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Analysis of Temporal Forest Cover Changes of Urksew Wahpathaw Village Protected Forest

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ABSTRACT

There are already a system of governance and customary law which has withstand centuries which pave the way for conserving different types of forests which are crucial for the healthy survival of all life form including human. Recently we have witnessed a fast pace of deterioration of these customs, this study sheds light on how community forest (Law Adong) of urksewwahpathaw protected forest have been degraded which is evident from the forest cover changes and this has impacted the services it provides ecologically and also to the people around this forest. Most of this change comes from human intervention in the name of development and pressure of population on land. By changing the land use within this protected forest, it has brought in an ecological imbalance where the health of the forest is being affected as well as the water sources. However, in order to give way for development address population growth there should be a proper system to understand the cost benefit ratio before changing the land use within the forest, an in this case we need to revive back the system of governance and customary law to limit further damage to this forest ecosystem.

Keywords: *Forest cover, Community forest, Traditional institutions, GIS, NDVI*

Introduction

Forests are one of the important elements in a dynamic ecosystem that play a crucial and critical role in maintaining environmental stability, regulating climate, conserving biodiversity, and provide services to millions of people. With the threat of global warming and climate change there is more reason to understand the dynamics of the forest, to take action plan to conserve this very important element so as to have a balanced ecosystem. Changes in forest cover particularly in ecologically fragile and socio-culturally sensitive regions such as Northeast India has become a major environmental concern. With rising population pressures, the ecosystems are being exploited which face serious degradation, fragmentation, and conversion, making it more imperative now to understand the spatial and temporal dynamics of forest changes and the factors that drive them (Hansen *et al.,* 2013; Achard *et al.,* 2014).

Meghalaya, one of India's most forested states covering 17,118.79sq km which is 76.32 % of the state total geographical area (Forest Survey of India, 2017). However, only 8% of the forest cover are Government Forest where approximately 92% of these forests are community or privately owned, governed through different traditional institutions rather than formal state agencies (Tiwari *et al.,* 2010). The intricate land tenure and forest management systems in Meghalaya, particularly among the Khasi and Jaintia tribes, have created multiple forest categories, such as Law Kyntang (sacred groves), Law

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Lyngdoh (priest-managed forests), Law Kur (clan forests), Law Raid (territorial forests), and Law Adong (village-reserved forests) (Barik *et al*., 2006).

One of the traditional forest governances is Law Adong which plays a key role in preserving forest in the state. These forests are reserved for community use only and are typically managed by the village headman and the Dorbar Shnong (village council). Access to resources from Law Adong is regulated through customary laws, and extraction is strictly for bonafide domestic use with due permission. Violations result in community imposed penalties and this system of management bring sustainability and promote a shared sense of responsibility. However, increasing pressure on land resources, weakening traditional institutions have put immense pressure on these community forests, threatening their ecological integrity (Upadhaya *et al*., 2018).

The Urksew Wahpathaw protected forest of Raid Shabong, situated in East Khasi Hills district of Meghalaya, represents one such traditionally conserved forest area that has witnessed noticeable changes in land cover. Traditionally managed under the Law Adong system, this forest area has increasingly faced encroachments, resource extraction, and fragmentation, raising concerns about the long-term sustainability. The forest also contains important natural water sources, wetland which are used by local communities and nearby villagers for drinking, washing, and other domestic needs, making its conservation not only an ecological necessity but a socio-economic imperative.

Advancements in geospatial technologies, such as remote sensing, satellite imagery analysis, and GIS-based tools, have made it possible to study changes of forest cover with high spatial and temporal resolution. Parameters like Normalized Difference Vegetation Index (NDVI), canopy height models, and land use and land cover (LULC) classifications are now widely employed to monitor forest health identify change hotspots, and model future scenarios (Roy and Joshi, 2021; Saikia *et al*., 2025). Integrating these tools with community-level knowledge and field-based validation enhances the accuracy and relevance of such studies.

