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Comparative assessment of remotely-sensed forest fire datasets over the Rarh region of West Bengal from the FIRMS and FSI portals

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1. Abstract:

This study assess and compares the reliability and comprehensiveness of the FIRMS (Fire Information for Resource Management System) and FSI (Forest Survey of India) databases for forest fire mapping in the Rarh region of West Bengal. With a focus on evaluating the consistency of fire counts and the temporal distribution of fire occurrences, alongside a careful examination of the varied fire types incorporated within each database, including forest fires, stubble burning, industrial fires, and mining fires, the research aims to furnish valuable insights crucial for the optimal selection and effective handling of fire point data, thereby ensuring accurate and reliable mapping outcomes. The study also highlights the discrepancies observed between the number of fire points depicted in the FSI's near real-time dashboard and those reflected in its exported datasets, warranting an in-depth investigation to ascertain their consistency across temporal dimensions. By refining the scope of analysis to encompass forest-specific fires and augmenting the reliability of the dataset through meticulous processing, this study provides pertinent insights into the intricate dynamics of forest fires, to provide stakeholders with actionable intelligence to devise effective forest fire management strategies.

Introduction

The worldwide importance accorded to forest fire studies emphasizes their continued occurrence across diverse ecosystems (Verma and Jayakumar, 2012; Clarke et al., 2022; Tyukavina et al., 2022). They are caused both by human activities and natural processes, and are particularly prevalent in tropical and subtropical regions (Moritz

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et al., 2012). In India, forest fires are relatively common, and have been a recurring anthropogenic and natural phenomenon for long (Schmerbeck and Fiener, 2015; Kale et al., 2018; Bar et al., 2021). Indeed, this phenomena occurs consistently each year during the spring to summer period in various parts of the country (Vadrevu et al., 2006; Sowmya and Somashekar, 2010; Giriraj et al., 2010). However, even though considerable attention has been devoted to forest fire investigations, burnt area assessment, risk and susceptibility analysis, along with discerning of fire regime characteristics (Lamat et al., 2021; Laha et al., 2021; Kumar et al., 2021; Fulé et al., 2021; Gholami et al., 2021; Godson et al., 2021; Kale et al., 2022), a notable limitation exists in investigation of the actual datasets on which such studies are often conducted. More pertinently, the accuracy and reliability of the forest fire datasets used in such analyses is almost unexplored, despite the fact that the reliability and consistency of a dataset is one of the most important aspects of any research. This study highlights the significance of assessing the intricacies of the datasets commonly used for forest fire mapping and the challenges associated with data selection and processing. It also underlines the importance of cleaning and collating accurate forest fire datasets for effective forest management and environmental conservation, emphasizing the need for reliable data sources given the growing global concern over recurring forest fires.

In recent years, satellite-based systems have emerged as indispensable tools for monitoring fire activity over large geographic areas within a short timeframe (Bhuian et al., 2024). Among the various systems available, the Fire Information for Resource Management System (FIRMS) holds significant importance in the global monitoring of forest fires. As a widely utilized platform for storing fire occurrence data, FIRMS grants access to geospatial information and products like satellite images, active fire spots, and standard fire data. This facilitates the identification of wildfire locations, their scale, and intensity, aiding both the broader fire management community and the public in staying informed about fire activity (earthdata.nasa.gov/firms; Schroeder et al, 2014; Giglio et al., 2018; Schroeder and Giglio, 2018). Likewise, the Forest Survey of India (FSI) portal plays a pivotal role as a primary source of fire occurrence data throughout India. FSI offers invaluable insights into fire occurrences across diverse landscapes and maintains a robust hold on forest fire alert systems. Its capabilities extend to near real-time forest fire monitoring, large-scale forest fire surveillance, pre-fire alerts, and various other forest-related monitoring activities. These functions are critical for both pre and post-fire forest management efforts, facilitating the recuperation of forest resources (FSI, 2019, 2020).

However, while the above platforms offer valuable information on forest fires, discrepancies in their data reliability and comprehensiveness can impact the accuracy of forest fire mapping and further analyses (cf. Sharma, 2019). Previous research has revealed that when assessed via ground-truth verification, the validation of such remotely denoted fire locations can be quite misleading (Colak and Sunar, 2020; Coskuner, 2022). Therefore, there is a need for systematic assessment and comparison of the reliability and comprehensiveness of the FIRMS and FSI databases for forest fire mapping. Understanding the strengths and limitations of these systems, selecting the most accurate and reliable data, and undertaking a prudent data cleaning process is essential for researchers and policymakers aiming to accurately document and respond effectively to specific forest fire occurrences.. Such research endeavors can provide crucial insights into the optimal selection and handling of fire data for accurate and reliable mapping, thus facilitating the development of more effective strategies for forest fire management and mitigation.

The FIRMS portal offers a wide array of fire data, including forest fires, stubble burning, industrial fires, and more. The FIRMS standard fire product demonstrates greater consistency in total fire counts and distribution. Therefore, it is important to understand the types of fires identified by the portal, segregate the fire types based on research interests, and identify where the denoted fire points are located. For instance, if the intended research focuses on forest fires, it is necessary to select only those fire point data that situate within forest patches and exclude all other points denoted outside forest boundaries. A similar practice should be applied for the detection of stubble burning, industrial fires, mining fires and so on. Thus, this study underscores the importance of data cleaning protocols and careful selection of relevant data points to ensure the accuracy and reliability of forest fire mapping analyses. By addressing these issues, this research seeks to enhance the understanding of forest fire dynamics and contribute to more effective forest fire management strategies in the examined study area.

