Sainmatika: Jurnal Ilmiah Matematika dan Ilmu Pengetahuan Alam
Volume 21 No. 1, June 2024 DOI 10.31851/sainmatika.v21i1.14810
https://jurnal.univpgri-palembang.ac.id/index.php/sainmatika

Geographic Information System (GIS) Spatial Analysis to Detect the Distribution Pattern of Unused Land Fires at Ogan Ilir Regency

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ABSTRACT

Land fires pose a serious threat to the environment and communities in Ogan Ilir Regency, South Sumatra. This study aims to analyze the distribution pattern of land fires using GIS spatial analysis technology. Through Sentinel-2 image classification and fire intensity analysis, it had been identified focal points of dormant land fires mainly in South Indralaya, North Indralaya, and West Pemulutan sub-districts. The results of this study provide in-depth insight into the spatial distribution of land fires and the factors that influence their occurrence. This research also produced a map of the distribution of fire hotspots in unused land areas. From the research, it can be concluded that spatial analysis can map in detail and comprehensively the burning locations on unused land. The implication of this research is the need to develop more effective mitigation strategies to address the risk of land fires in the future. Therefore, this study not only makes an important contribution to the scientific literature but also offers new directions for research and policy focused on sustainable and effective land fire risk management.

Keywords: GIS, Land Fire, Spatial, Technology

INTRODUCTION

The increasing frequency of forest and land fires has become a global problem, triggering concerns about the harmful environmental impacts and threats to human life and biodiversity (Edwards et al., 2020). Indonesia, as one of the countries with a high density of forests and land, is not immune to this challenge (Astuti & Fatimah, 2024). Forest and land fires have become a troubling problem in various parts of the world, including in Ogan Ilir Regency, South Sumatra (Lestari et al., 2020). This phenomenon not only has a negative impact ecologically but also economically and socially on the local community (Hein et al., 2022). Forest and land fires can threaten the safety of residents, impair health due to air pollution, and damage the productivity of agricultural land and valuable natural resources (Jager et al., 2020). Despite efforts to address the problem, there is no adequate solution to the overall problem of forest and land fires (Budiarti et al., 2021).

Ogan Ilir Regency, South Sumatra, is the main focus of this study, given the increasing incidence of fires in the region. As a consequence of rapid economic growth and climate change, an in-depth understanding of fire distribution patterns in the Ogan Ilir Regency's idle lands is crucial for mitigation and risk management. In the context of the Ogan Ilir Regency, the increasing incidence of fires highlights the need for a more sophisticated and

p-ISSN 1829 586X
e-ISSN 2581-0170

detailed approach to understanding the causes and distribution patterns of fires (Utomo et al., 2022). The Regional Disaster Management Agency (Indonesian: *Badan Penanggulangan Bencana Daerah* – BPBD) of Ogan Ilir Regency, South Sumatra, reported 259 forest and land fires during the period from January to October 15, 2023. The impacted land area is included in the report; by mid-October of that year, over 1,088 hectares of land had been devastated by flames. Most cases of forest and land fires in the timeframe mentioned occurred and were dominant in four sub-districts; Pemulutan, West Pemulutan, Indralaya, and North Indralaya.

Despite significant efforts to understand and address the problem of forest and land fires, there are problems in our understanding of fire distribution patterns in the unused lands of Ogan Ilir Regency (Zakiah et al., 2022). Existing scientific literature is limited in identifying the factors that influence fire occurrence and the spatial relationships between these factors. Previous research tends to be limited to analyzing forest and land fires in general, with a focus on larger areas (Syaufina, 2018). However, the Ogan Ilir Regency exhibits unique characteristics that require a more detailed and localized approach to understanding fire distribution patterns (Nurhayati et al., 2021). By complementing previous research that has not explored this area in depth, this study is expected to provide a more comprehensive understanding of fire distribution patterns in the idle lands of Ogan Ilir Regency.

A commitment to reducing the risk of forest and land fires requires an in-depth understanding of the causal factors and their distribution patterns with the characteristics of each region (Riyanto et al., 2020). However, to date, there is limited scientific literature that examines in detail the issue of forest and land fires in Ogan Ilir Regency. Therefore, the objective of this study is to examine particular aspects concerning the distribution patterns of fires in the unused lands of Ogan Ilir Regency by utilizing GIS spatial analysis to identify the patterns of fire distribution within the unused lands of Ogan Ilir Regency, located in South Sumatra.

