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Monitoring Wildfires in Thailand: A Case Study of the ECSTAR-TeroSpace's Earth Observation Project

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Abstract

The primary objective of this paper is to present a comprehensive case study on monitoring wildfires in Nakhon Nayok, Thailand, utilizing Earth observation platforms. This initiative project has been undertaken by the Excellence Center of Space Technology and Research (ECSTAR), in partnership with its spin-off startup, TeroSpace. The study aims to provide an in-depth analysis of the wildfire incidents in the region, utilizing advanced technologies such as satellite imagery and data analytics, and to identify ways to improve future wildfire management. In particular, the paper focuses on the wildfires including thermal area comparison that ravaged the land in Nakhon Nayok Province in central Thailand from March to April 18th, 2023. To conduct this study, the ECSTAR-TeroSpace analytic team utilized satellite images from Earth observation platforms: MODIS and Sentinel-2A. By presenting this case study, this paper contributes to the broader understanding of how to monitor and manage wildfires in a changing climate. The findings of this study underscore the importance of proactive and collaborative efforts in mitigating the negative impacts of wildfires in Nakhon Nayok and other regions in Thailand.

Keywords

Wildfires, Thailand, Earth Observation, Monitoring, Satellite Imagery

1. Introduction

Over the last few decades, forests around the world have been significantly impacted by a combination of climate change and human activities. To better understand the effects of wildfires on vegetation, biomass, and soil properties, researchers have conducted various studies (Halofsky et al., 2020; Flannigan et al., 2006). The findings have revealed the adverse impacts of wildfires on the environment, including soil erosion, the loss of organic matter, and the degradation of soil nutrients. Additionally, the destruction of vegetation due to wildfires has contributed to an increase in atmospheric carbon dioxide levels, contributing to global warming and climate change (Carnicer et al., 2022).

Climate change and human activities such as forest degradation and fragmentation have significantly increased the likelihood of fire-prone conditions globally. With rising temperatures and drier weather patterns, fires, whether caused by humans or lightning, are more likely to spread over larger areas and at higher temperatures (Lawrence et al., 2022). Forests that have been degraded due to logging or disease, or fragmented by deforestation, are particularly vulnerable to wildfires.

Thailand, in particular, has witnessed a steady increase in wildfires over the years (Arunrat et al., 2018). In 2021, the nation witnessed one of the most devastating wildfire seasons on record, as per the Global Forest Watch (GFW) web-based platform. These fires affected a wide range of areas across the nation, resulting in sizable economic losses and detrimental ecological effects, such as the degradation of the forest ecosystem and the loss of priceless biodiversity (Valderrama et al., 2018). It is imperative to take proactive measures to prevent wildfires and mitigate their impacts, with a view to conserving natural resources and reducing the harmful effects of wildfires.

In recent years, satellite technology has proved to be a valuable tool in monitoring and detecting forest fires or wildfires. The ability to use satellite imagery to detect and track wildfires in real-time is a critical asset in protecting the environment. Advanced satellite technology can identify the location and extent of forest fires with great accuracy. Satellites equipped with specialized sensors can detect the heat signatures generated by the fires and alert ground teams to their presence (Roy, 2003). This early warning system allows for timely deployment of firefighting resources to contain the blaze and prevent it from spreading.

In addition to monitoring ongoing wildfires, satellite imagery can also be utilized to map the extent of burned areas and assess the severity of the damage caused by the fire (Addison & Oommen, 2018). This information is critical in developing effective rehabilitation and recovery strategies for the affected regions. For instance, satellite data can help to identify areas where reforestation efforts should be prioritized to ensure ecosystem regeneration. Moreover, satellite imagery can be used to analyze the underlying causes of wildfires. Human activities such as land clearing or careless behavior, as well as natural factors like lightning strikes or drought conditions, can all contribute to the occurrence of wildfires. By identifying the root causes of these fires, preventive measures can be taken to minimize the risk of future outbreaks (Ding et al., 2022).

This paper is structured as follows. Firstly, it discusses the monitoring of wildfires using images obtained from Earth observation satellites. Next, it presents a case study of ECSTAR's Earth Observation Project, which focuses on the application of satellite images to monitor and respond to wildfire emergencies that broke out on March 29, 2023, in Nakhon Nayok province, Thailand. The subsequent sections include Results and Discussions, Recommendations, and Conclusion, which provide a detailed analysis of the study's findings, practical suggestions for managing future wildfire incidents, and a summary of the paper's key takeaways, respectively.

