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ການຕິດຕາມຈຸດຄວາມຮ້ອນຈາກການເຜົາໄໝ້ໃນພື້ນທີ່ເປີດດ້ວຍລະບົບດາວທຽມ ໃນປະເທດອາຊີຕາເວັນອອກສ່ຽງໃຕ້ຕອນເທິງ

Monitoring the Hotspot from Open Burning Area Detected by Satellite System on Upper Southeast Asia

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ແລະ ປະສົບສຸກ ລັດວິໄລວົງ[5]
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Phoutthasone KHOUANGVICHIT[4], Pasobsouk LATVILAYVONG[5]

ບົດຄັດຫຍໍ້

ການເຜົາໄໝ້ໃນພື້ນທີ່ເປີດໃນພາກພື້ນອາຊີຕາເວັນອອກສ່ຽງໃຕ້ຕອນເທິງແມ່ນສາເຫດຫຼັກຂອງບັນຫາໝອກຄວັນຂ້າມແດນ ເຊິ່ງສົ່ງຜົນກະທົບຢ່າງຮຸນແຮງຕໍ່ສຸຂະພາບຂອງມະນຸດ, ເສດຖະກິດພາກພື້ນ ແລະ ສະຖຽນລະພາບຂອງລະບົບນິເວດ. ໃນຂະນະທີ່ການປ່ຽນແປງສະພາບພູມອາກາດ ແລະ ກິດຈະກຳຂອງມະນຸດໄດ້ເລັ່ງໃຫ້ຊັບພະຍາກອນທຳມະຊາດຫຼຸດໜ້ອຍຖອຍລົງ, ການເຂົ້າໃຈຮູບແບບການກະຈາຍຕົວຂອງ ຈຸດຄວາມຮ້ອນຕາມໄລຍະເວລາ ແລະ ສະຖານທີ່ ໂດຍສະເພາະໃນຊ່ວງການລະບາດຂອງພະຍາດ COVID-19 ແມ່ນມີຄວາມຈຳເປັນຢ່າງຍິ່ງສຳລັບການວາງແຜນຄຸ້ມຄອງສິ່ງແວດລ້ອມ.

ການສຶກສານີ້ມີຈຸດປະສົງເພື່ອນຳໃຊ້ລະບົບດາວທຽມສຳຫຼວດທາງໄກເພື່ອກວດສອບການກະຈາຍຕົວຂອງຈຸດຄວາມຮ້ອນໃນ ສປປ ລາວ, ໄທ, ມຽນມາ, ກຳປູເຈຍ ແລະ ຫວຽດນາມ ໃນຊ່ວງລະດູແລ້ງ (ມັງກອນ–ເມສາ) ຂອງປີ 2019–2022, ໂດຍປຽບທຽບຮູບແບບກ່ອນ ແລະ ໃນຊ່ວງການລະບາດຂອງພະຍາດ, ພ້ອມທັງຢັ້ງຢືນຄວາມຊັດເຈນຂອງການກວດພົບຜ່ານການລົງເກັບກຳຂໍ້ມູນຕົວຈິງ.

[1,2,3,4,5] ພາກວິຊາວິທະຍາສາດສິ່ງແວດລ້ອມ, ຄະນະກະເສດສາດ ແລະ ສິ່ງແວດລ້ອມ, ມະຫາວິທະຍາໄລສະຫວັນນະເຂດ/ສປປ ລາວ.
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ການວິໄຈນີ້ໃຊ້ຮູບແບບການວິໄຈແບບປະລິມານໂດຍແບ່ງເປັນສອງໄລຍະ: ໄລຍະທຳອິດແມ່ນນຳໃຊ້ຂໍ້ມູນດາວທຽມ MODIS ເພື່ອວິເຄາະທ່າອ່ຽງໃນລະດັບພາກພື້ນ; ແລະ ໄລຍະທີສອງແມ່ນນຳໃຊ້ຂໍ້ມູນດາວທຽມ VIIRS ເພື່ອຢັ້ງຢືນຄວາມຖືກຕ້ອງຢູ່ພາກສະໜາມໃນນະຄອນໄກສອນ ພົມວິຫານ, ແຂວງສະຫວັນນະເຂດ, ໂດຍປຽບທຽບພິກັດຈາກດາວທຽມກັບຂໍ້ມູນ GPS, ຮູບພາບ ແລະ ການສັງເກດການສະພາບແວດລ້ອມຕົວຈິງ.

