Identifying Forest Fire Hotspots

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Outline of the presentation

Forest Fire and how it originates

- Forests are vital for Earth's ecological balance. Often remote and unmanaged, they contain dry wood and leaves. These elements form a highly combustible material and represent the perfect context for initial-fire ignition and act as fuel for later stages of the fire.

Alkhatib, A. A. A review on Forest Fire Detection Techniques. International Journal of Distributed Sensor Networks 10, 597368 (2014).

I Introduction

Natural causes of Forest Fire

High Temperatures
Prolonged heat waves increase fire risk.

Lightning Strikes
Natural discharges can ignite dry plants.

Spontaneous Combustion
Organic matter can self-ignite in heat.

Broken Glass Effect
Glass can focus sunlight on vegetation.

Human- Induced Causes of Wildfires

Negligence
Unattended fires and careless actions lead to wildfires.

Deforestation
Land clearing practices contribute to fire risks.

Power Lines
Electrical issues can ignite fires in dry areas.

Arson
Deliberate fire-setting poses significant dangers.

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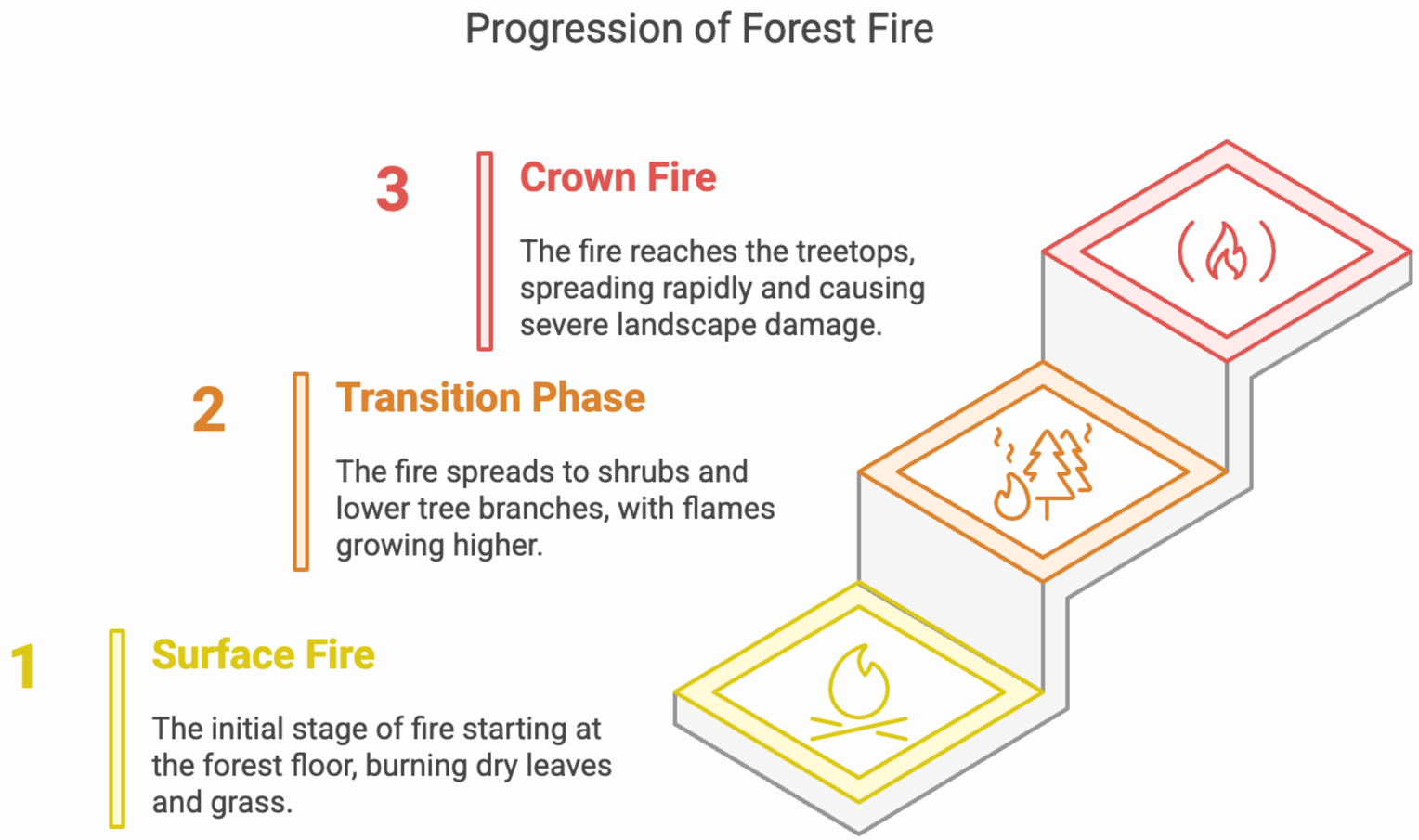
Forest Fire and how it originates



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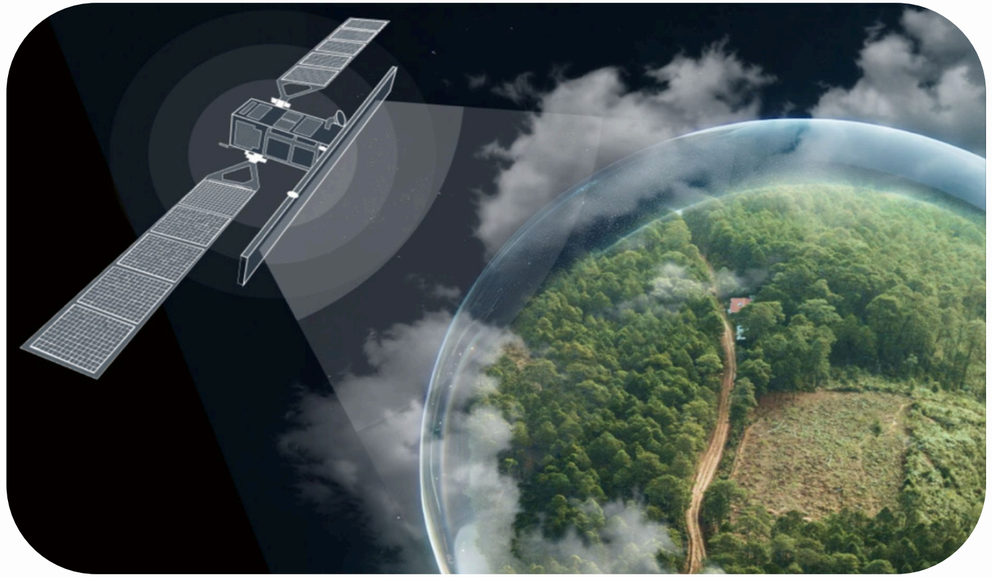
Monitoring Forest Fires with Satellite Remote Sensing