2. Monitoring Wildfires Using Images from Earth Observation Satellites

Wildfires are a significant threat to the natural ecosystems of forests and cause ecological, economic, and societal damage. Human activities, including logging, land conversion, slash-and-burn agriculture, and disputes over land use and property rights, are responsible for the majority of wildfires (Roy, 2003). Recent years have seen an increase in the frequency and size of wildfires due to prolonged periods of drought, over-exploitation of natural resources for commercial purposes, and conversion of forest land for other uses, leading to significant environmental impacts.

Even in the world's most remote regions, wildfires are unable to escape detection. Even the thermal signatures of these fires can be detected thanks to Earth-observing satellites outfitted with sensors. This extraordinary technology enables the rapid dissemination of information regarding the location and movement of individual wildfires, which has been a worldwide success in terms of saving lives and property. Utilizing satellites to monitor large-scale fires is a cost-effective approach. In recent years, the enhanced availability of mid- to high-spatial-resolution optical data obtained from earth observation remote sensing missions has empowered researchers and fire management officials to conduct a comprehensive post-fire evaluation. In this paper, we utilize earth observation platforms to investigate the impact of large-scale fires.

The capability to provide information about hotspots identified by instruments aboard Earth observing satellites, which has been available for over a decade through NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) instruments, in near real-time (Skakun et al., 2018). These instruments measure the radiation emitted by the Earth in the visible, near-infrared, and thermal-infrared regions of the electromagnetic spectrum. The thermal-infrared region, in particular, is sensitive to the temperature of the surface being observed, allowing for the detection of hotspots associated with wildfires. MODIS and VIIRS instruments differ in their spatial resolution, which affects their ability to detect fires and produce detailed background images (Riggs et al., 2017). The thermal band of MODIS has a 1000 meters resolution per pixel, while VIIRS has a higher resolution of 375 meters per pixel. This higher resolution enables VIIRS to detect fires that may be overlooked by MODIS. However, while VIIRS is more sensitive in detecting fires, MODIS is capable of producing crisper background images. This is due to the fact that MODIS has a spatial resolution of 250 meters for non-thermal bands, allowing for more detailed land surface images (Schueler et al., 2013).

The Suomi National Polar-orbiting Partnership (S-NPP) and Joint Polar Satellite System (JPSS) VIIRS instrument have inherited the scientific responsibilities of MODIS and provide long-term Earth System Data Records (ESDRs) (Justice et al., 2013). It is imperative to develop a consistent Leaf Area Index/Fraction of Photosynthetically Active Radiation (LAI/FPAR) dataset from these new sensors to continue the MODIS ESDR. The VIIRS is an instrument that was launched aboard the S-NPP satellite in 2011. One of the key objectives of the VIIRS instrument was to ensure continuity with the MODIS instrument aboard NASA's Terra and Aqua remote-sensing satellites. This continuity has allowed for the integration and comparison of data collected from both instruments, enabling more accurate and comprehensive analysis of a wide range of environmental phenomena, including wildfire monitoring (Skakun et al., 2018).

The Leaf Area Index (LAI) and Fraction of Photosynthetically Active Radiation absorbed by vegetation (FPAR) are two critical variables utilized to characterize the exchange of fluxes of energy, mass, and momentum between the surface and atmosphere (Xu et al., 2018). LAI is generally defined as the one-sided green leaf area per unit ground area in broadleaf canopies and as the projected needle leaf area in coniferous canopies, and it is widely used to describe the structure and function of vegetation. FPAR measures the fraction of radiation absorbed by leaves in the 0.4 - 0.7 μm spectrum and assesses the energy absorption capacity of a canopy (Myneni et al., 2002).

Satellite remote sensing has facilitated the generation of long-term LAI/FPAR products, which are crucial for the effective use of global models of climate, biogeochemistry, and ecology. The Earth Observing System (EOS) Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on board Terra and Aqua satellites have provided an opportunity to create new global LAI/FPAR products. The most recent version of global LAI/FPAR products from MODIS has been made freely available through the Land Processes Distributed Active Archive Center (LP DAAC) and is widely utilized by scientific, public, and private user communities (Xiao et al., 2014).

