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THE RELATIONSHIP BETWEEN RAINFALL AND LAND COVER ON THE NUMBER OF HOTSPOTS IN LORE LINDU NATIONAL PARK

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ABSTRACT

Forest and land fires in Indonesia need attention in mitigation efforts, specifically in conservation areas. Lore Lindu National Park (LLNP) is a conservation area that plays a role in preserving endemic plants and animals and their habitats. Forest fires often occur in the Lore Lindu National Park area, especially in the savanna area. Research on the factors that influence forest fires in LLNP needs to be carried out to protect and prevent the risk of forest fires to protect the ecosystem. This study aims to analyze the relationship between rainfall and land cover on the number of hotspots as an indicator of forest fires in LLNP in 2017-2021. Thus, preventive strategies can be carried out as early as possible to prevent forest fires. This research was conducted by spatially and statistically analyzing 2017-2021 rainfall data in Sigi and Poso Regencies, hotspot data from the TERRA/AQUA, SNPP, and MODIS-NASA satellite in 2017-2021 in LLNP, and LLNP land cover data. In statistical analysis, rainfall data for hotspots was analyzed using Bivariate Pearson, and land cover data for hotspots was analyzed spatially using ArcMap with categorical analysis. The results showed 55 hotspots in LLNP from 2017-2021. The Bivariate Pearson correlation test results between rainfall and hotspots are -0.028. The relationship between rainfall and hotspots shows a non-directional correlation. The lower the rainfall intensity, the more hotspots are found. Spatially, the highest number of hotspots occurred in areas with the land cover of secondary dryland forest types, with a total of 29 spots. LLNP will endeavour to increase security patrols in certain seasons and cover types that have the potential for forest and land fires.

Keywords: forest fires, hotspots, land cover, lore lindu, rainfall

INTRODUCTION

Forest fires in Indonesia havebecome national and global environmental issues (Ananda *et al.* 2022). Forest fires affects air quality, landscapes and ecosystems, soil and water quality, and causes major problems with greenhouse gas emissions (Badri *et al.* 2018). Forest fires occur due to climatic or artificial factors (Saputra *et al.* 2021). In addition, forest fires in Indonesia happen almost every year. In 2015, Indonesia's forest fires were the largest after forest fires in 1997 and 1998 (Endrawati *et al.* 2017). The government is still trying to prevent and deal with forest fires in Indonesia.

The government campaigns with the community to prevent forest fires in Indonesia, (Muzaki *et al.* 2021), strengthens policies, and takes concrete actions to protect forest areas. One of the government's policies in protecting forest and land areas is through the Forestry and Other Land Uses (FOLU) Net Sink 2030 program. FOLU Net Sink is a condition where the amount of carbon absorbed by forests equals or exceeds the carbon emissions produced. Efforts to prevent deforestation and forest fires are one of crucial mitigations in maintaining the earth cycle and the climate crisis so that emissions released by forests can be greater in 2030. Another effort to control forest and land fires is monitoring by remote sensing. Remote sensing is an approach to obtaining various information such as areas, objects, and data analysis without direct contact with the areas, objects, and studies being analyzed (Utomo *et al.* 2017). One of the remote sensing methods to detect forest fires is

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to use satellite image data, such as hotspot data. Hotspots can be used as indicators of forest fires with the MODIS (*Moderate Resolution Imaging Spectroradiometer*) sensor (Giglio *et al.* 2016). The satellite data used to detect hotspots is TERRA/AQUA, SNPP, and NASA satellite with the MODIS sensor (Indradjad *et al.* 2019). Data related to forest fires can be accessed through the Directorate General of Climate Change (PPI) website of the Ministry of Environment and Forestry via https://sipongi.menlhk.go.id. The Directorate General of PPI has also launched the Si Pongi application to monitor real-time hotspots in Indonesia.

