Scientific Research Publishing

Advances in Remote Sensing, 2023, 12, 47-69
https://www.scirp.org/journal/ars
ISSN Online: 2169-2688
ISSN Print: 2169-267X

Monitoring Hotspots Using Thermal Sensors on MODIS Aqua/Terra Satellite System: A Case Study of National Park Areas in Northern Thailand

Settapong Malisuwan[1*], Soemsak Yooyen[1], Ammarin Pimnoo[1,2], Cattleya Delmaire[3]

[1]The Excellence Center of Space Technology and Research (ECSTAR), International Academy of Aviation Industry (IAAI), King Mongkut's Institute of Technology Ladkrabang (KMITL), Bangkok, Thailand
[2]Thaicom Public Company Ltd., Bangkok, Thailand
[3]Environmental Protection and Sustainable Development Working Group, International Academy of Aviation Industry (IAAI), King Mongkut's Institute of Technology Ladkrabang (KMITL), Bangkok, Thailand
Email: *malisuwansettapong@gmail.com

How to cite this paper: Malisuwan, S., Yooyen, S., Pimnoo, A. and Delmaire, C. (2023) Monitoring Hotspots Using Thermal Sensors on MODIS Aqua/Terra Satellite System: A Case Study of National Park Areas in Northern Thailand. *Advances in Remote Sensing*, **12**, 47-69.
https://doi.org/10.4236/ars.2023.122003

Received: May 17, 2023
Accepted: June 25, 2023
Published: June 28, 2023

Abstract

This research presents the remote sensing data on hotspots in four national parks located in Chiang Mai province, Thailand: Sri Lanna National Park, Huai Nam Dang National Park, Doi Pahom Pok National Park, and Doi Inthanon National Park. To mitigate the devastating impacts of these wildfires, effective monitoring and management strategies are necessary. Remote sensing technology provides a promising approach for mapping burnt areas and understanding fire regimes at a regional scale. The primary focus of this research is to employ the MODIS Aqua/Terra satellite system for obtaining historical remote sensing data on hotspots. The advantages of remote sensing include accurate identification and mapping of burnt areas, regular monitoring, rapid data acquisition, and historical data analysis. The MODIS sensor, specifically designed for fire monitoring, offers enhanced fire detection and diagnosis, multiple channels for qualitative and quantitative analysis, and precision positioning capabilities. The research results presented in the analysis contribute to the understanding of fire incidents and hotspot occurrences within the four national parks studied. This paper suggests the optimization of early detection of forest and land fires through the utilization of Artificial Intelligence (AI), presenting it as a recommendation for future endeavors. The research emphasizes the significance of implementing efficient policies and management strategies to effectively tackle the challenges associated with fires in these ecologically significant areas.

Keywords

Forest Monitoring, Hotspot, Remote sensing, MODIS, Satellite, Northern Thailand

1. Introduction

Wildfire monitoring and management in the northern part of Thailand assumes paramount significance due to the recurring occurrence of extensive forest wildfires during the summer season. These wildfires inflict substantial damage upon forested and agricultural land, critical infrastructure, private properties, and even human lives. Consequently, the implementation of effective monitoring and management strategies becomes imperative to mitigate the devastating impacts of such incidents. In this regard, the utilization of remotely sensed images emerges as a promising approach for mapping burnt areas and fire regimes, particularly at the regional scale. Remotely sensed data provides valuable insights and a comprehensive understanding of the spatial distribution and temporal dynamics of wildfires. This technology offers distinct advantages over conventional methods employed for wildfire monitoring and management.

One of the key advantages of remotely sensed imagery is its high level of accuracy, enabling precise identification and mapping of burnt areas. By utilizing advanced sensors, such as those with high spatial resolutions, detailed information regarding the extent and severity of fire-affected areas can be acquired. The repeatability of remote sensing allows for regular and consistent monitoring, facilitating the tracking of fire patterns and changes over time. Another notable advantage lies in the rapid data acquisition capabilities of remotely sensed images. Satellite-based platforms can acquire data over large areas in a relatively short period, enabling timely assessment and response to wildfire events [1]. This prompt availability of information contributes to effective decision-making processes and the implementation of appropriate management strategies.

Furthermore, the long-term historical data archives associated with remotely sensed images are invaluable for studying fire regimes and understanding their dynamics. By analyzing past fire events, researchers and managers can gain insights into the factors influencing fire occurrence, spread, and behavior. This historical context enhances the ability to forecast and plan for future fire events. Additionally, the integration of remotely sensed data with other thematic information, such as land cover, topography, and weather data, further enhances the utility of satellite-based burnt area mapping. By combining multiple data sources, comprehensive assessments of fire risk and vulnerability can be conducted, leading to more informed decision-making and effective allocation of resources.

Satellite-based burnt area mapping employs various sensors with diverse spatial and temporal resolutions to capture the multidimensional aspects of wildfire dynamics. Different classification procedures are utilized to extract relevant information from remotely sensed data, facilitating the accurate identification and delineation of burnt areas [2]. Hotspots serve as indications of forest and land fires, and they have been widely utilized in numerous countries as a means to monitor such incidents from satellite platforms. The detection of forest and land fires relies on the observation of these hotspots. The timely acquisition of information pertaining to forest and land fires holds significant importance in mitigating their impact.

Remote sensing technology, particularly the utilization of Moderate Resolution Imaging Spectroradiometer (MODIS) images obtained from the Aqua and Terra satellites, can provide valuable insights into these fires. The MODIS is a sensor deployed on the Terra and Aqua satellites, launched by NASA in December 1999 and May 2002, respectively [3]. The Terra satellite orbits the Earth in a manner that it traverses the equator from north to south during the morning, while the Aqua satellite traverses the equator from south to north during the afternoon, thus resulting in global coverage every 1 to 2 days. Consequently, the data acquired from MODIS enables the display of daily information, benefiting from a temporal resolution of twice per day. Analysis of forest fires is carried out through visual examination of MODIS images and hotspot data [2] [3].

MODIS data plays a crucial role in the analysis of forest and land fires by utilizing hotspot data, which signifies elevated temperatures within a specific area. To generate hotspots from MODIS data, seven electromagnetic wave spectrums are employed: the thermal spectrums of 4 μm, 11 μm, and 12 μm, as well as the reflectance spectrums of 0.65 μm, 0.86 μm, and 2.1 μm. These spectrums are carefully selected to mitigate the influence of cloud interference, sunlight reflection on the sea (sun glint), coastal areas, and forest clearing. The MODIS bands employed for hotspot analysis include band 1 (0.65 μm), band 2 (0.86 μm), band 7 (21 μm), band 21 (4.0 μm), band 22 (4.0 μm), band 31 (11.0 μm), and band 32 (12.0 μm) as shown in **Table 1** [4] (Giglio *et al.*, 2016). Subsequently, specific algorithms are applied to process the data and generate hotspot information.

The MODIS sensor possesses significantly superior capabilities for monitoring fires in comparison to other sensors, primarily due to its instrument characteristics specifically designed for fire monitoring applications. In contrast to alternative remote sensing tools, MODIS offers several advantages for fire-related applications, including [5]:

1) Enhanced Fire Detection and Diagnosis: MODIS exhibits high sensor sensitivity and quantitative precision, enabling the detection and diagnosis of flames with greater accuracy. Its multiple channels dedicated to fire detection not only prevent saturation issues but also facilitate qualitative and quantitative analysis of fire characteristics.

2) Availability of Numerous Channels: The availability of multiple channels in MODIS allows for a comprehensive investigation of fire phenomena. By leveraging these channels, both qualitative and quantitative assessments of fire nature can be conducted, enhancing the understanding of fire dynamics.

Table 1. The band used to produce hotspot data from MODIS imagery.

Band	Central Wavelength (micrometer)	Usability
1	0.65	Minimize the error of detection due to reflection of sun glint, coast, and clouds.
2	0.86	Minimizing errors due to sun glint and coastal conditions.
7	21	Minimizing errors due to sun glint and coastal conditions.
21	4	Is a channel that has a high range for fire detection.
22	4	Is a channel that has a low range for fire detection.
31	11	For fire detection and minimizing errors of detection from clouds and forest clearing
32	12	To minimize detection errors due to clouds.

(Source: Giglio *et al.* 2016).

3) Precision Positioning Capabilities: MODIS is equipped with precision positioning capabilities, enabling accurate spatial mapping of fire incidents. This feature contributes to precise identification and delineation of fire-affected areas.

Existing research has utilized various MODIS fire detection methods that rely on the spectral properties of the mid and long-infrared channels, fire mask data products, and the combination of MODIS bands to extract information. The specific method employed typically depends on the scale of the study, the research subject, and the specific conditions of the study location. Choosing an appropriate method is essential to ensure the effectiveness and relevance of the fire analysis in line with the study's objectives.

The structure of the next sections of this paper will be as follows: first, the section on "Materials and Methods" will describe study areas and the workflow of the data for monitoring the risk of forest and land fires in Northern Thailand using MODIS Aqua/Terra satellite data. Following that, the section on "Results and Discussions" will explain the case study conducted in four national parks in Chiang Mai province: Sri Lanna National Park, Huai Nam Dang National Park, Doi Pahom Pok National Park, and Doi Inthanon National Park. This section will highlight the data obtained through thermal sensors on the Terra and Aqua satellites, employing the MODIS system for hotspot detection, during the period from 2019 to 2021. Subsequently, the "Recommendations" section will present optimizing the early detection of forest and land fires using Artificial Intelligence (AI) for future work. Finally, the paper will conclude, summarizing the key points and implications of the study.

