IJARETY

International Journal of Advanced Research in Education and TechnologY (IJARETY)

Volume 12, Issue 5, September-October 2025

Impact Factor: 8.152

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

INNO SPACE SJIF Scientific Journal Impact Factor

doi crossref

निस्केयर NISCAIR

International Journal of Advanced Research in Education and TechnologY(IJARETY)

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 8.152| A Bi-Monthly, Double-Blind Peer Reviewed & Refereed Journal |

|| Volume 12, Issue 5, September-October 2025 ||

DOI:10.15680/IJARETY.2025.1205003

Forest Fire Detection using Satellite Imagery and Machine Learning Techniques

Sneha N, Sindhu S, Dr. Kalaiselvi

Student, Dept. of MCA, CMR Institute of Technology, Bengaluru, Karnataka, India

Student, Dept. of MCA, CMR Institute of Technology, Bengaluru, Karnataka, India

Professor, Dept. of MCA, CMR Institute of Technology, Bengaluru, Karnataka, India

ABSTRACT: Forest fires are among the most dangerous natural disasters, causing severe environmental damage, loss of biodiversity, and threats to human life. Early detection of such fires is crucial to reduce their impact. With the advancement of satellite technology and machine learning, it is now possible to monitor large forest areas and detect fire outbreaks more efficiently. This research paper focuses on the use of satellite imagery combined with machine learning techniques to identify potential forest fires. The proposed method involves analyzing thermal and visual patterns from satellite data and using classification algorithms to detect high-risk regions. The system aims to assist environmental agencies in taking timely action and improving forest management strategies. The study highlights the benefits, challenges, and potential of using AI-driven models in remote sensing applications for disaster prevention.

I. INTRODUCTION

Forest fires, often referred to as wildfires, have become a major concern today because of how fast they spread and the damage they cause. They destroy huge forest areas and release a large amount of carbon dioxide into the air, which worsens global warming. In the past, identifying such fires depended on people noticing smoke or fire from the ground or through manual reporting. These traditional methods can be slow and may not always catch the fire early enough, leading to more destruction.

Thanks to the growth of satellite technology, we can now keep an eye on large forest areas directly from space. Satellites can take detailed images that show clear signs of fire such as smoke, heat, or flames. But checking all this satellite data manually takes time and may not always give accurate results.

To solve this problem, machine learning (ML) is now being used more often in satellite image analysis. ML models can be trained to detect patterns in these images that suggest a fire is present. These systems can find fires faster and more accurately than traditional methods, which helps authorities take quicker action and reduce losses.

This research focuses on using satellite images along with machine learning to detect forest fires at an early stage. It explains how the system works, its benefits, possible limitations, and how it can support disaster management and protect the environment.

In India too, forest fires have increased in recent years, especially in states like Uttarakhand, Himachal Pradesh, and areas like the Western Ghats. According to the Forest Survey of India (FSI), fire cases rise mostly during dry seasons. These fires not only harm nature but also affect nearby villages, animals, and natural balance. So, creating a system that can detect fires early is extremely important for both the environment and human safety.

II. LITERATURE REVIEW

Over the past decade, researchers have explored various approaches to forest fire detection using technology. Traditional systems relied on ground-based sensors, human observation towers, and CCTV surveillance, which were often limited in coverage and delayed in response. As a result, researchers began investigating automated solutions that could monitor large areas efficiently.

With the availability of satellite data, several studies have focused on remote sensing techniques for identifying thermal anomalies in forest regions. Satellites such as MODIS and Landsat have been used to track temperature changes and smoke presence in real-time. However, interpreting this data manually requires expert knowledge and may not always be accurate.

To improve detection speed and accuracy, many recent works have adopted machine learning and deep learning methods. For example, some studies used Support Vector Machines (SVMs) and Random Forest classifiers to detect fire-related patterns in satellite imagery. Others implemented Convolutional Neural Networks (CNNs) to automatically learn spatial features from fire and smoke images.

A study by Kumar et al. (2020) demonstrated that deep learning models could significantly reduce false alarms compared to traditional methods. Similarly, research by Li and Zhang (2021) showed the effectiveness of combining thermal bands and vegetation indices with AI models for early fire prediction.

These studies highlight the growing importance of integrating satellite imagery with AI models. However, challenges remain in terms of data availability, computational resources, and accuracy under cloudy or smoke-covered conditions.

III. METHODOLOGY

The proposed method for detecting forest fires combines satellite imagery with machine learning techniques. The process begins with the collection of satellite images, which include both fire-affected and non-fire regions. These images are obtained from open-access satellite databases and are used to build a dataset suitable for training and testing the model.