It is important to conduct a temporal analysis of forest cover changes in the Urksew wahpathaw protected forest using multi-date satellite imagery and ground survey to understand these changes within the traditional forest management systems of the Khasi community, highlighting both the strengths and challenges of customary governance. By combining study from the ecological, geospatial, and cultural lenses, this study will help to take forward the sustainable forest management practices and contribute to policy frameworks that recognize and support indigenous conservation systems.

Objective of the Study

The aim of this study is to examine the spatial and temporal dynamics of forest cover change in the Urksew Wahpathaw protected forest, with particular attention to its environmental and socio-cultural implications. The specific objectives are as follows:

1. To map and quantify forest cover changes using multi-temporal satellite imagery and geospatial analysis to identify forest loss, gain, and land use transitions between 2010 to 2025.
2. To identify and evaluate the principal drivers of forest cover change including anthropogenic pressures.
3. To analyse the implications of forest cover changes on ecosystem services, with a particular focus on water provisioning functions vital to local communities.

Material and Methods

The research methodology involves an integrated approach combining geospatial analysis with qualitative data collection. The key components of the methodology include:

Data Collection

(i) Acquisition of satellite imagery from Sentinel-2 for the years 2010, 2015, 2020 and 2025.

(ii) Use of high-resolution imagery and historical visual data from Google Earth to support spatial interpretation and validation.

Image Processing and Analysis

(i) Pre-processing of Sentinel-2 data, including atmospheric correction and geo-referencing.

(ii) Application of NDVI (Normalized Difference Vegetation Index) to detect changes.

Mapping and Visualization

(i) Creation of forest cover maps for multiple time periods to visualize spatio-temporal changes.

(ii) Use of change detection algorithms to identify areas of significant forest loss or gain.

Field Verification

(i) Ground-truthing through field visits to validate remote sensing data.

Data Analysis and Interpretation

(i) Integration of spatial data and qualitative findings to interpret the drivers and consequences of forest cover change.
(ii) Discussion of findings in the context of traditional governance systems and ecological impacts.

This mixed-methods approach ensures a comprehensive understanding of both the physical transformation of the landscape and the socio-cultural dimensions influencing forest conservation in Urksew Wahpathaw.

Study Area

Urksew Wahpathaw is a rural village located in the Pynursla Civil Sub-Division of the East Khasi Hills District, Meghalaya, around 53 kilometres south of Shillong, which is the state capital.

Between the Census years 2001 and 2011, Urksew Wahpathaw witnessed significant demographic changes. The number of households increased from 111 to 156, and the total population rose from 518 to 805, indicating a population growth rate of 55.4% over the decade. One of the most striking changes is in the sex ratio, which improved from 884 females/1000 males in 2001 to 1135 females/1000 males in 2011, reflecting a positive shift in gender balance. The average household size also increased slightly from 4.67 to 5.16 persons per household.

The study was conducted in the Urksew Wahpathaw Protected Forest, located in the East Khasi Hills District of Meghalaya, India. The forest lies between 25°17′50"N to 25°18'20"N latitude and 91°54′20"E to 91°54'40"E longitude. It is part of a subtropical hill ecosystem characterized by high annual rainfall, varied topography and rich biodiversity.

This forest is traditionally managed under the Law Adong system and is an important ecological site for the surrounding communities. It serves not only as a biodiversity hotspot but also plays a critical role in sustaining natural water sources, particularly two perennial streams *Wah Tongum* and *Wah Shrait* which flow through the forest. These streams provide essential water for drinking, washing and other domestic uses to residents of nearby villages.

The terrain is hilly with moderate to steep slopes and the forest vegetation includes subtropical broadleaf species, bamboo groves, and patches of regenerating secondary growth. The proximity of the forest to human settlements makes it vulnerable to pressures such as fuelwood collection, agricultural encroachment, and infrastructural development, highlighting the need of the hour for sustainable management informed by spatial analysis and community engagement.

