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Original Research Paper

Remote Sensing Based Habitat Mapping and Biodiversity Monitoring for Enhancing Wildlife Conservation and Environmental Management

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Key Words
Remote sensing, Habitat mapping, Biodiversity monitoring, Geographic information system (GIS), Wildlife conservation.

Abstract
Environmental degradation, habitat fragmentation, deforestation, urbanization, and global warming have adversely affected biodiversity and stability in ecosystems. The current research was conducted in order to identify the efficiency of remote sensing and geographic information system-based technologies in habitat mapping and biodiversity monitoring. Remote sensing data from various sources such as Landsat, Sentinel, MODIS, and UAVs have been used for conducting habitat mapping. Preprocessing of images, classification of habitats, vegetation index mapping, biodiversity hotspots determination, wildlife corridors mapping, and environment changes detection techniques have been applied for ecological evaluation of the habitat. Classification of habitat and ecological evaluation were performed using machine learning techniques like Random Forest and Support Vector Machines. Dense forests were found to take up the highest share of the study area amounting to 425 km² (34.2%) and agricultural land was found to cover 320 km² (25.8%). Biodiversity evaluation showed that there are 12 biodiversity hot spots and 7 major wildlife corridors in the study region. NDVI analysis showed that there is relatively healthy vegetation in the study region with an average of 0.71 and there is also moderate ecological disturbance with an index of 0.46. Species richness analysis showed that there are approximately 148 species within various habitats in the study area. Other environmental threats include forest degradation, wetland reduction, and urbanization. Overall, the study shows how the use of remote sensing techniques and geographic information systems can be effectively used for environmental assessment.

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Introduction

However, environmental degradation, habitat fragmentation, deforestation, urbanization, and climate change are factors that have posed threats to the global ecosystem and biodiversity. Biodiversity monitoring using conventional techniques is often cumbersome, labor-intensive, and location-specific, making it hard to survey vast landscapes and difficult-to-access areas (Nizamani et al., 2024; Iyer & Verma, 2023). In recent times, remote sensing techniques like satellite data analysis, unmanned aerial vehicle (UAV) imagery, LiDAR, and Geographic Information Systems (GIS) have gained popularity as effective techniques for habitat monitoring and environmental studies. Remote sensing techniques have allowed the study of land-cover changes, plant growth status, wildlife habitats, and other environmental factors from a spatiotemporal perspective. Remote sensing-based habitat monitoring has become an important area for wildlife conservation, biodiversity monitoring, and environmental sustainability (Mallick, 2025; Nihlani, 2025).

The main purpose of this study is to examine the significance of remote sensing technology as a technique that can be utilized in habitat mapping and biodiversity monitoring in order to enhance environmental management and conservation efforts. This study focuses on the assessment of how geospatial technology can help in the identification of crucial habitats, monitoring of ecosystem dynamics, evaluation of species distribution patterns, and provision of support to scientific-based conservation decisions.

Despite significant developments in the realm of remote sensing applications, there have also arisen a few obstacles in the realm of biodiversity monitoring and habitat assessment. It is mostly due to the fact that most research activities have been concentrated on analyzing land cover types without making the link between habitat and biodiversity. Low resolution, as well as absence of temporal monitoring along with limited use of field ecology data, has resulted in unsatisfactory habitat suitability assessment. Another obstacle involves the problem of developing standardized methods for integrating multi-source remote sensing data with biodiversity measurements.

The hypothesis of this research is that the integration of remote sensing technology in habitat mapping along with biodiversity monitoring techniques will result in a great improvement in terms of effectiveness and efficiency of wildlife conservation techniques. The use of advanced Geographic Information System (GIS) in ecological evaluations will aid in habitat mapping and detection of disturbances to environment and sustainable conservation programs.

The research makes an important contribution to the newly forming field of geospatial ecology through its suggestion of an exhaustive method on how remote sensing techniques can be used in conjunction with biodiversity monitoring techniques. It highlights the importance of taking into consideration multiple temporalities and sensors when studying habitat changes and ecological changes. Another significant aspect of the research relates to highlighting the importance of using GIS-based decision support systems in the conservation of endangered species and ecosystem restoration.

The paper is structured into the following parts: Abstract, Introduction, Literature Review, Methodology, Results, Discussion, and Conclusion. In the introduction part, the background of the research, objectives, research gaps, hypotheses, and contribution to the field are provided in Section 1. In the literature review part, the previously conducted research on remote sensing, geographic information system, biodiversity, artificial intelligence, and environmental management are described in Section 2. In the methodology part, the acquisition of data, habitat classifications, biodiversity analyses, and application of geographical information system in conservation planning are described in Section 3. In section 4, the habitat classification and biodiversity results are presented. The ecological implication and limitations are discussed in section 5, while the conclusions in section 6.

