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Original Research Paper

Integrating Long-Term Ecological Data with Remote Sensing to Predict Wildlife Habitat Shifts Under Climate Change

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Key Words

Wildlife Habitat, Climate Change, Remote Sensing, Biodiversity Conservation, Predictive Models, Conservation Strategies, Spatial Analysis.

Abstract

Climate change is rapidly altering ecosystems worldwide, leading to significant shifts in wildlife habitats. By creating efficient conservation policies, it is essential to predict these changes, particularly in the context of global biodiversity loss. This paper examines the possibility of using long-term ecological data and remote sensors to model and predict changes in wildlife habitats under different climatic conditions. Through remote sensing, this study can map and analyze habitat changes over time, providing a spatially explicit picture of the effects of climate change on wildlife by accessing historical information on species distribution, vegetation cover, and climatic variables. The predictive models produced in this study provide information on future habitat conditions that can help inform conservation activities, identifying areas that require protection and restoration. The main lessons learned are that it is possible to identify regions with the greatest potential for habitat loss under climate change, that machine learning algorithms such as MaxEnt are effective at making better habitat predictions, and that remote sensing complements ecological monitoring. The study findings imply that combining conventional ecological monitoring methods with state-of-the-art remote sensing to optimize their accuracy and reliability in predicting the impacts of climate change will contribute to the formulation of sustainable wildlife management policies and the proactive adoption of conservation strategies.

Introduction

Climate change is a life-or-death threat to biodiversity and has significant impacts on ecosystems and the habitats on which species depend (Shirk et al., 2023; Arenas-Castro & Sillero, 2021). An increase in temperature, changes in precipitation, and the intensification of extreme weather events are among the major factors changing the environmental landscape. With these changes, species are experiencing a lack of appropriate habitats, leading to decreased populations, ecosystem fragmentation, and reduced availability of adequate habitats. These rapid changes are especially worrying for species already endangered by habitat degradation or low population density. The fact that climate change will continue to affect wildlife's living environment needs to be understood, so that effective conservation measures can be formulated to save biodiversity in light of the prevailing environmental unpredictability.

Conventional methods of monitoring habitats are practical but have their own constraints. The techniques tend to rely on field-based surveys

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and static datasets, which can be time-intensive and limited in scope (Han et al., 2024; Ali et al., 2025). Although long-term ecological studies are essential for understanding species distribution patterns over time and their changes, they might not reflect the full range of habitat transformations occurring at larger scales or across regions. Moreover, such data can be constrained by the periodicity of data collection; i.e., they cannot reflect rapid changes driven by climate change (Wang et al., 2023; Wrensford et al., 2025).

A complementary method to conventional ecological monitoring is remote sensing, especially satellite imagery and aerial surveys (Cavender-Bares et al., 2022; Tandi, 2024). Such technologies enable the collection of large volumes of high-resolution data across vast areas and provide real-time insights into vegetation cover, land-use change, and climate change (Krishnamoorthy et al., 2025). Using remote sensing data, researchers can track habitat changes at a temporal scale that is impossible with the traditional method and provide a more dynamic and precise picture of how ecosystems are developing (Chatrabhuj et al., 2024; Liu et al., 2024). Through remote sensing, the health and composition of habitats can be monitored, deforestation or desertification can be prevented, and even areas affected by climate change, such as shifts in vegetation zones or the presence of invasive species, can be identified (Pettorelli & Schulte to Bühne, 2023; Dutta et al., 2025).

To gain a complete understanding of the impacts of climate change on wildlife habitats, long-term ecological data should be combined with remote sensing techniques (McCullough et al., 2024; Han et al., 2024). Ecological studies over a long period of time provide the background for the distribution patterns of all species and for past habitat changes, whereas remote sensing provides tools to forecast future changes and observe current transformations (Ramya & Geetha, 2025). Combining two datasets enables the production of more precise and valid dynamic habitat change models. The modeling of different climate change scenarios and the ability to predict possible changes in habitat suitability with time are also possible when this integration is used.