Ogan Ilir district has different problems from other regions because most of the land fires in this area have occurred in the same area for years. With an increase in the incidence of forest and land fires in the region, an in-depth understanding of fire distribution patterns is crucial for designing effective mitigation strategies (Budiarti et al., 2021). Through a GIS spatial analysis approach, it is hoped that this research can identify fire distribution patterns and their influencing factors, thus providing better insights for stakeholders in facing this challenge (Thoha et al., 2019)

The use of GIS technology in this context has great potential to integrate diverse spatial data, including data on land use, topography, rainfall, and vegetation, allowing us to conduct more comprehensive analyses (Thoha et al., 2023). This will enable accurate mapping of fire distribution patterns in the idle lands of Ogan Ilir Regency and explore the correlation between environmental factors and fire occurrence (Erianti et al., 2020).

The use of GIS spatial analysis to understand fire distribution patterns has become an increasingly relevant research topic in natural disaster risk mitigation efforts, especially in vulnerable areas such as Ogan Ilir Regency, South Sumatra (Yang et al., 2023). The uniqueness of this study lies in its combination of GIS spatial analysis and its specific focus on fires in the unused lands of Ogan Ilir Regency. By considering relevant environmental and

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e-ISSN 2581-0170

spatial variables, Environmental factors include variables such as vegetation type, topography, and weather conditions, which directly or indirectly influence wildfires. Spatial variables are concerned with the spatial distribution of wildfires and the relationship between fire occurrence and specific geographic features. (Junior et al., 2024). By understanding fire distribution patterns in more detail, it is hoped that this research can assist relevant parties in designing more targeted and effective mitigation strategies (Sarmiasih & Pratama, 2019). In addition, the knowledge contribution of this research can also enrich the existing scientific literature in the field of GIS spatial analysis and natural disaster management (Chen et al., 2023).

MATERIAL AND METHOD

This study was carefully and methodically carried out to comprehend the distribution of land fires in Ogan Ilir Regency, South Sumatra. South Inderalaya, North Inderalaya, and West Pemulutan sub-districts were chosen as study areas due to their high rates of land fires. The period of the study from February 2023 to February 2024 was chosen to observe land fire patterns for a full year, allowing for a comprehensive analysis of the factors influencing fire occurrence.

In addition, by using Sentinel-2 images at a scale of 1:50,000 and a spatial resolution of 10 meters, the digital image interpretation method is applied to classify land cover (Rahmi & Khalifah, 2020). Machine learning techniques, particularly the Random Forest algorithm, were applied in data collection and analysis, ensuring accuracy and efficiency in mapping fire distribution patterns (Babu et al., 2020) (Babu et al., 2023). The analysis process includes geometric and radiometric correction of the imagery, removal of cloud interference using cloud masking, image segmentation for object identification, and field ground check to validate the analysis results (Makumbura et al., 2024).

The data used in the preparation of forest and land fire-prone maps are land cover maps, soil type maps, climate distribution maps, administrative maps, *hotspot maps*, road and river maps, FMU, and Mangala Agni location maps. (Neidermeier et al., 2023). The number of hotspots detected by the MODIS (Moderate Resolution Imaging Spectroradiometer) instrument on board the TERA AQUA satellite was used to determine the intensity of land fires in the research area. *The* use of GIS analysis techniques results in spatially comprehensive mapping of land fire intensity. (Zhou, 2021). This approach provides an in-depth understanding of land fire distribution patterns, which is expected to make an important contribution to land fire risk management in the region, as well as potentially serve as a reference for similar research elsewhere.

RESULT AND DISCUSSION

Overview of the Research Area

West Pemulutan, North Indralaya, and South Indralaya sub-districts are located in Ogan Ilir Regency, South Sumatra Province, Geographically located at 3^0 05'00" - 3^0 20'00" LS and 104^0 30'00" - 104^0 45'00" BT. These three sub-districts are very close to the Palembang Municipality, and access from the city is only around 0.5 - 1 hour drive.

