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Research Article

Hotspot Spatial Patterns Using SNNP-VIIRS for Fire Potential Monitoring

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The province of East Kalimantan is officially designated as the State Capital because the area has the least risk of disaster, even though it cannot be separated from disasters such as forest and land fires. This study aims to determine the spatial pattern of hotspots using SNPP-VIIRS for monitoring potential fires. The research used the descriptive-analytic method to identify the research area and collect secondary data. Secondary data is spatial and nonspatial data consisting of hotspot data from the recording of the SNPP -VIIRS image, including frequency and distribution of hotspots. The data usage from 2012–2021 using SNPP-VIIRS morning and evening recordings. The study results show that the spatial pattern of potential hotspots in the capital city of a new country is quite varied. The spatial pattern of hotspots shows that Kutai Kartanegara Regency as one of the locations for the new State Capital, has the highest number of hotspots, namely 38,970 with the highest accuracy in East Kalimantan Province, namely, 1,616 (low), 36,253 (nominal), and 1,101 (high). The potential for fire disasters in Kutai Kartanegara Regency as an IKN location is high, so planning is urgently needed for future fire prevention, mitigation, and prevention strategies. The spatial pattern of hotspots is known, so it can be used to monitor potential fires and minimize fire occurrences.

1. Introduction

Disasters occur in developed and developing countries, including fire disasters. Fire disasters have occurred in Indonesia since 1980, occur almost every year, and have become a national and international disaster [1–3]. This disaster not only threatens life but also damages buildings [4] and local people's livelihoods [5, 6]. Forest and land fires have a detrimental impact on the environment [7–9], social and economic [7, 9, 10], health [9, 11], transportation [12], ecosystem damage leading to loss of biodiversity, and land degradation [2, 13–15].

The intensity of land and forest fires increases every year, especially during the dry season and when an el-Nino occurs [16]. Forests are an essential component of various ecosystem services [17, 18], such as for fauna and vegetation conservation [19] which increases significantly when the atmosphere changes and carbon dioxide concentrations increase. Namely to reduce greenhouse emissions [20–24], and it also reduces carbon sequestration, biodiversity conservation, supply water, and protection against soil erosion [25]. Forests are crucial for human welfare and environmental health [26]. Seeing this, forests must always be protected from disasters, including fires.

Fires in Indonesia are recurring events and contribute to the potential impacts of climate change [27–29]. The possible effects of climate change [30] from fires are numerous. Fires in Indonesia, including Kalimantan, have received international attention because they cause haze problems for neighboring countries [31–34], increase greenhouse gas emissions and CO2 concentrations, and raise the earth's surface temperature. The greenhouse gas that significantly impacts the environment is carbon dioxide (CO2) [35].

The increase in temperature causes the El-Nino Southern Oscillation (ENSO) phenomenon, which impacts global ecology and climate [36, 37]. Global climate change causes prolonged drought, one of the triggering factors for land and forest fires [38]. Burning forests and lands results in adverse effects such as loss of biodiversity, unpredictable climatic conditions, and destruction of terrestrial biodiversity ecosystems [39, 40]. Fires often occur in peat areas because peat when dry conditions reduce groundwater, making it more easily burned.

Indonesia is one of the developing countries with the world's largest peatland [41]. Peatlands in Indonesia are spread over Sumatra, Kalimantan, and Papua [42]. In 2015, the existing peatlands experienced fires and were damaged so that they decreased, including in East Kalimantan Province. Peat fires occur below the surface [43] and are difficult to extinguish. Subsurface peat fires will produce prolonged periods of smoke. Time to clear forest areas in peat ecosystems combined with fire results in uncontrolled fires [44]. Peatland fires in the long term will cause environmental degradation and cause environmental degradation. The most significant cause of environmental degradation is massive deforestation on peatlands.

In 2018, Forest Watch Indonesia (FWI) reported that East Kalimantan Province contributed the highest levels of deforestation and forest degradation. The deforestation and forest degradation rate doubled from 89 ha/year in 2017 to 157 ha/year in 2018. The official announcement of moving the capital city to East Kalimantan in 2019 added to the complexity of issues related to deforestation [45]. Many factors affect both physical and human forest fires in East Kalimantan [46–49]. Physical factors include fuel, land topography, hydrology, weather, and climate. Human factors are related to land management practices [48] and people's ignorance of clearing land by burning for land preparation [50].

Moving the location of the national capital will result in the conversion of land functions. Most of the existing land will be converted into agricultural, industrial, and residential areas. This land conversion creates new problems for the Environment and humans, one of which is land fires. As a result of land fires, it can also cause various other issues that result in losses such as social, economic, and human health being disrupted because the smog causes respiratory problems, environmental pollution, and ecosystem damage [12, 51–53], transportation system disturbances, conflicts between neighboring countries, and others.

