

Identification of Hotspots and Burnt Areas in Ogan Ilir District, South Sumatera Province

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Abstract

Ogan Ilir District is one of South Sumatra, Indonesia's regencies, prone to forest and land fires. This study aims to identify hotspot distribution and analyze fire and land hazard levels from 2017 to 2022 in Ogan Ilir District using Landsat 8 imagery with the Normalized Burning Ratio (NBR) method. The study's results show that from 2017 to 2022, 423 hotspots were recorded. Specifically, in 2017, there were 2 points; in 2018, 121 points; in 2019, 207 points; in 2021, 76 points; and in 2022, 17 points. North Indralaya is the sub-district with the highest level of forest and land fire vulnerability, with the number of events ranging from 80 to 164. West Pamulutan and Pamulutan are at a high hazard level, with incidents ranging from 33 to 79. Meanwhile, Indralaya and South Indralaya sub-districts have a medium level of danger, with events ranging from 19 to 32. The low threat level for forest and land fires is spread across all sub-districts in Ogan Ilir District, with the number of events ranging from 1 to 18.

Keywords

Hotspot, Forest and Land Fires, Calcification Land Fire

Received: 5 April 2024, Accepted: 3 June 2024

<https://doi.org/10.26554/ijems.2024.8.2.82-88>

1. INTRODUCTION

Forest and land fires are frequent natural disasters in Indonesia, particularly during the dry season, and especially during the long dry season (Lamat et al., 2021). Research indicates that these fires occur due to various environmental factors such as climate, soil type, land cover conditions, socio-economic factors, and policies that can increase human interaction with forests and land (Thoah et al., 2019). Nevertheless, according to Wetlands International's assertion, human actions, whether deliberate or accidental, are primarily responsible for Indonesia's forest and land fires, with no indication of natural causes prompting such incidents (Adrianto et al., 2020).

The intensity and quantity of forest and land fires can occur both inside and outside forest areas, affecting mineral soils and peat (Page and Hooijer, 2016; Juárez-Orozco et al., 2017), ecologically, the decrease in land area and land degradation caused by forest and land fires can pose risks and uncertainties in the recovery of ecosystem conditions (Souza-Alonso et al., 2022). Additionally, uncontrolled forest and land fires can lead to decreased water quality, river sedimentation, and increased erosion, while also causing

haze, which has socio-economic impacts (McLauchlan et al., 2020).

Ogan Ilir District covers an area of approximately 2,382.48 square kilometers, with 65% of the area consisting of swamps, including lebak swamps and tidal swamps. During the dry season, these areas are particularly susceptible to fires due to the significant reduction in water content (Lestari et al., 2019). According to Ogan Ilir District Statistics, approximately 4,000 hectares of peatland, 8,000 hectares of plantation, and 5,000 hectares of other land were affected by fires. In 2015 alone, there were 12,295 hectares of burnt land with 226 hotspots. Among these, 139 hectares of purun-vegetated peatland were located in five villages across two sub-districts of Ogan Ilir District. The identified causes of forest and land fires are mainly agricultural land clearing by communities and land clearing for plantations, especially during land clearing or replanting activities, with the majority of burning occurring on peatlands (Nurhayati et al., 2021). The resulting impacts of widespread plantation and burning activities can include reduced agricultural land and fish catches, as well as haze disasters (Juárez-Orozco et al., 2017).

