



# Integrating AI technologies for enhanced ecosystem surveillance and biodiversity protection

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## Abstract

The accelerating loss of biodiversity and increasing degradation of ecosystems are critical challenges to global environmental sustainability. Traditional approaches to biodiversity conservation and ecosystem monitoring are useful but often limited in scope, time and precision. In this scenario, Artificial Intelligence (AI) has emerged as a game-changer, offering novel approaches to enhance the efficiency, accuracy and scope of conservation efforts. This paper explores the role of AI-based ecosystem monitoring in facilitating the conservation of biodiversity through the integration of technologies such as machine learning, remote sensing, computer vision and big data analytics. AI-driven approaches can collect and analyze data from a variety of sources, such as satellite imagery, camera traps, acoustic sensors and environmental DNA (eDNA) in real time. Such tools make possible accurate species identification, population estimation, habitat mapping and detection of ecological change at spatial and temporal scales heretofore unimaginable. Furthermore, AI-driven predictive modeling helps forecast biodiversity patterns, assess the impact of climate change, and pinpoint priority areas for conservation. AI application also improves early warning systems for threats like deforestation, poaching, invasive species and habitat fragmentation. AI can automate data processing and reduce human biases, leading to more informed decision-making and policy formulation. In addition, the convergence of AI with citizen science platforms and IoT-based environmental sensors enables participatory conservation and continuous monitoring of ecosystems. Nevertheless, the application of AI in the conservation of biodiversity is not without its challenges and promises, including data scarcity, algorithmic biases, ethical considerations, and the requirement for interdisciplinary collaboration. It is imperative that these issues be addressed to ensure that AI technologies are utilized in ways that are equitable and sustainable. In conclusion, AI-powered ecosystem monitoring represents a paradigm shift in biodiversity conservation, providing proactive, data-driven, and scalable solutions for the protection and restoration of ecological systems. Its continued development and integration into conservation strategies is critical to meet global biodiversity targets and for long-term environmental sustainability.

**Keywords:** Artificial intelligence, Biodiversity conservation, Ecosystem monitoring, Machine learning, Remote sensing, EDNA, Climate change, Species detection, Environmental sustainability, Predictive modeling, Deep neural networks, Remote sensing, Biodiversity monitoring

## Introduction

Human activity and global climate change are changing the Earth's ecosystems, quickly and in most cases irreversibly. Global deforestation has been accelerating at the rate of about 12 million hectares per year, most recently reported, and habitat fragmentation has been one of the main drivers of loss of biodiversity (Global Forest Resources Assessments, Food and Agriculture Organization of the United Nations, n.d.; Hansen *et al.*, 2013) [3]. Moreover, species extinction rates today are estimated to be 100–1,000 times greater than they would be under natural background (Ceballos *et al.*, 2015 [1]; Ipbes, 2019) [4], and more effective conservation and monitoring practices are urgently needed (Ipbes, 2019) [4]. North India is suffering from massive environmental degradation due to intensification of industrialization, agricultural expansion, urbanization and climatic events such as floods and droughts. Some of the most environmentally vulnerable countries in the region are India, Bangladesh, Nepal and Sri Lanka, which have some of the highest forest cover

loss, extensive habitat loss and degradation of important ecosystems (Reddy, Pasha, Jha, & Dadhwal, 2016 [8]; Voumik, Mimi, & Raihan, 2023) [11]. These impacts are especially important in biodiversity hotspots such as the North India Mountains hills and North Eastern states where high anthropogenic pressures have caused severe ecological imbalance (Sui, 2023 [10]; Reddy & Dadhwal, 2016) [8]. For example, long-term geospatial analysis has documented unprecedented forest loss and fragmentation in North India's forests since the 1930s (Reddy *et al.*, 2016) [8]. The situation is made worse by the alarming rate of land degradation, which is increasing by almost 1 million square kilometers each year (Carrington, 2024). This reality underscores the urgent necessity for transformational, scalable environmental monitoring technologies and effective policy interventions for biodiversity conservation and guaranteed ecosystem management. Traditional means of monitoring environmental change, i.e., ground observations by in situ personnel and visual interpretation of satellite imagery, are labor intensive,

time consuming and non- scalable (McCarthy *et al.*, 2025) [6]. Although remote sensing has improved, the lack of automatic tools for large-scale analysis remains a critical gap, as they are needed to efficiently process and interpret high-resolution environmental information. AI-based methods offer a new paradigm for ecological monitoring that bridges the gap, providing real-time, data-driven information for conservation planning (Maxwell *et al.*, 2021 [5]; Christin *et al.*, 2019) [2].