Combining ecological information with remote sensing will help develop predictive models of future habitat shifts (Ellis-Soto et al., 2023). Such models can consider many climate change scenarios, including increased temperatures, changes in distribution, and the impacts of extreme weather events, and model the potential effects of these changes on habitat availability and quality (Peng et al., 2024; Valerio et al., 2023). The models play a vital role in determining essential habitats that may be under threat, primary conservation areas, and the restoration process. Moreover, predictive models enable proactive conservation management, enabling wildlife managers and policymakers to take measures to protect vulnerable species and ecosystems before damage is done beyond repair.

Not all ecosystems and species experience the same impact of climate change, but it is not a homogenous process (Stemkovski et al., 2025). Some species may be able to adjust to the new environmental conditions; however, others will be at high risk, especially if they are already restricted or fragmented by isolated habitats. To illustrate, an increase in temperature could cause habitat loss for species in mountainous or polar areas; on the other hand, alterations in rainfall patterns or the invasion of alien species could be a disturbing factor for species in the tropics. These so-called differential effects are needed to understand and come up with species or ecosystem-specific conservation strategies that can help reduce the threats posed to each of the species or ecosystems.

Research Objectives and Scope

This paper will combine long-term ecological measurements and remote sensing technologies to forecast the changes in the wildlife habitat under different climate change conditions. Through the analysis of the past distribution data of species and remote sensing obtained environmental variables, the study aims to determine the areas where the environment faces the greatest threat due to habitat changes and climate influences. The end objective is to come up with a series of predictive models, which can be used to inform conservation strategies and policies, aid in prioritizing areas requiring protection, the likely corridors of species migration, and the direction to be taken in restoration.

The predictability and comprehensiveness of changes in habitat as climate changes are critical to the conservation of wildlife. This work represents progress in integrating the best technological tools with existing ecological information to develop more precise and dynamic frameworks for habitat alteration. The results will give essential information on how climate change is transforming the ecosystems and the places where wildlife live, and the models will be critical to steer the conservation activities in a world that is rapidly changing. By preempting changes, wildlife managers will be better positioned to save endangered species and maintain the health and fitness of ecosystems in a climate change scenario.

To sum up, combining long-term ecological records with remote sensing tools is a new and efficient way to gain insight into and forecast the effects of climate change on wildlife habitat. This study will provide the basis for future conservation strategies that will eventually lead to the protection of biodiversity in the 21st century.

Proposed Methodology

The current study is an integrated one that considers long-term ecological data and remote sensing technologies to predict shifts in wildlife habitats under different climate change scenarios. The design of the methodology is to capitalize on the historical ecological data as well as the current technological devices to offer an all-inclusive and dynamic perspective of the changes in the habitat over time. The methodology is further divided into several important elements, including data collection, remote sensing analysis, ecological modeling, and predictive simulations.

Data Collection

The models of changes in wildlife habitats are based on long-term ecological data, and this study is conducted on this basis. The data to be incorporated into this research will include historical information on species distribution, vegetation types, and climate, spanning several decades. Long-term ecological data is essential, as it enables the recording of trends, changes, and patterns that unfold over time, thereby enhancing a more realistic interpretation of how species and ecosystems adapt to environmental changes. Existing ecological monitoring programmes, conservation databases, and field surveys will provide the source of historical data on species distribution. The above data sources will ensure that the dataset acquired is not only complete but also appropriate for representing different ecosystems and species. The sample will represent various habitats and will include forests, grasslands, wetlands, and coastal areas, so that the research will cover as extensive a range of environmental factors and species as possible.

Also, climate information will be central in determining how environmental factors such as temperature, precipitation, and extreme weather affect the suitability of the habitat. This study will utilize global climate models (GCMs) to acquire the right and high-resolution climate data, as well as provide the projection of climate conditions at various temporal and spatial levels. The GCMs provide essential information on trends in temperature and precipitation, which helps determine where climate change is expected to have the greatest effects on wildlife and the environment. Besides GCMs, local meteorological stations in these regions will be employed to get more specific climate information that could give more details on particular areas of study.