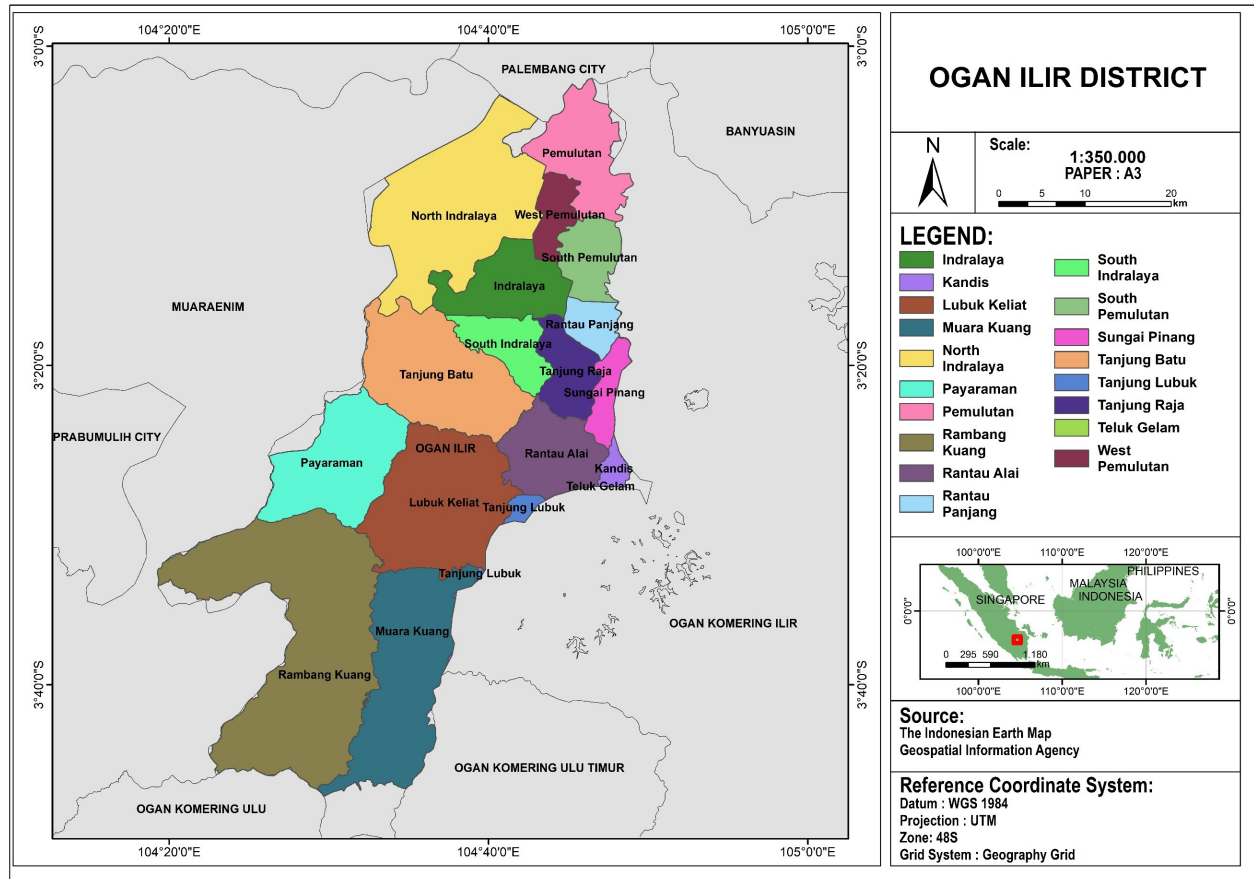


Figure 1. Study Area Ogan Ilir District

Previous research on forest and land fires in the Ogan Ilir District has been conducted. Utilizing remote sensing technology can offer a solution to monitor and measure the extent of forest and land fires with monitoring times closer to real-time compared to using field observation data (Jang et al., 2019). There are several research methods related to the identification and estimation of the extent of forest and land fires that can be employed with various approaches, such as using a variable method derived from the reflectance value of a spectral channel or an index that combines several spectral channel reflectance values (Lee et al., 2022), a method utilizing the NDVI (Normalized Difference Vegetation Index) value (Fraser et al., 2000; Lee et al., 2022), NDFI (Normalised Difference Fire Index) method (Normelani et al., 2024), and NBR (Normalised Burn Ratio) (Liu et al., 2020). This study aims to identify hotspot distribution and analyze fire and land hazard levels from 2017 to 2022 in Ogan Ilir District using Landsat 8 imagery with the Normalized Burn Ratio (NBR) method. This research illustrates the latest conditions of forest and land fires in the Ogan Ilir District and can serve as a reference for the government and regional disaster management agencies regarding the distribution of hotspots and areas prone to repeated fires.

