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Forest Fire Susceptibility Mapping: A Review of Satellite Remote Sensing and Spatial Modelling Approaches

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Forest Fires are a major environmental hazard affecting forest ecosystems, biodiversity, vegetation and human livelihoods. Geographic Information System (GIS) and remote sensing technologies provide effective tools for detecting, monitoring and assessing forest-fire risk over large and inaccessible areas. This review examines the application of GIS and remote sensing in forest-fire detection, risk assessment and management based on selected published studies. Previous research has integrated satellite derived information with climatic, vegetation, topographic and anthropogenic variables to identify fire-prone areas. Commonly used datasets include MODIS, VIIRS, Landsat and Sentinel imagery, along with digital elevation models and climatic data. GIS-based methods such as Analytical Hierarchy Process (AHP), weighted overlay, Frequency Ratio (FR), Evidential Belief Function (EBF), Index of Entropy (IOE) and machine-learning techniques have been applied for fire susceptibility assessment. GIS and advanced modelling technique can strengthen forest-fire monitoring, early warning and management.

Keywords: Forest fire susceptibility, Geographic Information System (GIS), Remote sensing, Risk mapping, Machine learning

Introduction

Forest Fire are an important disturbance to forest ecosystems and can cause vegetation loss, biodiversity, degradation, habitat destruction, carbon emissions and socioeconomic impacts. Fire occurrence is influenced by climatic conditions, vegetation characteristics, topography and human activities. Conventional ground-based monitoring is often difficult in extensive and inaccessible forest areas. Consequently, timely and spatially detailed information is required for effective forest-fire prevention and management. GIS and remote sensing provide important capabilities for forest-fire assessment. Satellite data can be used to detect active fires, monitoring vegetation conditions and map burned areas, while GIS enables the integration and spatial analysis of multiple environmental and anthropogenic factors. Studies in different regions have applied AHP, statistical techniques and machine-learning models to identify areas with greater fire susceptibility. For example, research in Malkangiri, Odisha used geospatial techniques and AHP to integrated temperature, elevation, NDVI, moisture, land use/land cover, wind velocity, slope and aspect for forest fire risk mapping (Bhuyan *et al.*, 2025). The resulting map classified the area into five risk categories and was validated using historical fire locations. Similarly, research in Mizoram compared Frequency Ratio, Evidential Belief Function (EBF) and Index of Entropy models and demonstrated the usefulness of data-driven approaches for forest-fire susceptibility assessment (Barman *et*

al.,2025). This review focuses on the major applications of GIS and remote sensing forest-fire assessment, the factors commonly associated fire susceptibility and the principal modelling approaches used in previous studies.

Applications of GIS and Remote Sensing

Remote Sensing is widely used for active fire detection and monitoring. Satellite products such as MODIS and VIIRS provide information on the location and distribution of fire events and can support large area and near real time monitoring (Parajuli *et al*., 2020). Landsat and Sentinel imagery can additionally be used for mapping burned areas and assessing changes in vegetation followed fire. Vegetation indices such as NDVI, EVI are useful for evaluating vegetation condition, while the Normalized Burn Ration (NBR) and differenced NBR (dNBR) can support burned-area and burn severity assessment. GIS complements remote sensing by integrating fire observations with environmental variables. Common factors include temperature, rainfall, elevation, slope, aspect, NDVI, land use/land cover, moisture conditions, roads and settlements. These variables can be reclassified and combined to produce fire risk or susceptibility maps. The Malkangiri study, for instance, identified temperature as an important factor and found considerable overlap between observed fore points and very high-risk areas (Bhuyan *et al*., 2025). Machine learning methods such as Random Forest can further capture nonlinear relationships between fire occurrence and environmental conditions (Razavi-Termeh *et al*., 2020).

Major Factors Influencing Fire Risk

The reviewed studies indicate that forest fire susceptibility is influenced by several interacting factors. Temperature can increase vegetation and fuel dryness, while rainfall and moisture conditions influence the availability of combustible material. Vegetation condition, commonly represented by NDVI and related indices, is important because dry vegetation can increase fire susceptibility. Topography also influences fire behaviour. Slope affects the rate and direction for fire spread, while aspect influences solar exposure and moisture conditions. Elevation can indirectly influence temperature, vegetation, and accessibility. Land use/land cover is another important factor because different land cover classes have different fuel characteristics. Human activities strongly influence fire ignition. Roads and settlements may increase accessibility and the probability of human-cause fire.

Challenges and Future Scope

Despite the increasing use of GIS and remote sensing, several challenges remain. Differences in spatial resolution, satellite data availability, factor selection and classification methods make comparison between studies difficult. AHP and weighted overlay approaches may involve subjective assignment of weights, whereas machine learning models require sufficient and reliable training data. Limited field observations and inadequate independent validation can also affect the reliability of fire risk maps. Future research should focus on integrating multi-temporal satellite observations, climatic data, high-resolution spatial information and machine learning techniques, combining near real time fire alerts with susceptibility maps could improve early warning systems and support rapid response. GIS based fire risk information can also assist forest managers in prioritising fire prevention, surveillance, fire line planning and allocation of firefighting resources.

Conclusion

GIS and remote sensing provide effective tools for forest fire detection, risk assessment, susceptibility mapping and management. The reviewed studies demonstrate that integrating climatic, vegetation, topographic and anthropogenic factors can provide useful spatial information about fire prone areas. AHP and weighted overlay methods remain useful because of their simplicity, while statistical and machine learning approaches offer opportunities for more data driven prediction. Greater integration and near real time fire observations can improve forest fire early warning and support more effective forest management.

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