The province of East Kalimantan is designated as the capital city of the State because the area has the least disaster risk, even though it is one of the provinces that cannot be separated from disasters such as forest and land fires [45]. Fires can be detected from the number of hotspots in each area [54]. Fire incidents are identified through the presence and intensity of hotspots [33, 48, 55]. Hotspot data for each area can be obtained from recording optical remote sensing images [56] and radar sensors [57].

Remote sensing imagery is an appropriate and accessible geospatial technology for monitoring fires [58]. Fires usually occur in huge areas, so the use of geospatial technology, in this case, remote sensing imagery, is the most appropriate choice to deal with fires [59]. The remote sensing image used in this research is the SNPP-VIIRS image which is then mapped for monitoring and developing strategies [60] for dealing with disasters. SNPP-VIIRS is currently used for regional and global hotspot detection, with a focus on hotspot detection [61–64]. Existing hotspots don't always appear as fires. Hotspots with a high level of confidence have a high potential to become fires [65–68]. The hotspots distribution in East Kalimantan is relatively high, especially in IKN locations (see Table 1).

It is feared that the distribution of hotspots is relatively high; it is feared that it will accelerate deforestation and land degradation, coupled with the relocation of IKN locations in the area. The rapid movement of deforestation and degradation will contribute to environmental damage, namely greenhouse gas emissions, loss of biodiversity, damage to peatlands, and a decrease in the quality of life of the world's people. It is necessary to conduct a particular study on fire disasters for better development plans and monitoring of potential fires in the future of the new capital city. Based on the above background, it is necessary to conduct a study entitled "Spatial Patterns of Hotspots using SNPP-VIIRS for Monitoring Potential Fires."

2. Experimental

2.1. Material. Globally [69], fire is a national and international disaster. The impact of haze fires reaches Malaysia, Singapore, and Brunei Darussalam, requiring serious attention [70–72]. Forest and land fires are a severe problem and have a significant impact on the ecosystem environment [52, 73]. The largest fires also occurred in Indonesia in 2015 due to El Nino [44, 74, 75]. Fires in Indonesia in 2015 mostly occurred in Kalimantan and Sumatra. Fires in Sumatra and Kalimantan occur almost every year, with large areas and long durations [76]. Fires occur due to natural and human factors [9, 77, 78].

Land fires after 2015 decreased from 2016 to 2018. Based on data released by Global Forest Watch, deforestation in Indonesia significantly decreased in 2017 and 2018. After 2018, deforestation increased again until 2019. Increased deforestation, followed by increased land degradation, caused long-term environmental problems. It is feared that deforestation and degradation will continue to grow as the National Capital City in DKI Jakarta will be moved to East Kalimantan Province. The reason for moving the state

Table 1: Number of hotspots recorded using SNPP-VIIRS in East Kalimantan in 2012–2021.

No.	District/cities	Total
1	Samarinda	737
2	Balikpapan	499
3	Kutai Kartanegara	38.970
4	Paser	24.439
5	Berau	20.215
6	Kutai timur	33.310
7	Bontang	1.204
8	Kutai barat	20.415
9	Penajam Paser Utara	4.086
10	Mahakam Ulu	4.314
	Total	148.189

capital to East Kalimantan Province is the decline in environmental carrying capacity and capacity in DKI Jakarta, marked by traffic congestion, pollution, a lowering of groundwater levels, and the emergence of various disasters [79]. It is feared that the relocation of the location of the national capital will also be followed by the emergence of various types of disasters, including fires.

Fire disasters often occur in the dry season [15]. Apart from the dry season, fires are also caused by deforestation in peat ecosystems. Fires can be detected by the number of hotspots in each area. Not always existing hotspots can cause fires. Hotspot data is taken from the remote sensing satellite recording SNPP-VIIRS. Hotspot data obtained from SNPP-VIIRS provides information on the hotspot location and the fire incident location. The point of occurrence of fires reflects fire events that are separate from each other and describes fire events that are still ongoing and cannot be extinguished. The frequency of fires increases every year, so more in-depth research is needed to determine the spatial pattern of hotspots using SNPP-VIIRS (see Figure 1).

The spatial pattern of hotspots can be identified using geospatial technology at various scales [80]. Geospatial analysis related to the spatial design of hotspots can find out which areas have a high potential for fires so as to prevent future fires [81]. The spatial pattern of hotspots is known so that future fire prevention, mitigation, and prevention strategies can be planned [82–84]. Seeing this, it is imperative to research the spatial pattern of hotspots, especially in the capital city of a new country. This research on spatial patterns of hotspots is carried out to support the smooth development planning for the location of the national capital and prepare communities in IKN locations to be resilient to disasters.