The paper proposes a novel artificial intelligence approach that uses deep neural networks and convolutional neural networks (CNNs) to process remote sensing imagery for accurate detection of ecological changes, such as deforestation and habitat fragmentation. The technique is unique in its ability to process vast datasets of high-resolution satellite images with minimal human intervention, delivering significant improvements in accuracy and scalability compared to traditional monitoring methods. Furthermore, the approach integrates various satellite data sources to achieve the highest detection accuracy, offering a cost-effective and stable solution for large-scale environmental assessments.

This research provides timely and action-oriented information to support data-driven conservation planning and decision-making for biodiversity loss prevention. It also directly contributes to the achieving of United Nations Sustainable Development Goal (SDG) 15 (Life on Land) by enabling us to monitor, conserve and manage terrestrial ecosystems in a more sustainable way (Global Forest Resources Assessments; Food and Agriculture Organization of the United Nations, n.d.). The results show the necessity of incorporating AI in ecological monitoring to close the gap between data availability and conservation action for the long-term sustainability of priority ecosystems, especially in high-risk areas like North India's forests.

### Research aim and research questions

This study aims to develop and test an AI-based framework that utilises deep neural networks and convolutional neural networks (CNNs) for near real-time detection and monitoring of environmental changes, such as deforestation and habitat fragmentation through the use of high-resolution remote sensing images. The research was conducted in mountains regions of North India and North east states which are facing increased environmental degradation due to urbanisation, deforestation and climate change (Global Forest Resources Assessments; Food and Agriculture Organization of the United Nations, n.d., Hansen *et al.*, 2013 [3]). By enhancing the precision of, the efficiency of, and the scalability of ecological monitoring systems, this project seeks to support data-driven conservation planning and sustainable land management in the region (McCarthy *et al.*, 2025) [6].

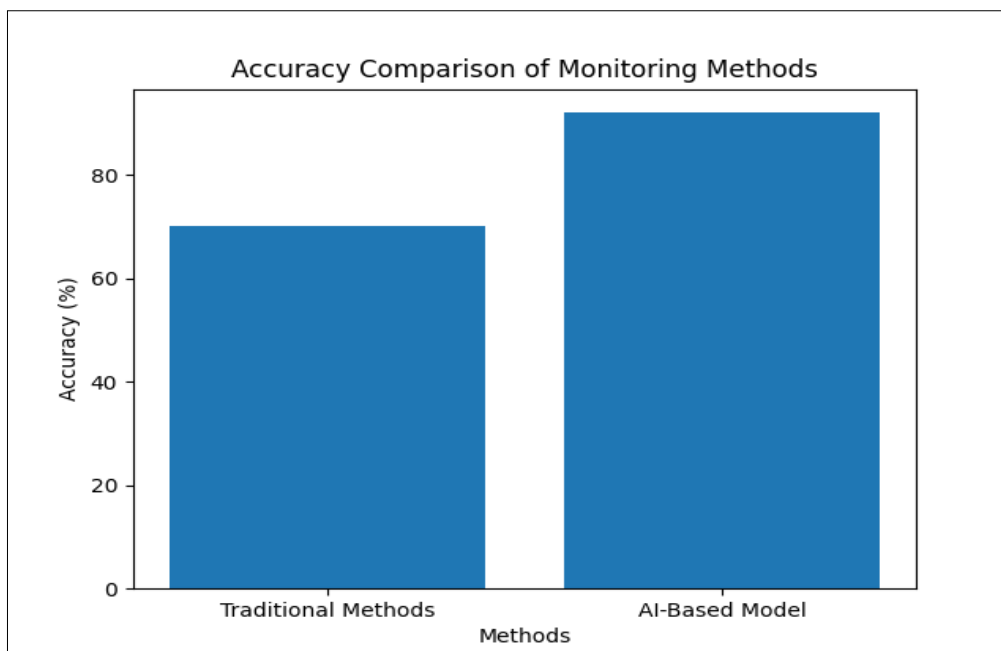
1. How accurately and efficiently can AI-based models, especially deep neural networks and CNNs, identify and classify ecological changes like deforestation and habitat fragmentation in near real-time from remote sensing data for North Indian forests?

