

Forest Fire Risk Mapping and Its Impact on Biodiversity Conservation

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Abstract

Forest fires are a severe danger to biodiversity because they result in the destruction of habitats, the displacement of species, and uneven distribution of ecosystem components. The purpose of this research is to investigate the use of Geographic Information Systems (GIS) and Remote Sensing (RS) in the mapping of forest fire risk in order to improve biodiversity conservation efforts. The identification of high-risk fire zones and the analysis of the possible impact that these zones could have on flora and fauna are accomplished by the integration of satellite imagery, climate data, and topography variables. In addition to highlighting the need for early warning systems and sustainable land management methods, the research underscores the significance that fire risk modelling has in proactive conservation planning. The findings highlight the significance of geospatial technologies in reducing the negative effects of forest fires and developing conservation policies that are driven by data.

Keywords: Forest Fire Risk Mapping, Biodiversity Conservation, Remote Sensing, GIS-Based Fire Prediction, Ecosystem Management.

Introduction

Forest fires represent a critical environmental issue, leading to extensive damage to ecosystems, wildlife habitats, and overall biodiversity. Climate change, deforestation, and human actions are all making forest fires more common and worse. This shows how important it is to be proactive about evaluating and managing risks. Traditional ways of predicting fires haven't been able to solve these problems very well. This shows that more advanced methods are needed, such as Geographic Information Systems (GIS), remote sensing, and machine learning, to accurately map the risks of forest fires. Utilising these technologies enables scholars and decision-makers to pinpoint high-risk regions, establish early warning systems, and execute focused fire prevention strategies.

The mapping of forest fire risk is essential for the conservation of biodiversity, as it helps reduce the harmful impacts of wildfires on plant and animal life. Fires result in the destruction of vegetation and contribute to habitat fragmentation, the displacement of species, and, in certain instances, the extinction of at-risk organisms. Furthermore, forest fires emit significant quantities of carbon dioxide, which plays a role in the acceleration of global warming and intensifies the degradation of the environment. Through the integration of sophisticated mapping methodologies with conservation approaches, involved parties can improve their capacity to safeguard ecosystems, rehabilitate degraded environments, and secure enduring ecological viability.

This article examines recent developments in the mapping of forest fire risks and their significance for the preservation of biodiversity. This study analyses a range of methodologies employed in the assessment of fire risk, including machine learning algorithms, satellite-based remote sensing, and GIS-based modelling techniques. Furthermore, the research emphasises case studies that illustrate the real-world applications of these technologies for reducing the risks associated with forest fires. This study seeks to elucidate the connection between fire risk mapping and the conservation of biodiversity, with the objective of informing

the creation of more effective policies and strategies aimed at safeguarding ecosystems and reducing the adverse effects of wildfires on global biodiversity.

Advancements in Forest Fire Risk Mapping: Tools and Techniques:- Geographic Information Systems (GIS), remote sensing, and machine learning have revolutionized forest fire risk assessment by enabling accurate prediction, monitoring, and management of wildfires.

GIS integrates multiple spatial datasets, such as topography, vegetation cover, and historical fire occurrences, to create risk maps that help authorities identify high-risk zones. Remote sensing technologies, including satellite imagery from MODIS, Sentinel-2, and Landsat, provide real-time data on fire hotspots, burned areas, and vegetation health. For example, the MODIS Active Fire Detection System has been widely used to track wildfires globally, providing critical information for disaster response. Machine learning algorithms further enhance fire risk mapping by analysing large datasets and identifying patterns that indicate fire susceptibility.