Results

Monitoring forest cover dynamics is vital for effective stewardship resource management. This study employs Normalized Difference Vegetation Index (NDVI)-based satellite imagery analysis to detect spatio-temporal changes in forest cover within the Urksew Wahpathaw Protected Forest over a 15-year period from 2010 to 2025. The analysis draws from Landsat 5 and Sentinel-2 satellite data, classifying forest cover into “High” and “Low” NDVI zones as indicators of vegetation health and density.

Temporal forest cover change detectionusing Sentinel and Google earth Image (2010–2025)

Change detection of Urksew Wahpathaw Protected Forest analysed from remote sensing data showed notable variation over the 15-year period (Table 1 & Figure 1):

Table 1. Forest Cover Changes

Year	Area (ha)	Area in km^2
2010	25.6	0.256
2015	20.1	0.201
2020	20.3	0.203
2025	20.5	0.205

Sources: Google Earth Image & Sentinel- 2

A net forest loss of 5.1 ha occurred between 2010 and 2025. This corresponds to a 19.9% decrease over the study period.

Annual Change Rate

The annual percentage change rate in forest cover was calculated for each 5-year interval (Table 2). The most significant decline occurred from 2010 to 2015, at an alarming rate of 4.30% per year. A minor recovery was observed post-2015, suggesting stabilization or natural regrowth.

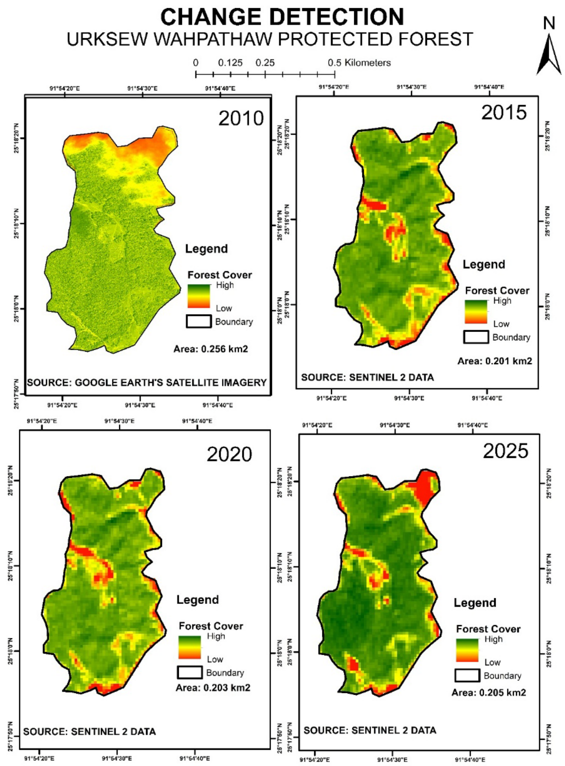

Fig. 1. Change Detection (2010-2025)

Spatial Patterns of Forest Change

(Figure 2) clearly illustrates the sharp drop in forest cover between 2010 and 2015, followed by a slow

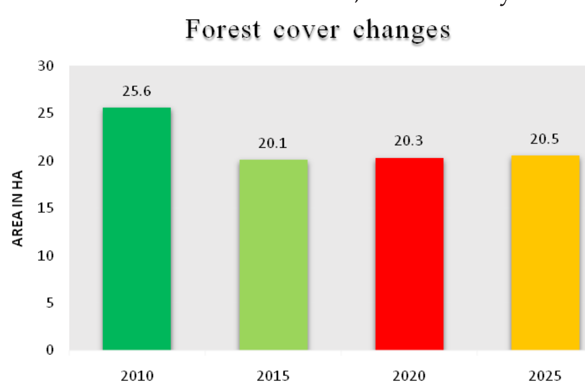

Fig. 2. Spatial Pattern of Forest Change

and steady rise through 2025.