Ogan Ilir Regency is an area that has a Wet Tropical climate (Type B) with the dry season ranging from May to October, while the rainy season ranges from November to April. Geometric correction is the transformation of remote sensing images so that they possess map-

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like properties in terms of form, scale, and projection. The most fundamental geometric transformation involves repositioning pixel locations in such a way that recognizable imagery can be observed in the transformed digital image (Taloor et al., 2021). Geometric correction is applied to satellite images of objects on the Earth's surface captured by sensors. One outcome of this transformation is the alteration of the coverage framework from a square grid to a parallelogram (Ghasemi et al., 2023). This stage is implemented on raw digital images (direct outputs of satellite recording) and serves as a correction for systematic geometric errors.

Radiometric correction involves improving pixel values by converting digital number (DN) values into spectral reflectance unit values (Ikhsan et al., 2023). Typically, standard products of medium-resolution optical image data have already undergone systematic radiometric correction. The radiometric correction process due to external atmospheric factors includes corrections for top-of-atmosphere (TOA) atmospheric effects, Bidirectional Reflectance Difference Function (BRDF), and Slope Correction (Liu et al., 2023). The outcome of radiometric correction due to external factors usually consists of object reflectance values, which are the ratio of radiance to irradiance.

Based on the classification, Ogan Ilir Regency is included in the classification of medium rainfall. Land Use in Ogan Ilir Regency based on its function is divided into 14 (fourteen) land uses which can be seen in Table 1 and Figure 1, whereas unused land is in Figure 2.

Table 1. Land Use in Ogan Ilir Regency

Land Use Ogan Ilir	Area (Ha)
Secondary swamp forest	2,208.48
Open land	7,689.21
Rubber plantation	111,852.43
Oil palm plantation	23,278.13
Sugarcane plantation	14,625.18
Rural settlements	2,753.86
Urban settlements	3,195.73
Open pit mining	133.81
Inland swamp	11,726.78
Rice fields	24,755.82
Shrubs	32,396.74
River	3,169.63
Farmland/field	1,548.17
Lake/Situ	84.20
Total	239,418.17

Source: DDDTLH Ogan Ilir Regency, 2020

Analysis of Fire Event Intensity in the Study Area

Burned areas can be defined as areas on the earth's surface that show characteristics of having experienced burning due to natural processes or burning by humans either intentionally or unintentionally (Haghani et al., 2024). The tendency to burn on land dominated by forest vegetation cover and non-forest vegetation such as bushes, shrubs, plantations, fields, or moorland is a common occurrence (Wulandari et al., 2022). Burned areas are characterized by the presence of charcoal and ash deposits and the loss of vegetation cover and fuel and are dominated by open ground (Kiely et al., 2021).

These changes identified by remote sensing and direct field measurements vary spatially (Figure 3 and Figure 4). The type of vegetation that burns or remains unburned, fire and burning behavior, post-fire regrowth, and the amount of ash and charcoal lost to wind and water as a result of several anthropogenic and biophysical variables (Rahmah, 2022). The kind and state of the vegetation before burning, as well as the intensity of burning, determine the size and direction of spectral alterations

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e-ISSN 2581-0170

brought about by charcoal and ash deposits (Adrianto et al., 2020).

In general, charcoal and ash have a low reflectance, typically 0.05 (400 nm) to 0.10 (2500 nm), although fires at high temperatures produce highly reflective white ash, e.g. 0.40 (400 nm) to 0.60 (2500 nm). (Ren et al., 2024). To determine the area that has been burned, mapping of burned areas was also carried out using Sentinel 2 imagery for the August-November 2023 period.