Sentinel-2, a satellite-based imaging system, is part of the European Space Agency's (ESA) Copernicus program. The system consists of a pair of identical satellites, Sentinel-2A and Sentinel-2B, that are designed to provide high-resolution optical imagery of the Earth's surface. The Sentinel-2 satellites are equipped with a Multispectral Instrument (MSI), which consists of 13 spectral bands ranging from the visible to the shortwave infrared regions of the electromagnetic spectrum. The MSI can provide imagery with a spatial resolution ranging from 10 to 60 meters, depending on the spectral band. This high spatial resolution enables detailed observations of small features on the Earth's surface, such as urban areas, agricultural fields, and forests. The primary applications of Sentinel-2 data include land cover and land use mapping, agriculture monitoring, forest monitoring, and disaster mapping. The data is also used for a wide range of other applications, including coastal monitoring, water quality monitoring, and urban planning. Sentinel-2 data is openly accessible to users worldwide through the Copernicus Open Access Hub, and the data is processed and distributed through a network of Copernicus data providers. This makes Sentinel-2 data widely available for use in scientific research, environmental monitoring, and commercial applications (Phiri et al., 2020).

In the next sections, we present our research project, which focuses on the monitoring of wildfires in Nakhon Nayok, Thailand, employing Earth observation platforms. We aim to leverage advanced technologies, specifically satellite imagery, to effectively monitor and analyze wildfires, thereby enhancing fire management strategies and mitigating additional damage. The project centers on the wildfires that severely affected Nakhon Nayok Province, situated in central Thailand, during the period spanning March to April 2023.

3. A Case Study of ECSTAR-TeroSpace's Earth Observation Project: Wildfire in Nakhon Nayok

The purpose of this study is to utilize the capabilities of Earth observing satellites in near real-time for monitoring wildfires. In our investigation of wildfires in Nakhon Nayok, we utilized the Visible/Infrared Imager Radiometer Suite (VIIRS) instrument on board the MODIS and the Suomi National Polar-orbiting Partnership (S-NPP) to compare the differences in times between 2022 and 2023. In addition, we also utilize Sentinel-2A, a satellite-based imaging system that is part of the European Space Agency's (ESA) Copernicus program. The system is comprised of a pair of identical satellites, Sentinel-2A and Sentinel-2B, which are designed to capture high-resolution optical imagery of the Earth's surface. By integrating data from these multiple sources, we can improve the accuracy and completeness of wildfire monitoring and management.

The wildfires are the latest cause for the worsening air quality in Thailand that's pushed levels of particulate dust particles known as PM 2.5 in some areas past the threshold into a hazardous zone. Bangkok and other Thai cities have grappled with poor air quality in recent years, with pollution tending to get worse in the dry season around December to February due largely to agricultural burning in Thailand and neighboring countries, and vehicular emission.

This case study focuses on the wildfires that broke out on March 29 and the urgent measures taken by the Thai government to extinguish forest fires in Nakhon Nayok province, situated to the east of Bangkok. Firefighters and other officials have been deployed to monitor the affected areas, as the burning of farmlands and illegal foraging occur during this time of the year. A mountain known as Khao Laem in Nakhon Nayok was engulfed in flames with several hotspots across the borders in neighboring Myanmar and Laos, a satellite heat map by a Thai space agency showed.

ECSTAR, a prominent research institute in space technology in Thailand, has launched the Earth Observation Project and established an analytical team to work on the research development aimed at dealing with wildfires in the country. The project aims to utilize advanced technologies, such as satellite imagery, to monitor and analyze wildfires, with the goal of improving fire management and preventing further damage. This project focuses on the wildfires that ravaged the land in Nakhon Nayok Province in central Thailand between March 1st-31st and April 1st-18th, 2023. To conduct this study, the ECSTAR research center collaborated with its spin-off startup company, TeroSpace. TeroSpace specializes in utilizing Earth observation technologies and data analytics to provide valuable insights for different industries. The collaboration between ECSTAR and TeroSpace has been instrumental in gathering accurate and timely data for wildfire analysis.

ECSTAR and TeroSpace utilized satellite images from two Earth observation platforms: MODIS and Sentinel-2. The Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument aboard two NASA Earth Observing System (EOS) satellites. The utilization of an open data policy has been implemented by both the National Aeronautics and Space Administration (NASA)/ United States Geological Survey (USGS)'s Landsat missions and the European Space Agency (ESA)'s Sentinel missions, which have provided an exceptional opportunity for the monitoring of large-scale areas (Defourny et al., 2019; Malenovský et al., 2012; Roy et al., 2014).