2. EXPERIMENTAL SECTION

2.1 Research Location and Methods

This study is situated in an area that consistently experiences forest and land fires in the Ogan Ilir District, South Sumatra, Indonesia. The four sub-districts involved are South Indralaya, North Indralaya, Pemulutan, and Pemulutan Barat (Figure 1). Geographically, Ogan Ilir District is positioned between 30° 02' N – 40° 02' N and 104° 20' East – 104° 48' East. The research was conducted in November 2023 and encompassed the preparation stage, data collection, and data processing. The selection of Pemulutan and Indralaya sub-districts as the research area was based on the frequency of fires in the area, the number of hotspots, information from community leaders, and accessibility of the research location. The landscape of the study area is predominantly low-lying, non-hilly terrain drained by rivers and swamps.

2.2 Research Population and Sample

The study analyzed the level of forest and land fire hazard and hotspot distribution in Ogan Ilir District, South Sumatra Province, using the population as the sample. This research employed a saturated sampling method, meaning

that the entire population was included as the sample.

2.3 Data Analysis

The data analysis technique employed in this research involves analyzing the forest and land fire hazard levels in Ogan Ilir District, which includes censoring and weighting analysis, followed by overlay analysis. Data collection included information on land use and climate data, such as rainfall and soil type. The collected data underwent classification using the scoring method. Subsequently, all scored parameter results were combined through overlay to map the forest and land fire hazard levels. The tools utilized in this research were a Personal Computer (PC), ArcGIS 10.8 software, a camera, and a Global Positioning System (GPS). Landsat 8 image data recorded in 2017, 2018, 2019, 2020, and 2022 were used for analysis. Following the provisions of the Head of the National Disaster Management Agency Regulation No. 2 of 2012 concerning forest and land fire hazards, each parameter was assigned its score and weight (refer to Table 1).

Table 1. Classification, Score, and Weighting of Forest and Land Fire Hazards

Classification	Parameter	Class
Type of Land	Forest	Low
	Garden / Plantation	Middle
	Grassland	High
Rainfall	≥ 3000 mm	Low
	1500 – 3000 mm	Middle
	≤ 1500 mm	High
Land Type	Non Organic/Mineral	Low
	-	Middle
	Mineral/Peat	High

To validate the burnt area of the 2015 fires in the study area, a Normalized Burn Ratio (NBR) calculation was performed on Landsat 8 satellite imagery. Before conducting the NBR calculation, initial image processing procedures were carried out, including geometric and radiometric corrections. Following the initial image processing stage, the NBR index was extracted using Equation (1) and Equation (2). Subsequently, after obtaining the NBR values and calculating dNBR, severity level classification was conducted, categorizing them as low, moderate, and moderately extreme by determining thresholds using Equation (3), Equation (4), and Equation (5).

$$NBR = \frac{NIR - SWIR}{NIR + SWIR} \tag{1}$$

$$dNBR = NBR_{prefire} - NBR_{postfire} \tag{2}$$

Description:

$dNBR$ = Difference of NBR before burning and NBR after burning.

$NBR_{prefire}$ = NBR before burning.

$NBR_{postfire}$ = NBR after burning.

$$\text{Overall Accuracy (\%)} = \frac{\text{Number of Correctly Classified Pixels}}{\text{Number of Samples}} \times 100 \tag{3}$$

$$\text{Producer Accuracy (\%)} = \frac{\text{Number of Samples Test Accuracy of A Class that is Correctly Classified}}{\text{Number of Accuracy Test Samples Classified As that Class}} \times 100 \tag{4}$$

$$\text{User Accuracy (\%)} = \frac{\text{Number of Correctly Classified Pixels}}{\text{Number of Accuracy Test Samples Classified As that Class}} \times 100 \tag{5}$$

Error Omission (%) = 100% - producer accuracy 7

Error Comission (%) = 100% - user accuracy 8

The accuracy test is also conducted by calculating the kappa value, which compares the tested classification results with random classification. In essence, the kappa value indicates the consistency and accuracy of the classification results (Pontius and Millones, 2011).