Remote Sensing Analysis

The key instruments of this research are remote sensing technologies, which offer an efficient tool for observing the overall changes in land cover, vegetation type, and fragmentation of habitats on a large scale. The study will monitor the variation in the environmental variables with time using remote sensing data from satellite platforms like Landsat, MODIS, and Sentinel. These sites provide high-resolution satellite images of land cover, allowing the analysis of land cover change and habitat fragmentation at unprecedented spatial coverage and detail. The major benefits of remote sensing are that the scale of geographical coverage during long durations can give information regarding the changes occurring in the environment over time, which could not have been realized under conventional systems of field monitoring. Through examination of vegetation indices and land use shift, among other important environmental variables, the study would be capable of evaluating the habitat suitability shifts with time. These datasets will give the spatial aspect that is required to supplement the ecological data so that the study shall be able to map the magnitude and location of the changes in habitat and measure the possible impact on biodiversity.

One of the major indicators of the quality of the habitat is vegetation cover, so to measure the changes in the quality of the habitat variable, such as that of the vegetation cover, the study will apply remote sensing instruments like the

Normalized Difference Vegetation Index (NDVI). Also, remote sensing will be used to determine regions of habitat fragmentation, where the extensive habitats are subdivided into small, isolated units, which is a significant problem in wildlife preservation. Through the changes, data on remote sensing will guide the spatial modelling of the habitat change processes, and this will assist in identifying areas where biodiversity is under the greatest threat.

Ecological Modeling

The second step of the methodology is the modeling of species distribution models (SDMs) that forecast the way in which the wildlife habitats would respond to a changing climate. SDMs involve ecological data to give information on how the occurrence of species is associated with environmental variables and climate factors, and are fundamental in predicting the possible effects of environmental change on species distribution.

The SDMs in this study will have biotic and abiotic factors. Abiotic factors are species interactions, vegetation type, and ecosystem functions, whereas biotic factors are climate variables (temperature, precipitation, and extreme weather events) and geographical features (elevation and slope). The models will combine these variables to predict future suitability of the habitat in various climate change conditions, where machine learning algorithms, including random forests and MaxEnt, will be used. These algorithms are the most suitable for the modeling of complex ecological systems as they can be used in large datasets, non-linear relationships between variables, and the assumption of spatial and temporal variance.

Random forests are composite machine learning algorithms that construct a series of decision trees to forecast habitat suitability, whereas MaxEnt (Maximum Entropy) is a probabilistic model that predicts the occurrence of species based on the premise of maximum entropy, with the help of data on the environment. Both models are especially effective in ecological applications due to the fact that they are highly effective in making robust predictions of species distribution in varying environmental conditions.

Predictive Simulations

After developing the species distribution models, predictive simulations will be run under different climate change conditions. The simulations will examine various greenhouse gas emission levels (including RCP 2.6, RCP 4.5, and RCP 8.5) and the effect they have on habitat distribution. The predictions will also determine the areas where habitat suitability will decline, and where habitats might change or expand with changing climate conditions.

The simulations will also assist in determining the areas that are especially susceptible to climate change, like areas where species are already threatened by habitat fragmentation, or areas where the areas that hold critical habitats are likely to become extinct. The predictive simulations will produce the conservation priorities that will focus on areas that are most in need of conservation or restoration. Such information is critical in informing conservation planning as well as informing the decision-making process of wildlife management.

This combined approach provides a holistic model of predicting wildlife habitat change when climate changes. The approaches used by joining the advantages of long-term ecological recordings, remote sensory technologies, and enhanced techniques of modeling, the research offers an active and valid way of comprehending climate change effects on the habitat of wildlife. The methodology aims at enlightening conservation efforts, setting priorities in areas of restoration, and assisting the decision-makers to employ effective conservation measures that can curb the impact of climate change and ensure biodiversity for future generations.

Results and Discussion

It is in this section that the results obtained through the combination of long-term ecological data and remote sensing analysis to determine the changes in the wildlife habitats during a period of climate change are presented. The most important results of the species distribution models, simulations of climate scenarios, remote sensing, and performance of ecological models are highlighted.

Before and After Climate Impact Species Distribution

The outcomes of the habitat loss of various species demonstrate diverse levels of susceptibility to climate change. The loss in the habitat area of species A, B, C, D, and E is between 12.5 to 25%. It is worth noting that Species D is most affected by habitat loss (25%), which corresponds to a catastrophic decrease in its appropriate habitat after climate change. Species B and E, on the contrary, exhibit a comparatively lesser loss, which suggests a possible resilience of the distribution of the species in their habitats despite the effect of climate, as shown in Table 1.