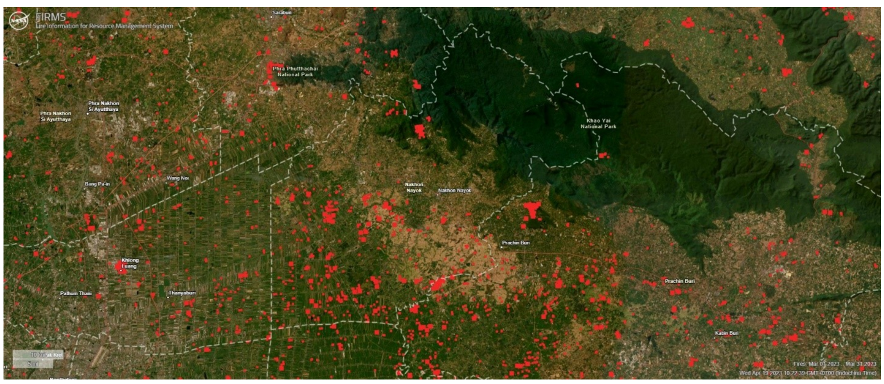
It has high spatial and temporal resolution and provides a wealth of information for fire monitoring and management. Sentinel-2 is a European Earth observation mission with a multispectral instrument that can detect changes in vegetation cover, which is important for tracking wildfire spread. The satellite images from MODIS and Sentinel-2 facilitated an in-depth analysis of the wildfires in Nakhon Nayok Province. The images provided detailed information on the spatial extent and severity of the fires. The team was able to monitor the progression of the fires, identify the areas most affected, and estimate the extent of damages caused by the fires.

4. Results and Discussions

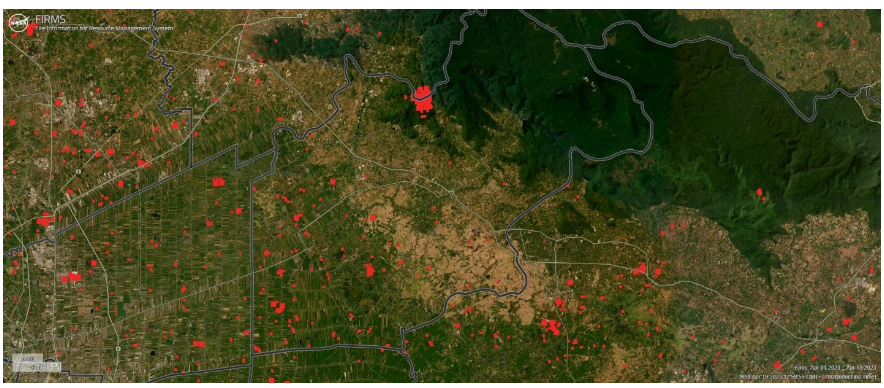
Our earth observation platform is equipped with advanced sensors that capture high-resolution satellite images and spectral data in the Visible and Infrared (VIR) frequency range, including the Moderate Resolution Imaging Spectroradiometer (MODIS) of Aqua/Terra. VIR sensors are commonly used in remote sensing and satellite imaging applications to detect temperature, vegetation, and other environmental factors.

Through this technology provided by Fire Information for Resource Management System (FIRMS), we have identified a hotspot in the Nakhon Nayok province area during March and April of 2023. In March 2023 alone, we detected between 200 to 300 hotspots as following in **Figure 1(a)**, representing a significant increase compared to the same period in the past. From 1 April to 18 April 2023, we identified 20 - 30 hotspots as follows in Figure 1(b). These findings demonstrate the effectiveness of our platform in detecting and monitoring hotspots, which is crucial for forest fire prevention and management. By analyzing and interpreting the satellite data, we can provide timely and accurate information to relevant authorities to take proactive measures to mitigate the situation. Our earth observation platform is a valuable tool for environmental monitoring and management, providing crucial insights into changes in temperature, vegetation, and other factors affecting the natural environment.