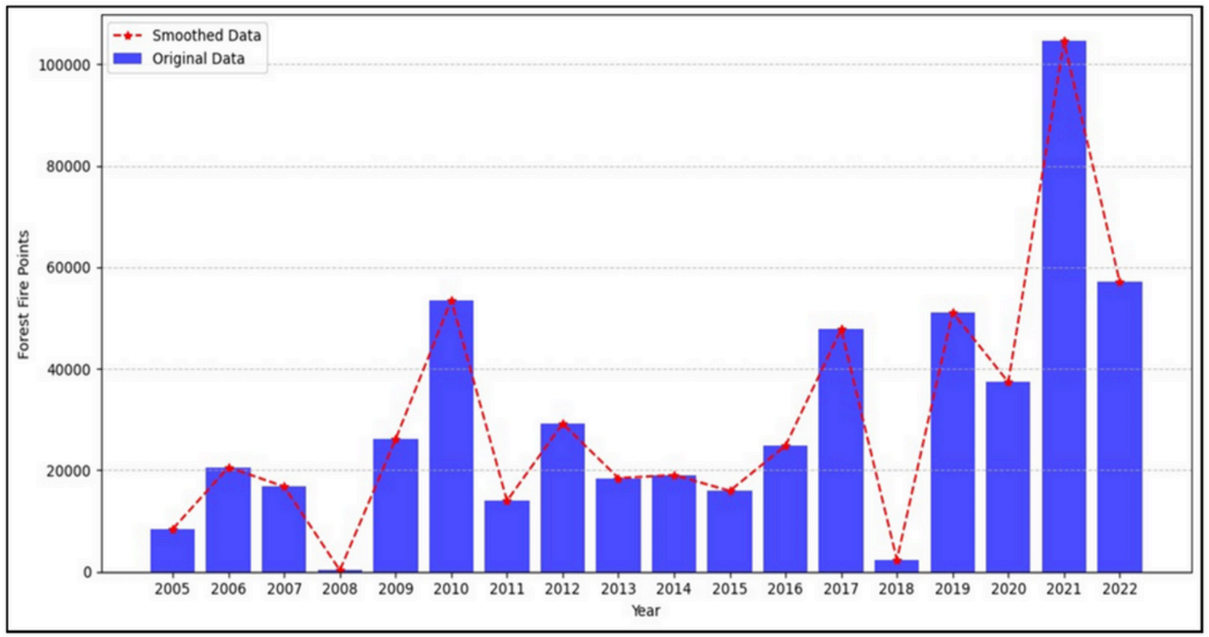
- Cost-Effective & Reliable: Captures vast, remote areas with essential environmental data at a lower cost.
- High-Tech Space-Borne Sensors: Short revisit times ensure frequent updates with high-accuracy measurements help detect fires early.
- Spatial Pattern Analysis: Supports fast, reliable identification of priority areas for management.
- Spatio-Temporal Insights: Spatial statistics reveal fire trends over time, aiding conservation efforts.



Reddy, C. S. et al. Identification and characterization of spatio-temporal hotspots of forest fires in South Asia. Environmental Monitoring and Assessment 191, (2019).

Why Forest Fire Prediction is Critical for India?

India lost 9.3 million hectares of forest to fires between 2003-2017. The 2021 fire season alone caused ₹1,100+ crores in direct damages (IIFM). Recent studies show fires killed over 400 endangered animals annually (NTCA 2022), while releasing 300 million tonnes of stored CO_2 in 2020 (MoEFCC). These are not projections - these are measured losses.



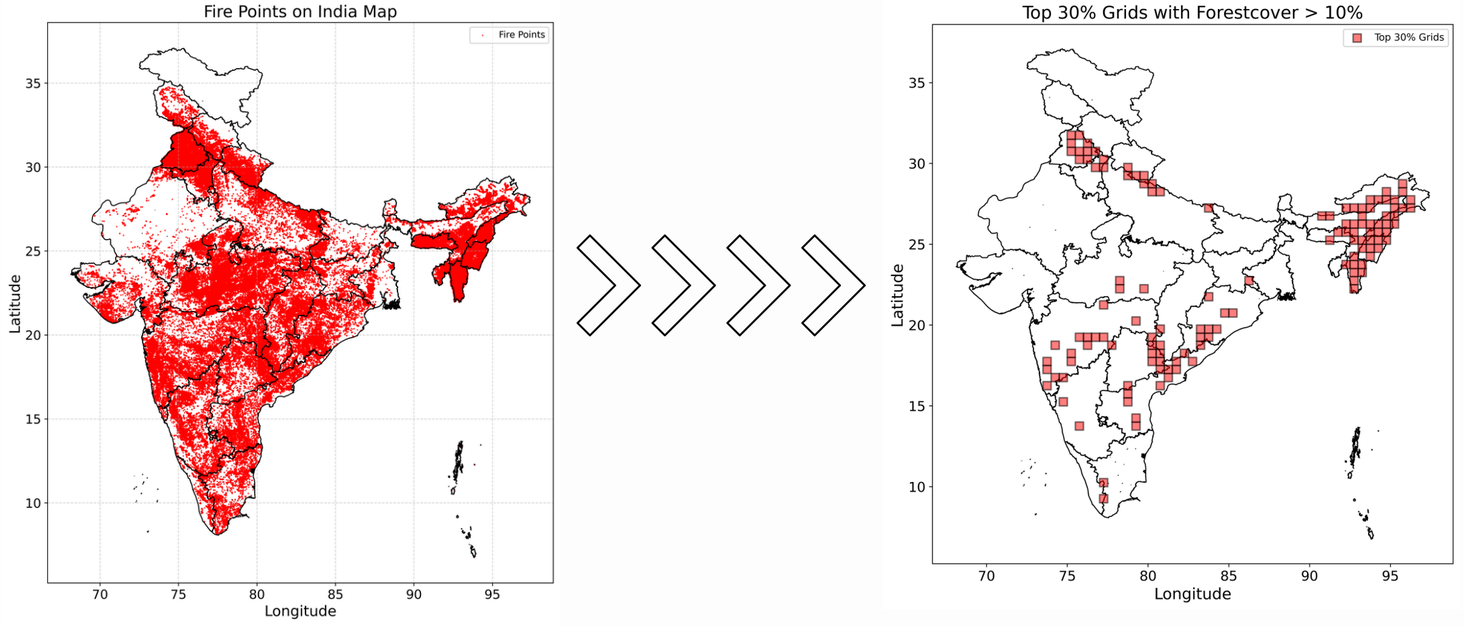
Temporal trends in forest fire points across India from 2005 to 2022.

Sagar, et al. Forest Fire Dynamics in India (2005–2022): Unveiling climatic impacts, spatial patterns, and interface with anthrax incidence. Ecological Indicators 166, 112454 (2024).

Hotspot analysis

- Hotspot analysis has become an advantageous technique for analysing and visualising geographically-distributed events, and therefore enabling their management. Hotspot analysis is usually conducted with the help of Geographic Information System (GIS), it enables the development of maps and the visualization of scenario's outcomes..

- This involves the visualisation of geographic data, which then enables the identification of 'hotspots' , which are areas with higher density or where events or activities are clustered.



Giving importance to the forest ecosystem and its services, and in view of socio-economic and environmental loss due to forest fire activities, monitoring and identifying forest fire hotspot regions are vital. It shall offer an effective management plan to regulatory bodies, which may be further helpful in reducing the harsh conditions associated with forest fire events in vulnerable zones.

II Literature Survey

- Sagar et al. 2024 highlights the direct influence of climate conditions on forest fire occurrences, with significant positive correlations found with average and maximum temperatures.

