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Next-Day Forest Fire Risk Prediction Using Machine Learning and Multimodal Satellite Data

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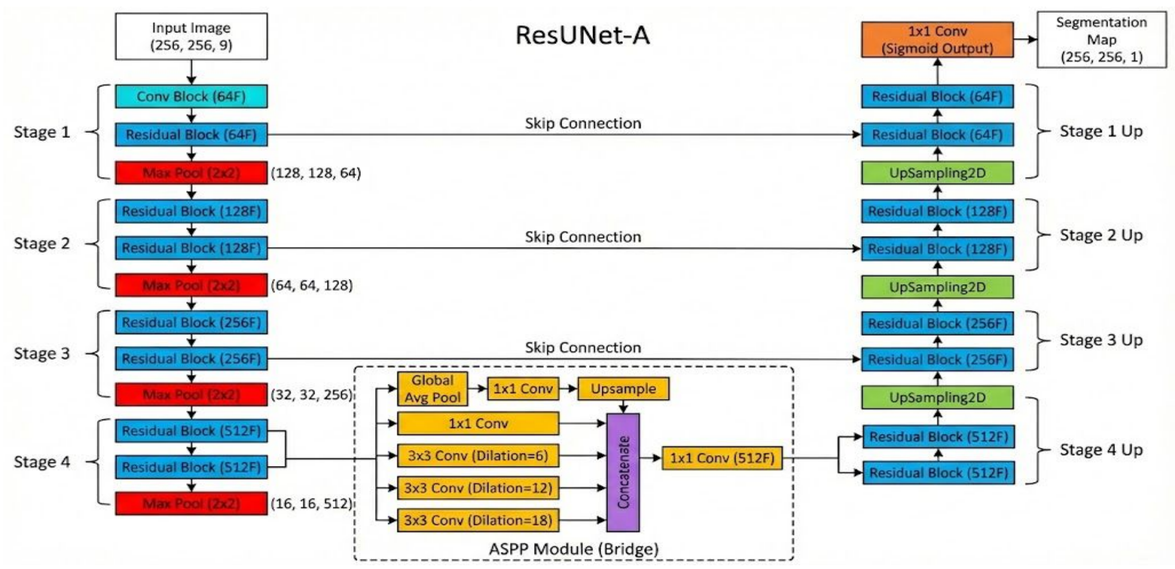
INTRODUCTION & AIM

- **The Problem:** Forest fires pose a significant environmental threat, with regions like Uttarakhand, India, experiencing frequent and severe incidents. In 2023, India recorded over 200,000 forest fire alerts.
- **The Gap:** Existing fire detection systems (e.g., MODIS, VIIRS-SNPP) are **reactive**, identifying fires only after they have started by detecting thermal anomalies.
- **Our Solution:** We propose a **predictive system** that uses **deep learning** to generate high-resolution (30m) fire risk maps one day in advance.
- **Impact:** This predictive approach enables early intervention and strategic resource allocation, supporting **UN Sustainable Development Goals 13 (Climate Action) and 15 (Life on Land).**