Data and methods

We utilize fire data sourced from the MODIS (Moderate Resolution Imaging Spectroradiometer) and VIIRS-SNPP (Visible Infrared Imaging Radiometer Suite on the Suomi National Polar-orbiting Partnership) sensors (Liu et al., 2018). These were extracted from the FIRMS (earthdata.nasa.gov/firms) and FSI portals (https://fsiforestfire.gov.in/index.php), respectively, for the period of 2018 to 2022. The FIRMS database is renowned for its extensive coverage of fire incidents across diverse land use categories, and provides standardized fire data for scientific research, offering consistent and well-calibrated records of Earth's geophysical properties. In contrast, the FSI portal specifically claims to provide fire data within forest boundaries and focuses on near real-time fire data delivery to support operational needs, such as fire monitoring and mitigation. Given the forest-centric focus of this study, a key methodological step involved filtering out non-forest fire points to maintain dataset integrity and ensure analytical accuracy. To address this, the Biodiversity Information System (BIS) LULC data at a detailed 1:50,000 scale, as presented in Figure 1, was used to systematically remove non-forest fire points. Furthermore, LULC data from the Bhuvan geoportal (forest cover only) at 1:10,000

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scale was employed to refine this selection. This approach ensured that fire points outside forest boundaries, including those in agricultural fields, mining areas, and industrial zones, were excluded from the analysis, allowing the focus to remain on fire points situated exclusively within forest boundaries.

Furthermore, ensuring data reliability requires careful consideration of low-confidence fire points, as their inclusion or exclusion depends on the user's tolerance for false alarms versus the need for comprehensive fire detection. For MODIS, confidence values range from 0% to 100%, categorizing fire pixels into low-confidence, nominal-confidence, and high-confidence classes. Similarly, VIIRS categorizes fire confidence as low, nominal, or high, based on algorithm-derived metrics that assess the quality of individual hotspot/fire detections. Low confidence (Class 7) daytime fire pixels are typically associated with sites of sun glint or water pixels, and lower relative temperature anomaly (<15K) (earthdata.nasa.gov/firms), making their inclusion or exclusion a critical decision that balances comprehensive detection against minimizing false alarms. We have not excluded any fire points, even those with low confidence, that were denoted to fall within forest boundaries, as these could represent potential fire sources, and removing them might lead to critical oversights. Such points could potentially be relevant for detecting potential fire spread, which could further impact forest patches. These data cleaning procedures are essential for enhancing data quality and ensuring robust analysis, with significant implications for forest fire management and mitigation strategies.

Study area

As per the India State of Forest Report (2021), West Bengal has substantial forest cover, accounting for 18.96% of the state's total geographical area. Moreover, the state comprises 2.35% of India's overall forest area, highlighting its importance in the national context. The predominant types of forest fires in West Bengal are surface fires, with particular emphasis on fires alighting amidst fallen leaves, which occurs during summer. Particularly in southern West Bengal, deciduous trees shed their dry leaves during this season, creating a thick layer on the forest floor. This accumulation of dry leaves serves as ample fuel, leading to their ignition and rapid spread of under-storey fires in this region. The recurrence of these events is a consistent phenomenon in this area’s forests. The districts of this region (more commonly referred to as the *Rarh* region (**Figure 1**) – Birbhum, Purba and Paschim Barddhaman, Bankura, Puruliya, Paschim Medinipur and Jhargram) were thus taken together as the focal zone for spatial analysis of forest fires and to compare the efficacy of the aforementioned databases for this purpose.