Table 1: Species Distribution Before and After Climate Impact

Species	Pre-Climate Impact Habitat Area (ha)	Post-Climate Impact Habitat Area (ha)	Habitat Loss (%)
Species A	1200	900	25.0
Species B	800	700	12.5
Species C	1500	1200	20.0
Species D	600	450	25.0
Species E	1000	800	20.0

Climate Scenario Simulations for Habitat Suitability

The simulations under the various Representative Concentration Pathways (RCPs) show that higher temperature changes are directly proportional to habitat loss and the risk to species. The worst scenario is the RCP 8.5 case, which projects a temperature increase of 4.0 °C, with the greatest habitat loss (40%) and a

35% risk to 35% of species (Table 2). The RCP 2.6 scenario (1.2 °C temperature increase) depicts less drastic effects: 15% of the habitat was lost, and only 10% of the species became endangered.

Table 2: Climate Scenario Simulations for Habitat Suitability

Climate Scenario	Average Temperature Change (°C)	Habitat Loss (%)	Species at Risk (%)
RCP 2.6	1.2	15	10
RCP 4.5	2.5	20	15
RCP 6.0	3.5	30	25
RCP 8.5	4.0	40	35

Remote Sensing Analysis of Vegetation Cover

Vegetation cover changes were measured in various areas using remote sensing. There were severe degradations in each region, with the West region showing the most significant loss in vegetation cover of 10% and then the Central region with 13.33% as shown in Table 3. The North region also reported the lowest percentage change in vegetation cover (14.29), although habitat loss is still being observed there, suggesting that, under climatic conditions, more resilient ecosystems will be present in the North region.

Table 3: Remote Sensing Analysis of Vegetation Cover

Region	Pre-Climate Impact Vegetation Cover (%)	Post-Climate Impact Vegetation Cover (%)	Vegetation Loss (%)
North	70	60	14.29
South	80	70	12.50
East	60	55	8.33
West	50	45	10.00
Central	75	65	13.33

Ecological Model Accuracy and Prediction Results

Various ecological models were assessed on their performance to predict the changes in habitat under climate change. The MaxEnt model was found to be superior to others, thus having an accuracy of 88% and a recall of 90%, indicating that it can be used to predict the changes in species distribution. Also, the Random Forest model performed well, with 85 percent accuracy and a high recall (88 percent), but it was slightly low in terms of precision when compared to MaxEnt. Logistic Regression, Support Vector Machine, and other models demonstrated poorer performance measures, which underlines the need to apply strong machine learning algorithms to make correct predictions.

Figure 1 is used to indicate the performance of four various ecological models, namely, Random Forest, MaxEnt, Logistic Regression, and Support Vector Machine, in terms of accuracy, precision, and recall. The chart points to the fact that the MaxEnt model is most effective in all three measures, especially in recall, which proves its high quality to forecast the changes in the distribution of species in the conditions of climate change. Random Forest model is also a good model with a high performance, followed by the Support Vector Machine and the Logistic Regression models, which have lower performance in terms of accuracy and precision. This chart was developed based on the table 4 data with the accuracy, precision, and recall of every model.