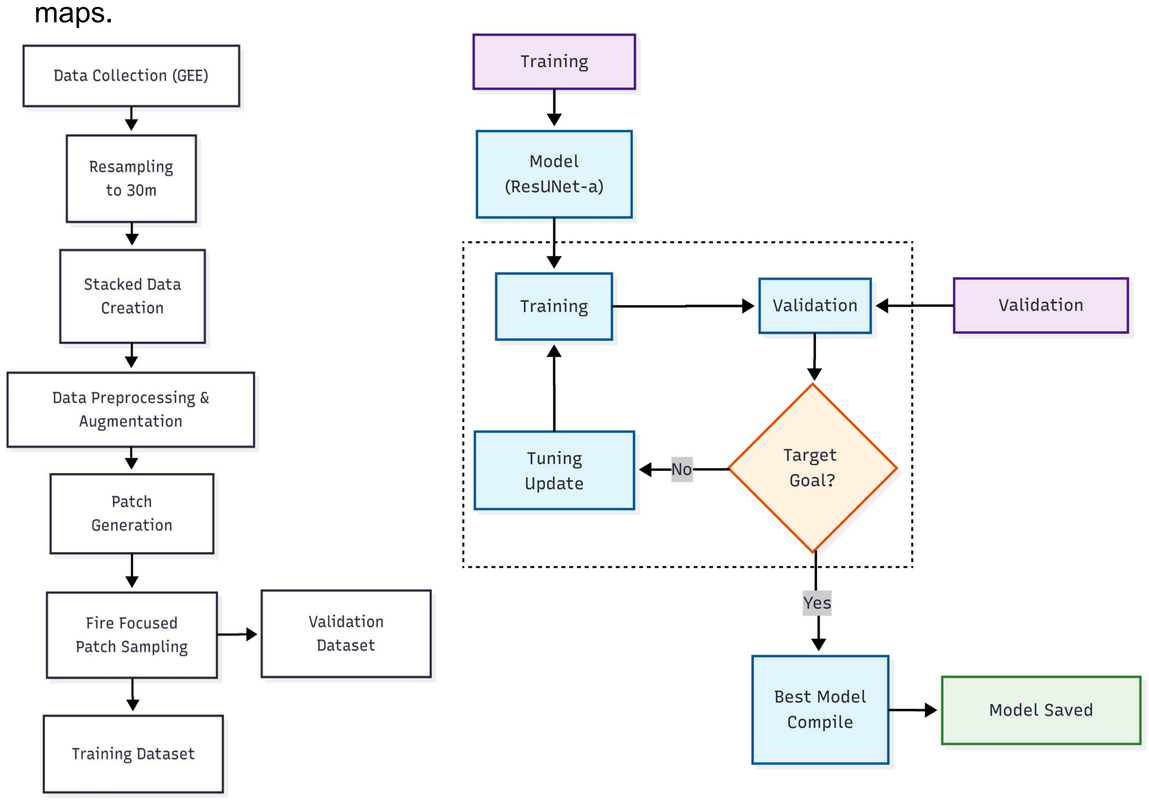
METHOD

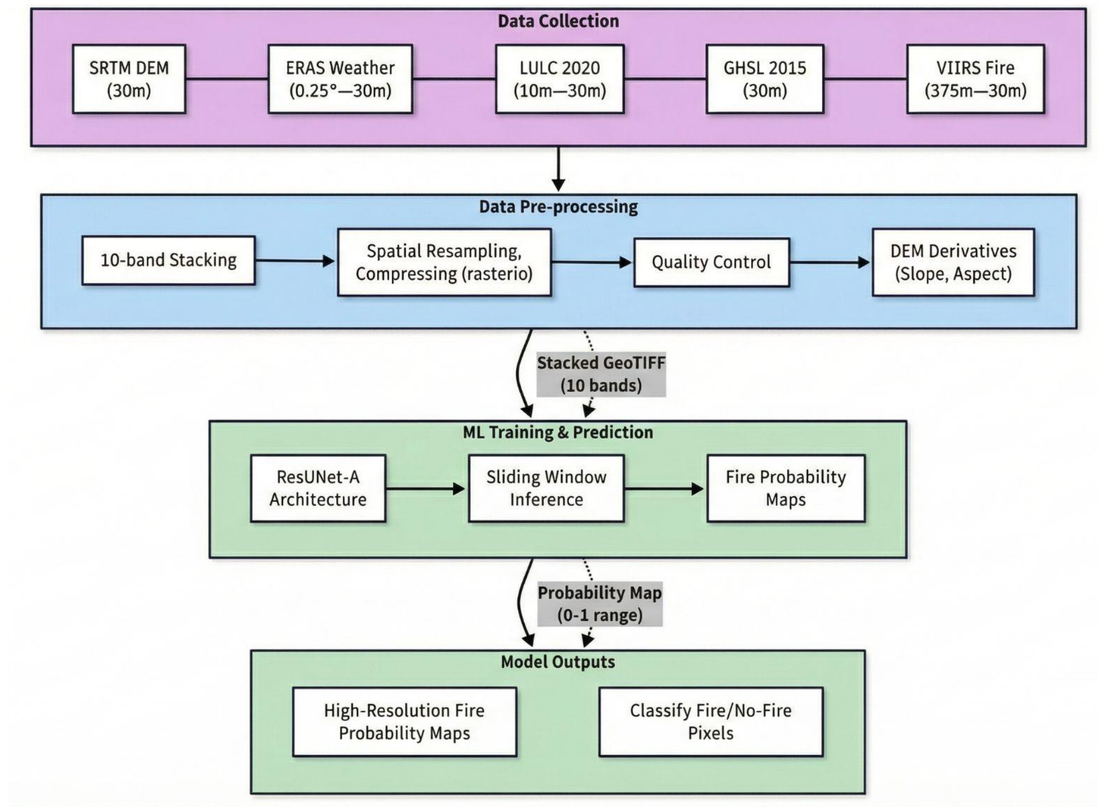
- **Study Area & Period:** The fire-prone **state of Uttarakhand**, India, focusing on the severe fire season from **1 April to 29 May 2016.**
- A **10-band daily GeoTIFF stack (30m resolution)** was created, including:
  - **Weather:** Temperature, wind, precipitation (from ERA5).
  - **Topography:** Slope, aspect (from SRTM DEM).
  - **Land Use:** Fuel map, land cover (from LULC).
  - **Fire History:** Fire mask (from VIIRS-SNPP).