2. Materials and Methods

2.1. Study Area

In this paper, remote sensing data pertaining to hotspots in four national parks situated in Chiang Mai province is presented. The national parks include Sri

Lanna National Park, Huai Nam Dang National Park, Doi Pahom Pok National Park, and Doi Inthanon National Park. Studying the hotspots in national parks in northern Thailand is crucial for several reasons. Firstly, it plays a significant role in the protection and management of forests. National parks are invaluable ecosystems that provide habitat for numerous plant and animal species, many of which may be endangered or unique to the region. By studying the hotspots, researchers and conservationists can identify areas of high fire risk and implement targeted forest management strategies to prevent and control wildfires. Understanding the patterns and causes of hotspots helps in the development of effective fire prevention measures, such as creating firebreaks, implementing early warning systems, and promoting public awareness about fire safety [6]. Moreover, studying the hotspots allows for the assessment of the impact of climate change on wildfires and helps to develop adaptive strategies to mitigate these effects.

Secondly, the study of hotspots in national parks is essential for understanding the impacts of climate change on the region. With the increasing frequency and intensity of wildfires worldwide, it is crucial to examine the relationship between climate change and the occurrence of hotspots. Rising temperatures, changes in rainfall patterns, and prolonged droughts can create favorable conditions for the ignition and spread of wildfires. By studying the hotspots, scientists can analyze the historical trends and patterns of fire occurrence, assess the influence of climate variables, and predict future wildfire risks. This knowledge is vital for developing sustainable land management practices, informing policy decisions, and implementing effective measures to mitigate the impact of climate change on national parks and their surrounding areas. Additionally, studying hotspots can aid in the development of strategies to restore and rehabilitate areas affected by wildfires, promoting the long-term resilience and conservation of these valuable ecosystems.

2.2. Methods

Forest fire monitoring and assessment encompass various approaches, including aerial circle mapping, data statistics, ground survey, and remote sensing image methods. These methods are employed to estimate the extent of forest fire-affected areas, with data statistics and remote sensing image methods being predominantly utilized for assessing large-scale forest fires. The former technique demands considerable labor and financial resources, rendering it unsuitable for estimating the size of forest fires on a large scale. In contrast, remote sensing satellites offer substantial advantages in terms of monitoring and evaluating forest fire sizes, owing to their rapid imaging capabilities and extensive coverage [7].

The extensive expanse of forested regions in Thailand poses a significant hurdle in accurately pinpointing the precise locations of forest fires. Satellite imagery data has emerged as the primary tool for detecting forest fires due to its expansive coverage and regular updates. There is a growing demand for spatial information pertaining to forest and land fires, driven by the necessity for prompt response in firefighting operations and criminal investigations. The Thai authorities are increasingly emphasizing the importance of achieving high accuracy and frequent availability in the early detection of forest and land fires.

The workflow of the data process for monitoring the risk of forest and land fires in Northern Thailand using MODIS Aqua/Terra satellite data can be outlined as follows [8]:

1) Data Acquisition: The study utilizes satellite imagery from the MODIS Aqua and Terra satellites. These satellites capture images of the Earth's surface and provide data on various environmental parameters, including temperature.

2) Hotspot Detection: Hotspots, which indicate areas of elevated temperature, are detected in the MODIS satellite data. These hotspots serve as indicators of forest and land fires. Detection algorithms analyze the thermal signature of the pixels in the satellite images to identify regions with unusually high temperatures.

3) Hotspot Analysis: The detected hotspots are analyzed to assess the distribution and intensity of potential forest and land fires in Northern Thailand. The analysis involves examining the spatial patterns and temporal evolution of the hotspots to understand the dynamics of the fire risk.

4) Burnt Area Mapping: To further understand the extent and impact of the fires, burnt area mapping is performed using various sensors and classification procedures. Different remotely sensed data with diverse spatial and temporal resolutions are utilized to extract relevant information about burnt areas. This process facilitates accurate identification and delineation of the areas affected by fires.

5) Visual Examination and Analysis: Forest fire analysis is carried out through visual examination of the MODIS images and hotspot data. Researchers visually inspect the imagery and compare it with the hotspot data to validate and verify the detected hotspots and burnt areas. This step helps in refining the accuracy of the results and gaining additional insights into the fire dynamics.

6) Result Interpretation: The findings of the study, including the distribution of hotspots and the analysis of burnt areas, are interpreted to assess the risk of forest and land fires in Northern Thailand. The results provide valuable information for the local community and stakeholders to anticipate and mitigate the impact of fires in the study area.

By leveraging MODIS satellite data and remote sensing technology, this approach enables the assessment and monitoring of forest and land fires, facilitating timely information acquisition and effective fire management strategies. This satellite is commonly utilized for regional detection due to the capability of one of its sensors to discern surface temperatures on both land and sea. One notable advantage is the satellite's frequency of revisiting a particular location twice a day and night. Additionally, it offers the advantage of being cost-effective. Hotspots, indicative of partially or completely burned areas, can be identified using this satellite; however, they do not provide precise information regarding the extent of the burned area. The number of hotspots detected can vary significantly in subsequent measurements, depending on the time of day, with fire activity decreasing at night and peaking in the afternoon, as well as weather conditions that hinder the sensor's ability to penetrate clouds and smoke. Moreover, the organization responsible for providing such data can influence the hotspot count. It is important to note that there is currently no universally established temperature or temperature threshold standard to identify hotspots [6] [9].

3. Results and Discussions

This section presents the remote sensing data regarding hotspots in four national parks located in Chiang Mai province: Sri Lanna National Park, Huai Nam Dang National Park, Doi Pahom Pok National Park, and Doi Inthanon National Park, respectively.

3.1. Sri Lanna National Park

According to the data acquired through the application of thermal sensors on the Terra and Aqua satellites, employing the MODIS system for hotspot detection, an investigation was conducted in the Sri Lanna National Park and its surrounding regions within the period spanning from 2019 to 2021. The analysis revealed an average occurrence of 151 hotspots between the months of January and April. Notably, the peak activity was observed in March, exhibiting an average of 109 hotspots, followed by a decline in April, with an average count of 28 hotspots. Conversely, no hotspots were detected in January, as depicted in **Figures 1-4**. The color-coding system in all hotspot figures utilizes red, orange, yellow, light green, and dark green to represent varying levels of risk, namely: very high, high, moderate, low, and very low, respectively.

3.2. Huay Nam Dang National Park

Based on the analysis of hotspot data acquired through the utilization of thermal sensors mounted on the Terra and Aqua satellites, employing the MODIS system

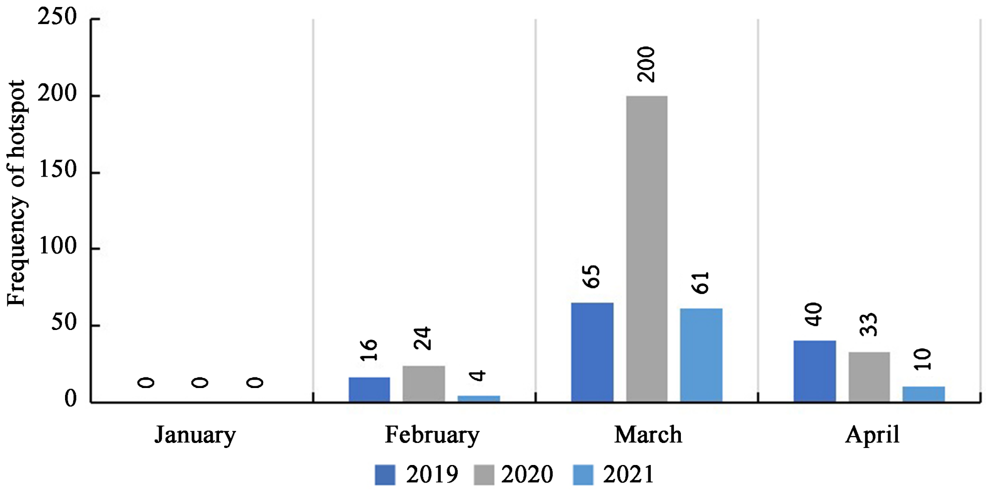

Figure 1. The frequency of hotspot occurrences from January to April, between the years 2019 and 2021, in Sri Lanna National Park.