Literature Review

The use of remote sensing and GIS technologies has become important methods of habitat mapping and biodiversity monitoring because of their ability to conduct ecological measurements on a large scale. With recent innovations in technologies such as satellite imagery, LiDAR, UAVs, and machine learning techniques, there has been significant progress in the precision of ecosystem monitoring and conservation techniques. Remote sensing technologies have been proven to be effective in monitoring ecological parameters such as vegetation health, habitat fragmentation, land use changes, and species distributions in environmentally sensitive areas (Nizamani et al., 2024; Kerry et al., 2022).

A number of research studies have pointed out the importance of remote sensing in management of Protected Areas and biodiversity conservation. Satellite data of multiple time periods have proved useful in habitat degradation, deforestation, reduction in wetlands, and increase in urbanization and hence have become useful tools in environmental monitoring and conservation planning (Wang et al., 2020; Reddy, 2021). Use of GIS in conjunction with ecological data has contributed to effective analysis of wildlife corridors, biodiversity areas and habitat suitability zones (Tandi, 2025; Dixit & Raje, 2024).

Use of latest developments in artificial intelligence and deep learning have added further impetus to methods of biodiversity assessment. CNN based methods and habitat monitoring framework using artificial intelligence have shown remarkable effectiveness in species identification, ecology and environment prediction and analysis (Makhammadiyev et al., 2025; Santhosh, 2025). Cloud based environmental data system for environmental monitoring and sustainability is another recent development in environmental management (Shah & Bansalm, 2023).

Furthermore, it is important to integrate geospatial technology with traditional ecological and indigenous knowledge in order to increase the effectiveness of conservation practices (Iyer & Verma, 2023). Advanced habitat monitoring tools, such as camera traps, acoustic devices, remote sensing satellites, and ecological models, have facilitated the assessment of species richness and ecosystem stability (Lahoz-Monfort & Magrath, 2021; Varela & Drexler, 2021).

However, a number of deficiencies are still evident, including poor temporal monitoring, moderate spatial resolution, and inadequate integration of field ecological measurements with remotely-sensed data. Therefore, further research efforts should be made in the direction of integrating various sources of data and utilizing AI for habitat assessments.

Methodology

Study Area Selection

Methodology begins with the selection of research sites which are ecologically significant and vary in different types of habitats like forests, swamps, grassland, and fragmented land. The selected sites should differ in population size of plants and animals as well as different levels of disturbances by human activities like urbanization, deforestation, and agricultural farming among others. The use of GIS technology helps demarcate the geographical boundaries of the research area.

Remote Sensing Data Acquisition

The multi-source data collected by remote sensing techniques includes satellite data such as the one from Landsat from NASA, Sentinel, MODIS, and high-resolution data from unmanned aerial vehicles (UAVs). The data collected includes multi-spectral, hyper-spectral, and LiDAR data that are used to assess the structural features of the vegetation, the land usage practices, and the habitat features.

Image Preprocessing and Data Correction

The images will undergo processing using techniques such as atmospheric correction, geometric correction, radiometric correction, and removal of noise. Cloud masking and mosaic technique are applied in the creation of seamless images that will be useful for analyzing the habitats. Once the images have been pre-processed, the images will be loaded into GIS and Remote Sensing software for analysis purposes.

Habitat Classification and Mapping

Both supervised and unsupervised classification approaches are used for classification of the land cover and habitats. Machine learning techniques, like the Random Forest technique, support vector machine (SVM), and maximum likelihood classification algorithm, are applied to enhance the discrimination accuracy of habitats. Vegetation indices such as the NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index) are calculated to estimate the vegetation cover and vegetation density in the ecosystems.

Biodiversity Monitoring and Species Distribution Analysis

The following data collection methods include field observations, camera trap surveys, GPS wildlife tracking, and ecological surveys, which are used together with remotely sensed information about habitats. Species distribution information is processed in order to detect biodiversity hot spots, migration routes, and suitable habitats for various species. Spatial analysis is used to model species distribution under different environmental and habitat conditions.

Environmental Change Detection Analysis

The multi-temporal remote sensing data sets are evaluated to analyze the degradation of the habitat, changes in land use, deforestation, and fragmentation of ecosystems. The methods for change detection include post-classification comparison, image differencing, and time series analysis. These analyses enable the identification of ecologically sensitive areas that need conservation actions.

GIS-Based Conservation Planning

These processed data from habitats and species diversity are analyzed using GIS systems to help make decisions on conserving them. The analysis of spatial location helps determine priority areas for conservation, corridors and restoration of degraded ecosystems. The GIS system helps in formulating sustainable wildlife conservation and management strategies.