The forest cover is low till 2015, likely reflects increased human activity, land-use changes, or ineffective enforcement of conservation. Slight gains post-2015 may indicate community protection efforts, passive regeneration, or policy impacts.

Change detection using NDVI

The following table and figure highlight the changes in forest cover area from 2010 to 2025, presented in both hectares and square kilometers. These results were analysed using satellite-based remote sensing techniques, with NDVI data supporting the observed variations in vegetation cover over time.

The forest cover area shows a declining trend from 2010 to 2025 (Table 3 & Figure 3), reducing from 25.6 hectares to 18.6 hectares. This consistent loss of forest cover indicates gradual degradation of vegetation. When assessed alongside NDVI data, the reduction aligns with a decrease in vegetation density, suggesting both spatial and spectral evidence of ecological stress over the 15-year period.

Table 3. Forest Cover Changes using NDVI

Year	Forest Cover Area (ha)	Forest Cover Area (km²)
2010	25.6	0.256
2015	20.1	0.201
2020	20.3	0.203
2025	18.6	0.186

Sources: Google Earth Image & Sentinel- 2

Periodic Changes

Table 2 highlights the changes in forest cover area from 2010 to 2025 (Table 4), presented in hectares. Analysis was done using satellite-based remote sensing techniques, with NDVI data supporting the observed variations in vegetation cover over time. The forest cover shows a declining trend, reducing from 25.6 ha in 2010 to 18.6 ha in 2025. The change analysis reveals that between 2010 and 2015, there was a sharp decline of 5.5 ha (-21.48%). In contrast,

Table 2. Annual Change rate

Period	Start Area (ha)	End Area (ha)	Change (ha)	Rate (% per year)
2010-2015	25.6	20.1	-5.50	-4.3
2015-2020	20.1	20.3	+0.20	+0.2
2020-2025	20.3	20.5	+0.20	+0.2

Sources: Google Earth Image & Sentinel- 2

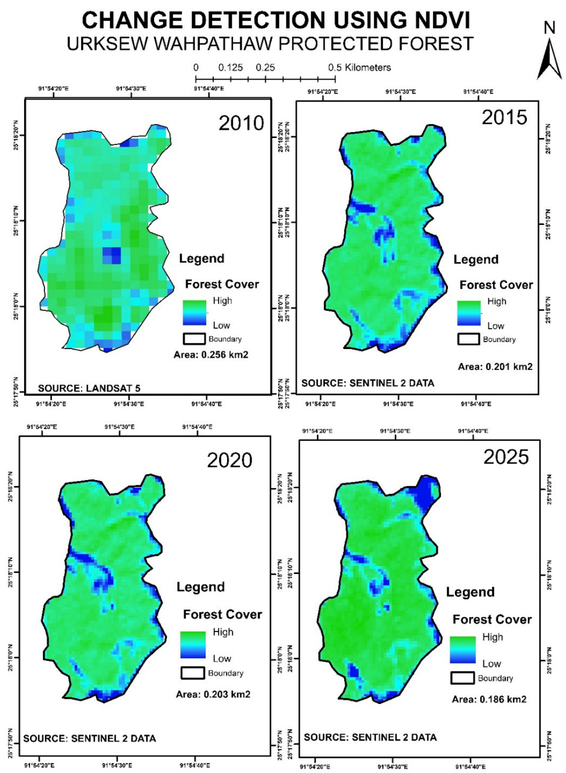

Fig. 3. Change detection using NDVI

the period from 2015 to 2020 recorded a slight gain of 0.2 ha (0.99%). However, the forest cover again declined by 1.7 ha (- 8.37%) from 2020 to 2025. These variations indicate fluctuating vegetation patterns over the 15-year period

Between 2010 and 2025, there was a net loss of 0.070 km² (or 7.0 ha) in forest cover, which amounts to a 27.34% decrease over the 15-year period. This substantial decline reflects a consistent reduction in vegetation extent, supported by NDVI-based remote sensing analysis.