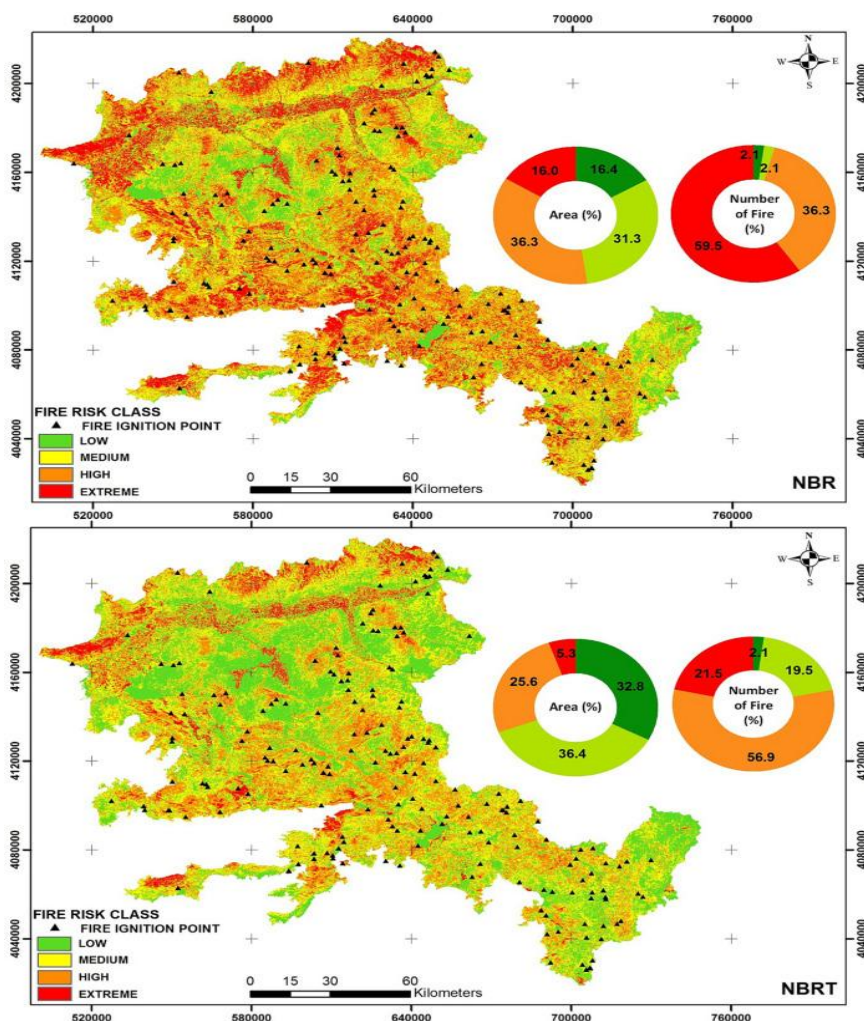
Techniques like Random Forest (RF) and Support Vector Machine (SVM) have been successfully applied in regions like California and Australia to predict fire-prone areas based on climate conditions, land cover, and past fire incidents. By combining these technologies, researchers and policymakers can improve early warning systems, allocate resources effectively, and develop targeted strategies to mitigate fire risks and protect biodiversity.

Satellite imagery from MODIS, Sentinel-2, and Landsat has played a crucial role in fire monitoring by providing real-time and historical data on fire activity, burned areas, and vegetation changes. For instance, the MODIS (Moderate Resolution Imaging Spectroradiometer) Active Fire Product has been extensively used in Indonesia to track peatland fires, which contribute significantly to carbon emissions and biodiversity loss.

In the Amazon rainforest, Sentinel-2 imagery has helped detect illegal slash-and-burn practices, allowing conservation authorities to intervene before fires spread uncontrollably. Meanwhile, Landsat-based fire severity mapping has been instrumental in assessing the impact of wildfires in California, where researchers used Landsat-derived Normalized Burn Ratio (NBR) to measure vegetation loss and recovery. These case studies demonstrate how satellite imagery provides accurate, large-scale monitoring capabilities that are essential for early warning systems, firefighting strategies, and post-fire ecological assessments, ultimately aiding in biodiversity conservation and sustainable land management.

Integrating climate, topographical, and vegetation data in fire risk modelling enhances the accuracy of wildfire predictions and mitigation strategies. For example, in Greece, researchers used climate variables such as temperature, humidity, and wind speed alongside topographical data (slope, elevation, and aspect) and vegetation indices (NDVI) to develop fire susceptibility maps, significantly improving early warning systems. In the Western Ghats of India, a fire risk assessment model combined digital elevation models (DEM), land surface temperature (LST), and forest density data to identify high-risk zones, aiding conservation efforts for endangered species. Similarly, in Australia, a machine learning-based approach integrated topographic features, historical fire occurrences, and vegetation moisture content to predict bushfire-prone areas, allowing for better resource allocation and community preparedness.

These case studies highlight how combining multiple environmental factors in GIS-based models enhances fire risk assessment, supports proactive fire management, and helps protect biodiversity in vulnerable ecosystems.



Landsat 8 images to determine the fire risk

Impact of Forest Fires on Biodiversity and Ecosystem Stability:- Wildfires have devastating effects on species habitats, forcing migration and increasing extinction risks, especially for vulnerable and endemic species. For example, the 2019–2020 Australian bushfires, known as the "Black Summer," destroyed over 12 million hectares of land, severely impacting species like the koala, whose population declined drastically due to habitat loss and food scarcity. In the Amazon rainforest, recurring wildfires caused by deforestation and climate change have led to the displacement of jaguars, pushing them into human settlements where they face poaching and habitat fragmentation. Similarly, in California, fires in the Sierra Nevada forests have severely affected the spotted owl, which relies on old-growth trees for nesting; repeated fires have reduced its viable habitat, increasing the risk of local extinction.