2.2. Method. The research location includes the location of the New State Capital in the Province of East Kalimantan. East Kalimantan Province is one of the provinces with the potential for forest and land fires to occur almost every year. This study uses descriptive-analytical methods to identify research areas and collect secondary data. Secondary data were obtained from government agencies in the form of spatial and nonspatial data consisting of hotspot data from the recording of SNPP-VIIRS imagery, frequency, and hotspots distribution. The study took the observation time of hotspot distribution from 2012 to 2021 using SNPP VIIRS. SNPP VIIRS recorded morning and evening [85, 86]. Research variables can be seen in Table 2.

The spatial pattern of hotspots is seen from the intensity and distribution of fire occurrences in each region. The power and distribution of fires were carried out using a hotspot data approach [33, 48]. The hotspot data used is a hotspot with a confidence level of 30% [55, 87]. Hotspot data 30% belongs to the nominal to the high class, which shows a relatively high predictive rate of fire events in the field and requires precautions that require vigilance [54, 88–89] (see Table 3).

The analytical method used is spatio-temporal analysis to show the distribution of fire characteristics that occur, both spatially (space) and temporally (time) [33, 49, 55]. The data processing and analysis technique is based on the Geographic Information System, namely ArcGIS 10.1 software. The analysis is divided into two stages of modeling, namely the scoring and overlay models. The scoring model is the stage of scoring and weighting on raster data, in which there is a mathematical operation process according to the parameters. The overlay stage is combining the two layers to create a new output feature class that contains information from both inputs [90]. Density analysis of fire events was carried out [49, 91]. This is done to identify potential fires in each research area so that potential fires can be identified, which can then be monitored for fires.

3. Result and Discussion

Forest and peatland fires to overcome them by knowing the distribution of hotspots, making laws for those who burn land intentionally will be imprisoned, building canals/reservoirs, and constructing boreholes [92]. A hotspot is an area that has a higher temperature than its surroundings, has the potential to cause fires, and can be detected by satellite [66, 76]. The satellite used to detect hotspots in this study is SNPP-VIIRS.

The location of IKN is East Kalimantan Province, one of the provinces with forest and land fires that ranks third in Indonesia [93]. Seeing this, it is essential to conduct this research so that the planning and implementation of disaster management in the new IKN locations can be more effective. The research was conducted by taking hotspot data from 2012 to 2021. The existing hotspot data processing results obtained the distribution and distribution of hotspots in East Kalimantan in each district. The distribution of hotspots in East Kalimantan fluctuate every year. After 2015 had experienced a decline, in 2019 there was an increase again in each region. The results of hotspot processing in 2012–2021 show that Kutai Kartanegara Regency, as the new IKN location, has the highest number of hotspots, namely 38,970 (see Tables 4 and 5).

The rate of fire occurrence or the number of hotspots is identified using the fire density value. Fire density can be seen from the level of confidence, namely low, medium and high confidence levels. The higher the hotspot density and confidence level, the greater the potential fire threat [48, 55].

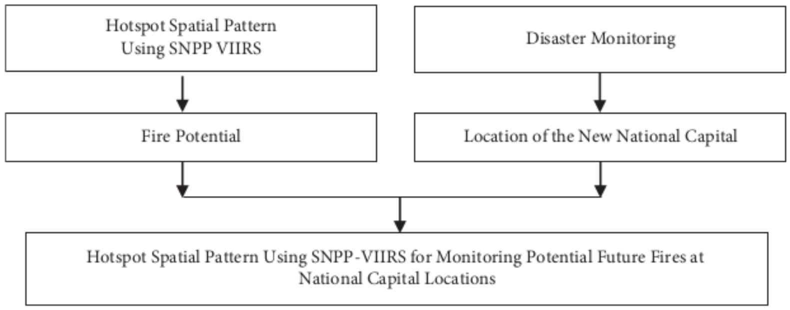

Figure 1: Hotspot spatial pattern using SNPP-VIIRS for monitoring fire potential.

Table 2: Variable research.

Nos	Variables	Indicators	Data collection
(1)	Hotspot spatial pattern	(a) Hotspot, (b) Spatial pattern (c) SNPP-VIIRS	Secondary data, mapping, and field observation
(2)	Fire potential	Disaster monitoring	Secondary data, mapping, and field observation

Table 3: Hotspot confidence level classification.

Confidence levels	Classes	Action
0% ≤ C < 30%	Low	Important to note
30% ≤ C < 80%	Nominal	Alert
80% ≤ C < 100%	High	Immediate response

Source: [54].

Table 4: Distribution of hotspots in East Kalimantan Province in 2012–2021.