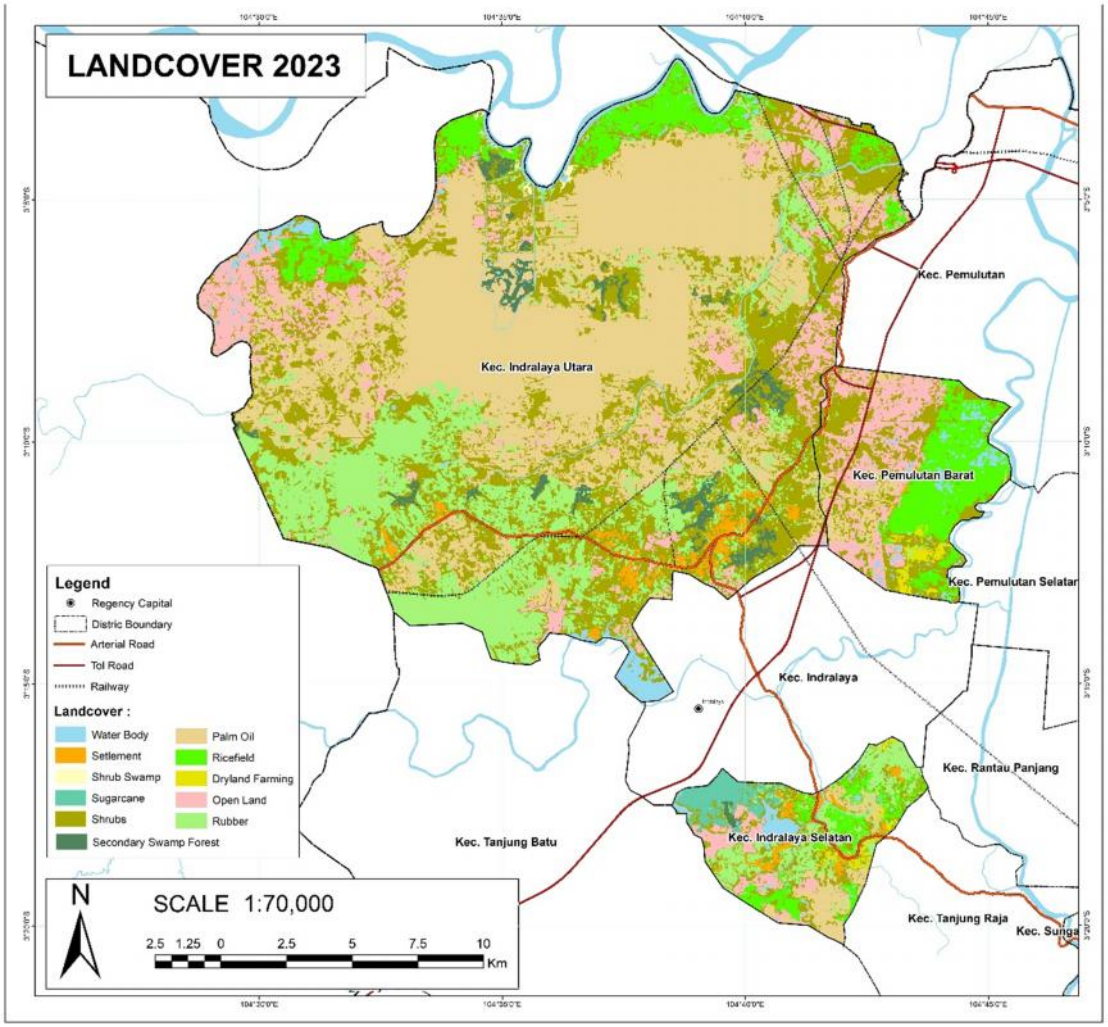

Figure 1. Landcover at Study Location, 2023.