Net Loss

(Forest Cover in 2010 - Forest Cover in 2025) $=0.256\text{km}^2 - 0.186\text{km}^2 = -0.070\text{ km}^2$

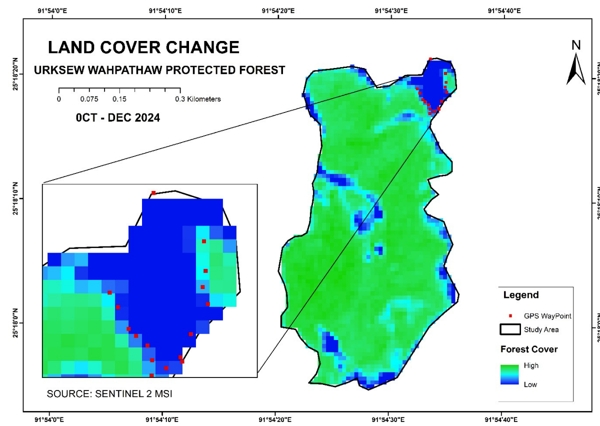

Fig. 4. Forest Cover Changes

Percentage Decrease

$$\left(\frac{0.070}{0.256}\right) \times 100 = \mathbf{27.34\%}$$

Recent dynamics of forest changes

Figure 4 indicates a rapid change in forest cover within a short period, with visible changes occurring in the northern part of the study area. Low NDVI values (blue zones) reflect active degradation, which

Fig. 5. Evidence of clearing of forest

Table 4. Periodic Changes

Period	Area Change (km²)	Change Type	Percentage Change	
2010 - 2015	- 0.055	Sharp decline	-	-21.48%
2015 - 2020	+ 0.002	Slight gain	+0.99%	
2020 - 2025	- 0.017	Decline	-	-8.37%

Sources: Google Earth Image & Sentinel- 2 was verified on the ground using GPS waypoints in August 2025. This degraded forest patch covers an area of 0.84 hectares contributing to the continuous forest loss recorded between 2010 and 2025.

Discussion

The analysis of forest cover change in Urksew Wahpathaw between 2010 and 2025 reveals a concerning trend of forest degradation, with a net loss of 7 hectares (27.34%) of forest area. While the results section has outlined the spatial and temporal dimensions of this loss, it is essential to interpret these findings within the socio-environmental context of the village.

One of the most likely drivers of forest cover reduction is the socio-economic transformation experienced by the village over the last decade. As highlighted in the study area profile, there has been a sharp rise in both population (by 55%) and number of households (by over 40%) between 2001 and 2011. This demographic expansion has created mounting pressure on land resources. Since the land in question belongs to the Raid Shabong traditional administrative territory and is managed locally by the Urksew-Wahpathaw Village Dorbar, the conversion of forest land into settlement areas has often occurred without a centralized land use planning mechanism.

Field verification during the study supports this interpretation. In several instances, forest patches were visibly cleared to make way for new houses, access paths (Figure 4 & 5). There are changes which are formal or organised land use change, where forest is cleared to make way for settlement and other purposed, on the other hand there are changes which are not always captured by formal land use records and reflect incremental encroachments driven by local needs. Although customary custodianship exists, enforcement appears limited, and trees are frequently felled for fuelwood, fencing, or construction without prior authorization from village elders or the Raid's authority. This pattern of unregulated use, especially in the absence of strict monitoring or conservation guidelines, contributes significantly to forest fragmentation and degradation.

Another concerning observation is the lack of detailed ecological assessment or long-term environmental monitoring in the area. While satellite data (including NDVI analysis) confirms a decline in vegetation density, there is currently no comprehensive study quantifying the impact of forest clearance on soil erosion, biodiversity loss, hydrology, or microclimate. This gap in understanding weakens the ability of local institutions to formulate informed conservation strategies.