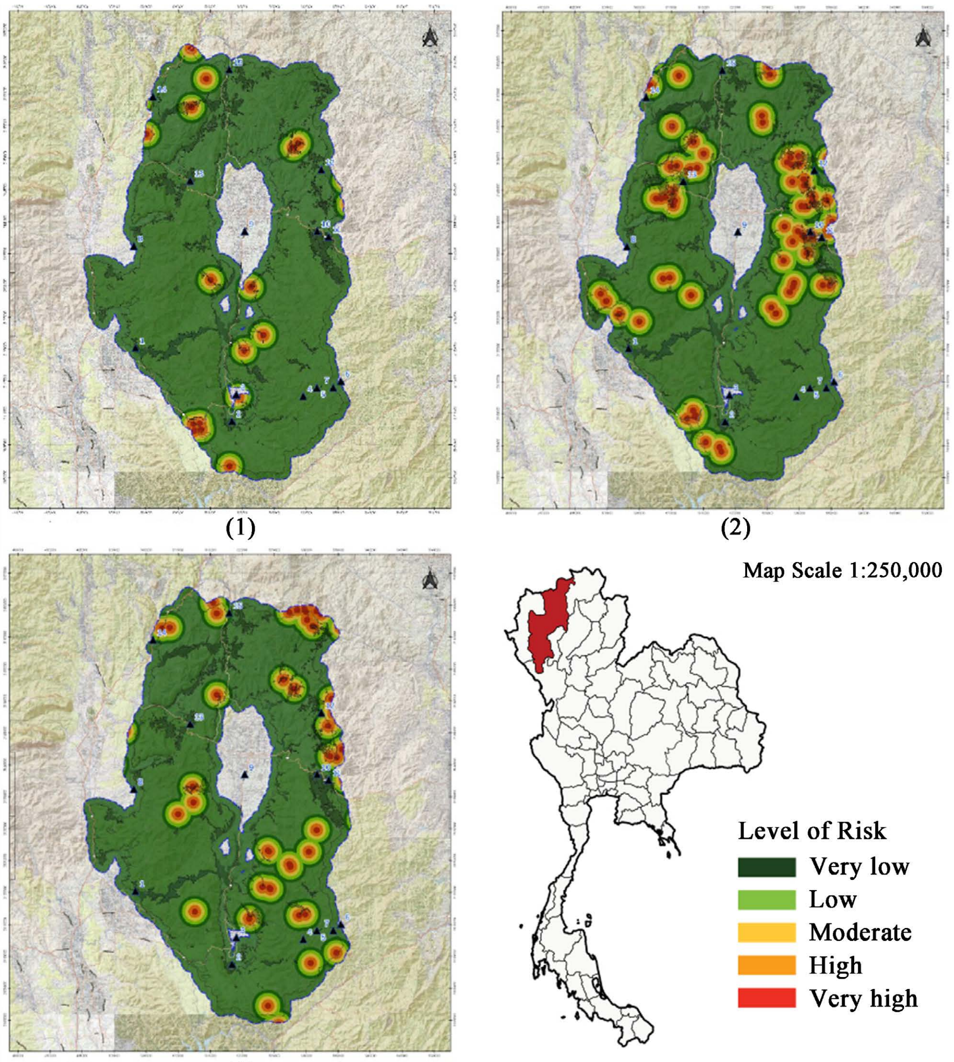

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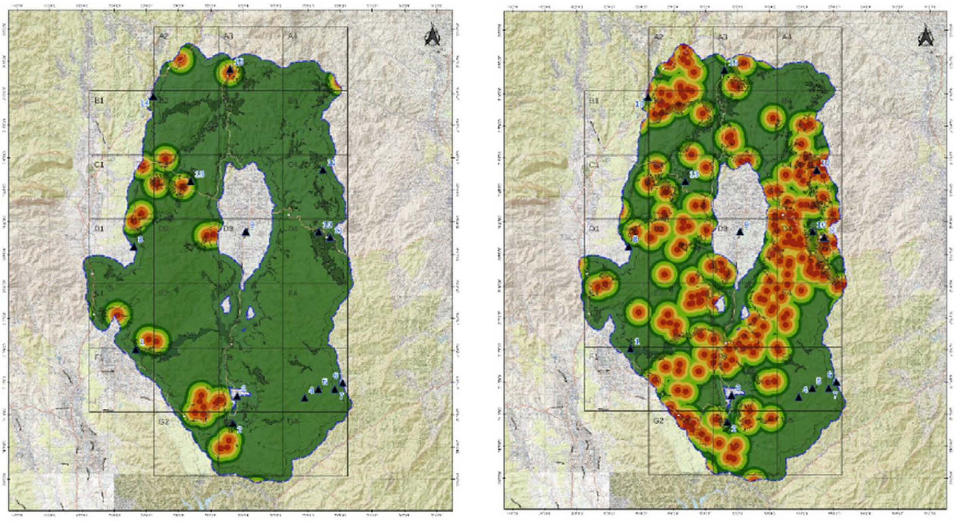
Figure 2. The hotspots during the period from January to April in the year 2019, in Sri Lanna National Park. Note: (1) February, (2) March, (3) April.



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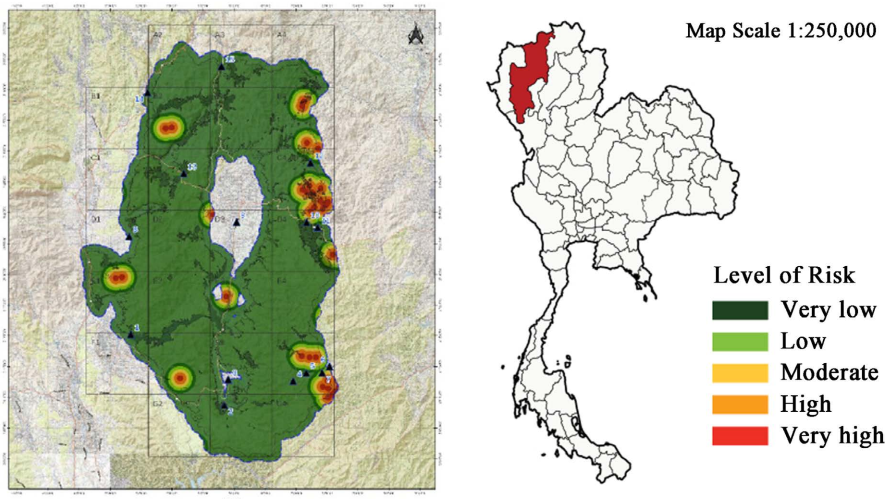

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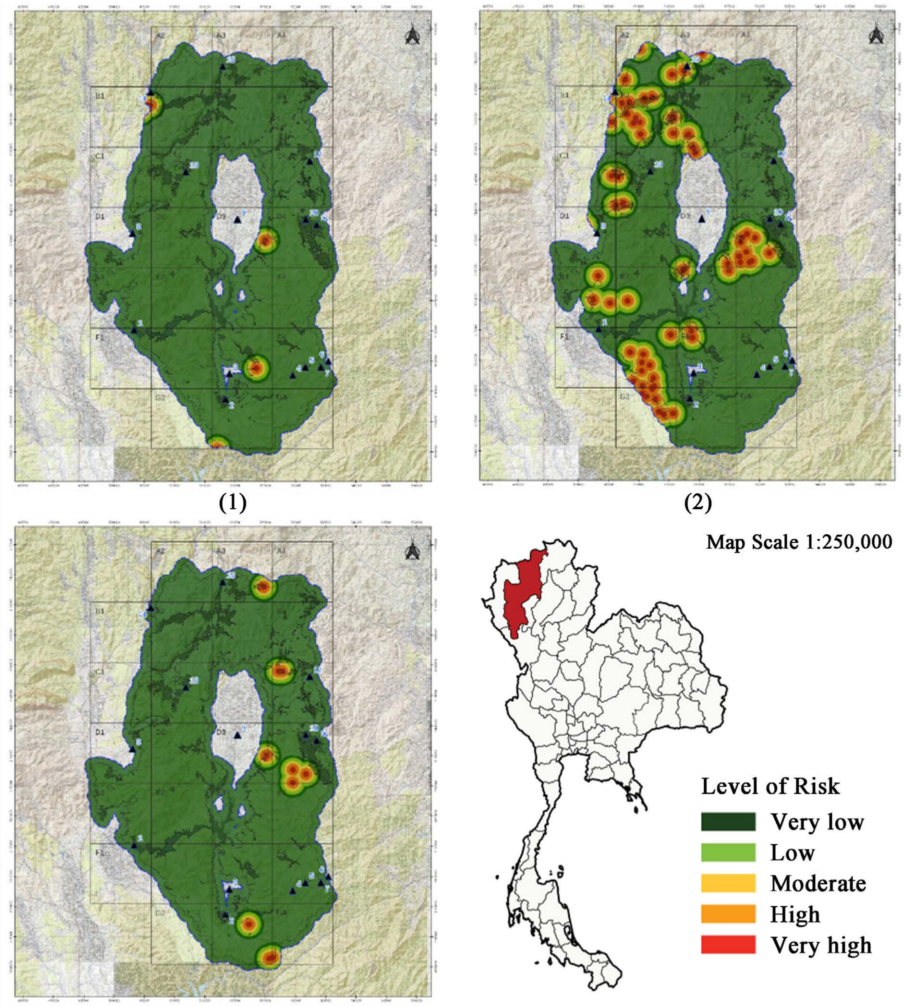
Figure 3. The hotspots during the period from January to April in the year 2020, in Sri Lanna National Park and connecting areas. Note: (1) February, (2) March, (3) April.



(1)

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Figure 4. The hotspots during the period from January to April in the year 2021, in Sri Lanna National Park and connecting areas. Note: (1) February, (2) March, (3) April.

for hotspot identification, a comprehensive investigation was conducted in Huai Nam Dang National Park and its adjoining areas. The findings revealed an average of 129 hotspots within the specified period from January to April, spanning the years 2019 to 2021. Notably, the highest frequency of hotspot occurrences was observed in March, exhibiting an average count of 62 hotspots, followed by a decrease in April, with an average of 43 hotspots. In contrast, the month of January recorded the lowest number of hotspots, with only one instance detected, as evidenced by Figures 5-8. The color-coding system in all hotspot figures utilizes red, orange, yellow, light green, and dark green to represent varying levels of risk, namely: very high, high, moderate, low, and very low, respectively.

