Impact of Land Use/Land Cover Change on Wildlife Habitat in Gautala Reserve Forest

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***Abstract*—One of the primary causes of habitat loss, fragmentation, and decline of biodiversity in forest ecosystems throughout the world is the Land Use/Land Cover (LULC) change. This paper discusses how LULC change affects the wildlife habitat in the Gautala Reserve Forest in the Ajanta-Satmala range of the Western Ghats in Maharashtra, India. The use of multi-temporal satellite imagery and geospatial methods was used to evaluate the dynamics of land cover between 2015 and 2025. The Landsat and Sentinel imagery was analyzed by supervised classification and change detection analysis to determine transitions between five major land cover classes; forest, agriculture, built-up land, water bodies, and bare land. The findings indicate that despite the slight increase in the net forest cover in the study area, there were major spatial changes along the forest boundary. About 53.23 km^2 of forest land was turned into agricultural land and 1.87 km^2 into built-up areas, which means that the anthropogenic pressure is growing around the boundaries of the reserves. On the other hand, an area of about 63.90 km^2 of agricultural land was converted to forest indicating potential natural regeneration or afforestation. Although the net forest area has increased, the spatial distribution of forest loss and regeneration suggests that there is a possibility of habitat fragmentation, loss of core forest areas and an increase in edge effects, which could adversely affect wildlife movement, habitat quality and ecological connectivity. The results indicate that the quality of habitat and spatial structure are more important to the conservation of wildlife than the total forest area. The paper concludes that sustainable land-use planning, preservation of the main patches of forests, ecological corridors restoration, and constant monitoring with the help of geospatial tools are essential in maintaining the wildlife habitats in the Gautala Reserve Forest landscape over the long term.**

***Index Terms*—Land Use/Land Cover Change, Wildlife Habitat, Habitat Fragmentation, Remote Sensing, GIS, Gautala Reserve Forest, Western Ghats, Landscape Ecology.**

I. INTRODUCTION

One of the major causes of habitat loss, fragmentation and degradation in the world is land use and land cover (LULC) changes because of agricultural expansion, infrastructure development, timber extraction and shifting human settlement [1]. Such changes modify the pattern and condition of vegetation, water and other landscape elements that animals rely on to feed, take shelter and reproduce, and usually decrease connectivity among patches of habitats, thereby restricting movement, gene flow and long-term population sustainability of numerous species [2], [3]. LULC change can tip vulnerable species to rapid declines and local extinctions in already stressed species in a landscape, where hunter or climate change pressure is already being felt [4]. Therefore, the knowledge of the LULC dynamics on wildlife habitat is critical in conservation planning, prioritization of the management of the protected areas and the reconciliation of human land-use demands and biodiversity persistence [5].

The Gautala Reserve Forest in the Sahyadri (Western Ghats) of Maharashtra, India, is an amalgamation of wet deciduous and semi-evergreen forest spots with grasslands and riparian corridors. The reserve is part of a much bigger network of preserved and unpreserved forest blocks which, combined, provide a habitat to a variety of mammals, birds, reptiles and amphibians, including several conservation-level species and endemic taxa. Its location in an agrarian environment that is changing very fast and its proximity to the growing settlements and roads put Gautala at a particular risk of land-use stress (conversion to agriculture, fuelwood harvesting, and infrastructure development) [6]. Since the Western Ghats is considered a global biodiversity hotspot, any alteration in one of the reserves such as Gautala can disproportionately impact the biodiversity in the region [7].