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e-ISSN 2581-0170

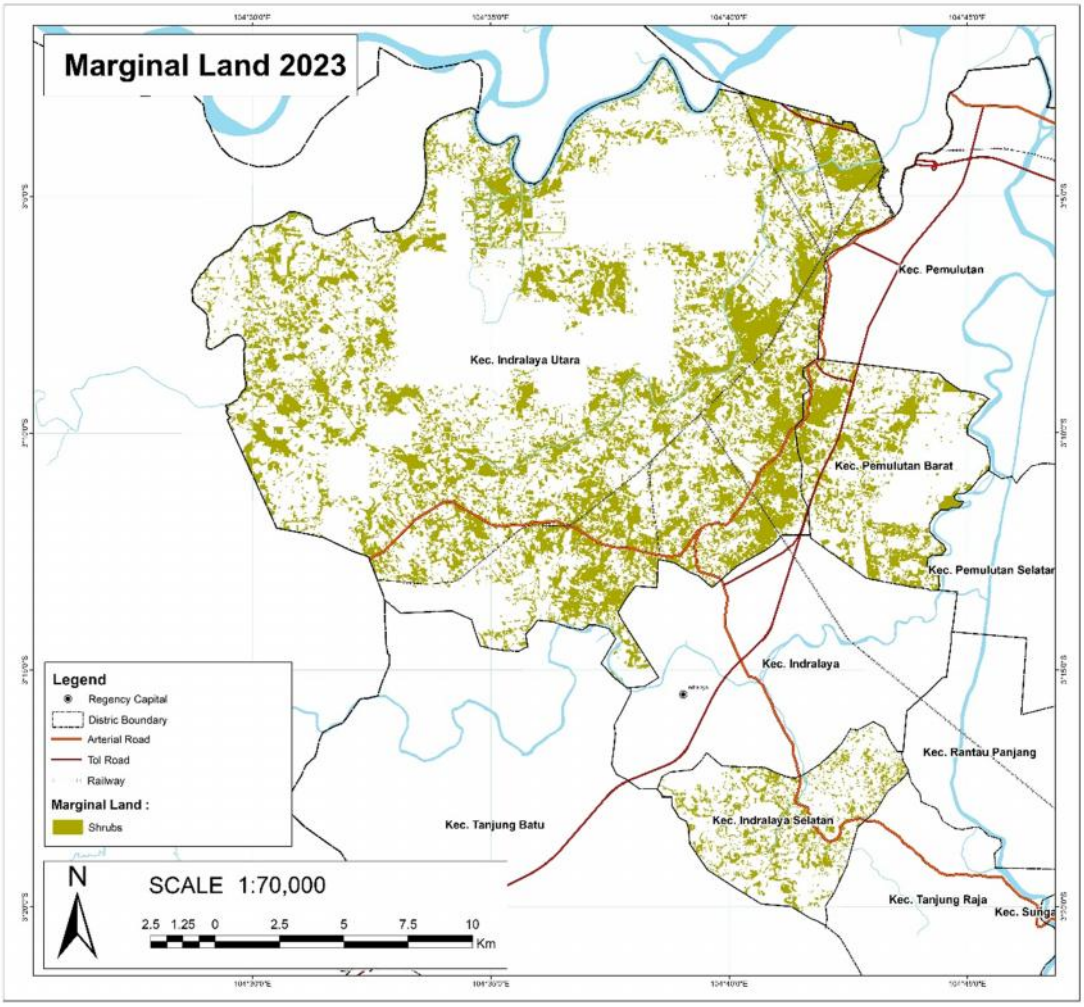

Figure 2. Marginal/Unused Land

Figure 3. Burned Area of Rubber Plantation

Figure 4. Burned Area of Secondary Swamp Forest

The demarcation method of mapping the burned region involves creating polygons on it, and identification is achieved by merging Sentinel 2 imagery's channels 12/8/4 (Figure 5). The obstacle faced when mapping the burned

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e-ISSN 2581-0170

area is the amount of smoke coverage on the image used, while the image used is the period from August to November 2023. For this reason, extra image processing efforts are needed to produce images that are good enough to interpret the characteristics of the burned area (Faisal et al., 2023). Figure 6 is a map of Sentinel imagery of the study area used to map burned areas.