3.3. Doi Pahom Pok National Park

According to the data derived from hotspot detection using thermal sensors mounted on the Terra and Aqua satellites, implementing the MODIS system for

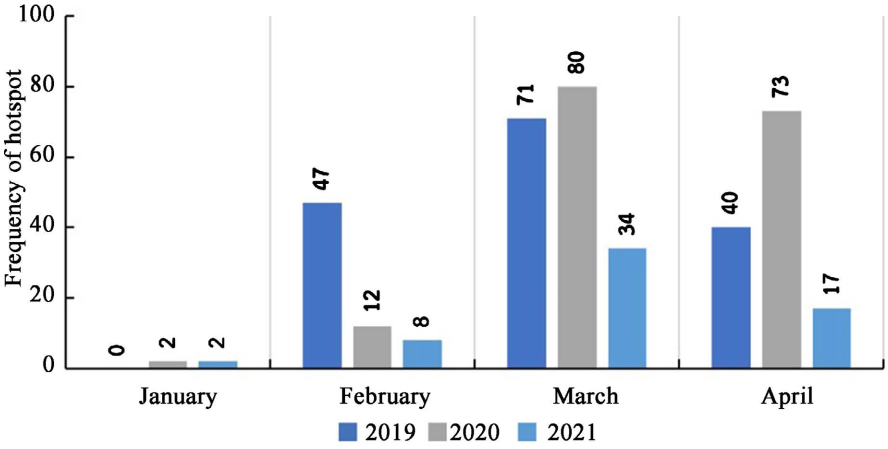
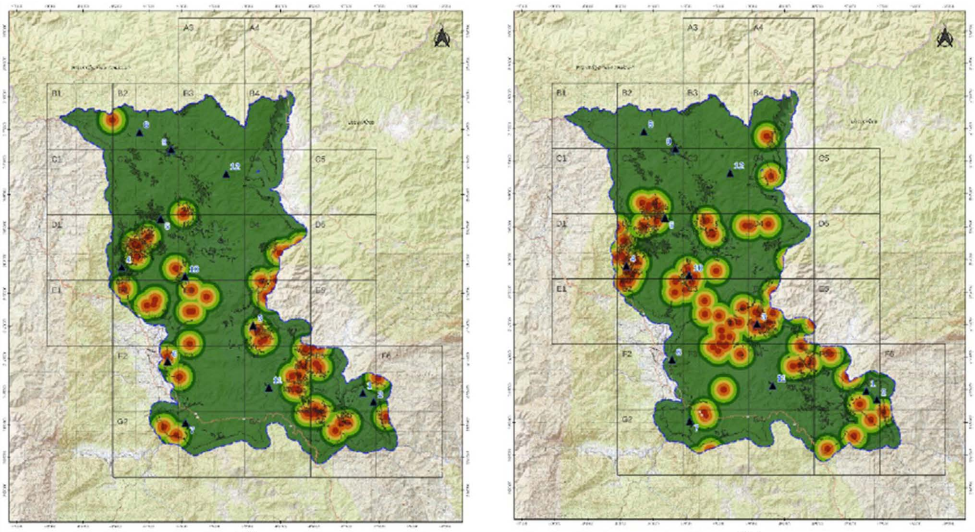


Figure 5. The frequency of hotspot occurrences from January to April, between the years 2019 and 2021, in Huay Nam Dang National Park.



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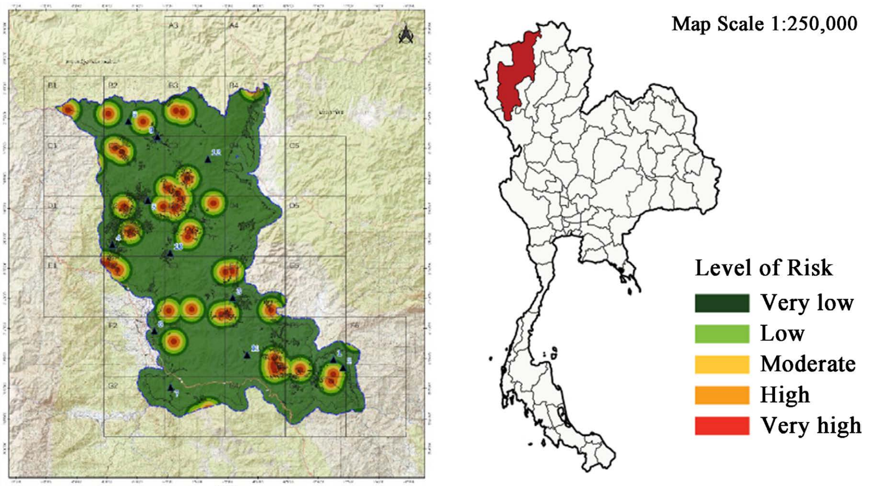

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Figure 6. The hotspots during the period from January to April in the year 2019, in Huay Nam Dang National Park. Note: (1) February, (2) March, (3) April.