- Jain et al. 2021 finds that from 2001 to 2020, 70% of yearly forest fires over the Central India region occurred during March (1,857.5 counts/month) and April (922.8 counts/month). Further, the study assesses quinquennial spatiotemporal changes in forest fire characteristics such as fire count density and average fire intensity.

- Reddy et al. 2019 focuses on the spatio-temporal patterns of forest fires and identifying hotspots using the novel geospatial technique “emerging hotspot analysis tool” in South Asia. Daily MODIS active fire locations data of 15 years (2003–2017) has been aggregated in order to characterize fire frequency, fire density, and hotspots.

- Ranjan et al. 2023 deployed long-term (2003–2021) MODIS fire datasets (namely, MYD14A1: Fire Radiative Power (FRP); and MCD64A1: Burned area (BA) product) to delineate the forest fire hot spots using the Getis-Ord Gi* approach over the Sundarban Biosphere Reserve.

III Methodology

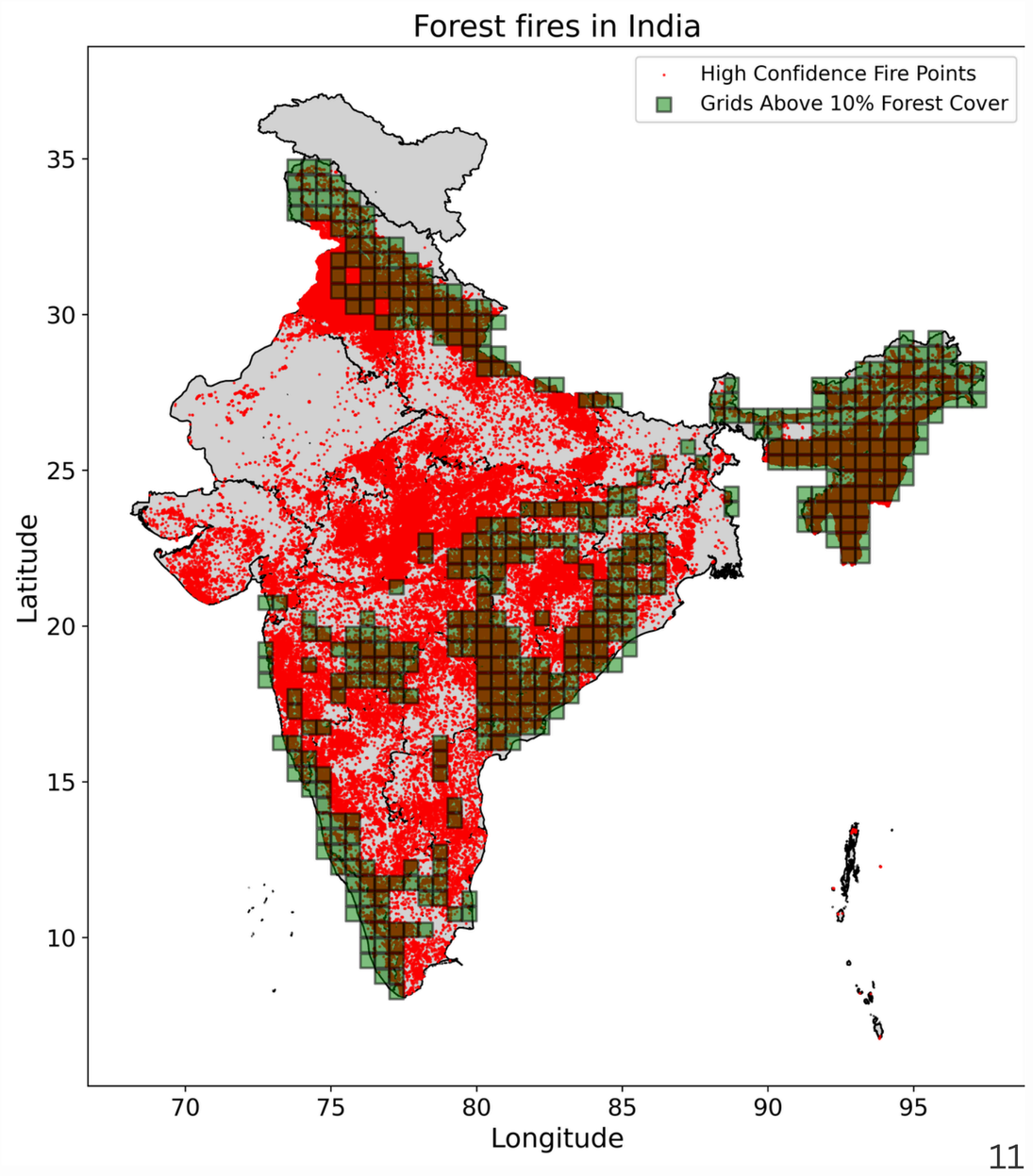
Study Area

- The study covers India, extending 3,287,263 sq. km between latitudes 6° 44′ N and 35° 30′ N, and longitudes 68° 07′ E and 97° 25′ E. With forest cover comprising 21.76 % of its land area, as defined by the Forest Survey of India.

- India's forests are predominantly tropical dry and moist deciduous, covering 68 % of total forested area.

- Forest fire occurrences in the Indian sub-continent are typically observed from March to April. The higher temperatures and reduced precipitation in the pre-monsoon spell (March to June) increase the severity of forest fires.

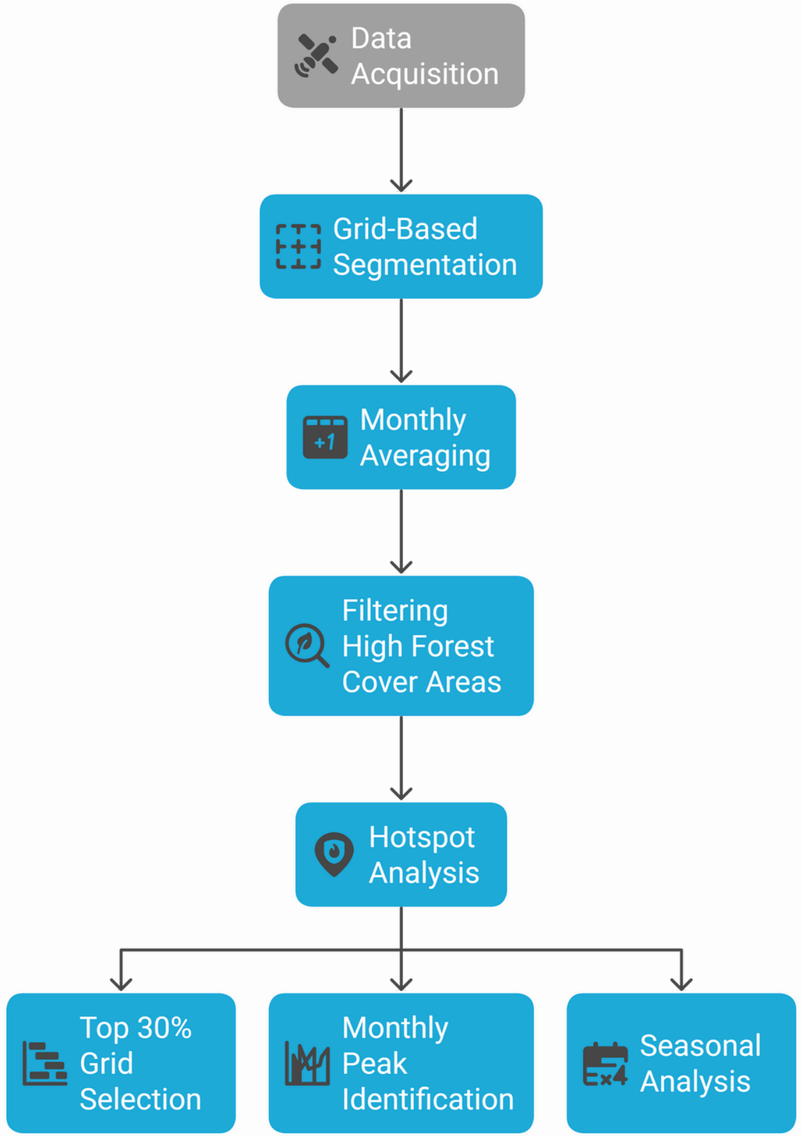
- Study time period is from January 2001 to July 2024