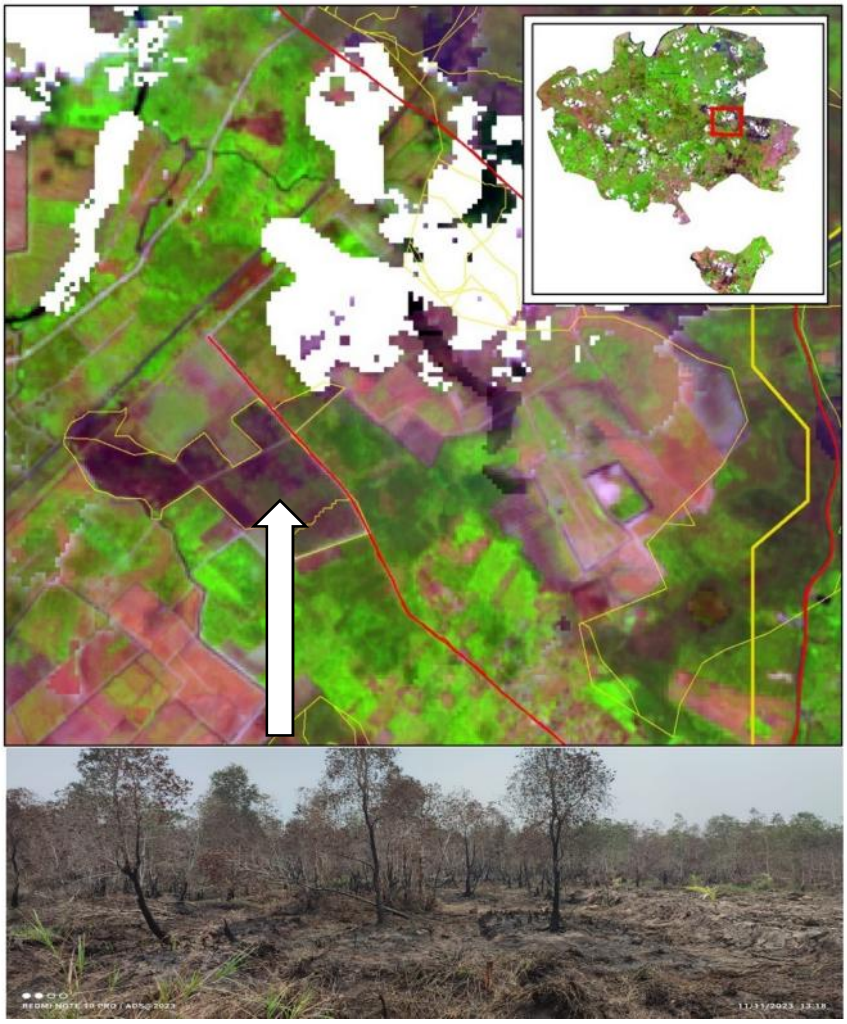

Figure 5. Characteristics of Burned Areas on Sentinel 2 Imagery

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e-ISSN 2581-0170

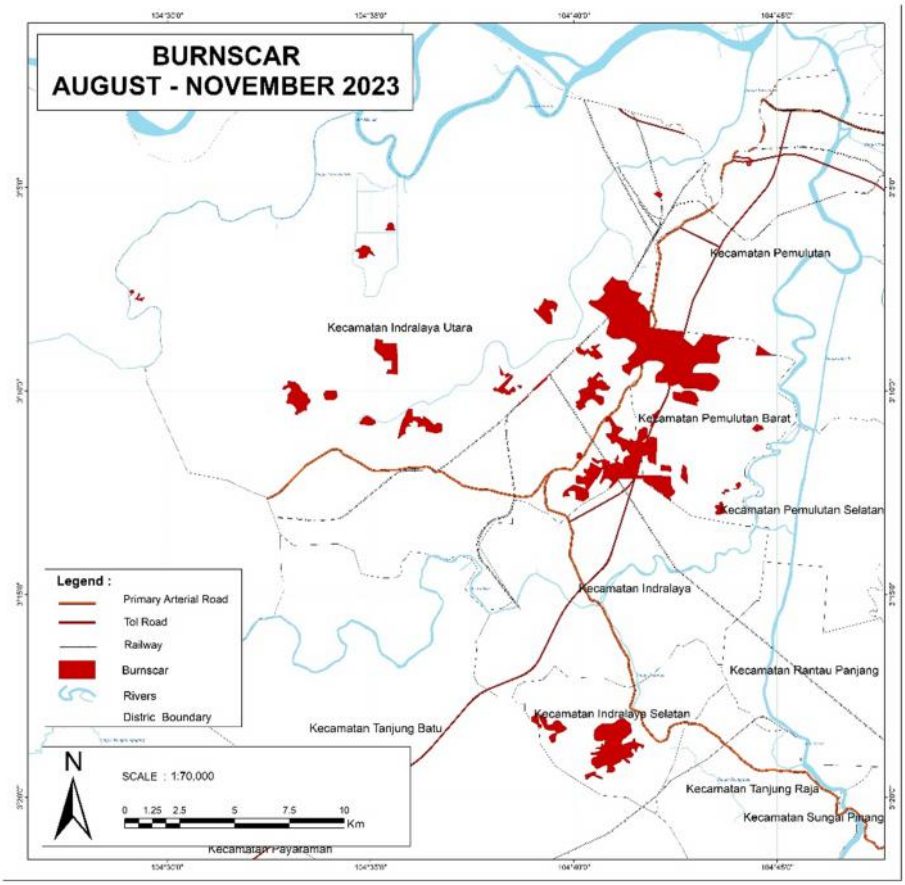

Figure 6. Map of Burned Areas in 2023 in the Study Area

The intensity of land fires in the study area was assessed by the number of hotspots recorded by the TERA AQUA satellite carrying the MODIS (Moderate Resolution Imaging Spectroradiometer) instrument (Eames et al., 2023a). This satellite has a sweep width of 2330 km and captures the entire Earth's surface in one or two days. It has 36 bands with three spatial resolutions of 250m, 500m, and 1,000m. Terra-MODIS data is used for the utilization of rice plant phases, potential fishing zones, and monitoring forest fire hotspots. MODIS-Terra data available at Pustekdata (Remote Sensing Technology and Data Center) is MODIS level 1B data, namely data that has been carried out de-striping correction and geometric correction (Xu & Wooster, 2023). Based on hotspot data that occurred between 2010 and 2023 that has been filtered with a 50% confidence level value, the distribution of hotspots is shown in Table 2. The map indicates that the North Indralaya Sub-district has a relatively high hotspot density, which is consistent with the hotspots (Figure 7). However, to find out the type of land that is often burned, a spatial analysis of the burned area against the land cover is needed (Moreno et al., 2023).

In addition, the study area burned in 2023 was primarily composed of shrubs that have been designated as marginal land, as opposed to open, cultivated land that is also overgrown by weeds, such as former dry land farms and fields that are about to plant. This means that when there is no rain and a lot of sunlight, the land is dry and flammable. The remaining portion of the study area is made up of oil palm and rubber plantations as well as secondary swamp forests, which are typically overgrown by species like gelam wood (Melaleuca leucadendron L.).

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Table 2. Distribution of hotspots 2010-2023 in the study area

Sub-District	Year													Total
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2023	
South Indralaya	2	3	6		4	8	1			3			4	31
North Indralaya	18	159	49	5	89	128	4	27	18	108	3	4	66	678
West Pemulutan	5	11	6	5	14	10	2	8		11	2	3	18	95
Total	25	173	61	10	107	146	7	35	18	122	5	7	88	804