Gautala Reserve Forest is in the Ajanta Satmala range belt of the Western Ghats (Sahyadri) between 20°09′30″ to 20°40′02″ N latitude and 74°49′26″ to–76°02′36″ E longitude in Jalgaon and Sambhajinagar district, Maharashtra, India. The reserve has an area of approximately 776.38 km² based on administrative boundary, and the landscape consists of a mosaic of moist deciduous forest on upper slopes and ridges, semi-evergreen patches in sheltered valleys, extensive grasslands and scrub on plateaus, and riparian corridors along streams and seasonal rivers [8]. Human pressures around and within the reserve are substantial and vary in intensity across the landscape. Agricultural expansion and shifting cultivation in the buffer areas has converted peripheral forest patches to cropland and fallow fields, decreasing the contiguous forest cover. There are several small settlements and hamlets near the reserve boundary, and fuelwood collection, grazing by livestock, and extraction of non-timber forest products place pressure on understory vegetation and regeneration [9], [10]. Parts of the reserve are divided by road networks and seasonal tracks that increase access for resource extraction and human–wildlife interactions and potential conflict. Collectively, these land-use pressures result in habitat loss, edge effects, and fragmentation that can change species distributions and ecosystem processes within Gautala [1], [3].

This research fills the knowledge gap that is critical because it has been shown that recent LULC changes have impacted wildlife habitat in Gautala Reserve Forest. In particular, the research goals are to: measure LULC change in and surrounding Gautala Reserve Forest during the last 20 years by remote sensing and GIS; determine the extent to which habitat extent and configuration have changed suitability of focal wildlife taxa; and define priority areas in the reserve to be restored or safeguarded as habitat to sustain wildlife in the long term. Our hypothesis is that the LULC change during the period of study has decreased the total habitat area and increased fragmentation in Gautala Reserve Forest, which has resulted in a decrease in habitat suitability and connectivity to forest-dependent wildlife species.

II. LITERATURE REVIEW

The conservation literature has long supported LULC change, especially forest-to-agriculture and settlements conversion, as a direct cause of wildlife habitat loss and degradation, and downstream effects such as fragmentation, reduced resource availability, and increased human-wildlife interactions [11],[12]. Protected forest landscapes have empirically demonstrated that as agricultural activities and settlements grow, forest deterioration is usually observed and interpreted as encroachment of the wildlife habitat and increased competition over vital resources (cover, forage, movement space) [11],[12]. This framing applies to Gautala Reserve Forest since it encourages the main hypothesis that habitat change is not merely a question of dwindling forest area but also altering landscape structure and gradients of human pressure in and around the areas of protection [12], [13].

Direct Gautala-specific remote-sensing data show that the forest cover in the Gautala Wildlife Sanctuary has seen a massive conversion over the years, with the loss of forests being converted to agricultural or other land-use purposes using classified satellite imagery (LISS-III) of 1997 and 2015 [14]. This study places forest-cover change in Gautala as fast as to be measured over a period of two decades by conventional methods of digital image classification, which supports the relevance of multi-temporal remote sensing to detecting habitat change in the reserve setting [14]. Moreover, the same study connects the deforestation trends with the larger environmental change indicators (rising temperatures and decreasing rainfall), suggesting that deforestation may be a probable associated factor (but not causal) [14]. Combined, this Gautala-specific evidence confirms the finding that habitat-relevant forest cover processes exist and can be quantified in the Gautala landscape and should be explicitly interpreted as wildlife-habitat interactions instead of being considered as land-management products [14], [12].

In addition to areal forest-cover change, Gautala-specific studies record intensive tourism activities at 39 locations and frequent disturbances that include noise, accumulation of plastic/solid waste, crowding, feeding of animals, vehicle movement, and extraction of resources (firewood, timber, fodder) [15]. This paper also adds that these disturbance patterns coincide with habitats of endangered species such as leopard and four-horned antelope, which suggests the possibility of habitat-quality degradation and displacement risks despite land cover potentially being nominally forest [15]. This observation is consistent with the larger literature on the topic of protected areas that habitat fragmentation and degradation may be instigated not only by direct conversion but also by increased human activities and unlawful/unsustainable use within reserves, which may decrease the effective suitability and connectivity of habitat [13], [12]. To Gautala, the literature indicates that any LULC-habitat analysis must explicitly combine disturbance layers (roads/traffic, pilgrimage/tourism nodes, extraction intensity) with land-cover classes since they can mediate the use of the remaining habitat patches by wildlife [15], [13].