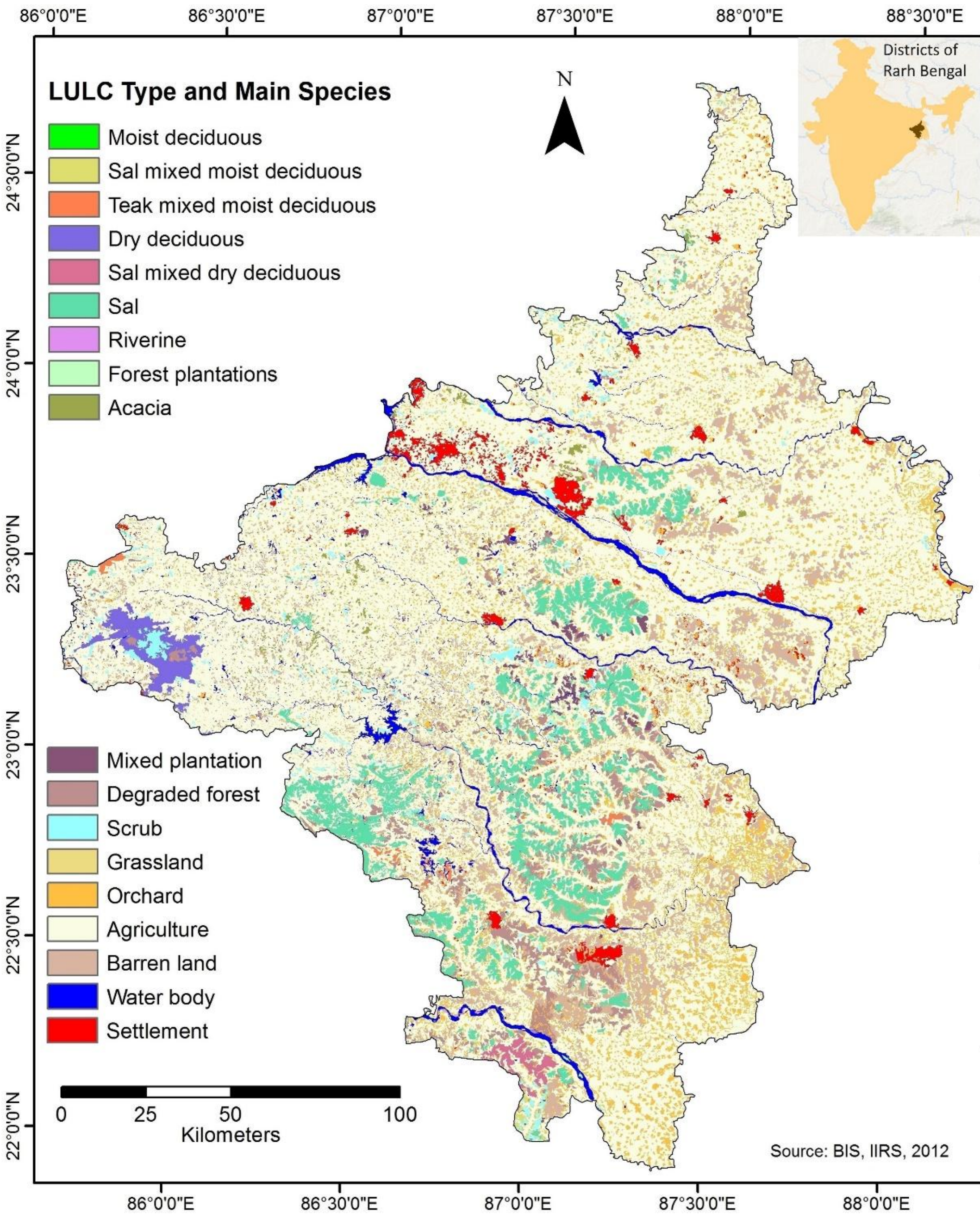

Figure 1: Location of the Rarh Bengal region in eastern India and its detailed LULC map, with main vegetation species.

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Results and discussion

Proper selection and handling of fire point databases is paramount as this profoundly influences the outcome. We undertake a comparison of the FIRMS and FSI databases for forest fire mapping and check the reliability of these data in the forests of Rarh Bengal, that are based on MODIS and SNPP-VIIRS fire point data. A significant disparity is apparent in the number of fire points recorded in the FSI Near Real-Time (NRT) database and the FIRMS standard processed fire product **(Figure 2)**. The total number of fire points in the FSI database is considerably lower than that in the FIRMS database **(Figure 2)**. Year-wise differences in fire points between FSI and FIRMS were substantial in 2018. Only 383 SNPP fire points are reported in the exported MS Excel file and a mere 59 fire points displayed on the FSI portal dashboard. In contrast, the FIRMS portal documented a total of 2,536 SNPP-derived fire points for the same period. This highlights a significant lack of fire point data in the FSI database, both in the annual total and throughout the years 2018–2023, compared to the fire data provided by the FIRMS portal. Similarly in 2021, significant data gaps are apparent between the FSI-downloaded fire products, particularly in the sensor-derived datasets from MODIS (3 fire points) and SNPP-VIIRS (17 fire points). In contrast, fire counts from the FSI dashboard, which recorded 3,300 and 651 fire points for SNPP-VIIRS and MODIS, respectively, show a strong alignment with the FIRMS dataset **(Figure 3)**. This substantial variance in the total and year-wise number of recorded fire points feasibly undermines the reliability of the FSI fire product.

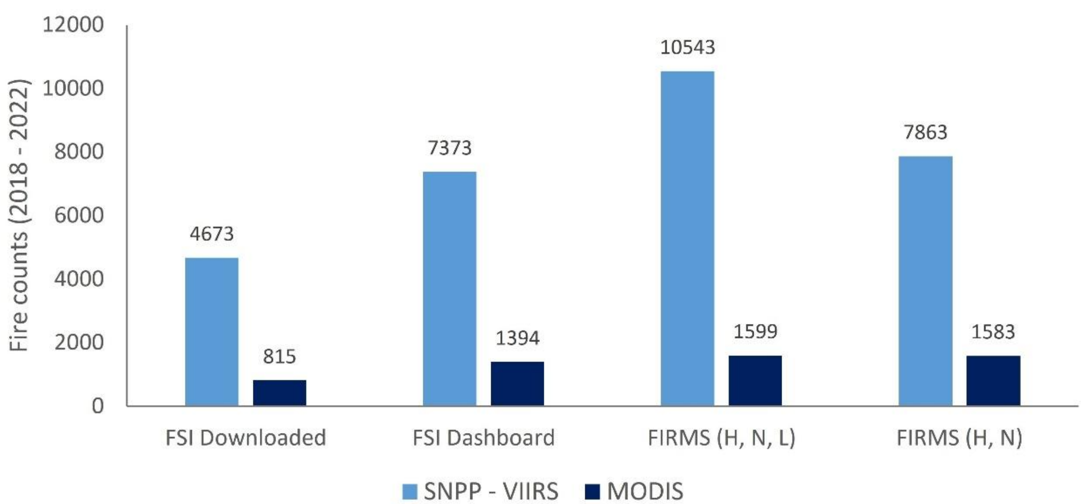

Figure 2: Number of forest fires from 2018 to 2022, as derived from the SNPP and MODIS data. Fire points are sorted into four categories, namely FSI downloaded, FSI dashboard, FIRMS (H, N, L – high, nominal and low confidence fire incidents), and FIRMS (H, N) respectively.