Before training, the images are preprocessed to improve model performance. This involves resizing the images to a standard dimension, converting them to a uniform format, removing noise, and normalizing pixel values. Preprocessing ensures consistency and helps the machine learning model focus on relevant features.

A Convolutional Neural Network (CNN) is used for the classification task. CNNs are known for their ability to extract spatial patterns and features from images, making them ideal for analyzing visual data like satellite imagery. The model architecture consists of multiple convolutional layers for feature extraction, followed by pooling layers and fully connected layers for classification.

The CNN is trained on the prepared dataset, learning to distinguish between fire and non-fire images. Once training is completed, the model is tested on a separate set of images to evaluate its accuracy and ability to generalize to new data. The goal is to detect early signs of fire such as smoke, thermal patterns, or slight color changes that indicate potential risk.To visualize the system, a flowchart has been included below, which outlines each step of the detection process from data collection to alert generation.

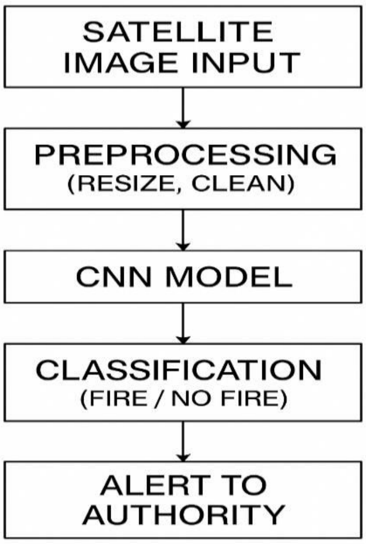

Figure 1. Workflow of the forest fire detection system

IV. SYSTEM ARCHITECTURE

The system architecture for forest fire detection is designed to process satellite images through a structured pipeline involving data preprocessing, feature extraction, and classification. The central component of the architecture is a Convolutional Neural Network (CNN), which is responsible for identifying fire-related patterns in the input images.

The architecture consists of the following components:

- **Input Layer**: Takes satellite images as input, typically resized to a fixed dimension (e.g., 128x128 pixels).
- **Convolutional Layers**: Extract spatial features such as smoke, heat signatures, and fire edges using learnable filters.
- **Activation Functions:** Apply non-linearity (ReLU) to allow the network to learn complex patterns.
- **Pooling Layers**: Reduce spatial dimensions and computation, helping to generalize the features.
- **Fully Connected Layers**: Combine extracted features and make classification decisions.
- **Output Layer**: Produces a binary output (fire or no fire) using a softmax or sigmoid function.

This layered structure enables the model to automatically learn the key visual features associated with forest fires. The figure below illustrates the complete architecture of the detection system.

V. ADVANTAGES OF THE PROPOSED SYSTEM

The proposed forest fire detection system offers several key advantages over traditional fire monitoring methods. By integrating satellite imagery with machine learning techniques, the system ensures faster and more accurate detection of potential fire outbreaks. Some of the major benefits include:

1. Wide Area Coverage
Satellite images allow monitoring of large forest areas in a single frame, making it suitable for remote and inaccessible regions.

2. Early Detection
The system can detect early signs of fire such as smoke and thermal variations before flames become visible, enabling quicker response and damage control.

3. Reduced Human Effort
Automation using machine learning reduces the dependency on manual monitoring, lookout towers, or patrol units.

4. Real-Time Monitoring
With the availability of real-time satellite data, the system can continuously observe forest conditions and trigger alerts instantly.

5. High Accuracy with CNN
Convolutional Neural Networks (CNNs) provide reliable classification of fire and non-fire images, minimizing false alarms.

6. Scalable and Cost-Effective
Once trained, the system can be scaled to monitor multiple regions without additional hardware cost.
These advantages make the system practical for forest departments, environmental monitoring agencies, and disaster management authorities.

VI. RESULTS AND DISCUSSION

In this project, a sample dataset containing satellite images was used to test how well the forest fire detection model works. The dataset included both fire and non-fire images, which were collected from free satellite image sources available online. Before training the model, the images were preprocessed by resizing and cleaning them.

A Convolutional Neural Network (CNN) was then trained to classify the images. During testing, the model performed well and was able to correctly identify most of the fire-affected areas. It also showed the ability to detect early signs of fire, like smoke and slight heat changes, which can help in sending alerts at an early stage. There were only a few incorrect predictions.