Nos.	District/city	Years									
		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Samarinda	45	24	121	206	108	20	55	120	37	1
2	Balikpapan	28	46	90	210	32	21	21	37	14	—
3	Kutai Kartanegara	3.269	2.328	6.704	13.624	4.170	794	2.160	4.933	935	53
4	Paser	1.665	836	5.083	11.155	554	355	968	3.094	690	39
5	Berau	1.996	1.394	3.467	6.437	639	593	1.324	3.518	842	5
6	Kutai timur	2.265	1.896	3.165	10.779	5.171	942	2.248	4.597	2.160	87
7	Bontang	113	87	181	329	237	78	69	68	42	—
8	Kutai barat	1.848	1.359	3.707	9.264	371	333	945	2.102	473	13
9	Penajam Paser Utara	307	173	602	2.601	139	38	81	112	32	1
10	Mahakam Ulu	456	438	525	1.075	309	210	418	486	397	—
	Total	11.992	8.581	23.645	55.680	11.730	3.384	8.289	19.067	5.622	199

The greater the potential danger of fire in an area, the greater the environmental damage. The high number of hotspots in the research area is located in the new IKN location, namely, in Kutai Kartanegara Regency.

Kutai Kartanegara Regency has the highest number of hotspots with the highest accuracy in East Kalimantan Province, namely, 1,616 (low), 36,253 (nominal), and 1,101 (high) (see Table 5). The results of processing the spatial pattern of hotspots can be seen as the potential for fires in each existing area. The potential for fires from the results of spatial pattern processing using spatial analysis indicates that Kutai Kartanegara Regency is one of the locations that will become a new IKN location and has a high potential for fire disasters. Spatial analysis can determine fire density and the area burned repeatedly [94]. Spatial analysis helps determine priority areas in the handling forest and land fires [95]. Seeing the high potential for fire disasters in Kutai Kartanegara Regency, it is urgently needed to plan for future fire prevention, mitigation, and prevention strategies [82–84] (see Figure 2). In addition, it is also necessary to carry out regular monitoring and early warning quickly so that larger negative impacts can be minimized, including loss of life, property, and environmental damage [96].

Table 5: Hotspot confidence level in East Kalimantan Province 2012–2021.

No.	District/city	Total	Total		
			Low	Nominal	High
1	Samarinda	737	17	715	5
2	Balikpapan	499	7	489	3
3	Kutai Kartanegara	38.970	1.616	36.253	1.101
4	Paser	24.439	1.180	22.609	650
5	Berau	20.215	803	18.883	529
6	Kutai timur	33.310	1.191	31.440	679
7	Bontang	1.204	32	1.155	17
8	Kutai barat	20.415	931	18.922	562
9	Penajam Paser Utara	4.086	165	3.804	117
10	Mahakam Ulu	4.314	199	3.940	175
	Total	148.189	6.141	138.210	3.838

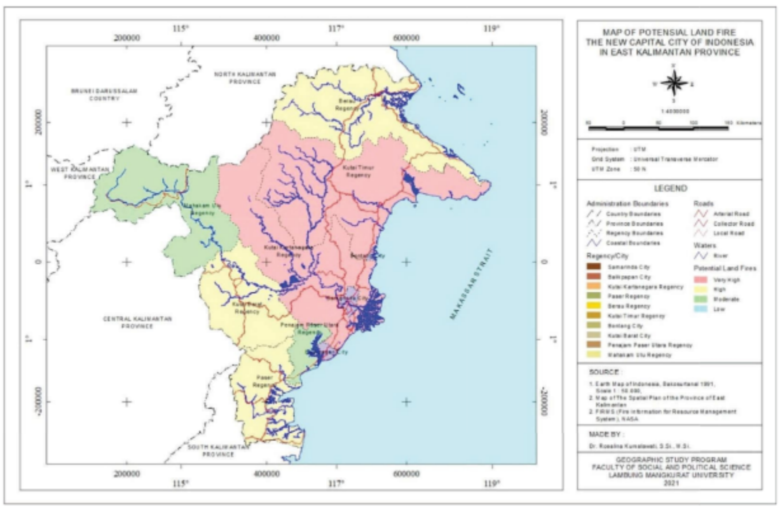

Figure 2: Map of potential hotspot distribution in East Kalimantan Province.

4. Conclusion

(a) Kutai Kartanegara Regency as the new IKN location has the highest number of hotspots, namely, 38,970

(b) Kutai Kartanegara Regency has the highest number of hotspots with the highest accuracy in East Kalimantan Province, namely 1,616 (Low), 36,253 (Nominal), and 1,101 (High)

(c) The potential for fire disasters in Kutai Kartanegara Regency as an IKN location is high, so planning is urgently needed for future fire prevention, mitigation, and prevention strategies.

Data Availability

The data in this study were obtained from reading hotspots through SNPP VIIRS images.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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