These examples illustrate how wildfires disrupt ecosystems, forcing species to migrate to unfamiliar and often unsuitable environments, leading to increased competition, food shortages, and, in extreme cases, population collapse. Effective fire management and conservation strategies are crucial to mitigating these risks and ensuring ecosystem resilience. Wildfires can significantly alter species richness and biodiversity indices, with varying effects depending on fire intensity, frequency, and ecosystem resilience. For instance, after the 1988 Yellowstone National Park fires in the U.S., researchers observed an initial decline in species richness but noted a gradual recovery as fire-adapted plant species like lodgepole pines and fireweed recolonized burned areas, attracting herbivores and pollinators. In contrast, the 2019 Amazon wildfires caused a severe loss in

biodiversity, with a sharp decline in mammal and amphibian populations due to habitat destruction, leading to lower Shannon and Simpson diversity indices. Similarly, in Mediterranean forests of Spain, post-fire studies revealed a shift in plant communities, favouring fire-resistant shrubs over tree species, which in turn affected bird and insect populations dependent on forest canopies. These examples highlight that while some ecosystems show resilience and can regain diversity over time, others experience long-term biodiversity loss, emphasizing the need for post-fire conservation and habitat restoration efforts. Biodiversity loss in fire-prone ecosystems has been extensively documented through various case studies worldwide, highlighting the severe impact of wildfires on flora and fauna. For example, the 2019–2020 Australian bushfires, which burned over 12 million hectares, led to the loss of nearly three billion animals, including mammals, reptiles, birds, and frogs. Species such as the greater glider and the Kangaroo Island dunnart faced critical population declines due to habitat destruction. In California, repeated wildfires in chaparral and coniferous forests have severely affected the Western monarch butterfly, whose population declined by nearly 99% due to the destruction of milkweed plants and breeding sites. Similarly, in the Amazon rainforest, the ongoing deforestation-induced fires have threatened species like the giant otter and the black-faced black spider monkey, which rely on dense forest canopies for survival. These case studies emphasize the urgent need for fire management strategies and conservation policies to mitigate biodiversity loss in fire-prone regions.

Strategies for Integrating Fire Risk Mapping with Biodiversity Conservation:- Integrating fire risk mapping with biodiversity conservation requires a combination of advanced technologies, proactive land management, and community-driven initiatives. One effective strategy is the use of Geographic Information Systems (GIS) and remote sensing to identify high-risk fire zones and prioritize conservation efforts. For example, in the Amazon rainforest, satellite-based fire risk models have been used to monitor illegal deforestation and predict wildfire outbreaks, allowing authorities to implement preventive measures. Similarly, in Australia, the integration of fire risk maps with biodiversity databases has helped identify critical habitats of endangered species, such as the koala, enabling targeted conservation efforts. Machine learning algorithms, such as Random Forest (RF) and Support Vector Machine (SVM), have also been employed in fire-prone areas like California to analyse climate, vegetation, and topographical data, improving early warning systems and minimizing fire damage to ecosystems. Another key strategy involves community-based fire management and ecological restoration. Indigenous fire management practices, such as controlled burning, have been successfully implemented in regions like Northern Australia, where Aboriginal communities use traditional knowledge to conduct low-intensity burns that reduce fuel loads and protect biodiversity. In South Africa's Kruger National Park, adaptive fire management strategies combining satellite fire risk mapping and ecological monitoring have helped maintain fire-dependent grassland ecosystems while minimizing harm to wildlife. Additionally, post-fire habitat restoration projects, such as reforestation efforts in Portugal's Serra da Estrela Natural Park, have played a crucial role in rehabilitating fire-damaged ecosystems and restoring species diversity. By integrating fire risk mapping with conservation strategies, stakeholders can develop more effective policies to mitigate wildfire impacts, protect vulnerable species, and enhance the resilience of fire-prone ecosystems.

Conclusion:- Forest fire risk mapping plays a crucial role in understanding and mitigating the devastating impacts of wildfires on biodiversity. By integrating advanced technologies such as GIS, remote sensing, and machine learning, researchers can accurately predict fire-prone areas and develop proactive management strategies. The use of satellite imagery, climate data, and topographical analysis enhances fire risk assessments, allowing for timely interventions that minimize habitat destruction and species displacement. Case studies from fire-prone regions such as Australia, the Amazon, and California demonstrate how fire risk

mapping can support conservation efforts by identifying vulnerable ecosystems and guiding resource allocation for fire prevention and habitat restoration. The impact of wildfires on biodiversity is profound, leading to habitat loss, species migration, and even extinction risks. Changes in species richness and ecological balance after fire events emphasize the need for integrating fire risk mapping with conservation strategies. Effective policies, including controlled burning, community-based fire management, and post-fire habitat restoration, are essential for maintaining ecosystem resilience. Moving forward, interdisciplinary collaboration between scientists, policymakers, and local communities is crucial to improving fire risk assessment tools and implementing sustainable wildfire management practices. By leveraging technology and conservation strategies, we can mitigate the threats posed by wildfires and safeguard biodiversity for future generations.

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