ຜົນການສຶກສາພົບວ່າການເຜົາໄໝ້ມີລັກສະນະເປັນວົງຈອນຕາມລະດູການ, ໂດຍເລີ່ມມີຄວາມໜາແໜ້ນສູງໃນກຳປູເຈຍຊ່ວງເດືອນມັງກອນ–ກຸມພາ ກ່ອນຈະຂະຫຍາຍຕົວເຂົ້າສູ່ມຽນມາ ແລະ ລາວໃນເດືອນມີນາ. ທີ່ໜ້າສົນໃຈແມ່ນພົບທ່າອ່ຽງການຫຼຸດລົງຂອງຄວາມໜາແໜ້ນຂອງຈຸດຄວາມຮ້ອນຢ່າງມີຄວາມສຳຄັນທາງສະຖິຕິແຕ່ປີ 2019 ຫາ 2022, ໂດຍພົບຈຸດຄວາມຮ້ອນໜ້ອຍທີ່ສຸດໃນປີ 2022, ເຊິ່ງອາດເປັນຜົນມາຈາກການປ່ຽນແປງວິຖີຊີວິດໄປສູ່ອາຊີບທີ່ນຳໃຊ້ເຕັກໂນໂລຊີຫຼາຍຂຶ້ນໃນຊ່ວງການລະບາດຂອງພະຍາດ.

ການສຶກສາຢັ້ງຢືນວ່າລະບົບສຳຫຼວດທາງໄກແມ່ນເຄື່ອງມືທີ່ມີຄວາມຊັດເຈນສູງ, ໂດຍມີຄ່າຜິດດ່ຽງຂອງເສັ້ນແວງສະເລ່ຍພຽງ -29.568 ແມັດ ລະຫວ່າງພິກັດດາວທຽມ ແລະ ຈຸດເຜົາໄໝ້ຕົວຈິງ. ຜົນໄດ້ຮັບເຫຼົ່ານີ້ສະໜອງຂໍ້ມູນທີ່ໜັກແໜ້ນໃຫ້ແກ່ຜູ້ກຳນົດນະໂຍບາຍໃນການວາງມາດຕະການແກ້ໄຂທີ່ສອດຄ່ອງກັບແຕ່ລະປະເທດ ເພື່ອຫຼຸດຜ່ອນການເຜົາໄໝ້ທາງການກະເສດ ແລະ ປັບປຸງຄຸນນະພາບອາກາດໃນພາກພື້ນ.

ຄຳສັບສຳຄັນ: ການກວດພົບຈຸດຄວາມຮ້ອນ, ການເຜົາໄໝ້ທາງການກະເສດ, ມົນລະພິດທາງອາກາດ, ລະບົບສຳຫຼວດທາງໄກ, ໝອກຄວັນຂ້າມແດນ.

Abstract

Open burning in mainland Southeast Asia is a primary driver of transboundary haze, severely impacting human health, regional economies, and ecological stability. As climate change and human activities accelerate resource depletion, understanding the spatiotemporal patterns of fire hotspots—especially during global disruptions like the COVID-19 pandemic—is essential for evidence-based environmental management.

This study aims to utilize satellite remote sensing to examine the spatial distribution of fire hotspots across Laos, Thailand, Myanmar, Cambodia, and Vietnam during the dry seasons (January–April) of 2019–2022, comparing pre-pandemic baselines with pandemic-era patterns and validating detection accuracy through field observations.

A quantitative, two-phase research design was employed: first, using MODIS satellite data for regional temporal analysis; and second, utilizing VIIRS data for ground-truth verification in Kaysone Phomvihane District, Laos, where satellite coordinates were compared with field GPS data, photographs, and environmental observations.