Figure 2 displays the temperature distribution in Nakhon Nayok province between March 1st-31st and April 1st-18th, 2023 which is distributed by the Google Earth Engine. Our Earth observation platform, developed by TeroSpace, utilizes thermal sensors to detect thermal anomalies or hotspots, which may indicate a risk of forest fires. This technology enables us to identify and monitor areas with a high probability of experiencing forest fires, allowing us to take proactive measures to prevent their occurrence or detect them early enough to respond promptly. The platform can also be used to estimate the extent of the fire, track its spread, and assess the damage caused. These capabilities make the platform a valuable tool for forest fire management and mitigation, enabling us to protect the environment and human lives.

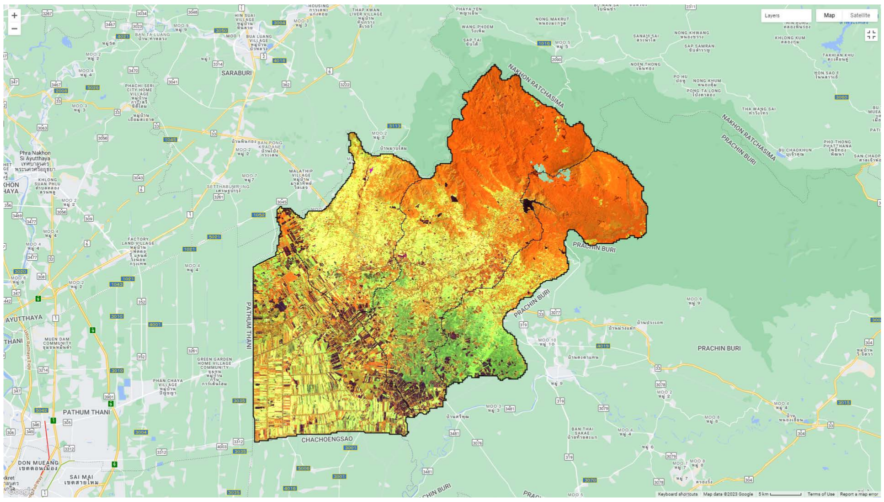


(a) March 1st-31st, 2023

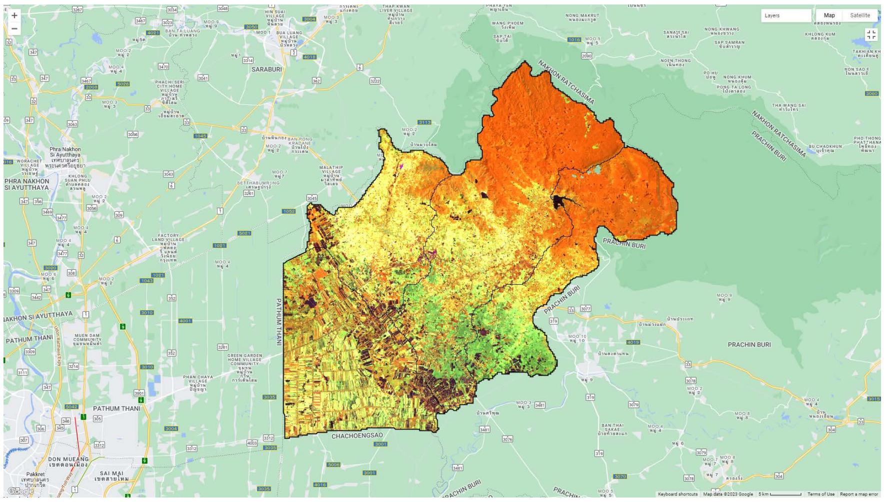


(b) April 1st-18th, 2023

Figure 1. Hotspot in the Nakhon Nayok comparison between March and April of 2023.



(a) March 1st-31st, 2023



(b) April 1st-18th, 2023

Figure 2. Temperature distribution in Nakhon Nayok province between March and April of 2023.

In **Figure 2**, our analytical team uses Landsat-8 and Landsat-9 satellite imagery to execute precise and comprehensive data analyses at the city and village scales. This enables the accurate identification of areas at risk of experiencing hotspots or forest fires, which is essential for forest fire prevention and mitigation. In addition, we employ Optical Remote Sensing satellites to monitor the observing areas for any peculiar or suspicious activity, such as construction or movement. These applications are crucial for the security and defense sectors because they can aid in the detection and prevention of unlawful activities and the protection of national security (Avtar et al., 2021). The technology of Optical Remote Sensing also enables us to monitor changes in land use, vegetation, and water resources, providing valuable data for environmental monitoring and management.