- **Model Architecture:** A deep convolutional neural network (CNN) based on the **ResUNet-a architecture** was implemented.

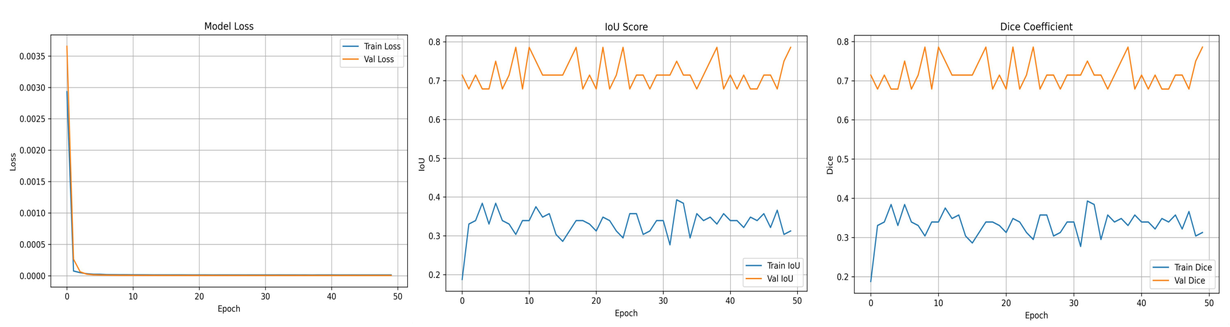


- **Training and Prediction:** Trained from scratch via patch-based sampling, the model uses sliding window inference to generate high-resolution, next-day fire probability maps.

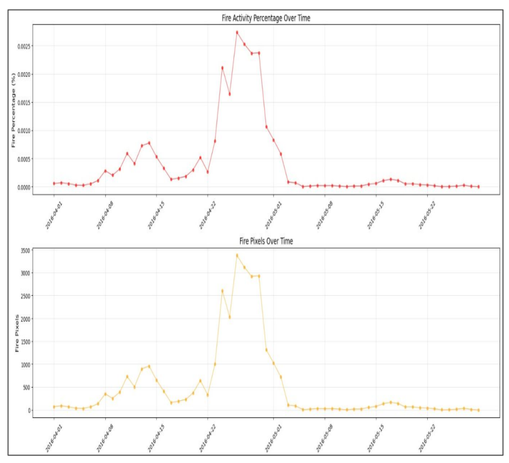


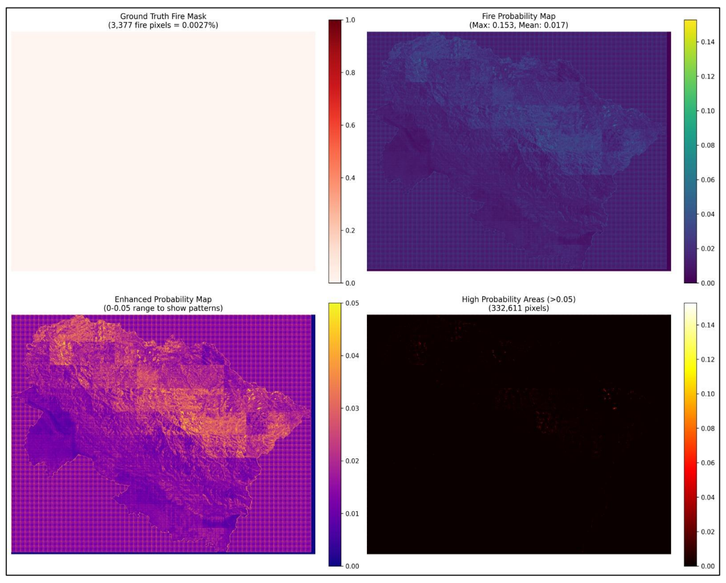


RESULTS & DISCUSSION



- **Accuracy: 84.2%**
- **IoU Score: 0.82**
- **Dice Coefficient: 0.857**





- **Rapid loss convergence** and **high validation IoU (0.82)** confirm effective learning.
- **Class Imbalance:** Fire is rare **(0.0027% of pixels)**, which suppresses raw prediction values.
- Prediction: Despite **low raw probabilities**, enhanced maps prove the model accurately localizes fire events.

CONCLUSION

- We successfully developed a deep learning-based system for predicting next-day forest fire risk using multimodal satellite data.
- Our proactive approach provides actionable, high-resolution intelligence crucial for disaster preparedness and environmental protection.
- The curated dataset and methodology serve as a valuable benchmark for future work in wildfire prediction with Earth observation data.

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