Results reveal a consistent seasonal progression, with burning peaking in Cambodia during January–February before expanding into Myanmar and Laos in March. Notably, a statistically significant downward trend in hotspot density occurred from 2019 through 2022, with the lowest activity recorded in 2022, likely due to pandemic-related shifts toward technology-based livelihoods.

The study confirms that remote sensing is a highly accurate monitoring tool, demonstrating an average longitudinal deviation of only -29.568 meters between satellite and ground-level coordinates. These results provide a robust framework for policymakers to implement staggered, country-specific interventions to mitigate agricultural burning and improve regional air quality.

Keywords: Agricultural Burning, Air Pollution, Fire Hotspots, Remote Sensing, Transboundary Haze.

Introduction

Climatic shifts are driven by natural variations and, more significantly, by unplanned human exploitation of resources. Activities such as forest encroachment for residential and industrial growth have drastically reduced global forest cover. A primary contributor to air pollution is open burning—including wildfires and agricultural incineration—which releases harmful gases (CO, CO_2, NOX, SO_2) and particulate matter. This widespread smog severely impacts human health and the natural environment (Kittiyaphon, 2015).

In mainland Southeast Asia (Lao PDR, Thailand, Myanmar, Cambodia, and Vietnam), transboundary haze is a critical international issue. Ignition sources range from natural phenomena to human-induced activities like hunting and illegal forest clearing. During the dry season (November to April), agrarian economies in this subregion rely heavily on slash-and-burn practices and crop residue burning, exacerbated by dry monsoon winds (Ratthakar, 2018). Satellite technology is essential for tracking fire hotspots. The MODIS system provides near-daily global coverage at a 1 km resolution, ideal for broad surveillance. Conversely, VIIRS offers a finer 375m resolution, detecting smaller, low-intensity fires with higher precision (Giglio et al., 2016; Schroeder et al., 2014). This dual-sensor approach allows researchers to monitor changes in land use and burning behavior, particularly during major societal shifts like the COVID-19 pandemic (Vadrevu et al., 2019; NASA, 2023).

Lao PDR serves as a representative case for the subregion's fire patterns. During the pandemic, the return of migrant workers and government promotion of household farming likely intensified agricultural burning. Kaysone Phomvihane District in Savannakhet Province is an ideal focal point for local-scale analysis due to its diverse agricultural landscape. VIIRS data is particularly effective here for mapping hotspot density within specific administrative boundaries (Schroeder et al., 2014; Justice et al., 2002).

This study investigates how COVID-19 disruptions influenced fire hotspot patterns across mainland Southeast Asia from 2019–2022. By utilizing MODIS for regional observation and VIIRS for local validation in Kaysone Phomvihane, the research bridges broad-scale trends with ground-level data (Xu et al., 2020; Lao PDR Government, 2020). The findings aim to inform environmental policies and management strategies to mitigate the impacts of open burning on regional air quality and health.

Research Objectives

The objectives of this research are as follows:

- **To examine spatiotemporal patterns of fire hotspots**: To utilize satellite remote sensing technology (MODIS) to monitor and examine the spatial and temporal distribution of fire hotspots across Laos, Thailand, Myanmar, Cambodia, and Vietnam during the dry seasons of 2019–2022.

- **To analyze the impact of the COVID-19 pandemic**: To compare and analyze how fire hotspot patterns shifted between pre-pandemic baselines and pandemic-era conditions.
- **To validate satellite detection accuracy**: To verify the precision of satellite-derived data (VIIRS) through empirical ground-truth observations and GPS coordinate comparison in Kaysone Phomvihane District, Laos.

Methodology

Research Design

This study used a quantitative, observational design in two phases. First, MODIS satellite data were analyzed to map fire hotspots across mainland Southeast Asia (January–April, 2019–2022), comparing trends before and during the COVID-19 pandemic. Second, VIIRS satellite data were cross-validated against field-collected GPS coordinates in Savannakhet Province, Lao PDR (April 2022), to verify spatial accuracy.

Study Area and Data Source

The regional analysis covered Lao PDR, Thailand, Myanmar, Vietnam, and Cambodia, selected for their agricultural focus and high fire frequency during the November–April dry season. Ground-truth validation was localized to Kaysone Phomvihane District, Savannakhet. Because the study utilized satellite datasets and field observations rather than human participants, the individual fire hotspot served as the primary unit of analysis.