Forest fires are generally caused by human activities (Dini *et al.* 2022). Cochrane (2013) generally described how human activities cause forest fires through deforestation, agriculture, and animal husbandry. Forest fires affect the condition of land cover, structure, density, composition, and forest productivity (Fitria *et al.* 2021). Moreover, deforestation, land cover changes, population growth, and climate deviations cause forest fires (Harrison *et al.* 2009). In addition to human factors, natural factors also affect forest fires, one of which is climate (Putra & Husni 2021). This is because the climate (temperature, humidity, rainfall, and wind speed) can affect the dryness of surface fuels, the amount of oxygen, and the spread of fire (Syaufina 2008). Low rainfall causes a prolonged dry season which impacts drought. This condition increases the level of vulnerability to forest fires. Other factors that influence the occurrence of forest fires are land cover conditions, soil types, and other biophysical environmental factors (Yusuf *et al.* 2019).

Rainfall is the height of rainwater that falls on a flat surface with conditions that do not evaporate, seep, and flow (Mulyono 2016). The unit of rainfall in Indonesia is expressed in millimeters (mm), which means that one square meter area on a flat surface accommodates one millimeter of water or one liter of water (Prawaka *et al.* 2016). Rainfall conditions play an important role in the hydrological cycle on the earth's surface. Low rainfall impacts a prolonged dry season and can trigger forest and land fires.

Lore Lindu National Park (LLNP) is one of the conservation areas in Central Sulawesi. Geographically, LLNP is located at coordinates 119^{o} 90' - 120^{o} 16' east longitude and 1^{o} 8' - 1^{o} 3' south latitude. Administratively, LLNP is located in Sigi Regency and Poso Regency and is surrounded by 71 buffer villages. The area of LLNP is 215,733.70 ha and has 1,532 hectares of a savanna ecosystem, which is prone to forest fires. LLNP is important in preserving endemic plants and animals and their habitats. Forest and land fires often occur within the LLNP area. These fires generally occur during the summer with low rainfall and in open areas. Efforts to protect and prevent the risk of forest fires must be carried out so that the ecosystem that becomes the habitat of wild plants and animals can be maintained.

Many researchers have investigated the level of forest fire susceptibility, including examining the relationship between hotspots and rainfall in Aceh Barat Regency (Saharjo & Nasution 2021); and analyzing forest fire susceptibility in various climates (rainfall) and vegetation (land cover, biomass, and humidity) (Jaya *et al.* 2007). However, research on the level of forest fire susceptibility in LLNP has never been published. Therefore, this research needs to be carried out to analyze the relationship between rainfall and land cover on the number of hotspots as an indicator of forest fires in LLNP in 2017-2021 so that preventive measures in preventing forest fires can be carried out as early as possible.

MATERIALS AND METHODS

This research was conducted from July to September 2022 in the LLNP. This study used stationaries, laptops with ArcMap GIS 10.5 software, Microsoft Office Word, Microsoft Excel, and SPSS 22. The materials used hotspot data from the TERRA/AQUA satellites, SNPP, and MODIS-NASA (with a medium (30 - 79%) and high (80 - 100%) confidence level) for the period 2017 to 2021 in LLNP, monthly rainfall data for Sigi District (Gimpu and Sungku Stations) and Poso District (Doda, North Lore, Lore Piore, and Maholo Stations) for the 2017-2021 period from the Meteorology, Climatology, and Geophysics Agency (BMKG), and LLNP land cover data which is the result of LLNP's proprietary land cover analysis and in collaboration with a third party.

The initial stage in the data analysis process classifies hotspot data for the 2017-2021 period based on time (month and year). The distribution of hotspots using TERRA/AQUA satellites, SNPP, and MODIS-NASA data accessed via https://sipongi.menlhk.go.id. Hotspot data in Central Sulawesi Province is overlaid with the *shapefile* map of the LLNP area using the ArcMap GIS ver 10.5 application. Furthermore, the hotspot data in Central Sulawesi Province is processed with a map *shapefile* of the LLNP area through the intersect function so that only hotspot data remains in the LLNP. Rainfall data for 2017-2021 is processed with a map of the LLNP area through the Inverse Distance Weighted (IDW) function in the ArcMap GIS ver 10.5 application. The radius used is a standard radius with a value of five times the output raster cell size. This stage is carried out to determine areas that have the potential for high, medium and low rainfall in the LLNP area. Rainfall classification refers to the classification level of the Meteorological, Climatological and Geophysical Agency (BMKG). Hot spot data in LLNP is overlaid (intersect) with a map of rainfall conditions in LLNP to determine the suitability between areas with certain rainfall conditions and the distribution of hotspots within them. Next, the hotspot data in the LLNP is overlaid with the *shapefile* of the land cover map in the LLNP. This stage is carried out to determine the distribution of hotspots based on land cover in LLNP.