3. RESULT AND DISCUSSION

3.1 Classification of Forest and Land Fire Hazard Level

The hazard level of a disaster describes the potential harm caused by the disaster. Similar to the classification of rainfall, the hazard classification of forest and land fires in Ogan Ilir District is divided into five levels. A higher level indicates a greater fire potential. All levels or classes have been categorized based on their respective scores and weights. This classification aims to facilitate the recognition of the level of danger resulting from forest and land fires (Lamat et al., 2021). The analysis of forest and land fire hazard levels in Ogan Ilir District reveals five risk classes: very high, high, medium, low, and not prone to forest and land fires (Figure 2).

North Indralaya is the sub-district with the highest forest and land fire hazard level, with incidents ranging from 80 to 164. Meanwhile, West Pamulutan and Pamulutan have

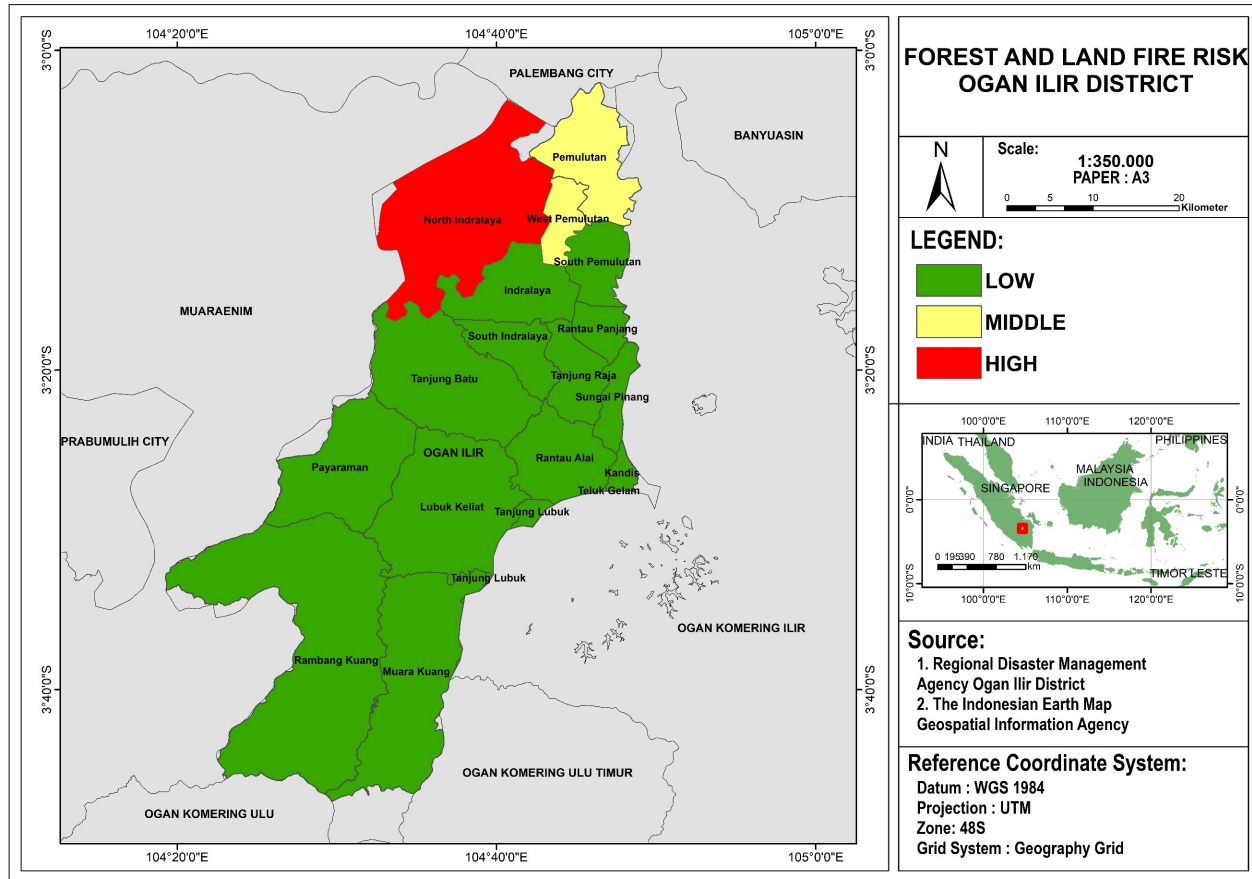


Figure 2. Forest and Land Fire Hazard Level

a lower (middle) level, with incidents ranging from 33 to 79 (refer to Figure 2). The high forest and land fire hazard level in these three sub-districts is attributed to the distribution of land cover types dominated by highly flammable moorland, shrubs, and grassland. Additionally, there is a relatively widespread distribution of peat soil types and low rainfall levels of ≤ 1500 mm/year (see Table 1). The low-level classification of forest and land fire hazard is observed across all sub-districts in Ogan Ilir District (Indralaya, South Indralaya, West Pamulutan, Rantau Panjang, Tanjung Raja, Sungai Pinang, Kandis, Rantau Alai, Tanjung Batu, and others), with incident counts ranging from 0 to 32 (Figure 2). The low level of forest and land fires can be attributed to the distribution of land cover types in forestry areas with high rainfall of 3000 mm/year and non-peat soil types (Vetrita and Cochrane, 2020).