Research on other conserved regions demonstrates that forest degradation and increase in human land use is often linked to fragmentation measures that show smaller and more discrete habitat units and diminished corridors [12]; [13]. Multi-temporal Landsat analyses of tourism-oriented reserves indicate that land-cover changes can be accompanied by more fragmentation of land-cover types, which supports the conclusion that the legal status of protection does not protect habitat against landscape-structural change completely [13]. Complementarily, the studies of corridor-oriented landscape ecology recognize agriculture and settlements as the dominant classes that lead to the fragmentation between the protected areas and prove that the combination of land cover, vegetation density, and threat proxies enhances the habitat suitability and identification of corridors by wildlife movement [16]. These results give a methodological and conceptual model of Gautala: Conversion of total habitat area to forest (e.g., forest to built-up) can decrease total habitat area, whereas fragmentation and functional barriers can decrease effective habitat area by disrupting movement, exposing edges, and concentrating wildlife in suboptimal patches [12], [16], [13].

A defensible synthesis across the reviewed literature is that wildlife habitat impacts in Gautala are likely to occur through (i) forest-cover conversion detectable via satellite classification[14], (ii) habitat-quality degradation concentrated around high-use tourism/religious nodes and extraction areas [15], and (iii) fragmentation/connectivity change driven by expanding human land uses and infrastructure, as widely documented in protected landscapes elsewhere [15], [13], [16]. However, the Gautala-specific corpus reviewed here still lacks a fully integrated study that jointly (a) quantifies multi-temporal LULC transitions and fragmentation metrics for Gautala and (b) links them to explicit habitat-suitability outcomes or species occurrence data [14], [15]. The literature therefore supports a clear research need: to combine Gautala-specific change detection (as demonstrated for forest cover) with fragmentation/connectivity analysis and disturbance mapping (as demonstrated for tourism pressures) to estimate changes in effective habitat for focal wildlife species in the Gautala Reserve Forest landscape [14]-[16], [12].

III. METHODOLOGY AND DATABASE

Data sources Satellite imagery and ancillary data: This paper relies on multi-temporal, satellite imagery to map LULC and identify changes. To detect historic change, we use Landsat series imagery (Landsat 8 OLI) because it has a long archive and a resolution of 30 m (Roy et al., 2014). In case of recent and higher-temporal-resolution mapping we utilize Sentinel-2 MSI images (10-20 m resolution) to enhance the discrimination between agricultural and plantation classes and better map recent small-scale clearings [17]. Topographic variables (elevation, slope, aspect) are obtained with the help of a digital elevation model (SRTM 30 m) and are used to make classification and habitat analyses [18]. The OpenStreetMap and the records of the state forest department provide the vector layers of roads, settlement locations and administrative boundaries. The foundation of wildlife impact assessment is species occurrence records (camera-trap detections, opportunistic observations, and local survey point records) [19].

LULC classification: Pre-processing Atmospheric correction, cloud masking and scene mosaicking are done to get cloud-free composites of target years. Our classification is supervised and pixel-based classification based on the maximum likelihood classifier, aided by training samples generated by field surveys, high-resolution Google Earth and available land-cover maps. The scheme of classification includes five major classes which are forest, bareland, agriculture, built-up, and water (Congalton and Green, 1999).

Change detection: To measure changes in classes and net and gross area change, we compare LULC maps at two points in time (2015 and 2025). Change matrices are generated to determine the prevailing transitions [20].

Wildlife impact assessment: Wildlife habitat impact is estimated with the help of a habitat suitability proxy. The LULC change maps are overlaid on the core forest patches (polygons of contiguous forests over a threshold size) and the species occurrence points to measure loss of suitable habitat area and the number of occurrence records lost to habitat conversion. In the case of focal species, where there are sufficient records, local habitat loss is estimated by simple pre/post comparisons of habitat availability within species home-range buffers (e.g. 1-5 km radius). In cases where this is possible, movement corridors are deduced by determining stepping-stone patches and computing connectivity measures before and after change [21].