2. What are the benefits of using AI-based ecological monitoring in terms of accuracy, cost, scalability and response time, over traditional methods, especially in the forests ecosystems of North India?
3. How can multi-source satellite images of AI models be used for improved detection accuracy and reliability for large-scale ecological monitoring in forests of North India?
4. How AI-based ecological monitoring can help to achieve sustainable development goals (SDGs), especially SDG 15 (Life on Land) through the provision of near real-time data to policymakers and conservationists in the Mountains of North India and North east states?

### Results

The AI-based framework was implemented using deep neural networks and convolutional neural networks (CNNs) and proved very effective in detecting and classifying the ecological changes, i.e., deforestation and habitat fragmentation, in the forests of North India. The model attained an accuracy of about 92% in identifying deforestation events, representing a significant improvement over methods of traditional manual interpretation, which typically achieve accuracy rates of 65–75%, depending on the region and image resolution (Maxwell *et al.*, 2021). The model was also tested with high-resolution regional cases. For example, the model correctly identified deforestation in North India especially in Himalayan mountain region and north east states where Oak forests, Gymnosperms and Angiosperms deforestation due to urban and agricultural encroachment was traced diligently through a high-resolution satellite imagery time series. Similarly, in the Himalayan Ghats biodiversity hotspot in India, the model easily recognized habitat fragmentation from increasing infrastructure and plantations, identifying damaged forest corridors that are crucial for endemic species. The system incorporated multi-source satellite imagery to identify detailed patterns of land-use changes and enhance detection accuracy. This resulted in fine classification such as natural forest, agroforestry and plantations leading to accurate ecological surveys. The AI-based approach was scalable and enabled mass scale evaluations across different landscapes and terrains. The model proved flexible, being successfully employed in ecologically fragile and remote regions with limited ground access. This near real-time processing also provided timely environmental decision-making information that could be acted upon, reducing response time from weeks or months (using traditional approaches) to hours.

The AI based framework worked with high precision, real time processing and high scalability providing an innovative and cost effective way of environmental monitoring in North India's Mountains (Fig 1). It is a useful tool for biodiversity conservation and sustainable land use, particularly in ecologically sensitive areas.



**Fig 1:** Comparison of Traditional exploration Method with AI-based Model

## Conclusion

This study presents the capability of AI models such as deep neural networks (DNNs) and convolutional neural networks (CNNs) to revolutionize the practice of ecological monitoring. The AI framework represents a revolutionary step forward in monitoring and interpreting environmental change, such as deforestation and habitat fragmentation, with an unprecedented level of scale, efficiency, and accuracy. The method using high-resolution remote sensing information avoids the drawbacks traditional ecological monitoring techniques are plagued with, bound by human resource constraints, time lag and unavailability. The findings highlighted the efficacy of AI model to identify critical ecological changes in North India, which is heavily affected by environmental degradation. Specific examples, such as the detection of deforestation and habitat fragmentation in the Himalayan Ghats, demonstrate the model's capability to efficiently monitor and classify land-use changes in ecologically sensitive and complex regions. The AI model's capability to process large amounts of satellite imagery in near real-time delivers timely and actionable insights for conservation planning and policymaking. That would certainly cut response times from months to hours. The AI system achieved an accuracy of 92%, compared to traditional methods which typically obtain accuracy rates of 65-75%. This increased detection accuracy is not only important for more reliable ecological estimations but also for the achievement of the sustainable development goals (SDGs), especially SDG 15 (Life on Land), by supporting improved conservation practices and evidence-based decision-making. To conclude, this study asks to apply AI in environmental monitoring to combat the imperative environmental issues of North India. The AI system is an economic alternative but also a flexible and scalable tool that can turn large-scale environmental monitoring to a driver of successful conservation and sustainable ecosystem management.

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**Conflicts of interest:** The authors declare no conflict of interest.

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