Instruments

The following instruments and tools were used for data acquisition, spatial analysis, and field verification:

Instrument / Tool	Purpose
MODIS Sensor (Terra / Aqua)	Regional hotspot detection at 1×1 km resolution across the five-country study area.
VIIRS Sensor (Suomi NPP / NOAA-20)	Local-scale hotspot detection at 375 m resolution for ground-truth validation in Kaysone Phomvihane District.
NASA FIRMS Web Portal	Free online platform (firms.modaps.eosdis.nasa.gov) for downloading MODIS and VIIRS hotspot data in shapefile format.
ArcGIS Software	Spatial overlay, hotspot distribution mapping, and Point Density analysis across the study area.
Microsoft Excel	Descriptive statistics, percentage calculation, and coordinate distance comparison between satellite and field hotspot locations.
Computer with Internet Access	Data downloading, processing, and cartographic output.
Smartphone (Google Maps)	Field navigation to satellite-identified hotspot locations.

Digital Camera	Photographic documentation of burn scars and surrounding environmental conditions.
Motorcycle	Ground transportation for field data collection within the study district.
Field Recording Form	Standardized form for recording GPS coordinates, weather conditions, and site observations at each burn location.

Data Collection

A. Secondary Data Collection

Secondary data formed the primary dataset for regional analysis. MODIS Active Fire data were downloaded in shapefile format from the NASA Fire Information for Resource Management System (FIRMS) portal for the dry-season months of January through April across four consecutive years (2019–2022). Additional secondary data included national administrative boundary files, land-use and land-cover layers, and road network data, used as spatial base layers in ArcGIS. Relevant published literature on MODIS-based hotspot monitoring and transboundary air pollution in Southeast Asia was also reviewed through library resources and online academic databases.

B. Primary Data Collection

Primary data were collected through structured field surveys in Kaysone Phomvihane District during April 2022. Prior to each survey, active hotspot coordinates for that date were identified via the NASA FIRMS portal and entered into Google Maps for navigation. At each burn site, the following information was recorded:

- **GPS coordinates** (latitude and longitude) of the actual burn location
- **Photographs** of the burn scar and surrounding landscape
- **Weather conditions** (wind direction, temperature, and visibility)
- **General environmental observations** of the surrounding area

This protocol enabled direct comparison of satellite-derived hotspot coordinates with verified field locations, providing the positional accuracy data required for the third study objective.

Data Analysis

Stage 1: Spatial Distribution and Density

Monthly MODIS hotspot data (2019–2022) were integrated into ArcGIS and overlaid with land-cover and administrative layers to produce distribution maps. The **Point Density tool** quantified hotspot concentrations per unit area, while descriptive statistics identified the magnitude and spatial patterns of fire activity across the subregion.

Stage 2: Temporal Comparison (Pandemic Impact)

To assess the impact of the pandemic, hotspot counts from the 2019 baseline were compared against the 2020–2022 period. A **One-way Analysis of Variance (ANOVA)** was utilized to determine if the annual and country-level differences in fire activity were statistically significant.

Stage 3: Accuracy Validation

VIIRS detection accuracy was evaluated by calculating the **Euclidean distance** between satellite coordinates and field-verified burn locations in Microsoft Excel. These positional offsets—mean, minimum, and maximum—were combined with qualitative field observations to contextualize discrepancies in Kaysone Phomvihane District.