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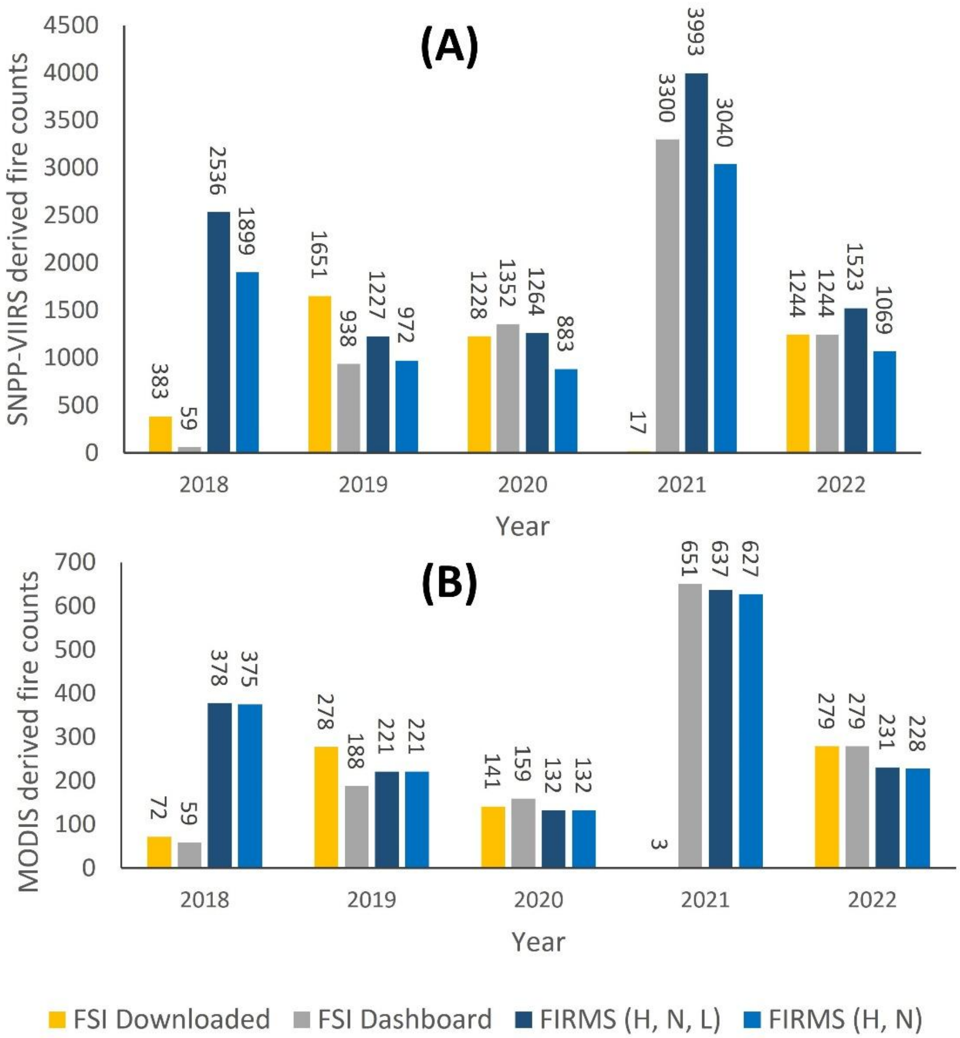

Figure 3: Number of forest fire points across consecutive years, with comparisons between different categories of data obtained from the FSI and FIRMS portals, respectively. These categories include FSI downloaded, FSI dashboard, FIRMS-based data encompassing high, nominal, and low confidence fire incidents, as well as data exclusively comprising high and nominal fire classes.

Furthermore, a notable inconsistency is evident within the FSI portal itself, where the number of fire points displayed on the FSI dashboard differs significantly from those present in the exported MS-Excel files **(Figure 4)**. This discrepancy introduces further uncertainty into the dataset and raises questions about the consistency of the FSI database, with confusion especially arising on which type of

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fire product should be used for analysis. Therefore, we compare the two FSI-derived fire products (FSI downloaded and dashboard) to understand the differences in the total number of fire counts and their year-wise distribution. After systematically cleaning the fire products (to only consider the data points within denoted forest patches), it was found that the total number of fire points varied considerably between the FSI dashboard-derived fire point and the FSI download-derived fire points. As shown in **Figure 4**, the total number of forest fire points is higher in FSI dashboard-derived data, which is 6463 and 1307 from SNPP-VIIRS and MODIS, respectively. Meanwhile, the number of forest fire points is found to be lower in the FSI downloaded file, which are 3596 and 754 from SNPP-VIIRS and MODIS respectively. Moreover, year-wise inconsistency in fire point distribution was also apparent in both the FSI download and dashboard-derived fire products **(Figure 3)**. This again highlights discrepancies in documenting the spatial locations of forest fire occurrences. Addressing these issues is thus critical for ensuring the reliability and integrity of forest fire mapping when using these datasets.