Analysis software: All image pre-processing, classification and spatial analyses will be done through a mixture of Google Earth Engine (to conduct large scale, repeatable remote-sensing processes and time-series composites) and desktop GIS (QGIS) to edit final maps, perform vector overlays, and visualize.

IV. RESULTS

Table I. Land Use/Land Cover Change in Gautala Reserve Forest (2015–2025)

LULC Change	Area (Sq. km)	Percentage of Forest Area (%)
Total Forest Area	776.3812	100
Change from Forest		
Forest → Waterbodies	0.3262	0.04
Forest → Agriculture	53.2260	6.86
Forest → Built-up Land	1.8652	0.24
Forest → Bare Land	0.0002	~0.00
Change to Forest		
Waterbodies → Forest	1.1298	0.15
Agriculture → Forest	63.9012	8.23
Built-up Land → Forest	0.0593	0.01
Bare Land → Forest	0.0042	~0.00

(Source: ArcGIS Pro Change detection modules)

Table I shows the Land Use/Land cover (LULC) change matrix of the study area in 2015 to 2025. The analysis revealed that the area covered by the forest in Gautala Reserve Forest was 776.38 sq. km in the period of the study. Nonetheless, several land cover changes were noted indicating both the loss and acquisition of forest cover owing to the alteration of the land use patterns around them.

The findings showed that there were conversion and regeneration of forest areas between 2015 and 2025. A significant amount of forest land was transformed into other classes of land use. The biggest change was the conversion of forest to agriculture which is 53.23 sq. km (6.86%), which shows that there is growing agricultural pressure on the forest boundary. A lesser area of forest was turned into built-up land (1.87 sq. km; 0.24%), implying the slow growth of settlements or infrastructure around the reserve forest. There was little conversion of forest to waterbodies (0.33 sq. km; 0.04%) and bare land (0.0002 sq. km).

Meanwhile, there were regions of forest regeneration or redesignation as forest. The largest increase was between agricultural and forest, 63.90 sq. km (8.23%), which shows that it could be a natural regeneration, afforestation, or alteration of land management practices. Also, 1.13 sq. km (0.15%) of waterbodies were converted to forest, and other small conversions took place between built-up land (0.059 sq. km) and bare land (0.004 sq. km) to forest.

Table II Figure 1 Land Use Land cover change Map legend

Class Code	Land Use/ Land Cover	Class Code	Land Use/ Land Cover
1	Waterbodies	3 to 2	Agriculture to Forest
1 to 2	Waterbodies to Forest	3 to 4	Agriculture to Builtup Land
1 to 3	Waterbodies to Agriculture	3 to 5	Agriculture to Bare Land

1 to 4	Waterbodies to Builtup Land	4	Builtup Land
2	Forest	4 to 1	Builtup Land to Waterbodies
2 to 1	Forest to Waterbodies	4 to 2	Builtup Land to Forest
2 to 3	Forest to Agriculture	4 to 3	Builtup Land to Agriculture
2 to 4	Forest to Builtup Land	4 to 5	Builtup Land to Bare Land
2 to 5	Forest to Bare Land	5 to 2	Bare Land to Forest
3	Agriculture	5 to 3	Bare Land to Agriculture
3 to 1	Agriculture to Waterbodies		

Generally, the increase in forest area caused by other land uses (65.09 sq. km) was marginally more than the decrease in forest area (55.42 sq. km) indicating that the increase in forest cover was positive over the period of study. The changes are, however, not