Ranjan, A. K. et al. Forest fire hotspot identification and assessment of forest fire impact on AOD over Simlipal Biosphere Reserve, Odisha (India). Tropical Ecology 65, 376–386 (2023).

III Methodology

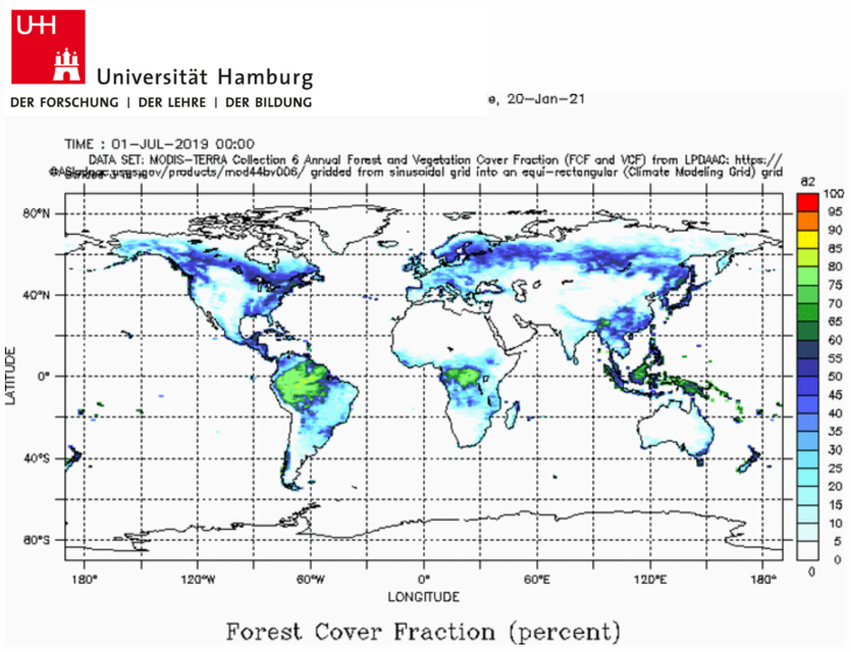
1. Data Acquisition:
   - Data was obtained from NASA's Fire Information for Resource Management System (FIRMS).
2. Grid-Based Segmentation:
   - The collected fire data was divided into spatial grids of 0.5 × 0.5 degrees for systematic analysis.
3. Monthly Summation:
   - Monthly fire counts were calculated for each grid to understand temporal variations.
4. Filtering High Forest Cover Areas:
   - Grids where the forest cover fraction exceeded 10% were retained.
5. Hotspot Analysis:
   - Top 30% Grid Selection: Grids with the highest fire count (top 30%) were classified as major fire-prone areas.
   - Monthly Peak Identification: Peak fire occurrences were analyzed across multiple years to detect recurring patterns.
   - Seasonal Analysis: The dataset was examined based on seasonal variations to determine seasonal fire trends.



Multi-sensors satellite/gridded datasets

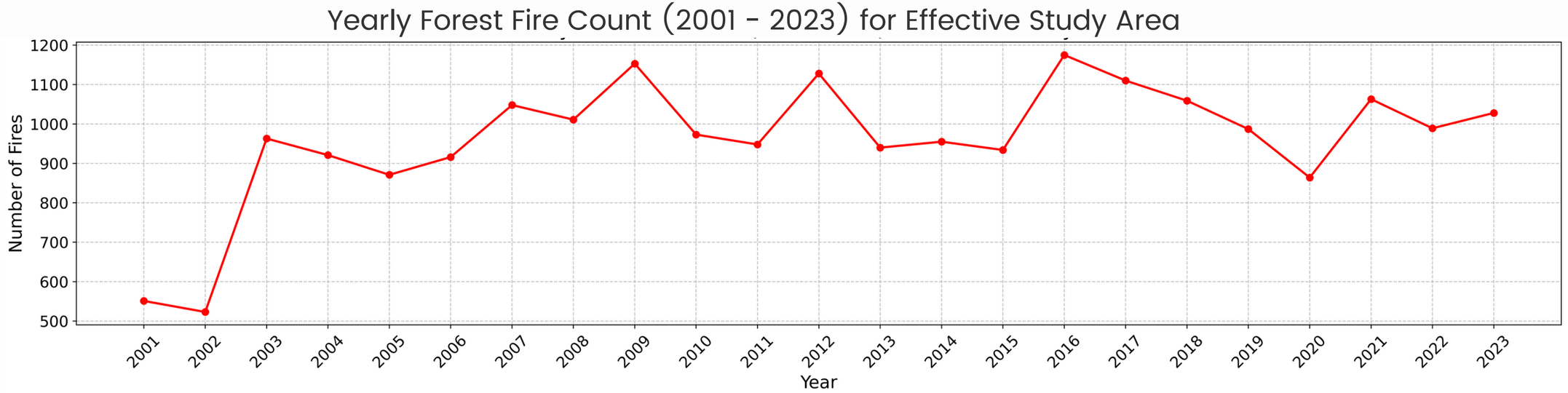
1. **Forest fire points**: The Fire Information for Resource Management System (FIRMS) distributes Near Real-Time (NRT) active fire data from the Moderate Resolution Imaging Spectroradiometer (MODIS) aboard the Aqua and Terra satellites.