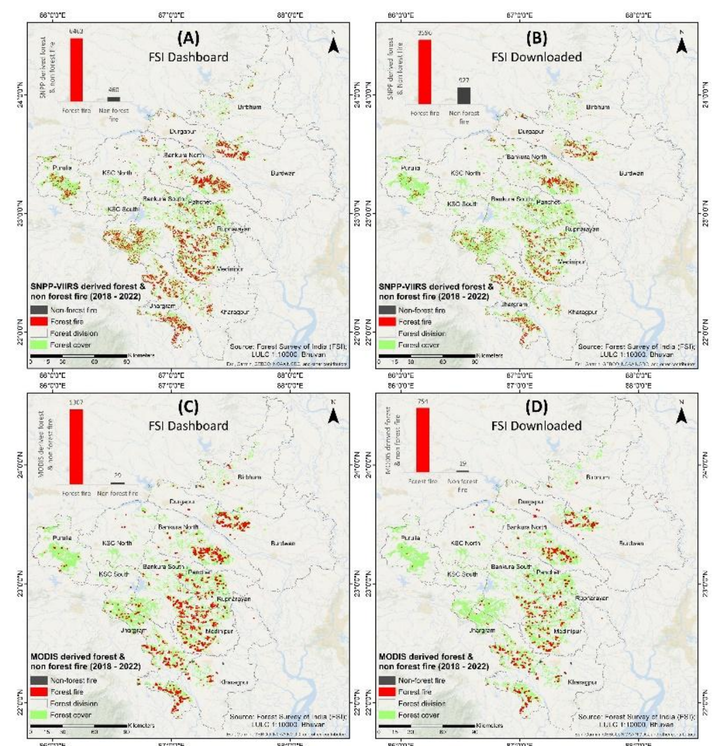

Figure 4: Distribution of forest fires from 2018 to 2022, derived from the SNPP data. Fig. 4.a, c shows fire points collected directly from the Forest Survey of India (FSI) dashboard, while Fig. 4.b, d exhibits fire points exported from the same portal. Notably, despite cleaning all the non-forest fire points, few fire points were still found to be non-forest fire points as those are situated in outside forest boundaries.

Likewise, the data cleaning process unveils the presence of non-forest fires in both the FSI-derived fire products. After manually checking all the fire point distributions, it was seen that most of the FSI-driven non-forest fires are predominantly situated over mining or industrial areas **(Figure 5)**. The SNPP-VIIRS-derived total number of non-forest fires was 927 (around 26%), as reported by the FSI exported fire product while only 460 (around 7%) fire points were reported by the FSI dashboard-derived fire product. On the other hand, the MODIS-derived total number of non-forest fire points was 19 (around 2.5%), as given by the FSI exported fire data product and meanwhile, 29 (around 2.2%) fire points were provided by the FSI dashboard-derived fire product. Despite this apparent discrepancy, the FSI asserts that it filters out fire hotspots originating from non-forest sources such as industrial and agricultural areas, ensuring that only fire points within forest boundaries are included in their data (FSI, 2019). We therefore advise further caution when using these datasets, with verification from other sources, and ground-truthing if possible, recommended.

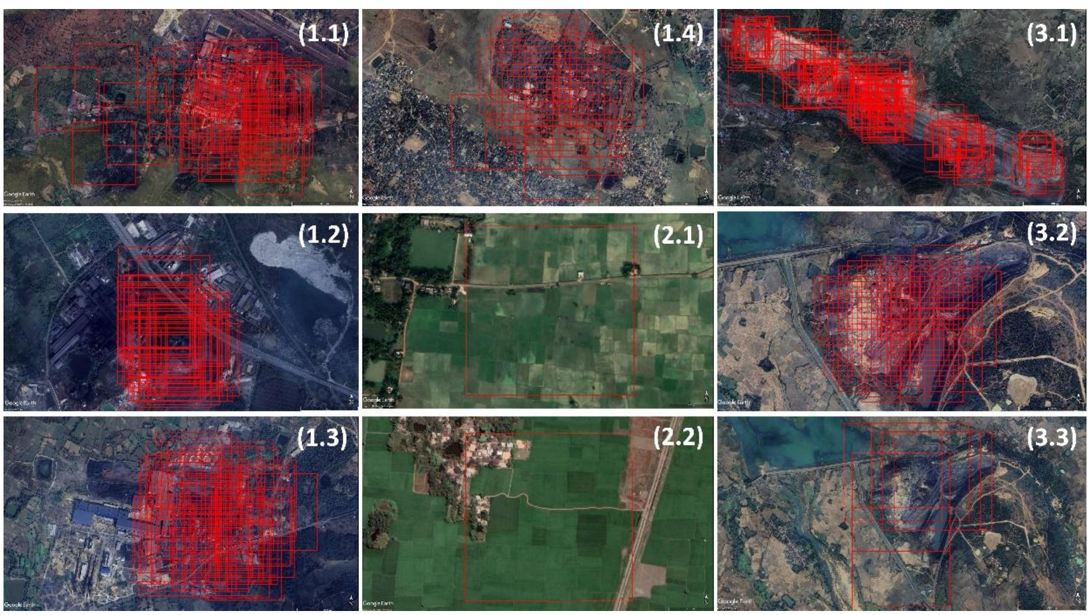

Figure 5: Examples of FSI-based forest fire pixels erroneously recorded over mining areas, industrial zones, and agricultural fields, despite the assertion that non-forest fire points have been removed. Discrepancies were found in both the downloaded and dashboard-derived fire products. The red squares highlight fire pixels detected by MODIS (3.3) and SNPP-VIIRS (1.1, 1.2, 1.3, 1.4, 2.1, 2.2, 3.1, 3.2) sensors, with spatial resolutions of 1000 m and 375 m, respectively.