Results and Discussions

Results

Density of Hotspots in 5 Countries from 2019-2022

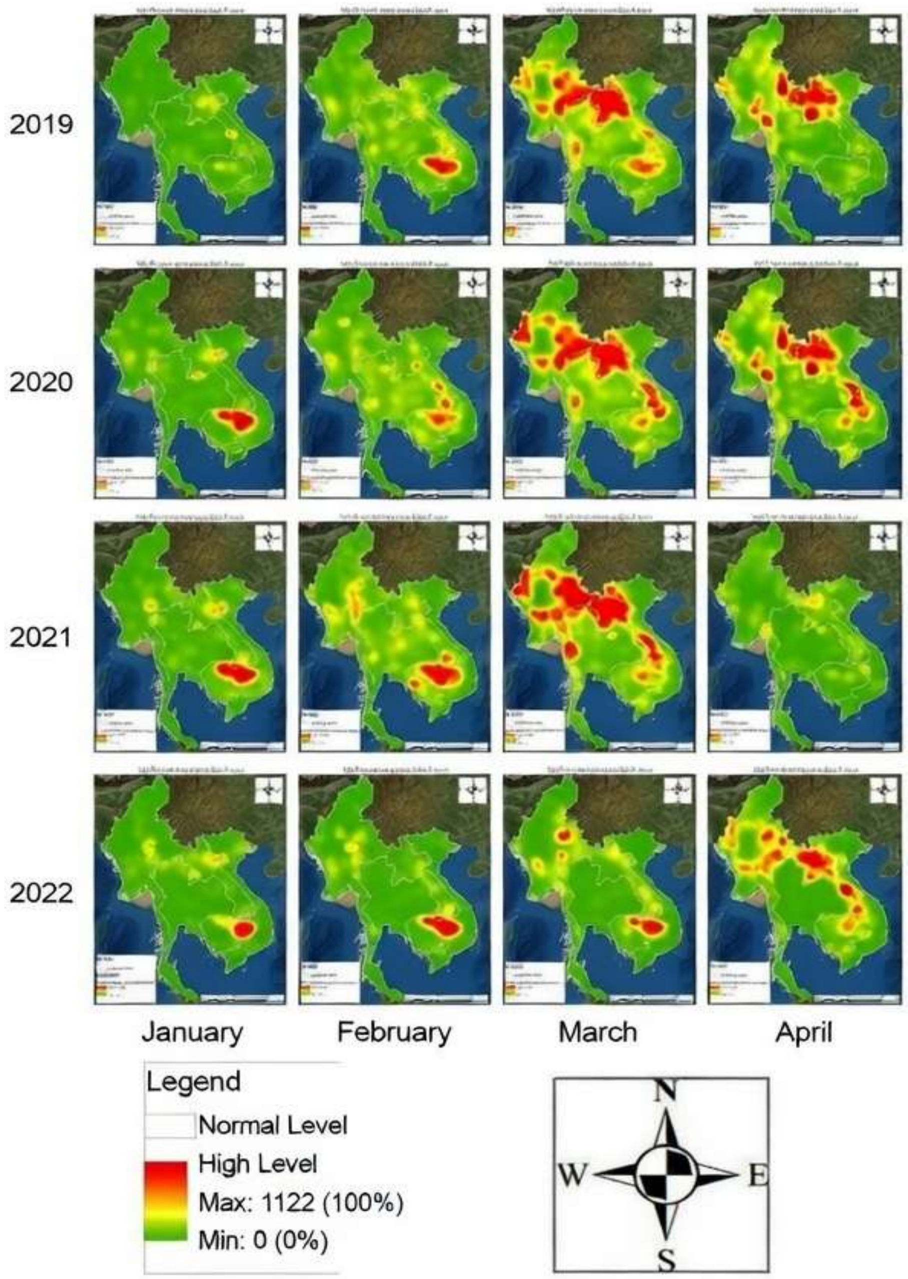

Figure 1: Heat distribution map in 5 provinces from 2019 to 2022

This figure presents a time-series analysis of hotspot density across five provinces (or countries) from 2019 to 2022, derived from MODIS satellite data. The density is visualized using a color gradient where red signifies the maximum threshold of 1,122 points (100%), based on the lowest baseline month of February 2019. The maps illustrate a cyclical pattern in fire activity. In January and February, high density (red) is concentrated in Cambodia, while by March, the red areas expand dramatically, dominating Myanmar and Laos before slightly receding in April. The data indicates that 2019 had the most extensive red areas, with a subsequent downward trend through 2022, likely influenced by the COVID-19 pandemic. The spatial distribution confirms that Myanmar, Laos, and Cambodia exhibit the highest densities, attributed to their reliance on agriculture and practices like swidden farming, whereas Thailand and Vietnam consistently show lower densities (green).