Statistical Analysis and Model Validation

Statistics is employed for determining the relationship between the variables, environmental and biological elements, and other ecological indicators. Correlation study, regression analysis, and other statistical tools are employed for understanding and proving the models generated. Comparisons are drawn between the end results and field observations.

Results

Classification of Habitat and Distribution of Land Cover Types

The use of remote sensing in habitat identification proved to be quite successful since various habitats were easily identified and classified, including forests, wetlands, grassland, agricultural land, and urban areas The combination of multispectral image data along with GIS technique was found effective in determining the types of habitats and depicting them geographically.

Table 1: Land Cover Classification and Area Distribution

Land Cover Type	Area Coverage (km^2)	Percentage (%)
Dense Forest	425	34.2
Grassland	210	16.9
Wetlands	115	9.3
Agricultural Land	320	25.8
Urban Area	170	13.8

Analysis of table 1 shows that the dense forests comprised the biggest area within the study region, suggesting the presence of adequate habitat areas. The agricultural and grassland areas represented significant parts of the region, whereas the wetlands and urban areas accounted for smaller portions. This distribution pattern signifies different ecological settings and impact of human activities on land cover.

Vegetation Health and Ecosystem Condition Assessment

Vegetation indices were derived from the satellite images to compare vegetation density and productivity of ecosystems in the region of interest High NDVI and EVI values were observed in forested zones, which suggested that these were healthy ecosystems, whereas the fragmentation and urbanization of ecosystems caused lower vegetation vigor.

Biodiversity Hotspot Identification

The spatial biodiversity study detected many hotspots where high biological richness and ecological connections prevailed. Wildlife presence data combined with GIS-based habitat suitability models found that ecosystems on forest borders and those near wetlands were rich in fauna and played the role of wildlife sanctuaries.

Wildlife Corridor and Habitat Connectivity Analysis

Connectivity assessment based on GIS showed that fragmentation was a determining factor for animal movement and behavior, affecting the efficiency of wildlife corridors. Ecological corridors have been found to exist among forest patches, which are crucial pathways to maintain genetic flow within the population.

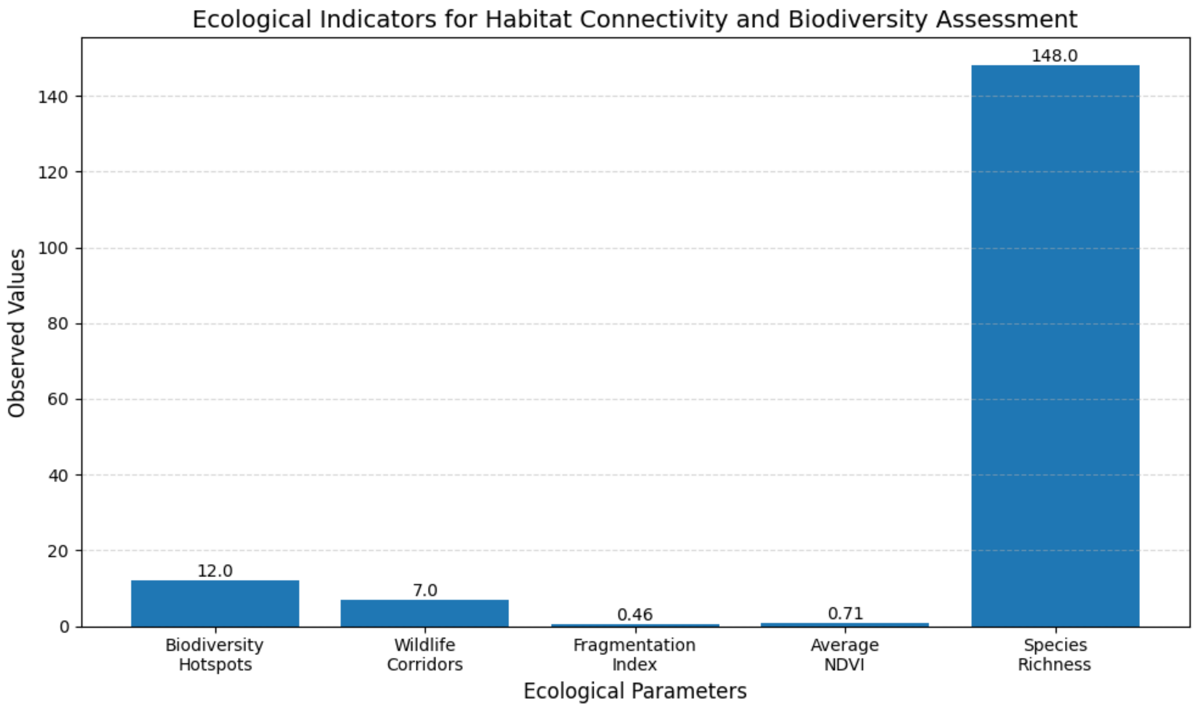

Figure 1: Ecological Indicators for Habitat Connectivity and Biodiversity Assessment

The following is the graphical representation of the major ecological indicators derived through the monitoring of biodiversity using remote sensing and the analysis of habitats, as presented in figure 1 above. These include areas of high biodiversity, wildlife corridors, fragmentation levels of habitats, vegetation condition based on NDVI, and species richness.