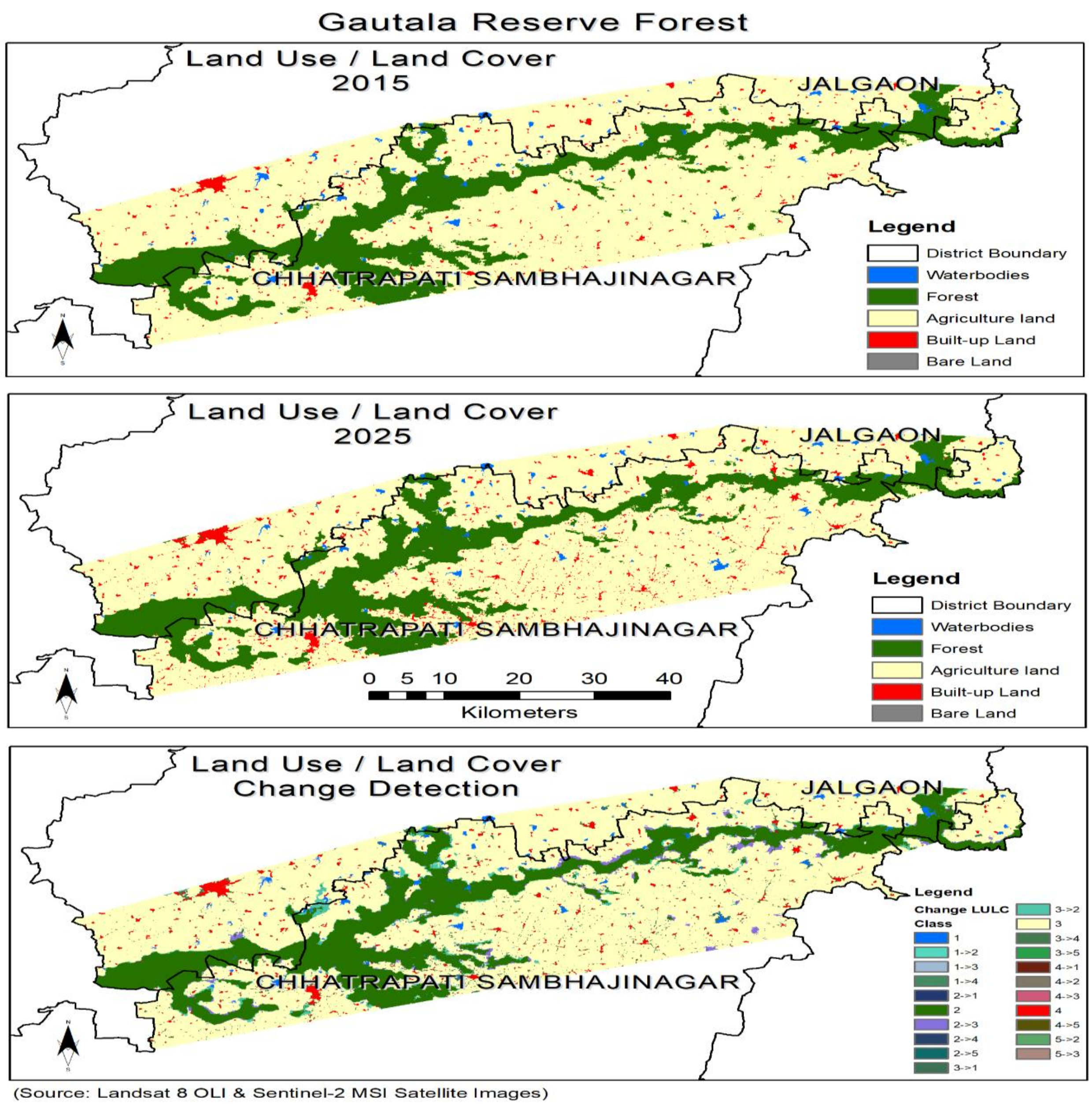

Fig. I Land use Land cover of Gautala reserve forest and its change detection (2015-2025) evenly distributed across space and can have an impact on habitat continuity.

The LULC maps for 2015 and 2025, as well as the change detection map, clearly show the spatial distribution of these transitions, with forest loss occurring primarily along the peripheral zones of the reserve forest (where agricultural activities and small settlements are concentrated) and forest gain occurring primarily in previous agricultural patches and marginal lands, which suggests possible ecological recovery or conservation.