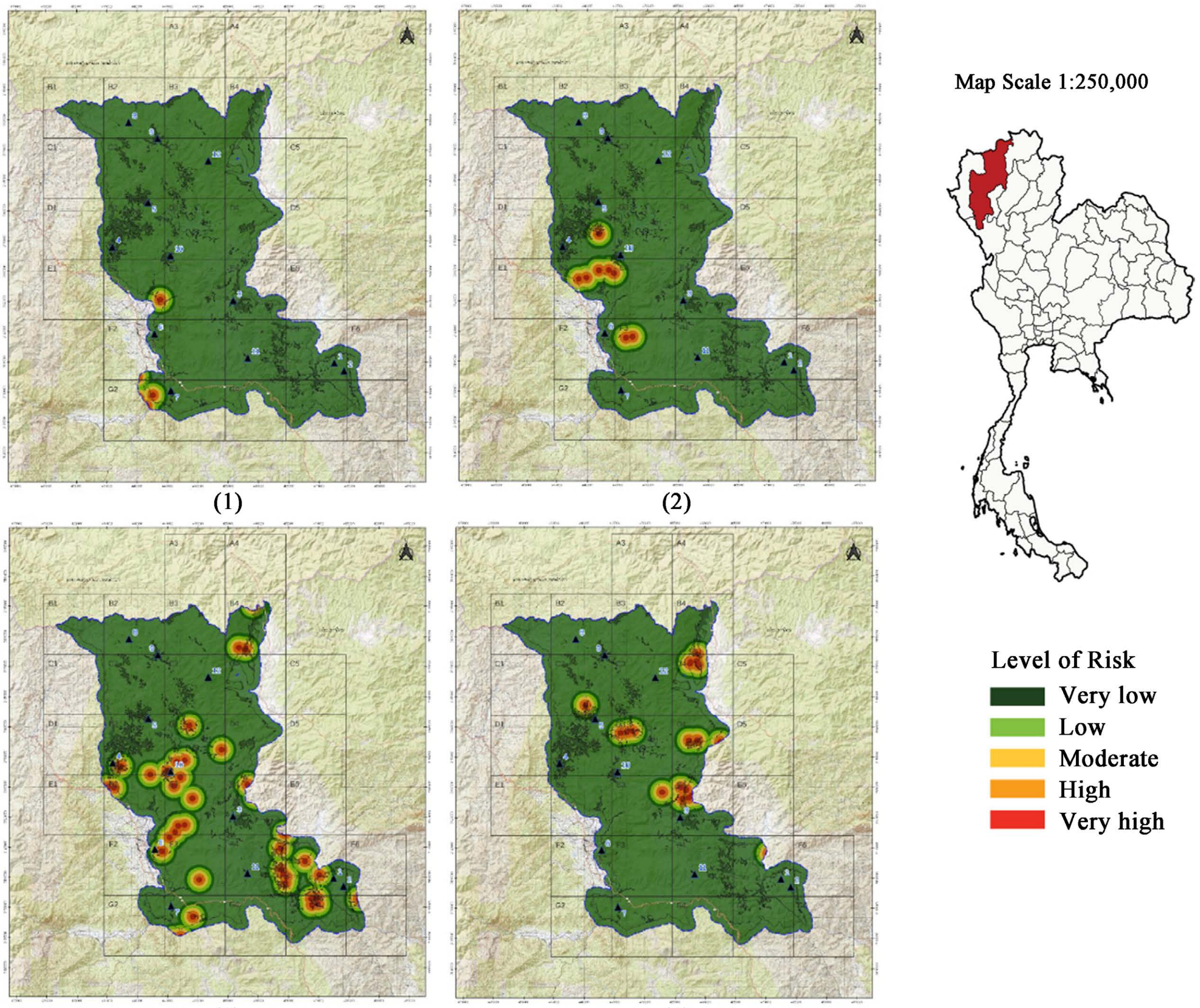

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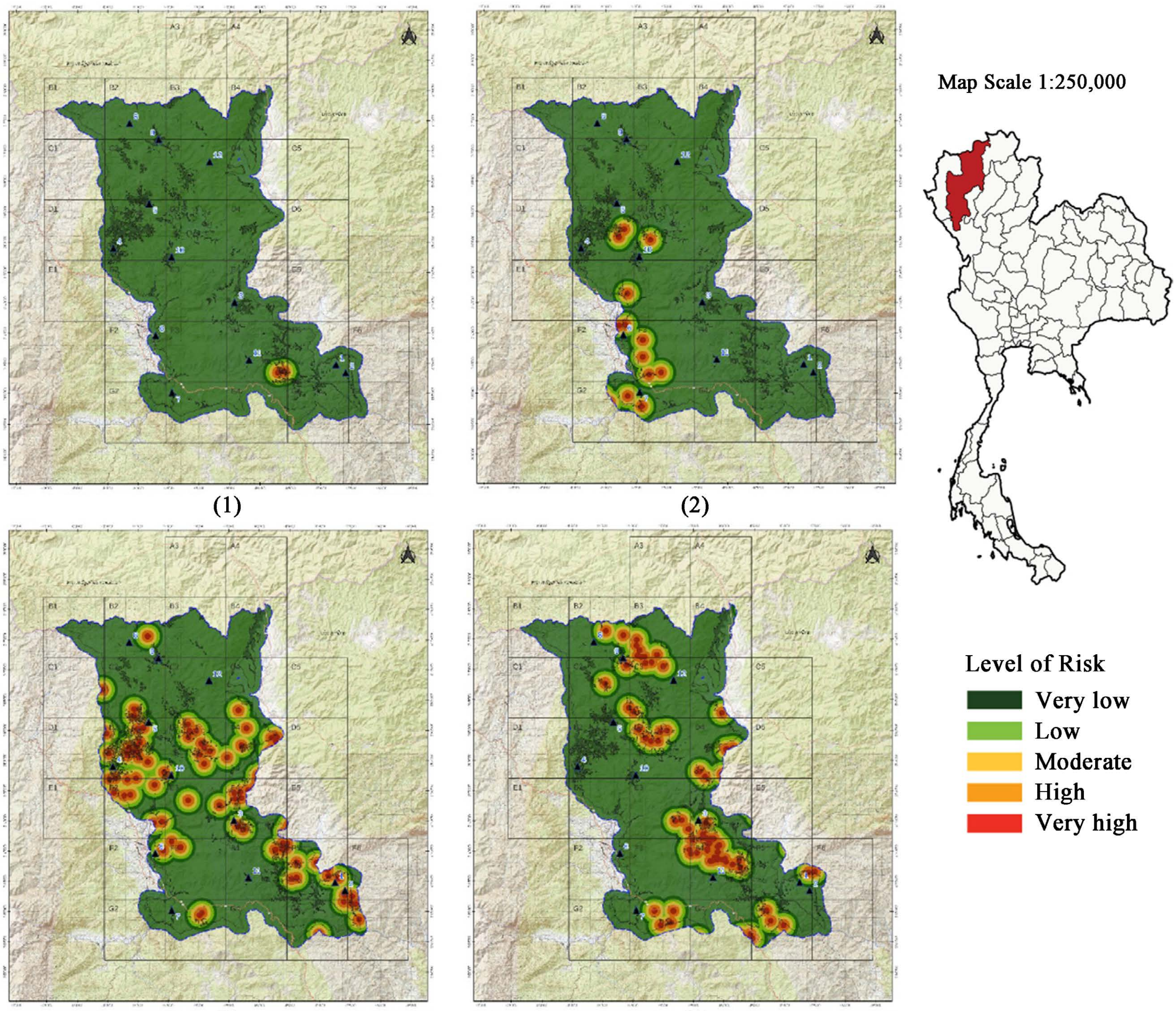
Figure 7. Hotspots during the period from January to April of the year 2020 in Huai Nam Dang National Park. Note: (1) January, (2) February, (3) March, (4) April.



(1) (2) (3) (4)

Figure 8. Hotspots during the period from January to April of the year 2021 in Huai Nam Dang National Park and the connecting areas. Note: (1) January, (2) February, (3) March, (4) April.

hotspot identification, an investigation was conducted within Doi Pahom Pok National Park and its adjoining regions. The analysis of Terra satellite data revealed an average count of 37 hotspots occurring between the months of January and April, spanning the period from 2019 to 2021. Notably, the peak hotspot activity was observed in March, with an average count of 31 hotspots, followed by a decline in April, with an average of 5 hotspots. Conversely, no hotspots were detected in January, as evidenced by Figures 9-12. The color-coding system in all hotspot figures utilizes red, orange, yellow, light green, and dark green to represent varying levels of risk, namely: very high, high, moderate, low, and very low, respectively.

3.4. Doi Inthanon National Park

Based on the data obtained from the detection of hotspots using thermal sensors

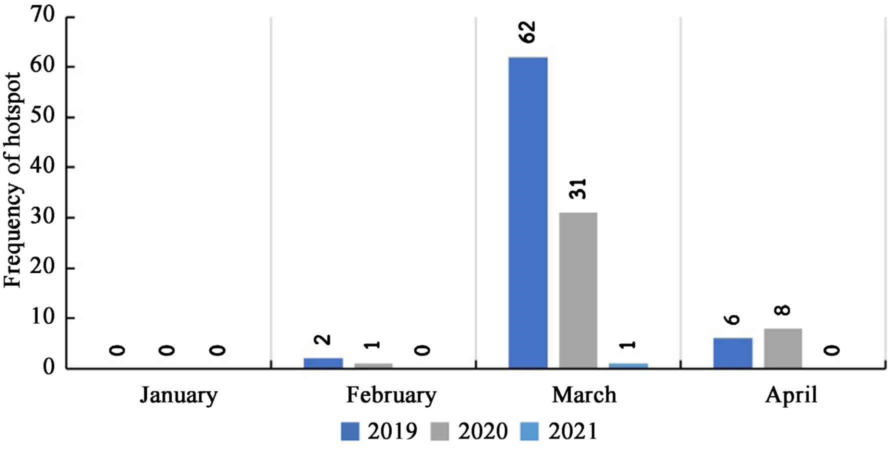


Figure 9. The frequency of hotspot occurrences from January to April, between the years 2019 and 2021, in Doi Pahom Pok National Park.

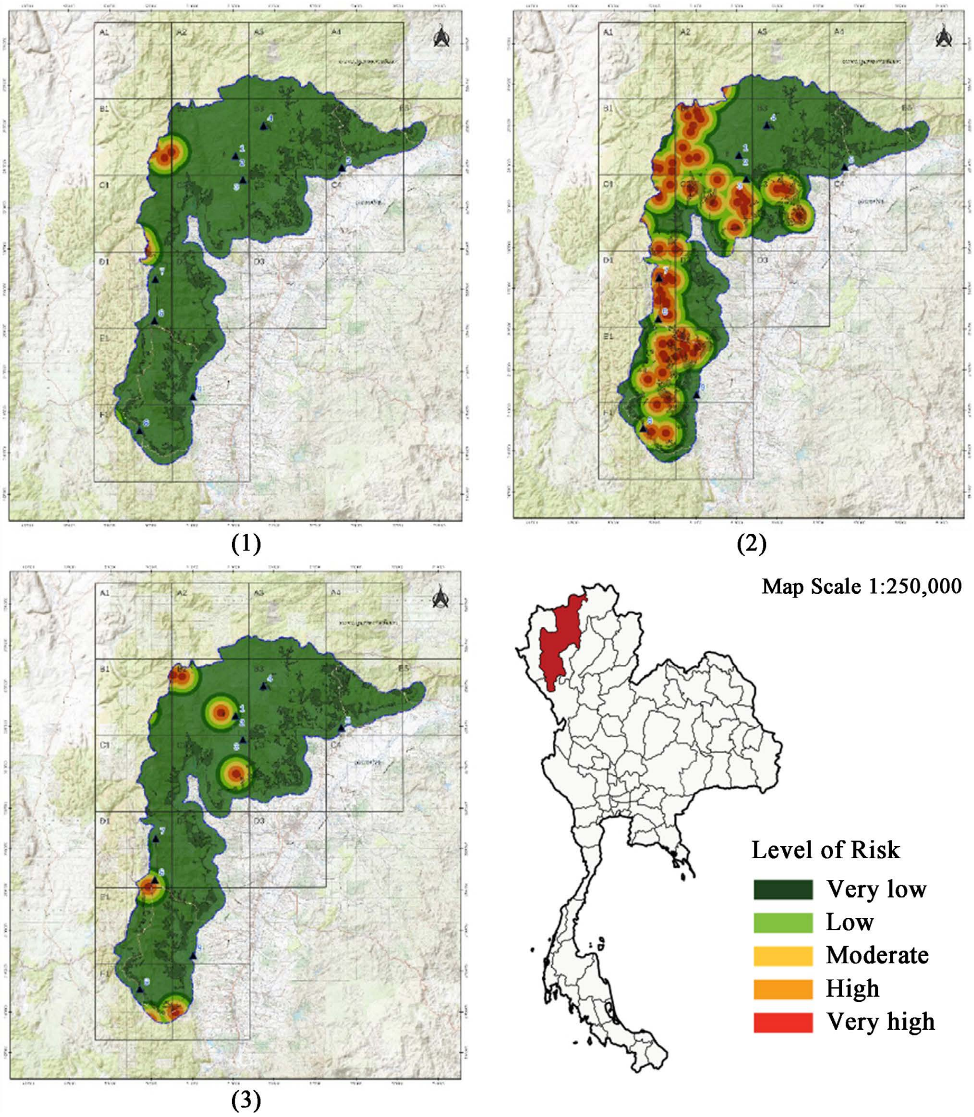


Figure 10. Hotspots during the period from January to April of the year 2019 in Doi Pahom Pok National Park and the connecting areas. Note: (1) February, (2) March, (3) April.