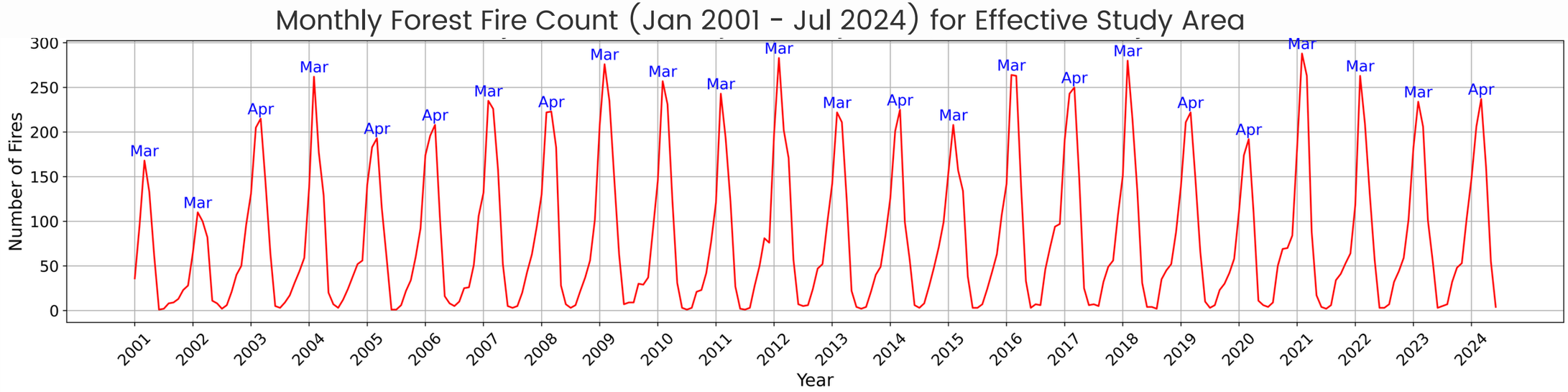
2. **Forest cover fraction**: The data set contains the forest cover fraction (FCF) derived from observations and products of the MODIS Sensor aboard EOS-TERRA.



IV Results

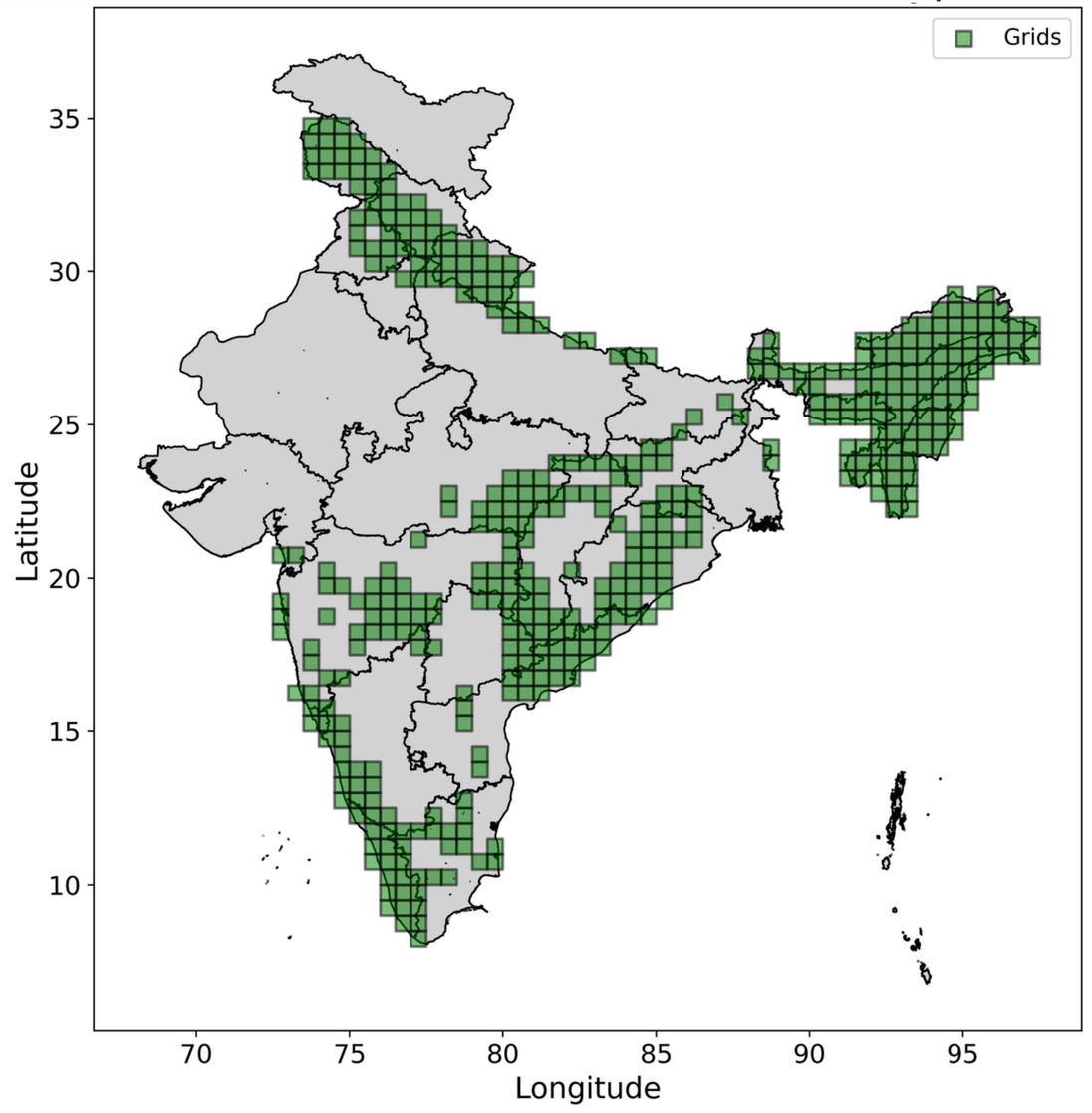
Time-series analysis:



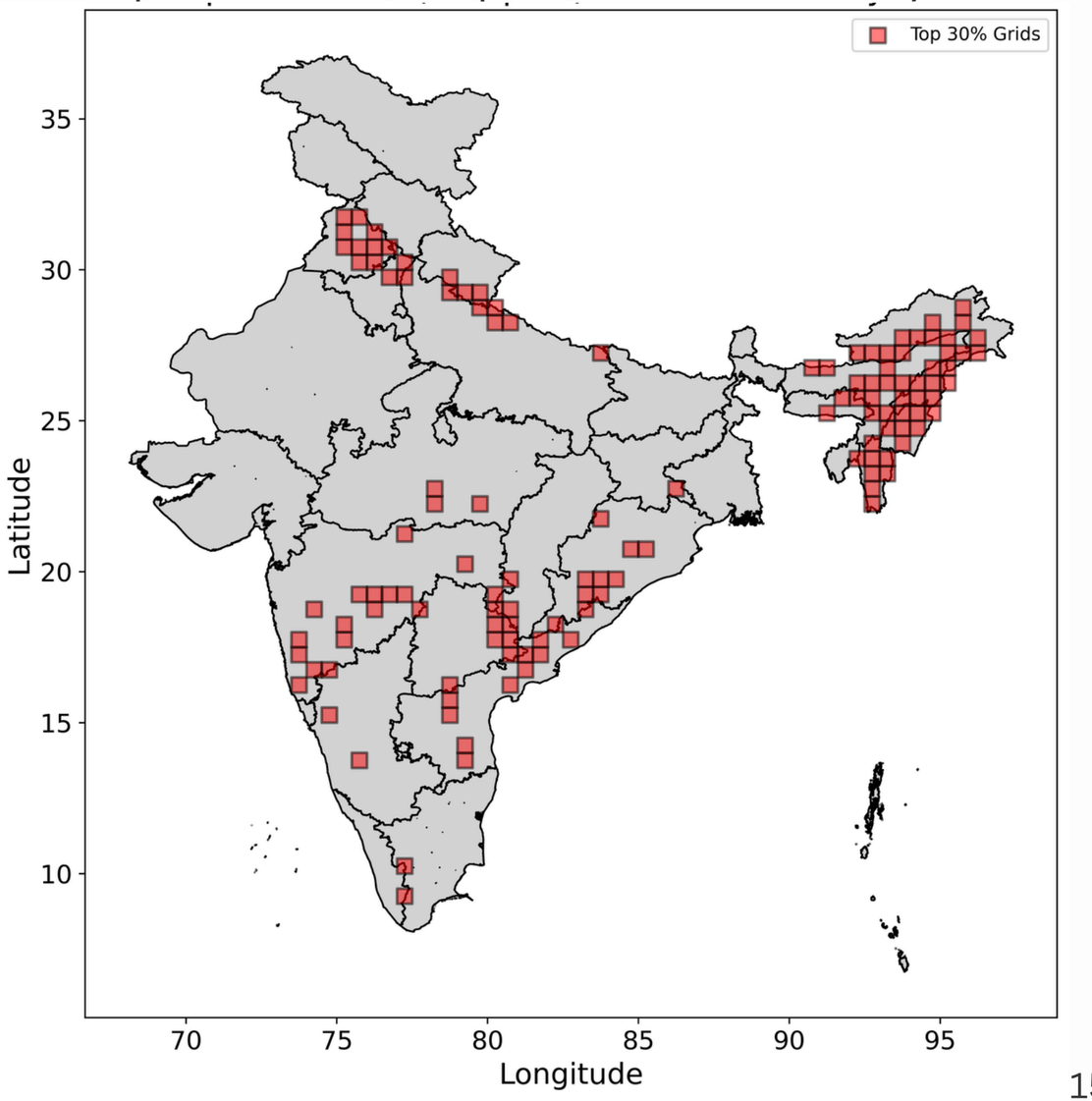


IV Results

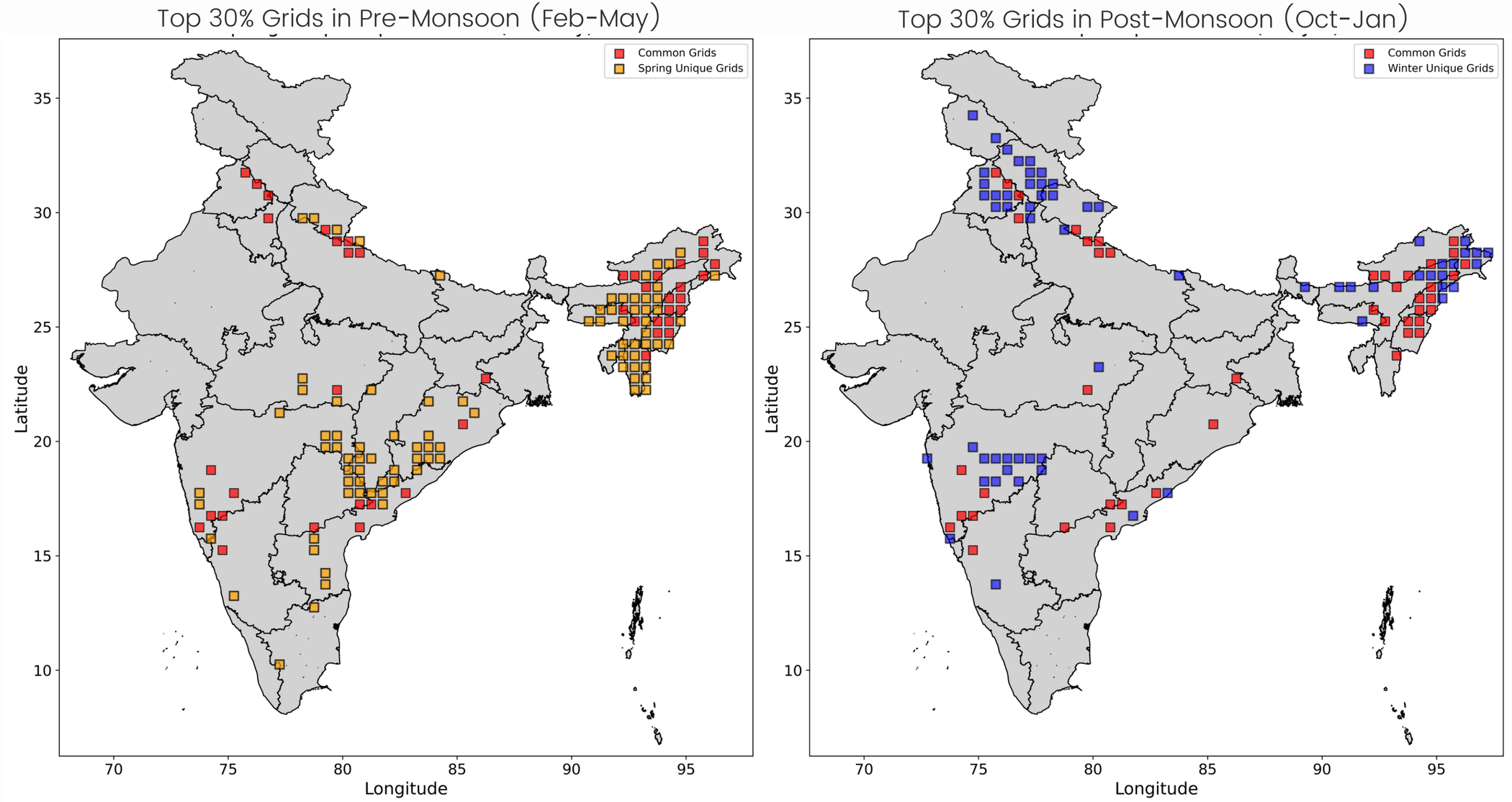
Grids above 10% Forest cover (Effective study area)