In statistical data analysis, *hotspot* data and rainfall data analyzed using *Bivariate Pearson* with SPSS ver 22 application. This step was carried out to determine the correlation value between hotspots and rainfall in LLNP. The Bivariate Pearson correlation equation is as follows:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x)^2}.\sqrt{n\sum y^2 - (\sum y)^2}}$$

Where:
r = Correlation coefficient
x = Independent variable
y = Dependent variable
n = Number of data

RESULTS AND DISCUSSION

Hotspots Distribution

A hotspot is a term for a pixel with a temperature value above a certain threshold from the interpretation of satellite imagery, which can be used as an indication of forest and land fires (The Ministry of Environment and Forestry 2016). Hotspots observed as indicators of forest fires are generally recordings from the MODIS sensor. Data from the TERRA/AQUA, SNPP, and MODIS-NASA satellites show hotspots recorded by sensors within the LLNP. The data used with a medium (30 - 79%) and high (80 - 100%) confidence level) Based on the results of monitoring hotspots in LLNP from 2017 to 2021, the number fluctuates yearly (Table 1).

Table 1 The number of hotspot in TNL

Year	Number of Hotspot
2017	6
2018	9
2019	16
2020	13
2021	11
Total	**55**

The number of hotspots from 2017 to 2021 is 55 spots. During the last five years, hotspot patterns increased from 2017 to 2019, with 6, 9, and 16 spots, respectively. The most hotspots occurred in 2019, with a total of 16 spots. Then, it decreased in the next two years with 13 and 11 spots, respectively (Figure 1).

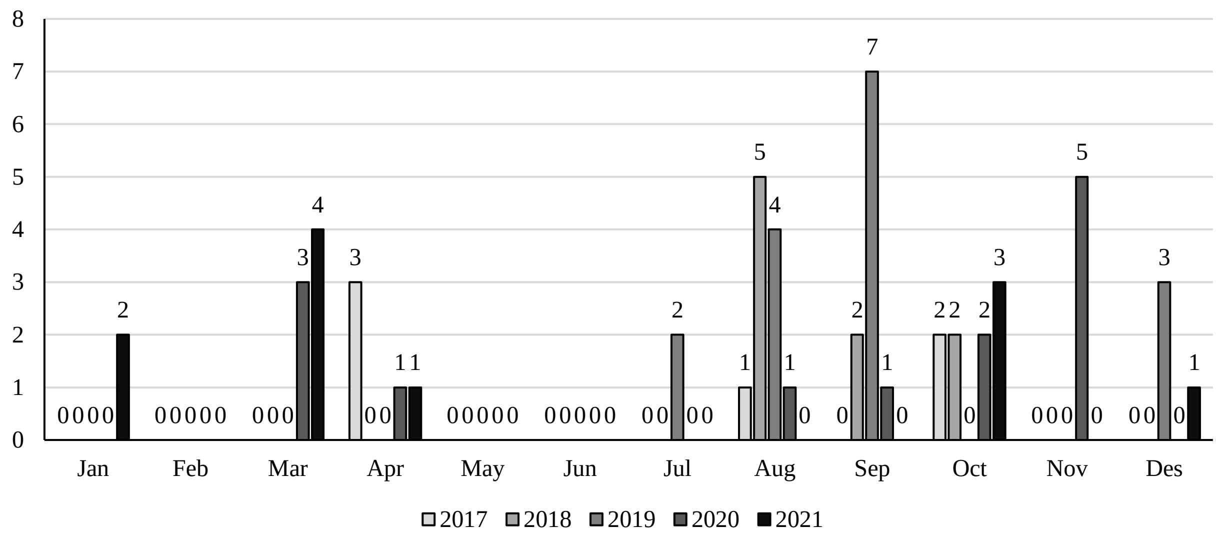

Figure 1 The number of hotspots each month from 2017 to 2021

The hotspot pattern occurring every month from 2017 to 2020 showed a low intensity at the beginning of the year, but in 2021 it showed a high intensity. The number of hotspots every month in the last five years showed an increasing pattern from July to November. At the end of the year, the hotspot decreased until the beginning of the following year. The highest number of hotspots occurred in September 2019, with seven spots. Meanwhile, in February, May, and June, no hotspots were found from 2017 to 2021 because of the changes in rainfall intensity, which were higher from the beginning to the middle of the year than at the end of the year. Rainfall is one of the factors that affect the emergence of hotspots. According to (Prabowo *et al.* 2020), the condition of high rainfall is caused by the appearance of convective clouds that cause rain, thus preventing the emergence of hotspots.