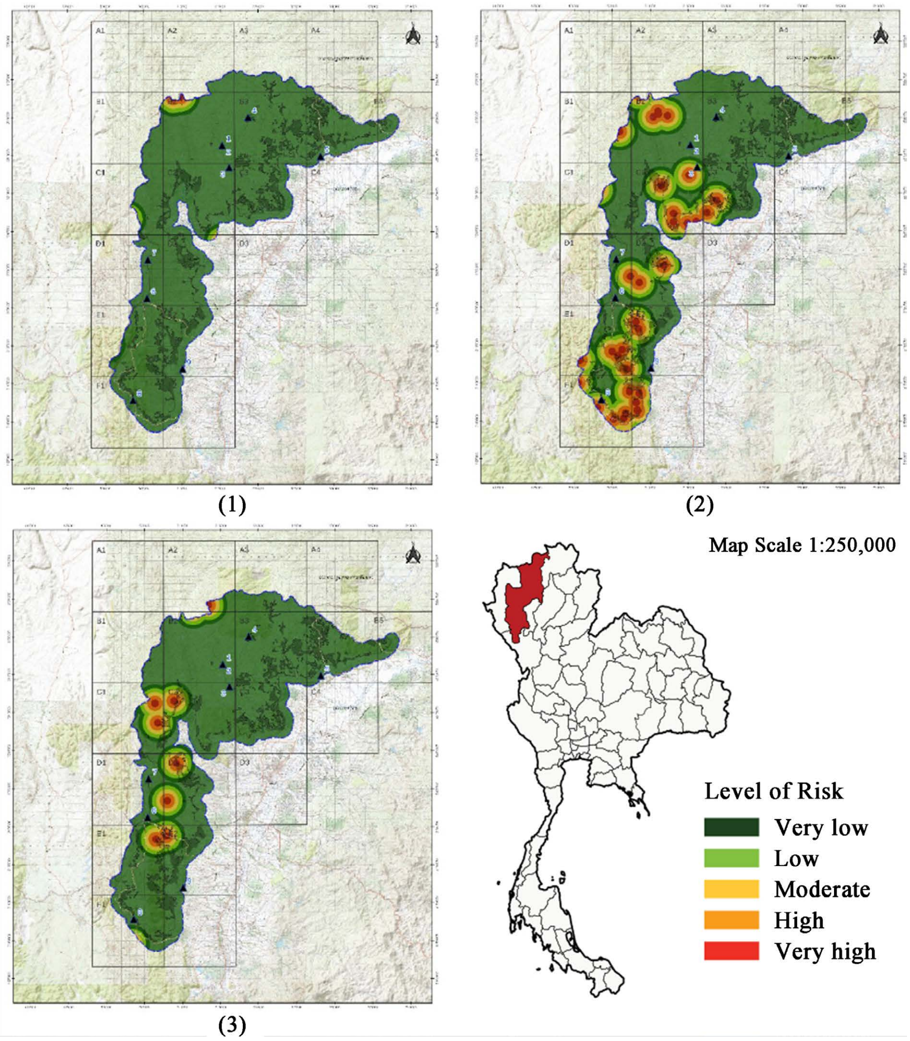


Figure 11. Hotspots during the period from January to April of the year 2020 in Doi Pahom Pok National Park. Note: (1) February, (2) March, (3) April.

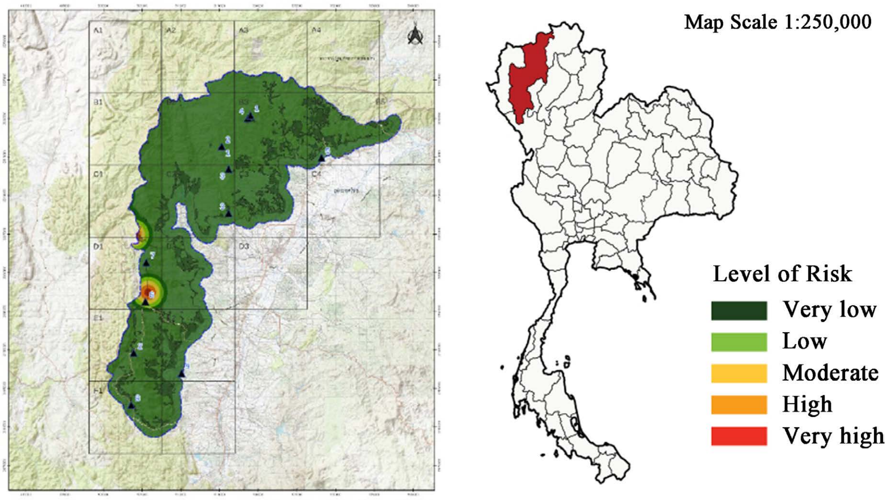


Figure 12. Hotspots during the period from January to April of the year 2021 in Doi Pahom Pok National Park and the connecting areas. Note: (1) March.

from the Terra and Aqua satellites, which employ the MODIS system for hotspot detection, information regarding the hotspots in the Doi Inthanon National Park area and the connecting areas during the years 2019-2021 is available. A total of 55 hotspots were identified within the period from January to April. The highest occurrence of hotspots was recorded in February, with an average of 18 hotspots. Following this, March exhibited a slightly lower average of 17 hotspots, while January had the lowest number of hotspots, totaling 8. These findings are illustrated in Figures 13-16. The color-coding system in all hotspot figures utilizes red, orange, yellow, light green, and dark green to represent varying levels of risk, namely: very high, high, moderate, low, and very low, respectively.

Table 2 provides an overview of the number of hotspot occurrences in four national parks. The data presented in the table spans the period from January to April, covering the years 2019 to 2021.

Specifically focusing on Sri Lanna National Park, the research findings offer valuable insights into the frequency of hotspot occurrences within the park.

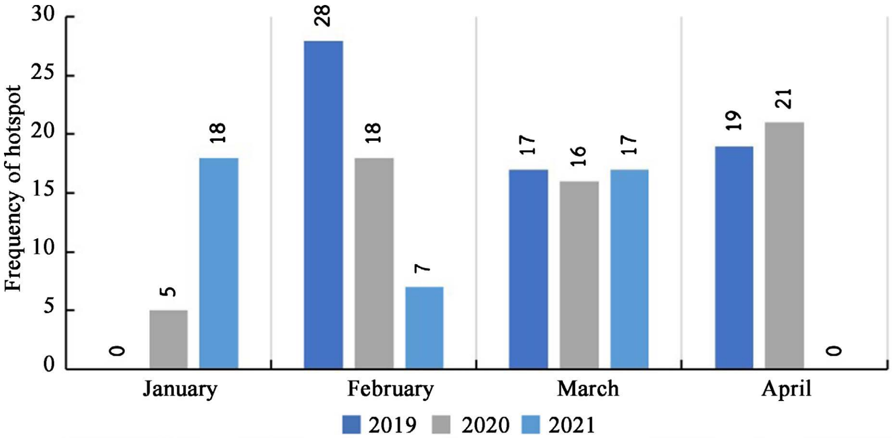
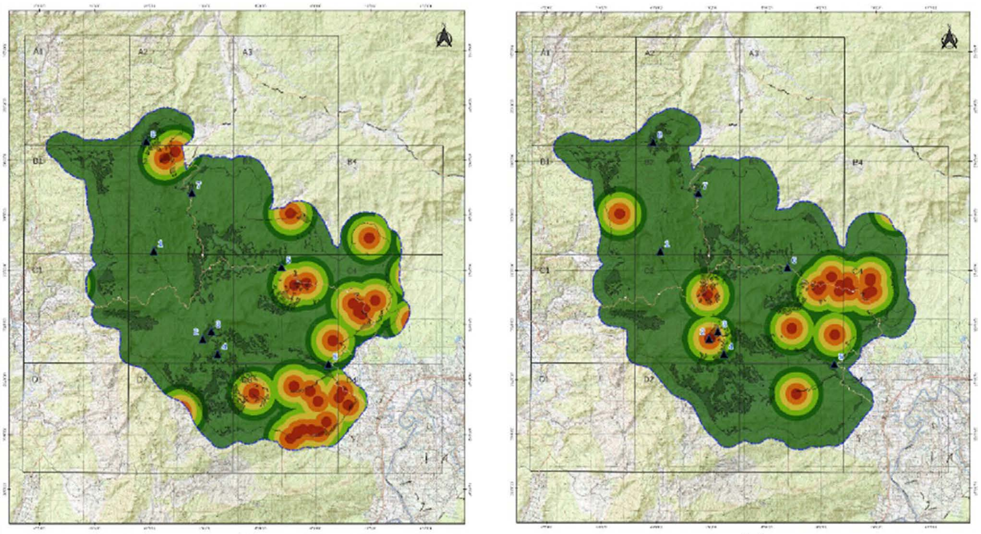


Figure 13. The frequency of hotspot occurrences in Doi Inthanon National Park during the period from January to April, between the years 2019 and 2021.



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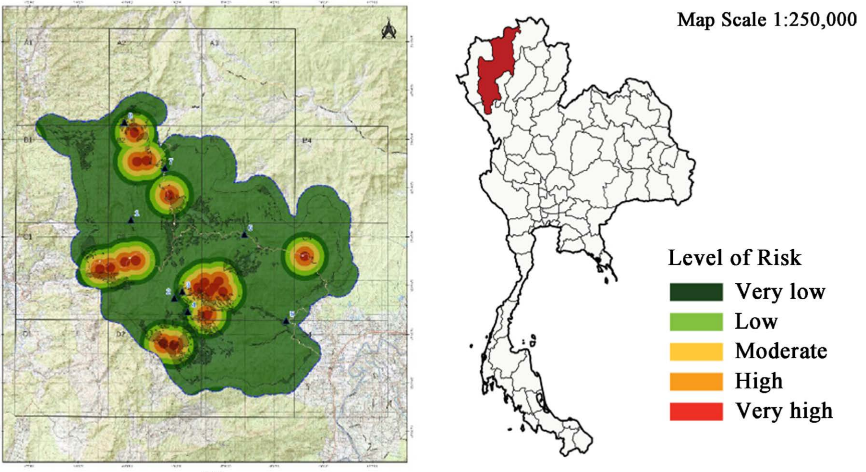

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Figure 14. The hotspots during the months of January to April in the year 2019 in Doi Inthanon National Park. Please note the following: (1) February, (2) March, and (3) April.