Notably, this presence of non-forest fires poses a potential challenge, particularly in studies addressing fire clustering analysis, as these may erroneously be selected as highly clustered forest fire hotspots. Such discrepancies underscore the

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importance of rigorous data checking and cleaning protocols and highlight the need for enhanced accuracy and consistency in forest fire reporting within the FSI database. Another significant observation from our study is that the FISMS portal demonstrates a higher degree of consistency in terms of total fire counts and annual distribution patterns when compared to its counterpart, the FSI. Furthermore, FIRMS offer a broader spectrum of fire data, encompassing forest fires, stubble burning, industrial fires, fires in mining areas, and to a certain extent, residential area fires. Our analysis (**Figure 7**), reveals that a substantial number of fire pixels detected by SNPP (around 75% of the total dataset or 32768 in number) and MODIS (roughly 48% or 1529 in number) are categorized as non-forest fires. Furthermore, the annual distribution of non-forest fires remains consistently high each year (**Figure 6**). This underscores the importance of excluding non-forest fire points when the primary focus is on forest fire mapping, to ensure accuracy and keep focus on the targeted forest patches (**Figure 7**).

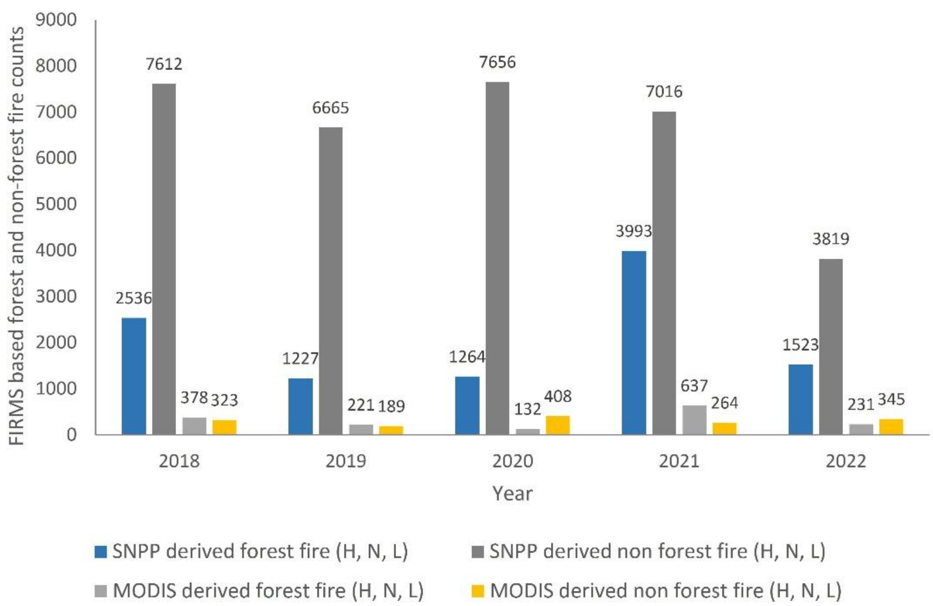

Figure 6 Year-wise distribution of forest fires from 2018 to 2022, using data derived from SNPP and MODIS, collected from the FIRMS portal. Four categories of bars are displayed, but only the SNPP derived forest fire (H, N, L) categories are recommended for use, as this data is internally consistent, according to the FIRMS portal. Additionally, if the focus is on forest fires, it would be risky to exclude potential low-confidence fire points from any analysis before ground verification.

Neglecting to properly assess and clean the obtained fire point data can lead to misleading conclusions, as demonstrated in **Figure 8**. Here, FIRMS-based fire data incorrectly records fires in industrial, mining, and agricultural areas. If these non-forest fire pixels were included in computing spatial statistics or clustering analyses of forest fires, they could falsely categorize industrial, mining, and agricultural zones as high-risk fire clusters. Consequently, it is essential to implement thorough data cleaning protocols to maintain the integrity of forest fire mapping. This was achieved by overlaying the fire points on a detailed forest cover map to verify their accuracy. Specifically, the Biodiversity Information System (BIS) LULC data at 1:50,000 scale, as shown in Figure 1, was used to systematically exclude non-forest fire points first. Additionally, the LULC data from Bhuvan (which focuses on forest cover) at a finer scale of 1:10,000 scale was utilized to identify and select landcover classes specific to forests and refine the earlier data, ensuring a more accurate analysis of forest fire locations through these double checks. By doing so, we can ensure that the finally obtained forest fire point data used for any subsequent hotspot/cluster analysis are feasibly the most accurate, leading to reliable and meaningful outcomes. This is crucial for developing effective forest fire management strategies.