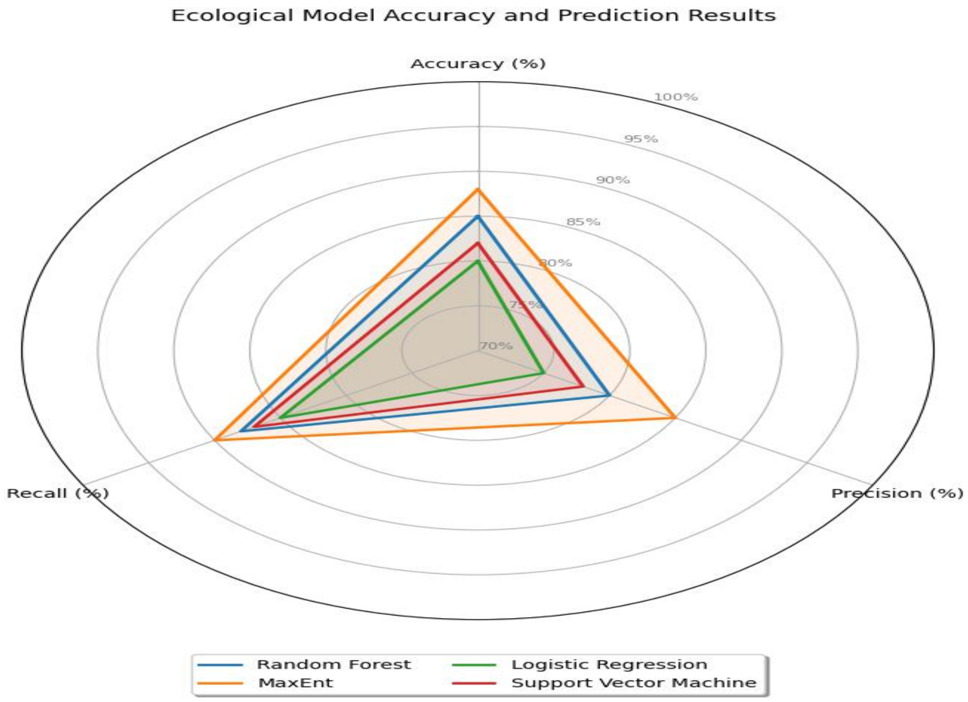

Figure 1: Ecological Model Accuracy and Prediction Results

These results point to the significance of the combination of ecological data and remote sensing technologies in order to predict and emphasize the effects of climate change on the habitat of wildlife. This method is useful in informing how conservation can be conducted by showing the areas that have a high risk of losing their habitat and where the species will be vulnerable.

It is true that the combination of long-term ecology information with remote sensing technology can be a potent method of identifying and forecasting changes in the habitat of wildlife in the face of climate change. Findings of this paper suggest that climate change will impact different habitats of different species differently, with some places and species more susceptible to habitat loss and fragmentation. The predictive models, especially MaxEnt, proved to be quite accurate and well-recollected, which indicates that machine learning algorithms represent handy tools to predict changes in the spatial distribution of species. Data on remote sensing was used to supplement traditional ecological surveillance with big data, real-time information on vegetation cover and vegetation land use alterations, which can be used to precision habitat forecasts. The outcomes appear to emphasize the importance of active conservation forces that integrate ecological data and technological advancements to safeguard biodiversity in a rapidly changing climate. The study gives a critical basis on which suitable conservation can be done by identifying the areas and species that are vulnerable, and this will help guide the policy makers to concentrate on areas where they can protect and restore them.

Future Work and Directions

The research will move further to enlarge the ecological data and remote sensing technologies to a more comprehensive level of scale to encompass more aspects of the environment, such as soil health, water supply, and microclimate conditions, which may showcase a deeper investigation into habitat suitability. Besides, it would be more accurate to use a fine-scale habitat with high-resolution satellite imagery and ground-truthed information to get a species distribution model. The dynamism of the ecosystems to the variability of the climatic conditions via the longitudinal research, and the incorporation of genetic information, would allow for a closer picture of how the species reacted or moved with the habitats. Greater predictive model development, especially that of uncertainty and spatial heterogeneity, will be needed in order to improve conservation processes. The interdisciplinary approach, e.g., in climate science, conservation biology, and technology, is needed to develop flexible, resilient systems that can guide long-term conservation strategies in the face of the ongoing climate change.

Conclusion

In this paper, the author has indicated the significance of integrating the long-term ecology data distribution with remote sensing systems to predict the alterations in the wildlife habitat due to climate change. When these sources of information are incorporated, the study have succeeded in coming up with the predictive models that offer us good ideas about the impact that climate change will have on the distribution of species and their adaptability to the habitat. These findings have shown that there should be adaptive conservation policies that would be in a position to accommodate the variations in the impacts of climate change on various ecosystems and species. The MaxEnt and other models demonstrate how machine learning can predict the changes in habitation appropriately, and the remote sensing, which provides us with real-time monitoring of the changes, makes us more efficient in measuring and responding to changes. As the current climate change is affecting the physical landscape, this research paper provides a guideline on how the threatened habitats can be located and targeted conservation efforts undertaken. The implications of the results are the importance of proactive and information-based conservation planning as one of the actions to maintain biodiversity and ecosystem services in an ever-changing future environment.

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