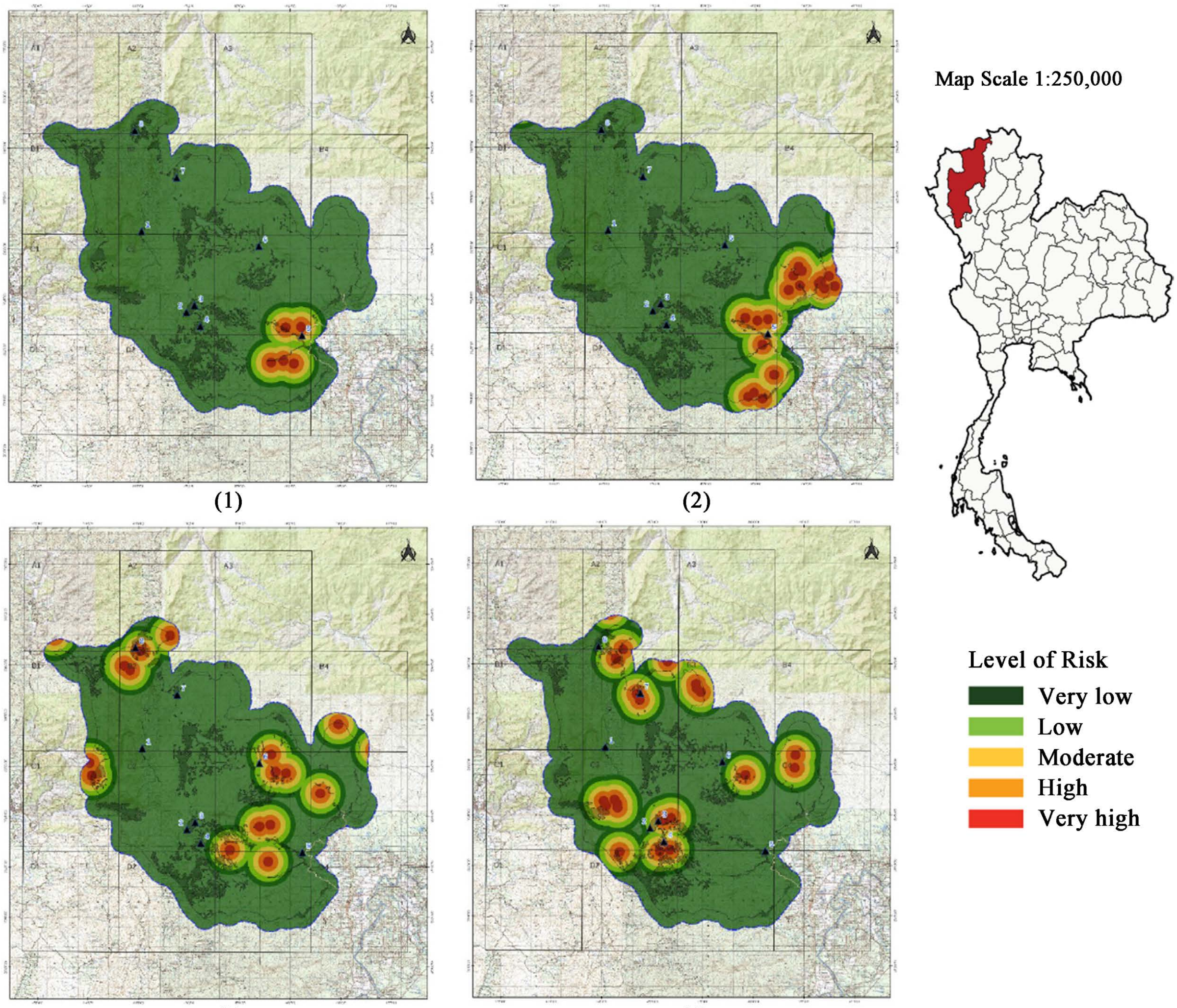

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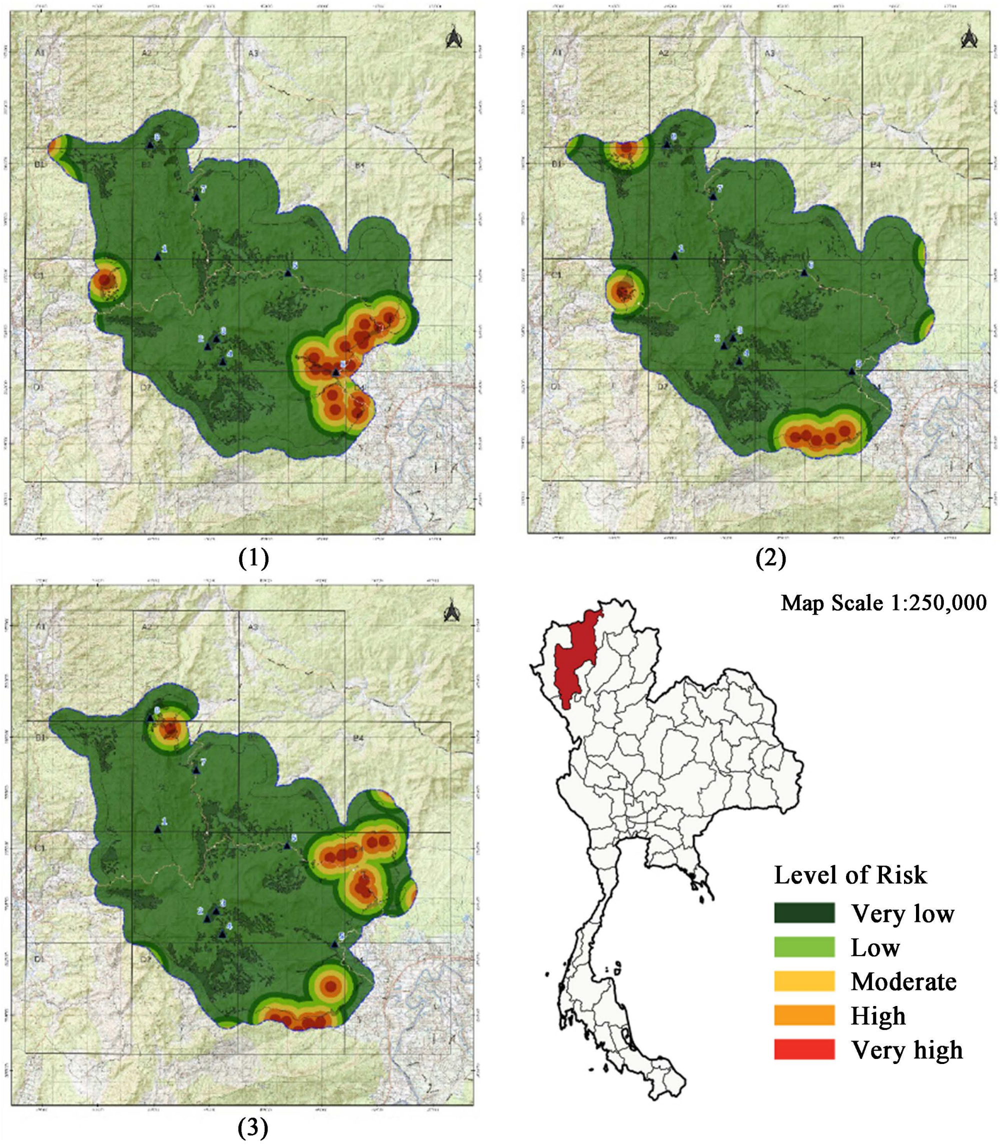
Figure 15. The hotspots during January to April in 2020 in Doi Inthanon National Park. Notes: (1) January, (2) February, (3) March, and (4) April.



(1) (2) (3)

Figure 16. The hotspots during January to April in 2021 in Doi Inthanon National Park. Notes: (1) January, (2) February, and (3) March.

Table 2. The number of hotspots from January to April 2019-2021.

Target Areas	The number of hotspots during the dry season (January-April) for each year			Total
	2019	2020	2021	
Sri Lanna National Park	121	257	75	453
Huai Nam Dang National Park	158	167	61	386
Doi Pahom Pok National Park	70	40	1	111
Doi Inthanon National Park	64	60	42	166
Total	**413**	**524**	**179**	**1116**

Analyzing the data collected during the study period reveals noteworthy observations. In the year 2019, a total of 121 hotspots were recorded, indicating a substantial number of fire incidents within the park. The subsequent year, 2020, exhibited a noticeable increase, with the number of hotspots surging to 257, signifying a significant rise in fire occurrences. Notably, 2020 experienced a substantial escalation in hotspot incidents compared to the preceding year. However, the year 2021 witnessed a decline in hotspot occurrences, with a recorded total of 75 hotspots, indicating a decrease in fire incidents within the park. By considering the cumulative data from 2019 to 2021, a comprehensive understanding of hotspot occurrences in Sri Lanna National Park can be attained. The total number of hotspots during this three-year period amounted to 453, providing an overview of the overall prevalence of fire incidents within the park.

Subsequently, the focus turns to Huai Nam Dang National Park, where this research study unveils valuable insights regarding the frequency of hotspot occurrences within the park. The meticulous analysis of the collected data reveals compelling findings. In 2019, the recorded hotspots amounted to a total of 158, indicating a significant prevalence of fire incidents within the park during that year. Similarly, in 2020, the hotspot occurrences remained at a comparable level, with a total of 167 hotspots detected. However, a notable decline in hotspot occurrences was observed in 2021, with only 61 hotspots recorded. When considering the cumulative data encompassing the years 2019 to 2021, the overall number of hotspots documented within Huai Nam Dang National Park reached 386.