Figure 3 is a map displaying the geographic and surveillance areas of the province of Nakhon Nayok which is also distributed by the Google Earth Engine.

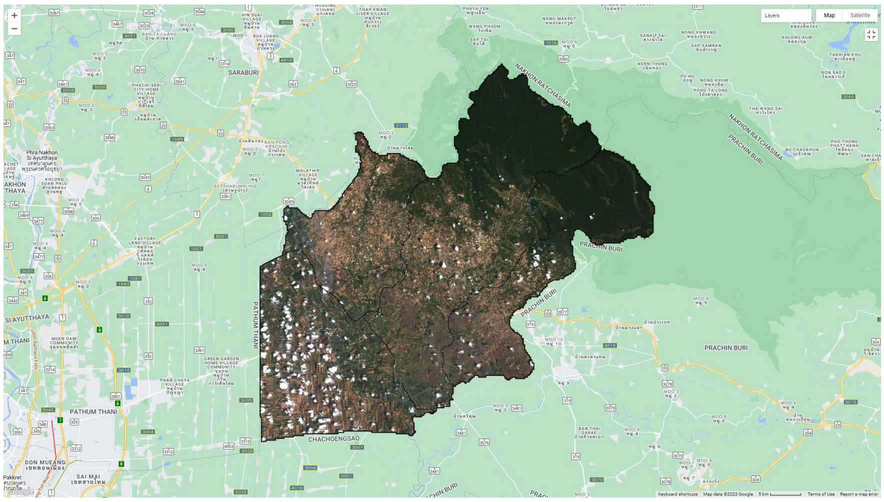


Figure 3. The geographic and surveillance areas of the province of Nakhon Nayok.

The high-resolution satellite image analysis made use of data retrieved from the Sentinel-2A satellite, which operates with Visible and Infrared (VIR) frequency range detection. This inventive application enables the detection and monitoring of anomalous behavior in observed areas, such as changes in land use, movement, and construction. By analyzing the spectral reflectance properties of various features on the Earth's surface, the satellite can provide a detailed assessment of the observed areas, making it a valuable instrument for environmental monitoring, disaster management, and land-use planning (Parra, 2022).

Our Earth observation platform, developed by TeroSpace, encompasses a range of advanced technologies and sensors that enable us to gather precise and timely data about our natural environment. The incorporation of VIR sensors, such as the MODIS of Aqua/Terra, aids in the detection and monitoring of various environmental factors like temperature, vegetation, and hotspot occurrences. By harnessing thermal sensors, we can identify thermal anomalies or hotspots, which serve as early indicators of potential forest fires. This information allows us to take proactive measures to prevent or respond promptly to such incidents, safeguarding both the environment and human lives.

Moreover, the utilization of Landsat-8 and Landsat-9 satellite imagery facilitates meticulous data analysis at both the city and village scales. This analytical capability plays a crucial role in accurately identifying areas at risk of experiencing hotspots or forest fires, bolstering forest fire prevention and mitigation efforts. The integration of Optical Remote Sensing satellites further enhances our platform's functionalities by enabling the monitoring of land use changes, vegetation dynamics, and water resources. In addition to its environmental applications, the technology of Optical Remote Sensing also proves instrumental in supporting security and defense sectors by detecting and preventing unlawful activities and safeguarding national security (Avtar et al., 2021).

Through the combination of these cutting-edge technologies and data analysis techniques, our Earth observation platform equips relevant authorities with the means to make informed decisions and take proactive measures to address environmental challenges effectively. By providing valuable insights into changes in temperature, vegetation, and other factors affecting the natural environment, we contribute to better environmental monitoring and management practices. Ultimately, the utilization of our platform enables the protection of ecosystems, the prevention of forest fires, and the sustainable management of our planet's resources.

5. Recommendations

Recommendations for enhancing the capabilities of Earth observation platforms in detecting and responding to wildfires in Thailand. Wildfires pose a significant threat to the environment and communities in Thailand, and their timely detection and response are of utmost importance. Earth Observation (EO) platforms have proven to be an effective tool in providing valuable data and information to support the management and response to wildfires.