The relationship between rainfall and hotspots

The Meteorology, Climatology, and Geophysics Agency (BMKG) divides the classification of monthly rainfall into three categories: dry season (0-100 mm/month), humid season (100-200 mm/month), and wet season (>200 mm/month). Based on the observations of rainfall data from 2017 to 2021, the average rainfall in Sigi and Poso Provinces overall is 162,45 mm/month in the category of medium-level rainfall or humid conditions. The highest rainfall was recorded in 2017, with an average of 177 mm/month. The number of hotspots in 2017 was recorded at six spots, the year with the least hotspots in five years. Rainfall recorded in five years from June to September has a lower intensity than the average rainfall in other months. On the other hand, hotspots that occur from July to October have a fairly high number compared to other months. Therefore, the higher the intensity of rainfall, the fewer the number of hotspots found (Figure 2).

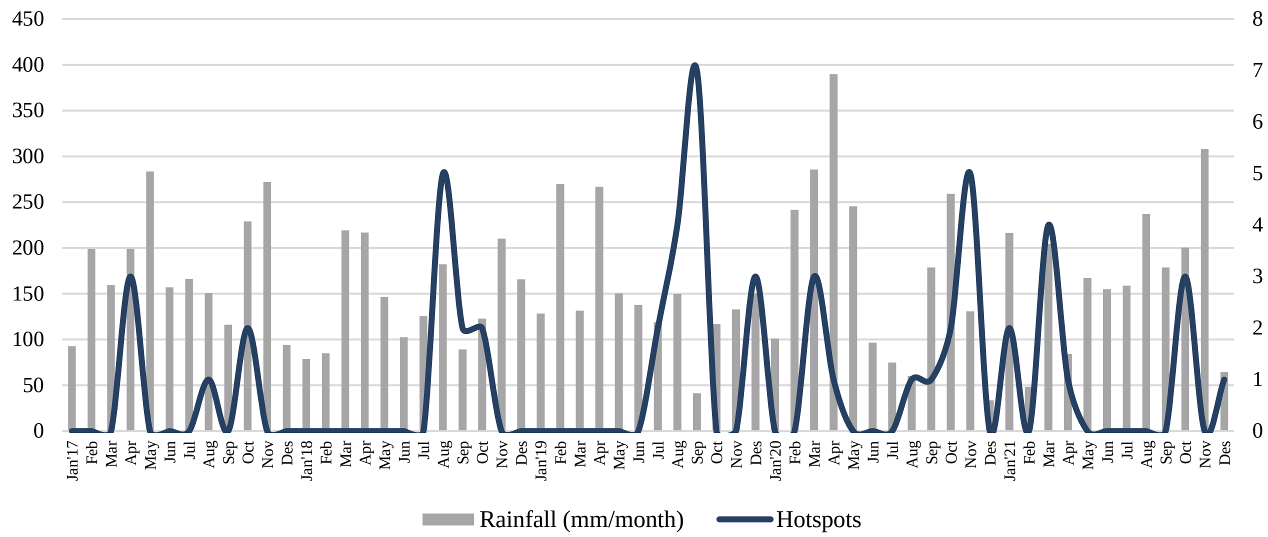

Figure 2 Graph of the relationship between rainfall and the number of hotspots in LLNP from 2017 to 2021

Based on the distribution map of the hotspots to rainfall, the presence of hotspots is more widely distributed in areas with categories of humid and dry season. The number of hotspots in the dry season is 14 spots (22.45%), 39 spots in the humid season (70.91%), and 2 spots in the wet season (3.64%) (Figure 3). The lower rainfall intensity causes this condition in Poso Regency (average 130.50 mm/month) than the rainfall intensity in Sigi Regency (average 226.34 mm/month). The number of hotspots distributed in areas with dry and humid conditions is estimated to be influenced by the El Nino phenomenon (Hadiyani & Nurhayati, 2022), which inhibits the growth of clouds that cause rain so that air and soil conditions become drier. It shows that high and low rainfall intensity in an area can control the number of hotspots in that area.