The alterations in land use and land cover in and around forest ecosystems are very important in defining the availability, quality and persistence of wildlife habitats. The outcomes of the LULC change analysis in the Gautala Reserve Forest in 2015 and 2025 show that the changes in the habitat structure can be measured and can potentially affect the distribution, movement, and survival of wildlife.

The greatest effect on wildlife habitat was caused by the transformation of forest to agricultural land which was 53.23 sq. km (5,322.6 ha). The agricultural growth is usually accompanied by the destruction of the native vegetation and the introduction of monoculture crops, which decreases the complexity of the structure and food supply of various species that depend on forests. This may especially impact herbivorous mammals, arbor species, and terrestrial fauna that depend on thick vegetation to forage, nest, and breed. Moreover, agricultural landscapes tend to augment the interface between the wildlife habitats and human activities and this may escalate human-wildlife conflict and disturbance.

Habitat degradation is also caused by the fact that forest is being converted into built-up land (1.87 sq. km or 186.52 ha). The development of built-up areas brings in permanent infrastructure like roads, settlements and other human amenities that disintegrate the landscape. The habitat fragmentation limits natural migration of wildlife, isolates populations and can interfere with ecological processes including migration, dispersal, and gene flow. Such fragmentation is especially sensitive to species which need large areas of continuous forest, such as several carnivores and large mammals.

Although the loss of forest cover was about 55.42 sq. km (5,542 ha), the analysis also showed an increase in forest area by the transformation of other land use categories. It is worth noting that 63.90 sq. km (6,390.12 ha) of agricultural land was converted to forest and this could be a result of natural regeneration of vegetation or afforestation efforts. Wildlife wise, such regeneration can potentially restore ecological niches and increase the habitat available to several species, especially those which can adapt to secondary forests. Nevertheless, the ecological worth of regenerated forest is determined by the maturity of vegetation, species composition and structural diversity.

Other minor increases were recorded on waterbodies (1.13 sq. km), built-up land (0.06 sq. km), and bare land (0.004 sq. km) to forest. Although these patches are quite small, they can help to enhance habitat connectivity and create ecological corridors that can help wildlife move across fragmented landscapes.

In general, the LULC dynamics indicate the net gain in forest cover, but the quality and spatial arrangement of habitats are also the key factors to be considered in terms of wildlife conservation. The loss of forests in the area surrounding the reserve can have a disproportionate impact on edge-sensitive species and can raise their vulnerability to anthropogenic disturbances. Therefore, continuity of habitat and ecologically viable forest regeneration is necessary to sustain wildlife in the Gautala Reserve Forest.

V. DISCUSSION

Land Use/Land Cover (LULC) change analysis between 2015 and 2025 showed significant changes in the landscape of the Gautala Reserve Forest, and the analysis has significant implications to the structure of the wildlife habitat and ecological processes [22]. Though the findings showed an increase in the net area of forest, the spatial distribution of forest loss and gain indicates that the quality and continuity of the habitat might be influenced. The fact that forest is being converted into agriculture and built-up land is an indication of the growing human pressure on the forest margins and this may result in habitat fragmentation, loss of core forest, and edge habitat increase. Fragmentation breaks up continuous patches of habitat and forms isolated pieces of forests which might not be capable of supporting viable populations of many wildlife species [23]. The most endangered species are those that rely on the intact forest interior, since the shrinkage of the core habitat can change the feeding and breeding patterns and migration routes.

The agricultural land (53.23 sq. km) that has been cleared of forest cover suggests that farming activities continue to be one of the major causes of landscape change in the environs of the reserve forest. In many cases, agricultural encroachment will cause the replacement of heterogeneous forest cover by uniform crop fields, which will decrease the variety of plant species and their related wildlife habitats. On the same note, the fact that forest is being turned into built-up land (1.87 sq. km) indicates that there is progressive development of settlements, infrastructure and even roads in the area. These developments intensify human activities such as noise, human intrusion, and vehicular traffic, which have the potential to impact negatively on the behavior and habitat utilization of wildlife. Physical barriers such as roads and settlements can also be used to limit the movement of wildlife and pose a threat to the life of some species.