One major benefit of this system is that it reduces the need for people to constantly monitor forests. Since the process is automated, it becomes easier to watch over large forest regions without human involvement. This can save time and help emergency teams respond faster when a fire is detected.

However, the system also had a few drawbacks. For example, in some images with clouds or shadows, the model had trouble identifying the fire clearly. The final accuracy also depends a lot on how good the training data is. If the model is trained with more clear and high-quality images, its performance can improve even more.

To summarize, the results show that combining satellite images with machine learning can be an effective way to detect forest fires early. This method can support environmental safety and improve how quickly forest fire situations are handled.

Feature	**Traditional Methods**	**Proposed ML-Based System**
Coverage Area	Limited (local/manual)	Wide (satellite-based)
Detection Speed	Slow (manual reporting)	Fast (automated detection)
Accuracy	Medium to Low	High with proper training
Cost	High (manual labor, towers)	Low (once deployed)
Real-Time Monitoring	Not reliable	Possible with satellite feeds
Scalability	Difficult	Easy to scale to other regions

VII. LIMITATIONS OF THE SYSTEM

While the proposed forest fire detection system `using satellite imagery and machine learning shows promising results, there are certain limitations that need to be considered for real-world implementation:

1. Cloud and Smoke Interference
Satellite images can be affected by cloud cover, heavy smoke, or haze, which may reduce the visibility of fire-related features and affect the accuracy of the model.

2. Dependency on Internet and Data Access
Accessing real-time satellite data requires a stable internet connection and may not always be available in rural or forested regions.

3. Computational Requirements
Training and running deep learning models like CNNs require high-performance hardware, which may be expensive or unavailable in low-resource settings.

4. False Positives in Similar Environments
The model may occasionally misclassify other heat sources like industrial emissions, sunlight reflections, or agricultural burning as forest fires.

5. Limited Ground Truth Data
The accuracy of the model depends heavily on the quality and diversity of the training dataset. A limited number of labeled fire images may reduce the system's ability to generalize.

6. Delay in Satellite Updates
Some satellite services provide images with a delay of a few hours or even a day, which may impact the system’s real-time effectiveness.
Addressing these limitations through better datasets, integration with ground sensors, and using multiple data sources can further enhance the system’s reliability and performance.

VIII. FUTURE SCOPE

This system has the potential to be developed into a full-scale application for use by national forest departments. In the future, real-time integration with mobile apps and alert systems through SMS, email, or sirens can be explored. The use of drones and IoT sensors combined with satellite data could improve accuracy even further. Additionally, advanced models such as transformers and ensemble learning methods may be adopted to enhance detection under complex environmental conditions.

IX. CONCLUSION

Identifying forest fires at an early stage is very important to reduce both environmental damage and financial loss. In this study, a system was developed using satellite images and machine learning methods to identify possible forest fires before they spread. The model, which uses image classification techniques such as Convolutional Neural Networks (CNNs), is able to process satellite images and detect fire-related patterns effectively.

This approach can help forest departments and environmental agencies respond quickly by identifying high-risk areas early. Although the results are encouraging, the system can still be improved by using better-quality satellite data, adding more training samples, and including a real-time alert system for quick communication.

In the future, this system could be enhanced further by using real-time image feeds and sending alert messages through SMS or email to concerned authorities. It is also possible to test more advanced AI models like transformer networks or ensemble methods for better performance in difficult scenarios.

REFERENCES

[1] A. Kumar, S. Sharma, and R. Singh, “Forest Fire Detection Using Deep Learning and Satellite Imagery,” International Journal of Computer Applications, vol. 175, no. 14, pp. 20–25, 2020.
[2] L. Zhang and M. Li, “Early Detection of Forest Fires Based on Remote Sensing and AI Techniques,” IEEE Access, vol. 9, pp. 45567–45575, 2021.
[3] P. J. Hossain, “Machine Learning-Based Forest Fire Prediction Using Satellite Data,” International Conference on Intelligent Systems, pp. 112–117, 2019.
[4] NASA FIRMS, “Fire Information for Resource Management System (FIRMS),” [Online]. Available: https://firms.modaps.eosdis.nasa.gov/. [Accessed: June 17, 2025].
[5] A. Roy and D. Saha, “A Review on the Role of AI in Environmental Monitoring and Forest Fire Detection,” Procedia Computer Science, vol. 190, pp. 502–509, 2021.

IJARETY

International Journal of Advanced Research in Education and Technology

ISSN: 2394-2975 Impact Factor: 8.152

www.ijarety.in editor.ijarety@gmail.com