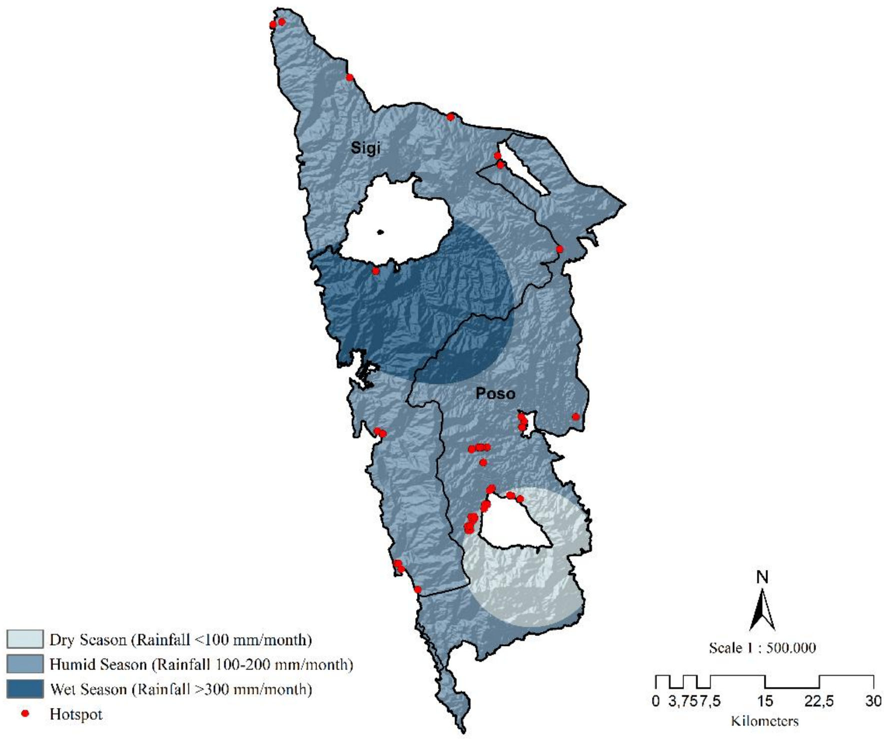

Figure 3 Distribution of hotspots based on rainfall in LLNP

The Bivariate Pearson correlation test results between rainfall and hotspots are -0.028, which shows a negative correlation in the relationship between rainfall and the number of hotspots. It means that the two have a non-directional correlation. Thus, the higher the rainfall intensity, the smaller the number of hotspots found, and vice versa. It is in line with the results of Syaufina & Sukmana (2008), that the increase and decrease in the number of hotspots in a certain month are related to the increase and decrease in rainfall intensity. The value of -0.028 in the analysis of rainfall and the number of hotspots interprets the two as having a very low correlation. The P-Value between rainfall and hotspot shows 0.833. This value is above the 0.05 significance value limit (5% error probability), so rainfall cannot be used as the only factor/parameter that affects the number of hotspots (Table 1). Syaufina & Hafni (2018) described the P-Value is higher than the maximum error limit value because the hotspot is not normally distributed, and there is a difference in the time of occurrence.

Table 1 The results of the statistical test of the correlation of rainfall with the number of hotspot in LLNP

		Rainfall	Hotspot
Rainfall	Pearson Correlation	1	-.028
	Sig. (2-tailed)		.833
	N	55	55
Hotspot	Pearson Correlation	-.028	1
	Sig. (2-tailed)	.833	
	N	55	55

According to Aflahah *et al.* (2019), rainfall is closely related to temperature. Temperature changes can affect rainfall patterns which impact the length of the dry season, thereby allowing the potential for forest and land fires to occur. The rainfall factor does not significantly influence the number of hotspots in LLNP, so it is necessary to analyze other climatic factors such as temperature, humidity, and others.