Environmental Change Detection and Habitat Degradation

Analysis of multi-temporal satellite images showed significant changes in the environment over the period of study. The decrease in forest cover, wetland reduction, and urbanization have been identified as some of the main factors responsible for the deterioration of the habitat. Change detection studies showed that human intervention caused habitat fragmentation.

Accuracy Assessment and Model Validation

Habitat classifications performed satisfactorily in terms of overall classification accuracy as well as predictive capabilities. Field survey data supported the successful application of machine learning algorithms to the categorization of habitat types and biodiversity distributions. The combination of field ecological data and satellite remote sensing outputs proved effective for analysis purposes.

Conservation Planning and Environmental Management Implications

These maps provided a spatial context that was beneficial for environmental management and conservation purposes. The zones that required conservation, those where restoration should take place, and migration routes were all clearly outlined for a more sustainable practice aimed at protecting biodiversity from extinction and destruction of their habitats.

Discussion

In this study, it was proven how effective remote sensing and GIS could be used to carry out habitat mapping and biodiversity assessment in areas where there exists ecological vulnerability. The forest formed the largest habitat covering an area of 425 km2 (34.2%), while agriculture came second, occupying an area of 320 km2 (25.8%). During biodiversity assessment, 12 biodiversity hotspots and seven important wildlife corridors were established. With regard to NDVI analysis, it indicated that vegetation existed in good condition since it was 0.71, while habitat fragmentation was 0.46, meaning disturbed environmental conditions. There were 148 species during species richness analysis. High NDVI values in heavily forested regions confirm a healthy ecosystem, while fragmented areas and urban areas experienced ecologically stressful conditions. The wildlife corridors identified in the analysis point to the need for ecological connectivity for effective species' movement and breeding. Moreover, biodiversity hotspot zones observed within forest edges and wetlands point to the critical role of transition zones in conserving wildlife biodiversity. It is worth noting the importance of geospatial technology in environmental and wildlife management programs. Such an approach will facilitate better habitat monitoring and assessment, biodiversity monitoring, and ultimately help in developing appropriate conservation strategies. The methodology used in this paper was mainly based on remotely sensed data and only a few ground observations, and hence might not adequately represent seasonal changes in biodiversity and interactions between different species. Moreover, there is likely to be some spatial and temporal issues with the use of medium-resolution satellite images in terms of accurate habitat classification and change detection analyses. Future research would therefore be expected to incorporate higher resolution satellite images, drone monitoring, and field surveys over extended periods for more accurate biodiversity assessments.

Conclusion

The present study has been carried out in response to increasing problems like habitat degradation, biodiversity losses, and ecosystem fragmentation due to fast-paced urbanization, deforestation, agriculture, and environmental disruptions. The findings have shown that the application of remote sensing and GIS technology is crucial in efficient monitoring of habitats, biodiversity and conservation of wildlife. Unlike conventional monitoring techniques in ecology that are limited by low spatial and temporal resolution, remote sensing can help monitor the environment continuously at a larger scale. According to the findings from the study, dense forests covered the largest land of the study area amounting to 425 km² (34.2%), followed by agricultural land that took 320 km² (25.8%). The assessment of biodiversity showed that there were 12 areas with high biodiversity value and 7 wildlife corridors that help maintain biodiversity connectivity in the area Furthermore, the mean NDVI value of 0.71 implies satisfactory vegetation condition within the forest ecosystem, whereas the habitat fragmentation index of 0.46 indicates moderate environmental disturbance. Additionally, species richness analysis has revealed that there are 148 species within different types of habitat. Overall, this case study reveals that the combination of the application of remote sensing technique, GIS, and biodiversity analysis is a viable way of handling and monitoring the environment. One of the lessons learned from this case study is that geospatial technologies can be effectively used to develop conservation strategies, monitor habitat destruction, ecological restoration, and environmental management.

Author Contribution

Conflict of Interest

The authors declare no conflict of interest.

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No funding was received for this study.

Ethical Consideration

There was no unethical use of geospatial and biodiversity data during this study since it minimizes disturbances to the natural habitats of the wildlife, thus promoting transparency and accuracy in ecological data analysis. All geospatial and field observation data were used solely for scientific research, conservation planning, and sustainable environmental management purposes.

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