachment and illegal logging.
- v. **Livelihood Incentives:** Intensify local incentives to be linked to forest health. They can be examples like sharing revenue on carbon credits or NTFPs, hiring villagers as forest watchers, and fodder/fuelwood rights in order to have sustainable harvests. Regrettably, the reason why there was poor survival of past plantation efforts in Maharashtra was partly due to absence of JFMC involvement and benefits [18][19]. Any emerging program should have real community benefits (e.g. income-producing fruit/nut plantations).

### **Challenges**

1. **Deforestation Drivers:** As mentioned, the agricultural development and the development of infrastructure are the most prevalent threats [11]. Even large areas of a smallholding (a patch of woods, a clearing to make farms or to widen a road) matter in the fractured landscape of Kalwan. Data around the globe and national specialists alert that these sub-hectare losses are not necessarily reflected by satellite-based datasets [20], so they should be on the alert.
2. **Plantation Survival:** Plantation schemes in Maharashtra have been very low in terms of long term survival in the past. A state testing discovered that 0 out of 124 plantation sites tested were successfully developed; more than 80% had lower than 40-percent survival rates [18]. Some of the causes mentioned were improper species choice, improper site preparation and failure to maintain them [19]. Kalwan is a dry area, and it is difficult to irrigate young trees and prevent fire/grazing. Survival depends on the post planting care (watering, weeding) that has not been taken seriously.
3. **Community Engagement:** Weak community incentive was also a cause of failure in the past. The assessment observed that there was a lack of JFMC participation in the plantation activities and no responsibility to manage the supervision activities [19]. This highlights the necessity of actual participatory planning and sharing of benefits.
4. **Limitations to monitoring:** It is difficult to detect loss in fragmented landscapes. Numerous little clearing (forest widening, minor encroachment) can be invisible in rough forest maps [20]. In this way, it is essential to incorporate satellite warning with local intelligence (forest guard reports, complaints of people).

### **Conclusion**

The analysis in this paper shows that the forests at Kalwan Tahsil have been fairly steady between 2024 and 2025 due to the continued plantation work and forest reserves. Nevertheless, agricultural, developmental and fire threats continue to be experienced in low intensity areas. The elimination of further loss may be achieved by harmonizing conservation plans with the local circumstances: plant indigenous species which grow well in semi-arid slopes, engage the villagers through JFM in all plans and share of benefits and install watershed conservation systems to improve the survival of trees. On the ground action and technology have to be hand-in-hand. The use of Sentinel-derived maps and community patrols will play a role in capturing and responding to forest losses at an early stage. Through them, the forests of Kalwan can be preserved, and they would still be able to deliver essential ecosystem services (water, carbon, habitat of biodiversity) and support the livelihoods of locals.

Planting should be made permanent greening by a strong forest policy framework supported by initiatives such as the Green India Mission and grassroots programs. It is also critical to enable the locals to become custodians of forests. Scientific monitoring and participatory management are the most effective way forward to ensuring that the forests of Kalwan Tahsil are maintained under the influence of development and climate change [14][19]. Tahsil's forests in the face of development and climate change [14][19].

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### **Conflicts of interest**

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

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