Land and forest fires are not new disasters but routine occurrences yearly. Ogan Ilir District is one of several districts in South Sumatra Province prone to this disaster. According to data on forest and land fires in 2015, Ogan Ilir District ranked among the top ten areas with the largest burnt area, reaching 122.96 km² or 1.67% of the total available area (Budiningsih, 2016). Subsequently, forest and land

fires recurred in Ogan Ilir District in 2016, 2017, and 2018. In 2017, the burnt area reached 26.14 km², while in 2018, it amounted to approximately 39.25 km² (Lestari et al., 2019).

3.2 Distribution of Hotspots in Ogan Ilir District

A hotspot is a location on the earth’s surface with a relatively high temperature compared to the surrounding area, often indicating forest and land fires in the region. The number of hotspots correlates with the potential for such fires; the greater the number, the higher the risk. Hotspot confidence intervals are categorized into three classes: low (0%-30% confidence interval), medium (30%-80% confidence interval), and high (80%-100% confidence interval). A higher confidence level indicates a greater likelihood of fire occurrence (Tan et al., 2021).

The hotspot analysis in this study has a confidence interval of $\geq 80\%$, indicating a high category. Ogan Ilir District consistently recorded the highest number of hotspots from 2017 to 2022 compared to other districts. Over this period, Ogan Ilir District had 423 hotspots, with two in 2017, 121 in 2018, 207 in 2019, 76 in 2021, and 17 in 2022 (refer to Figure 3). Four sub-districts South Indralaya, North Indralaya, Pemulutan, and West Pemulutan consistently experienced