Comparison of Hotspots Before and During the COVID-19 Pandemic During the Dry Seasons of 2019–2022

(I) Year	(J) Year	Mean Difference (I-J)	Standard Error SD	P-value	Significance
2019	2020	-94.628	120.971	0.434	No Significant Difference
	2021	195.125	121.221	0.108	No Significant Difference
	2022	768.30000*	121.221	0	Significant Difference
2020	2021	289.75289*	120.971	0.017	
	2022	862.92789*	120.971	0	Significant Difference
2021	2022	573.17500*	121.221	0	

Note: Significance level 5% ($p<0.05$)

Table 2: Comparison of Hotspots Before and During the COVID-19 Pandemic During the Dry Seasons of 2019–2022

This comparative table quantifies the interannual variability in fire hotspot occurrence across the study period, distinguishing between pre-pandemic (2019) and pandemic-era (2020–2022) conditions during the dry seasons (January–April). The data demonstrate that 2019 recorded the highest density of fire activity, characterized by the most extensive red areas across Myanmar, Laos, and Cambodia, reflecting these countries' heavy reliance on agriculture (Cambodia 70%, Laos and Myanmar 50%). A systematic decline is evident from 2020 onward, with 2020 maintaining relatively high densities comparable to 2019, followed by a notable reduction in 2021 and the lowest densities observed in 2022. This downward trend is attributed to pandemic-related socioeconomic disruptions, which catalyzed an occupational transition from agriculture-dependent livelihoods toward technology-based development, including online services (Anan, 2020). The table illustrates that yellow areas remained generally distributed across Thailand and Vietnam throughout the study period, consistent with their focus on rice farming, which generates fewer hotspots compared to swidden agricultural practices.

Comparison of Satellite Hotspot Locations and Actual Ground-Level Hotspots within Kaysone Phomvihane City (April 2022)

Location	Date	Forest Type	UTM Coordinates lommghaoss	
			UTM (m) East	UTM (m) North
Point 1	30-Mar	Mixed Forest	-191.346 E	233.197 N
Point 2	6-Apr	Bamboo Forest	-32.795 E	177.005 N
Point 3	9-Apr	Dry Dipterocarp Forest	51.099 E	49.675 N
Point 4	20-Apr	Bamboo Forest	-21.141 E	50.892 N
Point 5	20-Apr	Mixed Forest	46.341 E	-82.807 N
Average			-29.568 E	85.592 N
Standard Deviation SD			98.14	123.49

Note: Negative (-E) means West,
Negative (-N) means South

Table 3: Comparison of Satellite Hotspot Locations and Actual Ground-Level Hotspots within Kaysone Phomvihane City (April 2022)

This methodological validation table presents a systematic comparison between remotely sensed hotspot data and empirical ground observations conducted in Kaysone Phomvihane City during April 2022. The table documents the correspondence between locations identified as hotspots by MODIS satellite detection and those verified through ground-level investigation. This comparative analysis serves as a ground-truthing exercise to confirm the accuracy and reliability of satellite-based fire detection methods. The data presented in this table establishes the validity of using remote sensing technologies for monitoring fire activity in the region and provides confidence in the broader spatial analysis conducted throughout the study.