Top 30% Grids (Hotspots) of Effective Study Area

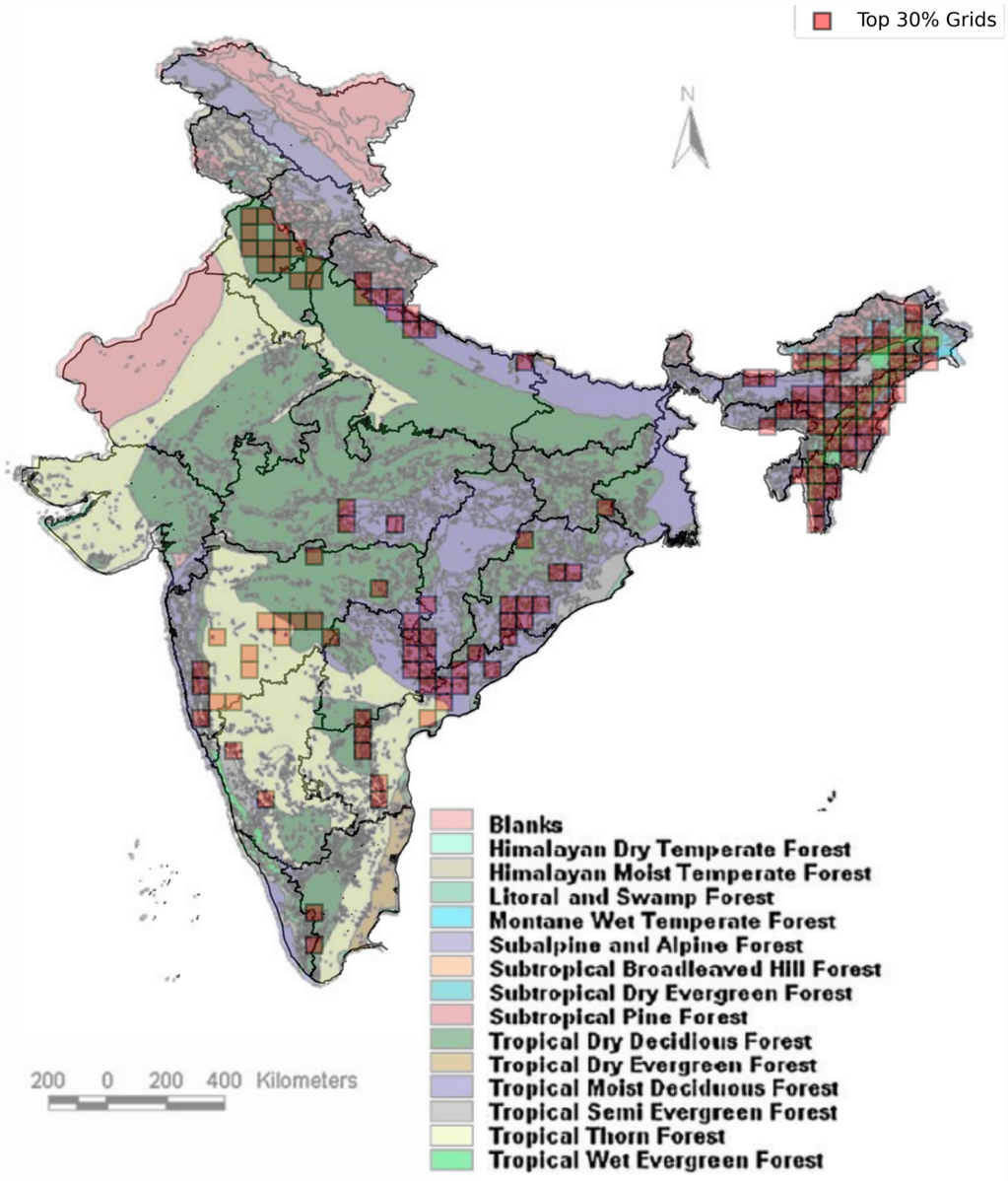


IV Results



The following figure shows the top 30% grids for pre-monsoon (Feb-May) (left) and for post-monsoon (Oct-Jan) (right). The orange grids are hotspots only in the pre-monsoon period, the blue grids are hotspots only in post-monsoon period and the red grids are hotspots in both the seasons

V Discussion

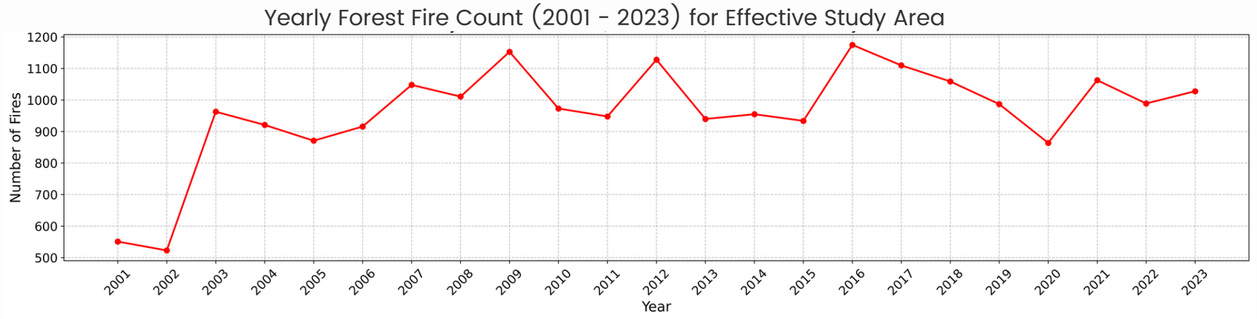


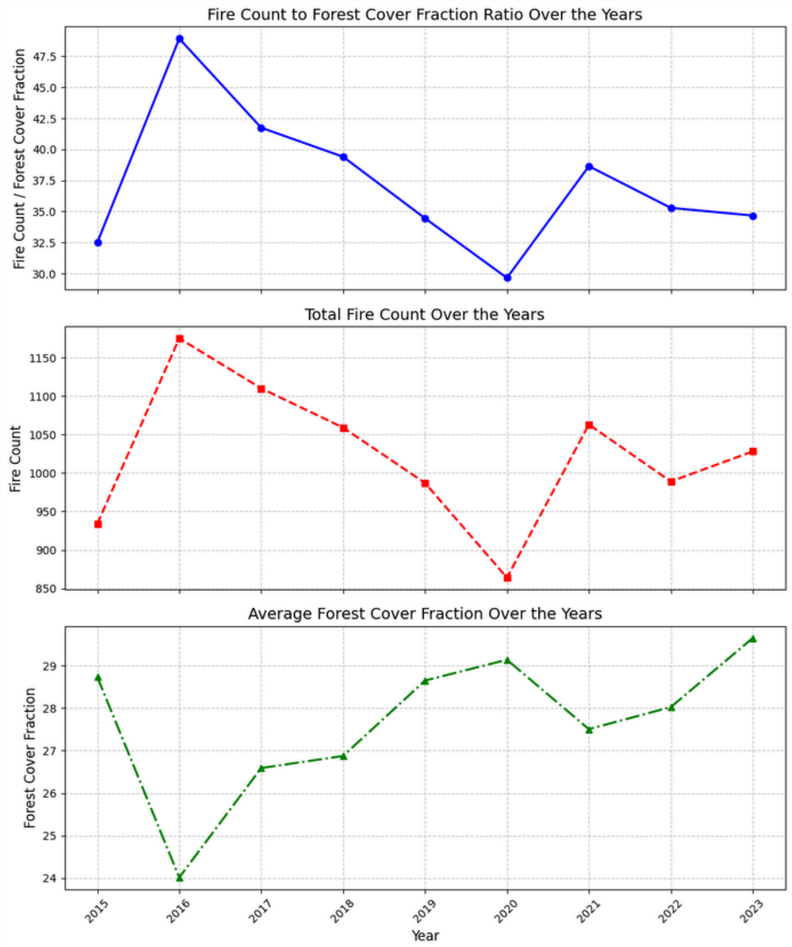
Tallying Forest Types with Fire Hotspots:

- Tropical Dry Deciduous Forests (Central India) → Major fire hotspots (matches with Madhya Pradesh, Chhattisgarh, Odisha, Maharashtra).
- Tropical Thorn Forests (Punjab, Haryana) → Fire hotspots in these regions (matches with Punjab's increasing fire incidents).
- Subtropical Pine & Broadleaved Forests (Himalayan foothills) → Hotspots in Uttarakhand & Himachal Pradesh.
- Montane & Moist Deciduous Forests (Northeast India) → Major fire hotspots in Assam, Nagaland, Manipur, Arunachal Pradesh.

V Discussion

The figure presented alongside indicates that, contrary to findings reported in the existing literature, there is no evident increasing trend in forest fire occurrences when examining the yearly time series of forest fire counts.