Interestingly, the data suggested/recorded a minor increase in forest cover between 2015 and 2020, in contrast to the sharp decline witnessed during the earlier period (2010–2015). One of the reasonable explanations for this temporary gain lies in the COVID-19 pandemic and its associated nationwide lockdowns, particularly between 2020 and 2021, where during this time, all forms of human activity in the village economic, social, and even construction come to a standstill. As a result, there was also less forest disturbance, which may have provided time and space for natural regeneration of vegetation. This reflects that a strong governance will still be able to conserve this forest and maintain as evidence even short-term interruption of human pressure can positively influence forest recovery, albeit modestly.

However, this process of recovery proved shortlived, where between 2020 and 2025, forest cover again showed signs of decline, suggesting that once restrictions were lifted, land conversion activities resumed, reinstating the continuous pattern of gradual degradation. This fluctuation highlights the fragility of forest recovery when governance is weak to implement the law whether its government or customary law.

While socio-economic development in the region has improved through, it has also intensified the pressure on forested landscapes, particularly in the absence of enforceable land-use regulations. The findings underscore that there is an urgent need for community led conservation to strengthen the long customary laws and governance, improved awareness, and formulation of guidelines for sustainable land management, especially in areas under traditional custodianship like the Raid Shabong protected forest.

The environmental consequences of forest degradation are also becoming evident in the shrinking of local water sources and wetland in the forest area, notably, the *wahtongum* and *wahshrait* streams once reliable sources of water for the entire community, now experience reduced flow or completely dry up during most months of the year (Figure 6). This change has a strong correlation with the trend of declining forest cover and vegetation density observed over the past 15 years. Forests play a critical role in maintaining the hydrological cycle, particularly through canopy interception, infiltration, and groundwater recharge. The removal of forest vegetation can lead to increased surface runoff, reduced soil moisture retention, and diminished groundwater recharge-all of which contribute to the drying up of springs and streams. The loss of forest cover in catchment areas surrounding wahtongum and wahshrait likely disrupts the natural water balance, leading to their present state of seasonal drying. This situation underscores the broader ecological impacts of unregulated forest use and highlights the need to prioritize forest conservation as part of local water resource management.

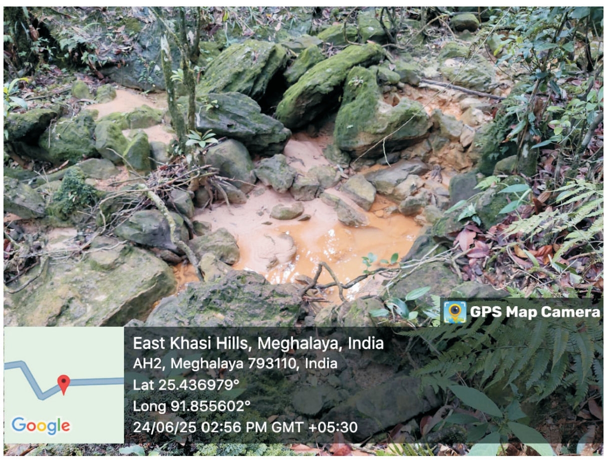

Fig. 6. Shrinking of water sources

Conclusion

The findings accentuate a clear path of environmental change in Urksew Wahpathaw, marked by a continuous decline in forest cover over a last 15-year period. This trend suggests and indicated a deep transformation in land use and community-resource interaction. Beyond the visible loss of green cover, the density of the forest other consequences extends to the village's water systems, as witnessed by the shrinking flow of Wah Tongum and Wah Shrait streams where people depend for drinking and other domestic purposes. These changes if not address at the earlies will lead to an irreversible ecological imbalance.

To tackle these challenges, one must understand that it requires more than monitoring there is an urgent need for strategies that combine traditional governance with sustainable resource management. Strengthening awareness, regulating land conversion, and restoring degraded forest areas will be vital not only for conserving biodiversity but also for securing essential ecosystem services for the future of the village.

Conflict of Interest – None

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