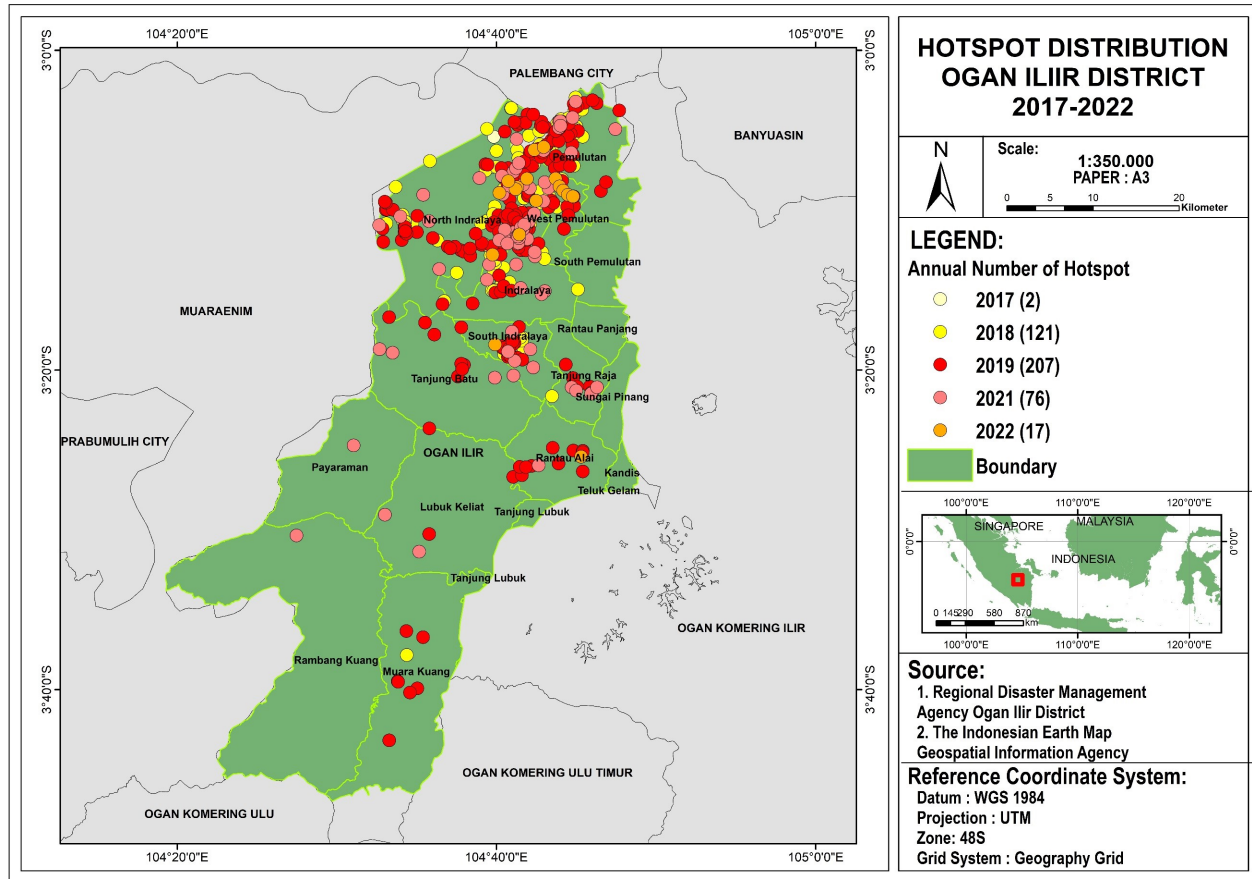


Figure 3. Distribution of Hotspots in Ogan Ilir District

forest and land fires (Figure 3). According to Wetlands International, human actions, whether deliberate or accidental, are primarily responsible for Indonesia’s forest and land fires, with no indication of natural causes prompting such incidents. The distribution of hotspots from 2017 to 2022 confirms this assertion. Hotspots often result from natural causes, indicating that areas with a high level of vulnerability have the potential for forest fire disasters. Thus, a relationship exists between forest and land fires in an area, their vulnerability level, and hotspot occurrence. Both vulnerability maps and hotspot points help in understanding and verifying the level of vulnerability to forest and land fires.

According to data from the South Sumatra Provincial Forestry Service, the size of forest and land fires in Ogan Ilir District has varied in recent years. In 2014, the burned area reached 17,728 hectares, then decreased to 12,297 hectares in 2015. In 2017, the burnt area dramatically reduced to 2,614 hectares but slightly increased in 2018 to 3,925 hectares. This data reveals yearly fluctuations in forest and land fires in the region, highlighting the need for serious attention in future disaster risk management and mitigation efforts.