Source: TERA AQUA Satellite

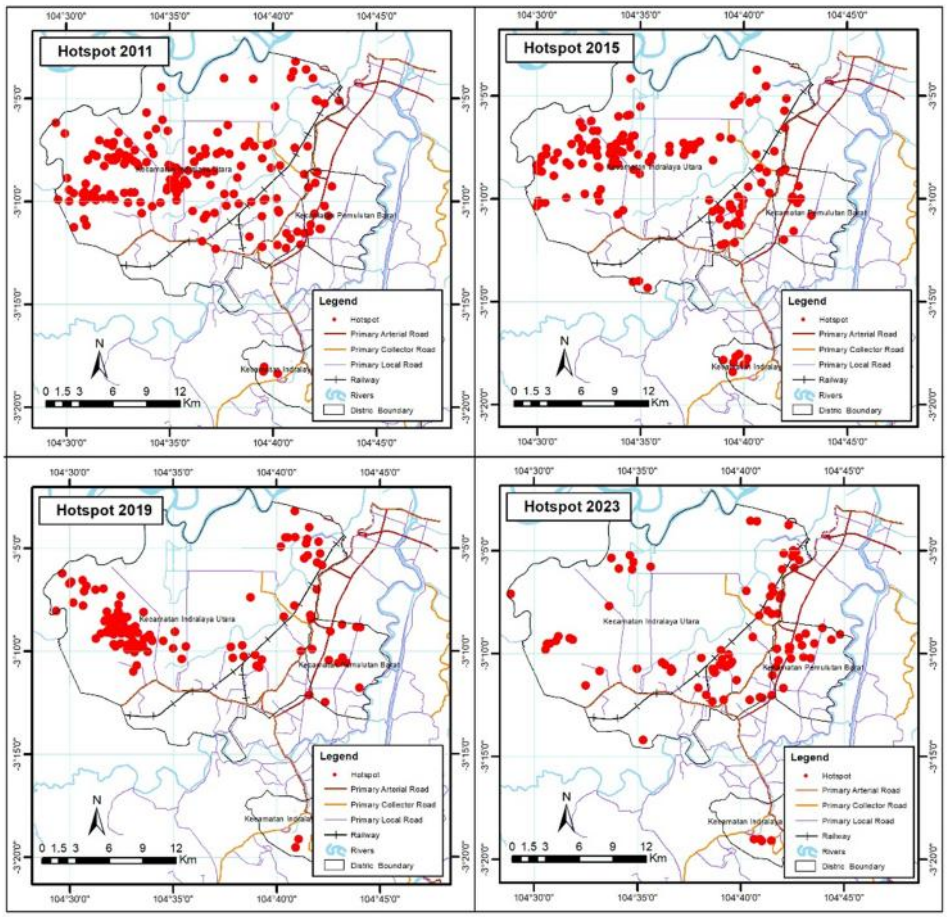

Figure 7. Map of Fire Spots Distribution in 2011, 2015, 2019, and 2023

Ogan Ilir Regency had a large area burned from 2011 to 2023, but not as much as in areas with peatlands. Most of the fires in the Ogan Ilir region occurred on agricultural lands caused by land use or accidental due to the dry conditions of grass and weeds that make it easy to ignite fires (Nurhayati et al., 2020). Mechanical land clearing using heavy equipment is more expensive, so many companies still practice land clearing by burning which is detrimental to many parties, the public, and the environment (Maynard et al., 2020). In addition to land-clearing activities to meet economic needs by corporations, communities are also involved in the practice of land clearing by burning (Davies-Barnard et al., 2023).

There are three main pillars in forest and land fire control, namely prevention, suppression, and recovery (Eames et al., 2023b). The first steps in preventing forest and land fires were to assess each village's potential for these types of fires, organize the community

p-ISSN 1829 586X
e-ISSN 2581-0170

into groups, plan activities based on the potential of the villages, and prepare assistants.

CONCLUSION

The spatial distribution of land fires focused in Inderalaya Selatan, Inderalaya Utara, and Pemulutan Barat sub-districts highlights the urgency of developing effective mitigation strategies. The analysis of fire occurrence intensity has made an important contribution to enriching the theoretical and practical understanding of natural disaster management. In the context of using GIS, this research demonstrates the crucial role of technology in mapping and understanding complex natural phenomena, and provides a strong foundation for the development of GIS methodologies in the field of wildfire risk mitigation. Spatial analysis can map areas prone to land fires. The area includes 3 sub-districts, namely North Indralaya, South Indralaya and West Pemulutan. However, it is important to recognize that this study has limitations, such as the restrictions in field data collection and the assumptions used in the analysis. Therefore, suggestions for future research include expanding the scope of the study to include a wider range of variables and using more sophisticated methods to improve the accuracy of the analysis. Moreover, further research that integrates cross-disciplinary approaches and collaboration with local stakeholders will enrich our understanding of the complexity of land fires and strengthen future mitigation efforts.

Acknowledgments

This research owes its success to the invaluable support and collaboration from numerous individuals and entities who wholeheartedly contributed at every step of the way. We extend our heartfelt gratitude to the Regent of Ogan Ilir, Panca Wijaya Akbar, as well as government officials and relevant agencies for their transparency and cooperation, which served as the cornerstone in accessing vital data and information from the local government. We also express our appreciation to the stakeholders, local communities, and village heads who generously shared their insights, actively participated, and provided valuable feedback throughout the research journey. Their involvement was instrumental in enriching the study and ensuring its comprehensiveness.

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