Next, we focus on Doi Pahom Pok National Park. In the year 2019, the recorded instances of hotspots amounted to a cumulative total of 70. Subsequently, in 2020, the frequency of hotspot occurrences decreased, with a recorded total of 40 hotspots. Notably, a significant decline in hotspot incidents was observed in the succeeding year, 2021, with only a solitary hotspot being recorded. Upon considering the comprehensive data encompassing the period spanning from 2019 to 2021, the aggregate number of hotspots documented within Doi Pahom Pok National Park amounted to 111.

Lastly, the focus shifts towards Doi Inthanon National Park, specifically, in the year 2019, a total of 64 hotspots were recorded, indicating a substantial number of fire incidents. The subsequent year, 2020, exhibited a slightly lower number of hotspots, with a recorded total of 60. Furthermore, the year 2021 witnessed a decline in hotspot occurrences, as indicated by the recorded total of 42 hotspots, reflecting a decrease in fire incidents within the park. By considering the cumulative data from 2019 to 2021, a comprehensive understanding of the frequency of hotspot occurrences in Doi Inthanon National Park can be attained. The total number of hotspots observed during this three-year period amounted to 166, providing a comprehensive overview of the overall prevalence of fire incidents within the park.

The research results presented in the analysis contribute to the understanding of fire incidents and hotspot occurrences within the four national parks studied: Sri Lanna National Park, Huai Nam Dang National Park, Doi Pahom Pok National Park, and Doi Inthanon National Park. The contributions of these results are as follows:

1) Fire Incident Patterns: The findings offer valuable insights into the frequency and patterns of fire incidents within each national park over a three-year period. By documenting the number of hotspots recorded each year, the research provides an overview of the prevalence of fire incidents in these areas. This information helps in understanding the temporal dynamics of fires and identifying potential trends or anomalies in fire occurrence.

2) Comparative Analysis: The analysis allows for a comparison of hotspot occurrences across the different national parks. By examining the data for each park individually, researchers can identify variations in fire incidence rates and assess the relative fire risk in different locations. This comparative analysis helps in prioritizing fire management efforts and allocating resources effectively to areas with higher fire occurrences.

3) Fire Management Strategies: The research results can inform the development and improvement of fire management strategies within the national parks. By identifying periods of increased or decreased fire incidents, park authorities and stakeholders can adapt their fire prevention and suppression efforts accordingly. The information can guide the implementation of measures such as controlled burns, firebreak construction, public awareness campaigns, and enhanced monitoring systems to mitigate fire risks and protect the park ecosystems.

4) Conservation and Biodiversity Protection: Understanding the prevalence and patterns of fire incidents is crucial for conservation efforts within the national parks. Fires can have detrimental effects on ecosystems, including the destruction of habitats, loss of biodiversity, and changes in vegetation composition. The research findings contribute to the knowledge base necessary for conserving and managing the natural resources, flora, and fauna of these protected areas.

5) Policy and Planning: The research results provide empirical evidence that can support policy-making and planning related to fire management and land-use practices in and around the national parks. Authorities and policymakers can utilize this information to enact regulations, guidelines, and land management practices that minimize the risk of fires and promote sustainable land use.

4. Recommendations

In this paper, optimizing the early detection of forest and land fires using Artificial Intelligence (AI) is a recommendation for future work [10]. Advancements in remote sensing, the internet, and communication technology have fostered the availability of geospatial data with high resolution, wide-coverage, and frequent updates, enabling near real-time studies. The emergence of Artificial Intelligence (AI) has further revolutionized the processing of complex geospatial data, which is traditionally challenging to analyze using conventional spatial analysis methods. These developments in the geospatial and AI domains are bolstered by advancements in computer technologies, including Graphics Processing Units (GPUs) that facilitate efficient data processing, and cloud computing that enables virtual data storage.

However, there is a need to enhance AI capabilities for early detection of fires and law enforcement, encompassing automatic spatial analysis, reporting, and dissemination. The AI model for detecting Forest and Land Fires requires further enrichment in terms of datasets, variables, features, and other relevant aspects. As a machine learning model, several measures can be taken to improve its accuracy, such as:

1) Increasing the Training Dataset: Expanding the range of satellite imagery years utilized in training the model can enhance its predictive abilities and delineation accuracy.

2) Incorporating Additional Variables and Enhancing Feature Processing: The AI model, predominantly developed based on geospatial expertise, can benefit from incorporating inputs from other domains. Expert insights on new variables relevant to forest and land fires would contribute to refining the model's performance.

3) Utilizing Higher Resolution and More Frequent Satellite Imagery: Employing satellite imagery with higher spatial resolution and/or greater temporal frequency can improve the model's capabilities, particularly for accurate delineation. Notably, SWIR bands are crucial for effective delineation purposes.

4) Including Data Verification and Validation Results as Model Input: Integrating verification and validation outcomes obtained through ground checks into the model can enhance its reliability and accuracy.

To optimize the early detection of forest and land fires, it is essential to continuously refine the AI model by considering the expansion of training datasets, inclusion of additional variables, utilization of appropriate satellite imagery, and validation through ground checks. By addressing these aspects, the AI-based approach can deliver more accurate and reliable results, contributing to effective fire management and law enforcement efforts.

To mitigate the risk of wildfires and improve forest management in the national parks of northern Thailand, several policy and management recommendations are essential. Firstly, enhancing fire prevention measures through the establishment and maintenance of firebreaks is crucial. These barriers serve as effective tools to slow down or stop the spread of wildfires, protecting valuable ecosystems. Additionally, implementing early warning systems equipped with surveillance technologies can ensure prompt detection and response to fire incidents, minimizing potential damage. By combining these measures, the parks can significantly enhance their ability to prevent and manage wildfires. Increasing ranger presence and conducting regular patrols are vital components of effective fire management. By augmenting the number of rangers and strategically deploying them throughout the parks, early detection and suppression of fires can be achieved. Rangers play a crucial role in identifying and suppressing fires in their early stages, preventing them from escalating into larger and more destructive incidents. Furthermore, public awareness campaigns targeting both visitors and local communities are essential. Educating them about fire safety, responsible behavior, and the significance of preventing wildfires will foster a culture of responsible stewardship and minimize human-induced fire risks.

Strengthening forest management practices is integral to mitigating fire risks and promoting sustainable ecosystems. Monitoring and managing vegetation density is crucial in identifying areas prone to wildfires. By implementing strategies such as selective thinning and removing dead vegetation, fuel loads can be reduced, minimizing the likelihood and intensity of fires. Controlled burns, conducted under controlled conditions, are also effective tools for reducing fuel accumulation and maintaining ecosystem health. Furthermore, reforestation efforts using native species should be promoted to restore and enhance the resilience of forest ecosystems. By developing and implementing a comprehensive fire management plan that incorporates early detection systems, rapid response mechanisms, and efficient firefighting operations, the parks can ensure a coordinated and effective approach to fire management.

These recommendations aim to strengthen fire prevention, early detection, and effective response strategies while promoting sustainable forest management practices in the national parks of northern Thailand. Involving relevant stakeholders, including local communities, government agencies, and conservation organizations, is crucial for collective efforts to mitigate the risk of fires and preserve the ecological integrity of these valuable natural areas. By implementing these measures and fostering a sense of ownership and stewardship, we can protect these national parks for future generations.

5. Conclusion

This research emphasizes the importance of monitoring and managing forest and land fires, particularly in the northern region of Thailand where wildfires are frequent and pose significant risks. Remote sensing technology, particularly the utilization of the MODIS Aqua/Terra satellite system, offers valuable insights into hotspot distribution and fire risk dynamics. By analyzing the data from four national parks in Chiang Mai province, including Sri Lanna, Huai Nam Dang, Doi Pahom Pok, and Doi Inthanon, this study has demonstrated the advantages of remote sensing for accurate identification and mapping of burnt areas, regular monitoring, rapid data acquisition, and historical data analysis. Based on the findings, recommendations for optimizing the early detection of forest and land fires using Artificial Intelligence (AI) are proposed as future work. The integration of AI technologies can enhance the accuracy and efficiency of spatial analysis, reporting, and dissemination, contributing to early detection and effective management of fires. Suggestions for improving the AI model include expanding the training dataset, incorporating additional variables, utilizing higher-resolution and more frequent satellite imagery, and integrating ground verification and validation results. To mitigate the risk of wildfires and improve forest management in the national parks of northern Thailand, several policy and management recommendations are crucial. These include enhancing fire prevention measures through firebreak establishment, implementing early warning systems, increasing ranger presence and patrols, conducting public awareness campaigns, strengthening forest management practices, developing comprehensive fire management plans, establishing partnerships, conducting training programs, implementing robust monitoring systems, and engaging in community outreach programs. Involving relevant stakeholders and fostering a sense of ownership and stewardship among local communities, government agencies, and conservation organizations is vital for collective efforts to preserve the ecological integrity of these national parks.

Acknowledgements

The authors gratefully acknowledge the support and funding provided by the Thai government and the International Aviation Academy and Industry, King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand. Their financial assistance has been instrumental in the successful execution of this research project. Additionally, we express our sincere gratitude to the aforementioned institutions for providing valuable resources, facilities, and access to relevant information, which greatly contributed to the overall quality and comprehensiveness of this study. Without their support, this research would not have been possible.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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