The National Disaster Management Agency of South

Sumatra has reported that forest and land fires occur annually in Ogan Ilir District, with certain areas experiencing recurrent incidents. Hotspots often ignite these fires, rendering the region susceptible to forest and land fires. In particular, North Indralaya and Pemulutan areas are prone to routine fire incidents, indicating high vulnerability.

Forest and land fires on peatlands in Ogan Ilir District highlight the susceptibility of dry peat to combustion. Dry peat, an organic material, is highly combustible, decreasing its burning rate as moisture content increases (Palamba et al., 2018). Drought conditions on peatlands are typically observed on degraded land, which tends to experience drought during the dry season and waterlogging during the rainy season (Stirling et al., 2020). Peatland degradation can result from various human activities, including deforestation, land clearing for agriculture or plantations, and improper waste disposal (Medrilzam et al., 2014; Sakuntaladewi et al., 2024). These activities compromise the structure and quality of peatlands, reducing their capacity to store water. Consequently, this exacerbates drought conditions during the dry season, as the land cannot retain water effectively. Conversely, degraded land is prone to flooding during the rainy season due to its diminished ability to absorb water.

The rate of forest and land fires is primarily attributed to the conversion of forest areas into non-forest areas, mainly for establishing plantations and agricultural land. This conversion is often driven by encroachment by large companies and local communities (Voigt et al., 2021). Forest areas and the incidence of forest and land fires are closely interconnected, with extensive forest areas often experiencing high levels of degradation. This is the case in Ogan Ilir District, one of eleven priority districts targeted for peatland restoration. Sporadic forest and land fires occur annually in the region, primarily due to the use of fire for land clearing. The factors driving forest and land fires in Ogan Ilir District and South Sumatra generally align with previous research findings (Utomo et al., 2022).

Identifying the problems associated with forest and land fires involves considering several aspects. One of the main issues is the practice of land clearing by burning, often undertaken to reduce operational costs and support agricultural expansion and shifting cultivation. Land conflicts between communities and corporations also represent a significant concern, particularly regarding land use change and agricultural expansion (Fajrini, 2022). The drivers of forest and land fires encompass demographic, economic, technological, policy, institutional, and cultural factors. Land clearing for agriculture, shifting cultivation, and plantations are the primary drivers of forest and land fires. Additionally, land use change is influenced by factors such as topography, accessibility, and the distribution of urban and agricultural land (Tola, 2023; Antonio et al., 2012).

In addition, forest destruction is also caused by unsynchronised regulations, weak capacity, and roles of central and local government agencies, resulting in social instability and open access to state forest areas. Obstacles to policy synchronization also result from differing perceptions and high conflicts of interest between various stakeholders. Addressing the problem of forest and land fires requires collaborative efforts between the government, communities, and the private sector to identify and address the underlying root causes. There is a need to increase understanding of the importance of maintaining environmental sustainability, implementing sustainable policies, and strengthening law enforcement to reduce the risks and impacts of forest and land fires.

4. CONCLUSIONS

In 2017, there were two hotspots; in 2018, there were 121 hotspots; in 2019, there were 207 hotspots; in 2021, there were 76 hotspots; and in 2022, there were 17 hotspots. North Indralaya is the sub-district with the highest level of forest and land fire vulnerability, with the number of events ranging from 80 to 164. West Pamulutan and Pamulutan are at a high hazard level, with incidents ranging from 33 to 79. Meanwhile, Indralaya and South Indralaya sub-districts have a medium level of danger, with events ranging from 19 to 32. The low level of risk for forest and land fires is

spread across all sub-districts in Ogan Ilir District, with the number of events ranging from 1 to 18.

5. ACKNOWLEDGEMENT

The authors are grateful to Regional Disaster Management Agency Ogan Ilir District, South Sumatra, has facilitated the data of research.

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