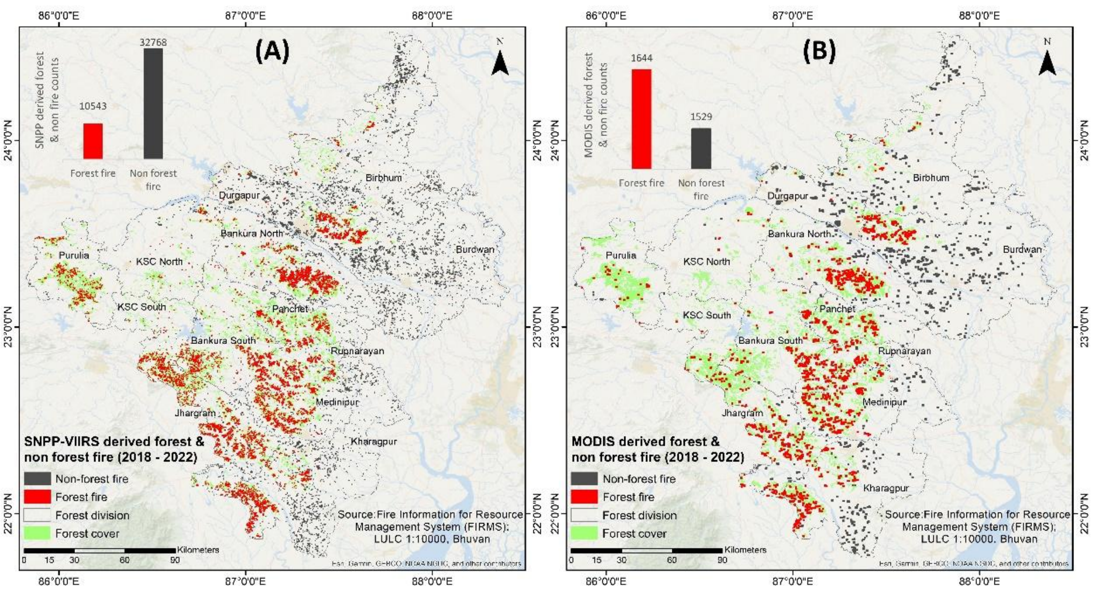

Figure 7: Distribution of forest fires from 2018 to 2022, derived from the SNPP and MODIS data. Both maps' fire point data were collected from the FIRMS portal. Figure 7.a exhibits fire points derived from the SNPP sensor, while Figure 7.b shows fire points derived from the MODIS sensor. Gray-colored pixels represent non-forest fires, that are predominantly located in Purba Barddhaman, Paschim Barddhaman, Birbhum, and parts of Paschim Medinipur, where most such events are related to stubble burning. Additionally, a significant clustering of non-forest fires can be observed in mining and industrial areas.

Despite the discrepancies observed in the forest fire products (i.e., forest fire data repository) provided by the Forest Survey of India (FSI), it remains an invaluable resource for monitoring fire incidents across India's forests. The FSI maintains a robust and efficient fire alert system, delivering near-real-time (NRT)

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data on forest fires, which was validated through our ground surveys (Figure 9). This system provides precise fire coordinates, along with detailed information on forest beats, divisions, and circles, enabling accurate identification and access to affected forest sites. Furthermore, FSI's long-standing record of large-scale forest fire surveillance and issuing pre-fire alerts is essential for both proactive and reactive forest management strategies (FSI, Forest Fire Alert System 3.0, 2019; Sharma, 2019). These capabilities play a critical role in mitigating fire damage, supporting post-fire recovery, and ultimately contributing to the restoration and conservation of forest resources.

Contrastingly. the FIRMS-driven standard fire product, along with the SNPP-VIIRS sensor-driven fire data, proves to be more consistent and reliable for spatial forest fire analysis compared to the FSI repository fire product. The SNPP-derived fire product offers a superior spatial resolution of 375 meters, in contrast to the 1000-meter resolution of the MODIS-derived product. This enhanced resolution allows for more precise detection and monitoring of fire events, particularly smaller and more localized low-intensity fires, making the SNPP-VIIRS data more effective for detailed fire analysis. Choosing the relatively higher spatial resolution fire product is obviously more appropriate for any type of spatial or statistical analysis. Since the SNPP-VIIRS fire product can provide more fire pixels than that from MODIS (Fu et al., 2020), it enables greater frequency and feasibility of physically investigating targeted forest patches.

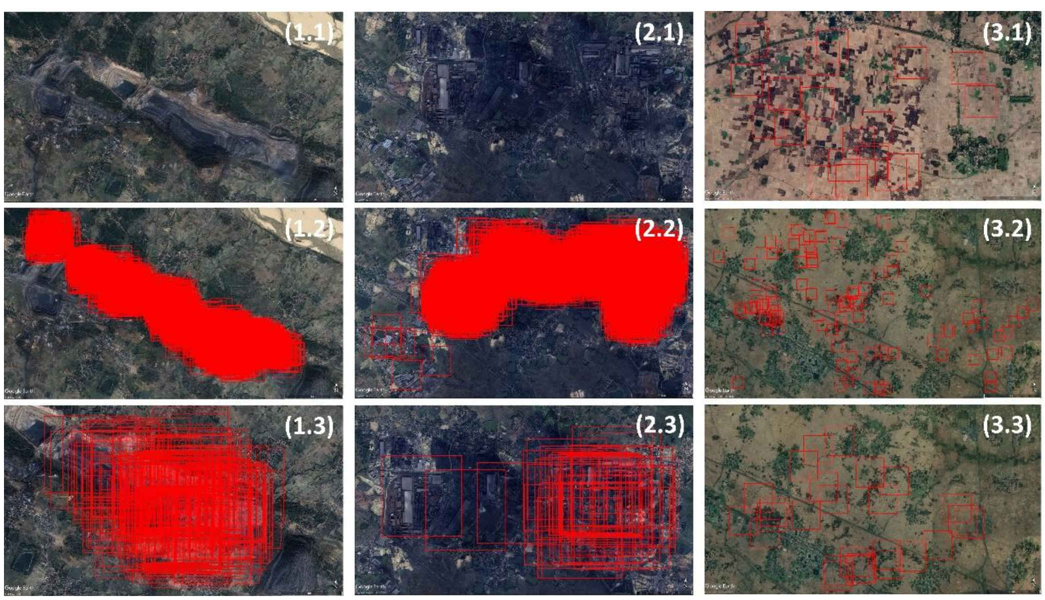

Figure 8: Examples of FIRMS-based forest fire pixels located over non-forest areas, such as mining sites, industrial zones, and agricultural fields. These pixels, while correctly identified, require cleaning before analysis, particularly in studies focused exclusively on forest fires. The red squares indicate fire pixels detected by MODIS

(1.3, 2.3, 3.3) and SNPP-VIIRS (1.2, 2.2, 3.1, 3.2) sensors, with spatial resolutions of 1000 m and 375 m, respectively.