1) Integrate and link related information from GISTDA to ECSTAR's EO facility

To enhance the capacity of EO platforms in detecting and responding to wildfires in Thailand, it is recommended to integrate and link relevant information from the Geo-Informatics and Space Technology Development Agency (GISTDA) to the ECSTAR's Geoinformatics and Earth Observation Laboratory (GEOlab) facility. ECSTAR's GEOlab can use cloud services to modernize and deliver apps without worrying about the underlying software-defined data center infrastructure. ECSTAR leverages remote IT infrastructure provided by the National Telecom Public Company Limited (NT) called the Government Data Center and Cloud Services (GDCC), which is managed by the Thai government. The broadband connectivity of NT provides cloud-based SD-WAN for organizations to outsource the managing of infrastructure and connectivity to GDCC, while GDCC is exploring data analytics-as-a-service to enable GEOlab to process and analyze large amounts of data without complex coding. This integration will enable the efficient and effective use of available data and information, thereby improving the detection and response to wildfires.

2) Apply Artificial Intelligence (AI) and Deep Learning (DL) technology

Artificial Intelligence (AI) and Deep Learning (DL) technology have demonstrated tremendous potential in various applications, including wildfire detection and response. AI and DL techniques can be applied to Earth Observation (EO) platforms for the detection and management of wildfires. AI and DL can also be used for prediction and forecasting, risk assessment, and decision support for fire managers (Priya & Vani, 2019). This will automate and optimize the analysis process, increasing the capacity and real-time ability of the project. Additionally, this technology can enhance the accuracy of wildfire detection and reduce false alarms, thereby saving resources and improving response times.

3) In order to further enhance the capabilities of ECSTAR's Earth observa-

tion (EO) platform in detecting and responding to wildfires in Thailand, it is strongly recommended to explore the utilization of the THEOS-2 EO system, developed and operated by the Geo-Informatics and Space Technology Development Agency (GISTDA). THEOS-2 is an advanced EO satellite system that provides high-resolution imagery and data, enabling precise monitoring and analysis of various environmental phenomena, including wildfires. By integrating THEOS-2 into ECSTAR's EO platform, it will be possible to access valuable and up-to-date information on wildfire occurrences and their dynamics within Thailand. This integration will greatly strengthen the ability to detect wildfires promptly and accurately, enabling more effective response measures. Collaborating with GISTDA and leveraging the THEOS-2 EO system can offer several benefits. Firstly, THEOS-2's high-resolution imagery will provide detailed visual insights into the spatial extent and severity of wildfires, enabling better assessment and understanding of their impact on the affected areas. Secondly, the utilization of THEOS-2's data, in combination with ECSTAR's existing capabilities, will enable more accurate wildfire risk assessment, facilitating proactive measures for fire prevention and mitigation. Additionally, the integration will enable the fusion of data from multiple sources, enhancing the overall situational awareness and decision-making process during wildfire events.

4) Engage ECSTAR with Real-time Wildfire Analytic System of International Organizations

Finally, it is recommended to engage ECSTAR with the real-time wildfire analytic system of international organizations, such as the Global Wildfire Information System (GWIS). This engagement will facilitate information sharing and collaboration in wildfire management and response (Sharma et al., 2022). It will also provide access to additional resources and expertise to support the efforts to detect and respond to wildfires in Thailand.

6. Conclusion

This paper has presented a comprehensive case study on monitoring wildfires in Nakhon Nayok, Thailand, utilizing Earth observation platforms. The study aimed to provide an in-depth analysis of the wildfire incidents in the region, utilizing advanced technologies such as satellite imagery and data analytics, and to identify ways to improve future wildfire management. The findings of this study underscore the importance of proactive and collaborative efforts in mitigating the negative impacts of wildfires in Nakhon Nayok and other regions in Thailand. Moreover, this paper provides recommendations to enhance the capabilities of EO platforms in detecting and responding to wildfires in Thailand. The integration of relevant information, the application of AI and DL technology, and the engagement with international organizations are crucial steps to improving wildfire management and response in Thailand. These recommendations can increase the capacity, efficiency, and real-time ability of the project and support efforts to detect and respond to wildfires in a timely and effective manner. By presenting this case study and recommendations, this paper contributes to the broader understanding of how to monitor and manage wildfires in a changing climate. It is hoped that these findings and recommendations will be useful to policymakers, researchers, and practitioners in their efforts to mitigate the negative impacts of wildfires in Thailand and other regions of the world.

Conflicts of Interest

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

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