Despite these pressures, there was also a substantial change in agricultural land to forest (63.90 sq. km) that could be due to natural vegetation regeneration, marginal agricultural lands being abandoned, or the influence of forest conservation and afforestation schemes. The restoration of forests will slowly rebuild the ecological processes and offer a home to other wildlife species. Newly regenerated forests, however, are not always similar to mature forests in their canopy structure, species composition, and complexity of habitat, i.e. their suitability to wildlife may not be the same across species and forest development stage.

This study has found that its results agree with those of other parts of India where the agricultural expansion and settlement growth have been cited as the key cause of forest fragmentation and loss of wildlife habitat. It has been demonstrated in the past that LULC transformations in the forest landscape have a considerable impact on the distribution of biodiversity and ecosystem stability [24]. Other related trends of forest cover conversion and recovery have also been reported in several of the protected and reserve forest cover where human activities at the forest periphery are very important in determining the dynamics of the habitat [25].

Nevertheless, there are some limitations to this study. The LULC classification was based mostly on satellite imagery and hence the quality of the results is dependent on the spatial resolution and classification methods. Small scale landscape features like small forest corridors or small settlements may not be captured by moderate-resolution satellite data and may affect the connectivity of habitats. Also, the study was primarily based on remote sensing data and there was little field-based observation of wildlife, which limits the potential to directly attribute land cover changes to species-specific habitat responses. Further studies using more detailed satellite data, using long-term ecological studies, and on-the-ground survey of wildlife would give a more in-depth insight into the dynamics of the habitat in the Gautala Reserve Forest. In general, the discussion indicates that although the forest cover might be recovering in certain regions, the spatial structure and ecological fitness of habitats are critical to the conservation of wildlife. The key factors to ensure ecological balance and preserve the habitat of wildlife in the area are sustainable land management policies that restrict agricultural encroachment, control the growth of infrastructures, and promote the regeneration of forests.

VI. CONCLUSION

The Land Use/Land Cover change analysis of the Gautala Reserve Forest in 2015-2025 showed that there are some observable changes in forest and the surrounding land use patterns that have direct effects on the wildlife habitats. Even though the study registered a small net increase in the forest area, a significant part of the forest land was turned into agricultural land and built-up land, especially in the forest margins. The result of these changes is habitat fragmentation, loss of core forest, and increase in edge environments, which may adversely impact forest-dependent wildlife species. The destruction of about 55.42 sq. km (5,542 ha) of forest habitat by other land uses can interfere with the movement of wildlife, as well as food and shelter, and lead to the risk of human-wildlife contact. Simultaneously, the reclamation of forest out of agricultural and other types of land implies that there is a certain level of ecological restoration, which can be slowly applied to the restoration of habitats. Overall, the results indicate that the spatial distribution and ecological quality of the forest patches are more significant to the conservation of wildlife than the total forest cover increase.

VII. RECOMMENDATIONS

1) Conservation of central forest areas: There should be strict conservation measures to preserve large and continuous forest cover in the reserve forest. It is also necessary to keep the core habitats undisturbed to sustain vulnerable wildlife species that require interior forest environments.
2) Rehabilitation of ecological corridors: The degraded or broken patches of forests are to be rehabilitated to form habitat corridors that would link the isolated forest patches. These corridors may support migration of wildlife, gene flow and long-term population stability.
3) Land use conversion control: Agricultural, settlement and infrastructure development close to the forest boundary must be well controlled. Further encroachment and habitat degradation can be reduced by land-use planning and buffer zone management.
4) Frequent observation with geospatial methods: The changes in land use should be monitored continuously with the help of remote sensing and GIS-based analysis and periodic field surveys to trace the changes in the habitat and evaluate its effects on the wildlife populations over time.

These can help in the preservation of ecological integrity and sustainable conservation of wildlife habitats in the Gautala Reserve Forest landscape.

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