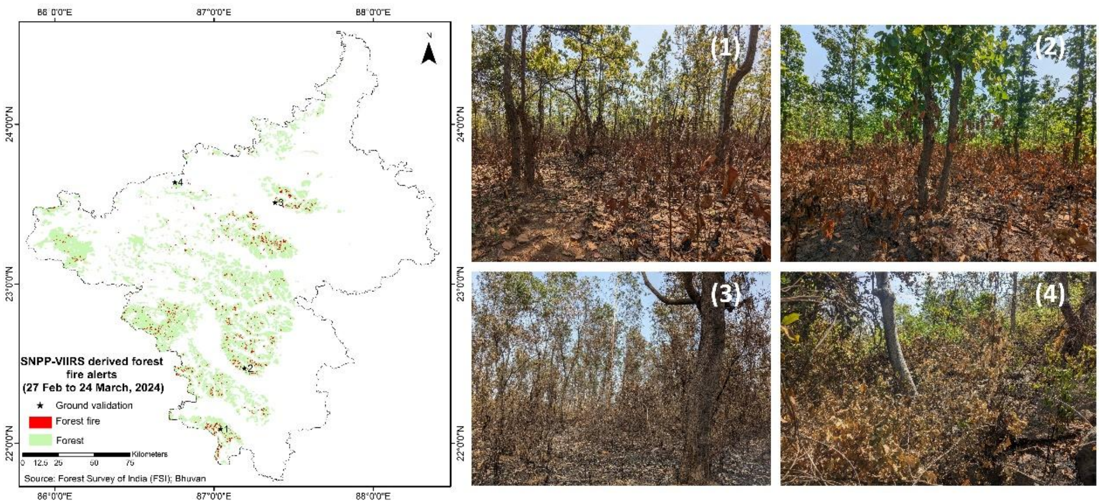

Figure 9: Field validation of forest fire locations identified using SNPP-VIIRS-based fire alerts provided by FSI. The images depict charred ground surfaces and leaf litter with green canopy foliage, that are characteristic of under-storey fires in the deciduous forests of Rarh Bengal. Verified locations include: (1) Narda, Jhargram; (2) Lakshmichak, Paschim Medinipur; (3) Arrah Kalinagar, Paschim Barddhaman; and (4) Panchakot Pahar, Puruliya. This figure highlights the strength of FSI's fire alert system, which provides precise forest fire coordinates, enabling targeted validation. By linking field observations with the fire alert data, it emphasizes the spatial accuracy and practical utility of these alerts for effective forest fire research and management.

Conclusion

Forest fires pose a significant global concern, necessitating comprehensive studies for effective management. Understanding their characteristics, especially their spatial and temporal recurrence patterns, requires accurate and consistent data. This study has assessed and compared the reliability and comprehensiveness of the FIRMS and FSI databases for forest fire mapping in Rarh region of West Bengal. By evaluating the consistency of fire occurrence counts and the distribution of fire events over time, as well as examining the types of fires classified by each database, the study provides insights into the optimal selection and handling of fire point data for accurate and reliable mapping. Furthermore, this study highlights the importance of data cleaning protocols in refining fire mapping analyses and underscores the need for vigilance in selecting relevant data points to ensure the validity of results.

The analysis reveals notable discrepancies exist, particularly in the total and year-wise counts of fire points between FSI's Near Real-Time (NRT) data and the

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FIRMS precisely processed data. NRT data, essential for immediate management and mitigation, significantly differs from the FIRMS standard processed data, largely due to intrinsic errors in the former, such as false fire occurrences caused by phenomena like sun glint and reflected surface light on solar panels. Moreover, inconsistencies within the FSI portal, including discrepancies in fire point counts from different sources, variations between forest fire counts as reported on the FSI dashboard and in the subsequent exported data, add to concerns on the reliability of the FSI database. The presence of non-forest fires (industrial, mining, stubble) in both the FIRMS and FSI fire products necessitates systematically checking and cleaning to ensure that no non-forest fire points remain in the eventual dataset, as their inclusion in spatial statistics or clustering analyses could mistakenly identify forest fire hotspot locations or skew any analysis. Hence, rigorous data cleaning protocols are indispensable to maintain the integrity of forest fire mapping, using a detailed high-resolution LULC layer.

The FIRMS-driven standard fire product, along with the SNPP-VIIRS sensor-driven fire data, proves to be more consistent and reliable for spatial forest fire analysis compared to the FSI repository fire product. The SNPP-derived fire product offers a superior spatial resolution of 375 meters, in contrast to the 1000-meter resolution of the MODIS-derived product. This enhanced resolution allows for more precise detection and monitoring of fire events, particularly smaller and more localized low-intensity fires, making the SNPP-VIIRS data more effective for detailed fire analysis. Furthermore, this study underscores the necessity of including all fire points, even those with low confidence, in forest fire analysis. Such points, despite their lower confidence, can potentially denote fires that spread and further diminish forest patches, and thus it is prudent to include them in the database. Conversely, for non-forest fire analysis, the inclusion of low-confidence fire data may introduce errors by misidentifying false fire points (i.e., bright surface, solar panel, sun glint, water surface). Therefore, the context of the analysis is critical in determining the appropriate use of fire data, ensuring the accuracy and reliability of both forest and non-forest fire assessments.

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