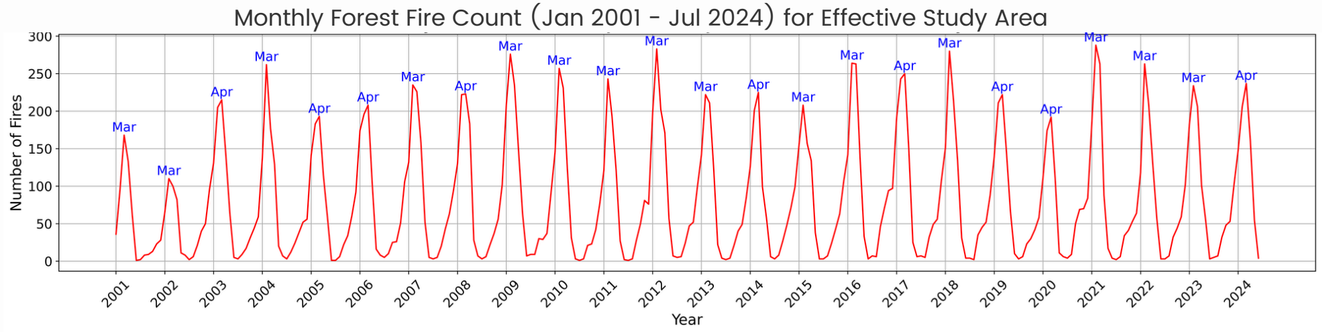
We hypothesized that forest fire count relative to forest cover might be increasing, as the literature suggests a decline in forest cover. To examine this, we analyzed the time series of forest fire counts, forest cover, and their ratio.

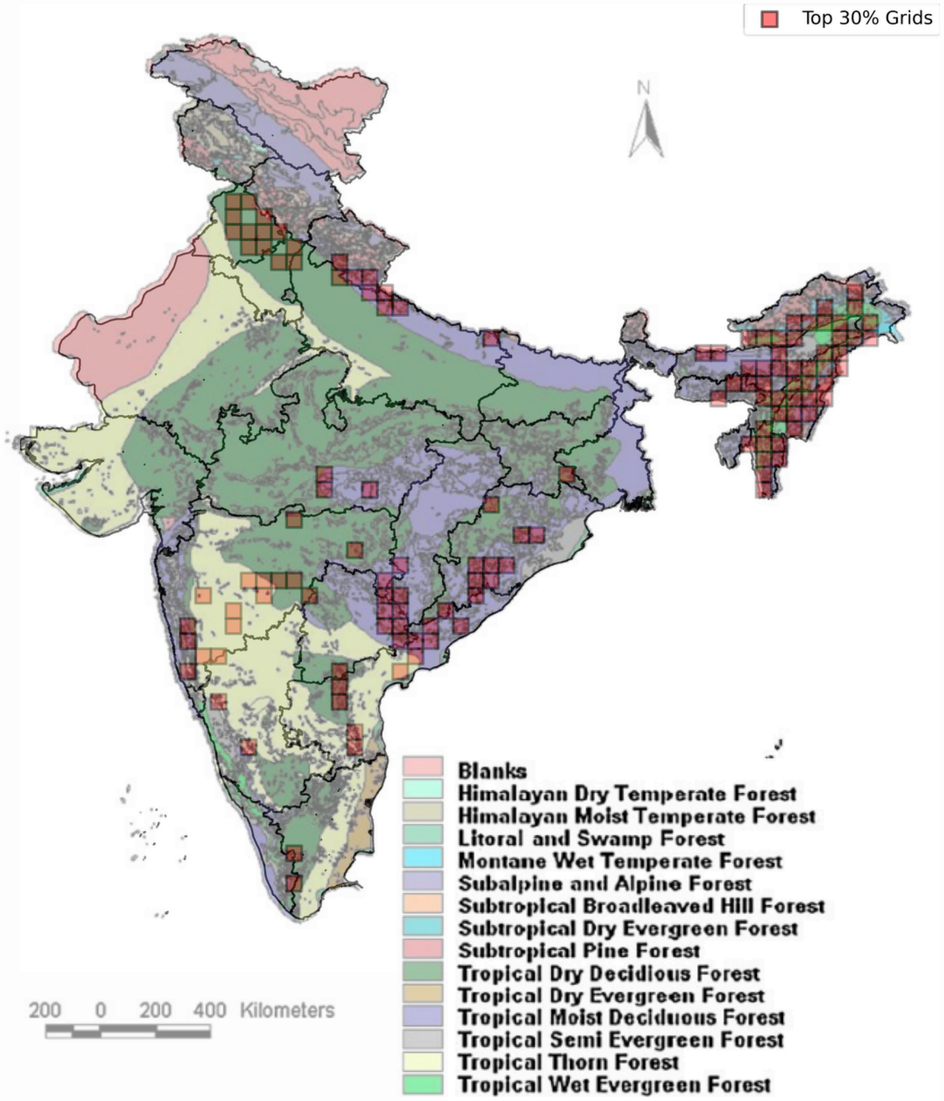
Our results contrast with the findings in the existing literature. The observations are as follows :

1. The forest cover fraction shows an increasing trend within our study area.
2. Forest fire shows a decreasing trend till 2020 and is followed by a changing trend.
3. The ratio of forest count to forest cover fraction follows the trend of forest count, except for 2023

VI Key Takeaways

- If we consider a monthly scale, we observed that March is a hotspot in the temporal context.
- Odisha, Maharashtra, Madhya Pradesh, Andhra Pradesh and almost all states of Northeast India, are with the most number of hotspots.
- Topical dry decidious trees are the most prone to forest fires and they account for majority of hotspots.





VII Conclusion

The forest fire situation across the globe is expected to worsen due to extreme climate events, climate change activities, and immense population pressure. Therefore, preparing the spatial database of forest fire hotspots across the various climatic zones of the globe (especially those most vulnerable to extreme climatic events - such as India) shall be helpful in understanding vegetation response to fires for setting up future conservation plans and ecological research. Our recommendations:

VIII Author Contributions

Sohan Pandit

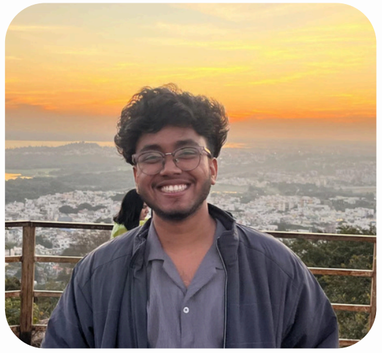
- Data downloading
- Assisted in data cleaning
- Contributed to drafting the presentation

Saurabh Toraskar

- Conceptualization and methodology design
- Preprocessing, assisted in data cleaning and visualization
- Assisted in interpretation of results

Anirudh Arora

- Research framework and literature review
- Interpretation, validation and discussion of results, and policy recommendations
- Presentation development



Akshat Ghritlahre

- Major contribution in the literature review.
- Assisted in seasonal hotspot analysis
- Contributed to drafting the presentation

Shri Krishna Mishra

- Visualization of methodology.
- Assisted in monthly hotspot analysis
- Assisted in literature review

Sparshika Wankhade

- Time-series analysis
- Key takeaways and policy recommedations.
- Proofread the presentation

IX References

- Alkhatib, A. A. A review on Forest Fire Detection Techniques. International Journal of Distributed Sensor Networks 10, 597368 (2014).

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Thank You!