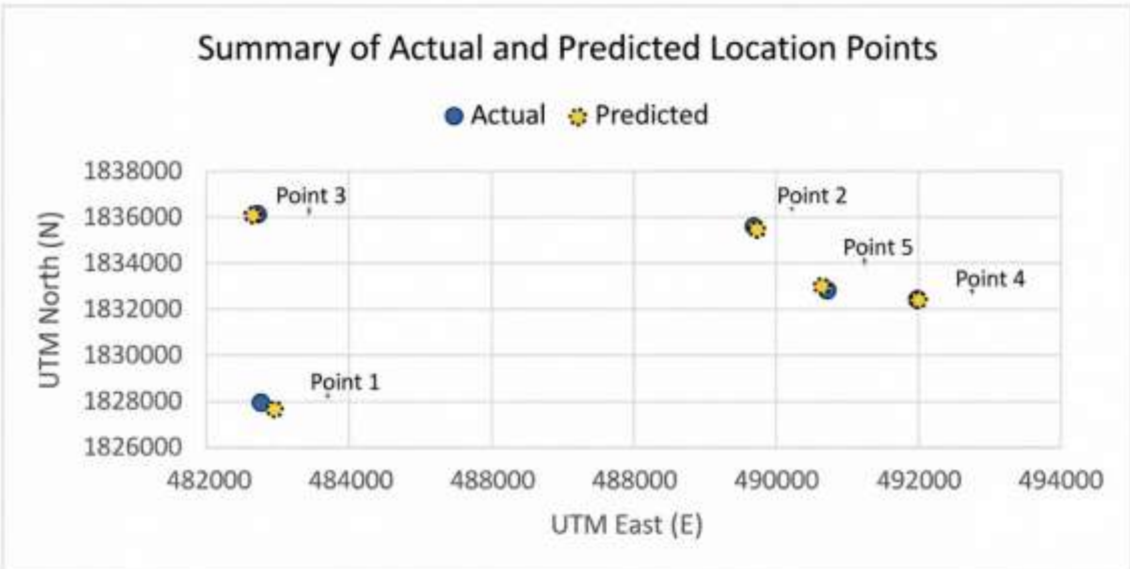

Figure 2: Summary of actual and predicted location points

This figure provides a quantitative summary of the validation results comparing actual ground-verified hotspot locations with predicted locations derived from satellite imagery analysis. The visualization presents the correlation between satellite-detected points and empirically observed fire locations within Kaysone Phomvihane City during April 2022. This summary serves to illustrate the accuracy of remote sensing methodologies in detecting ground-level fire activity and supports the reliability of the MODIS satellite data utilized throughout the study for hotspot density analysis across the five countries.

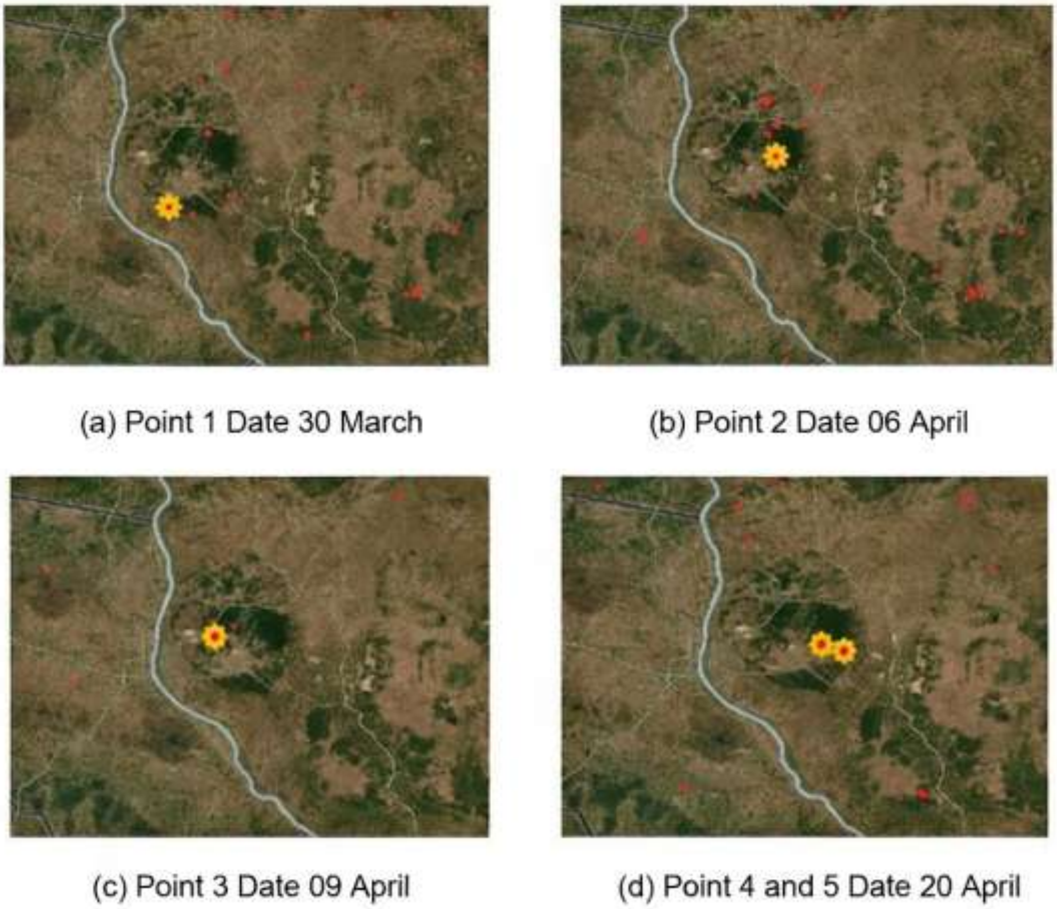

Figure 3: Map showing the location and data from satellite imagery

This figure displays a detailed spatial visualization of satellite-detected hotspot locations within Kaysone Phomvihane City, overlaid on base satellite imagery. The map presents precise geographic coordinates of detected fire hotspots during April 2022, providing spatial context for the validation exercise. This visualization enables the identification of spatial patterns in fire occurrence at the local level and facilitates comparison with the ground-level photographic evidence presented in the accompanying validation materials. The map enhances understanding of the spatial distribution of fire activity within an urban setting and contributes to the methodological rigor of the study by enabling visual confirmation of satellite detection capabilities at fine spatial scales.

Discussion

MODIS data shows a clear seasonal burning progression across mainland Southeast Asia, driven by agricultural calendars and the dry season. High-density fires peak in Cambodia during January–February before shifting north to Myanmar and Laos in March–

April. These patterns, linked to traditional shifting cultivation, align with findings by Biswas et al. (2021) regarding Indochinese fire regimes.

A significant decline in hotspots occurred from 2019 to 2022, with 2022 marking the lowest recorded densities. This trend contradicts early predictions that the pandemic would increase burning. Instead, as noted by Sharma et al. (2021), labor shortages and economic contraction likely reduced fire activity, mirroring broader trends across tropical Asia.

Thailand and Vietnam maintained consistently lower hotspot densities than their neighbors. Research by Nguyen et al. (2023) suggests this is due to intensive rice cultivation in areas like the Mekong Delta, where residue burning is less intense and more dispersed than in swidden (slash-and-burn) systems. This suggests that transitioning to permanent cropping could further reduce regional fire occurrences.

Satellite Validation

Fieldwork in the Kaysone Phomvihane District confirmed that VIIRS satellite data accurately identifies burn sites within complex agricultural landscapes. Supporting the framework of Liu et al. (2022), this validation proves that medium-resolution sensors are reliable for both local-scale management and broad regional surveillance.

Future Outlook

It remains uncertain if the pandemic-era fire reduction is permanent. While Chen et al. (2023) suggest some behavioral shifts toward alternative livelihoods may last, Panyasiri et al. (2022) warn that rising food prices could pressure farmers to intensify production, potentially reversing recent progress in fire reduction.

The accuracy of VIIRS data provides a practical tool for monitoring and enforcement, especially where ground capacity is limited. Following Phompila et al. (2021), integrating satellite surveillance with community-based management offers a viable path to sustain fire reductions while supporting rural livelihoods in Laos and beyond.

Recommendations

Based on the research findings, the following recommendations are proposed:

- **Implement Staggered Regional Interventions**: Policymakers should implement country-specific mitigation strategies based on the identified seasonal burning progression, starting with Cambodia in early dry season followed by Myanmar and Laos in March.
- **Promote Technology-Based Livelihood Transitions**: Governments should support the transition from agriculture-dependent livelihoods to technology-oriented sectors, as this shift demonstrated a statistically significant reduction in fire activity during the study period.
- **Integrate Satellite Monitoring with Community Management**: Regional environmental authorities should utilize remote sensing as a core monitoring tool, integrating high-accuracy satellite surveillance with community-based fire management to sustain fire reductions.
- **Transition to Permanent Cropping Systems**: Future agricultural policies should encourage a shift from traditional swidden (slash-and-burn) practices to permanent cropping models to minimize the intensity of residue burning.

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