The relationship between land cover and hotspots

Land cover is a physical form of an object that covers land and is natural (Utomo *et al.* 2017). Forest fires can occur due to the influence of the land cover type on the surface of an area. Different types of land cover affect the characteristics of the material on it to burn. The hotspots mapping to land cover in LLNP (data from the LLNP and third-party analyses) shows that hotspots were recorded in five types of land cover: 29 spots of secondary dryland forest (52.73%), 16 spots (29.09%) of savanna, 8 spots (14 .55%) of plantations, 1 spot (1.82%) of scrubland and dry riceland, respectively (Figure 4).

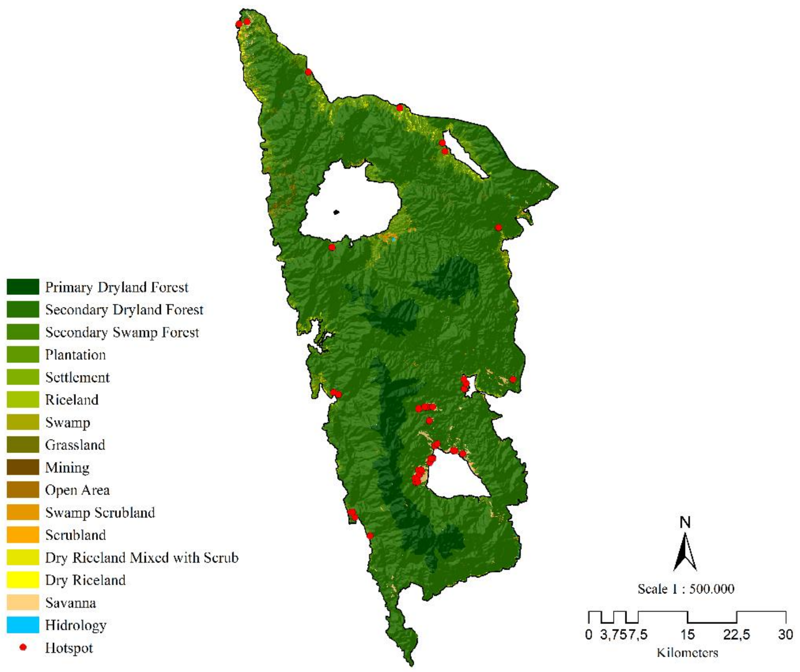

Figure 4 Distribution of hotspot based on land cover in LLNP

Secondary dryland forest is the most extensive type of land cover in the LLNP area, with an area of 174,411.20 ha. The condition of the secondary dryland forest that covers most of the LLNP area causes the hotspots to be more widely distributed. According to Sinaga & Darmawan (2014), secondary dryland forest is the appearance of lowland, mountainous, and hilly forests that have shown the occurrence of former logging activities. It indicates that the secondary dryland forest type land cover is an area where human activities utilize forest products. Figure 4 shows that the type of secondary dryland forest land cover is close to the settlements around the LLNP area, so human activities possibly cause the hotspot for this type of land cover. Like secondary dryland forests, land cover types of plantations and dry riceland are also areas that local residents widely use. Plantation activities have a close relationship with land clearing so forest fires can occur intentionally by humans. Savanna and scrubland are the areas recorded as having a total of 16 and 1 hotspot, respectively. These two types of land cover have the characteristics of areas with no forest and vegetation. This condition causes higher temperatures, more flammable surfaces, or low rainfall during the dry season.

Based on the distribution pattern of hotspots in the LLNP, the number of hotspots on the edge of the LLNP is higher than the center of the LLNP area. This is because the hotspots recorded in the LLNP are mostly caused by human activities related to plantation activities by local residents. This has an impact on the incidence of forest fires which are more often found around areas that are easily accessible by local residents. Whereas in the central area of the area no hotspots were found because the area is far from the reach of human activity so no hotspots were found in the middle of the LLNP area. Based on Rasyid (2014), forest fires are generally caused by the human factor. Some of the causes of forest fires due to human activities include: (1) traditional farming system, (2) forest clearing, and (3) structural causes.

Impact on biodiversity

Forest fires have an impact on biodiversity in these ecosystems. Burning forests will damage ecosystem conditions and are difficult to restore. Ecosystem conditions that experience forest fires will cause loss of vegetation on the land surface and the occurrence of open areas. The opened area in an ecosystem has an impact on the loss of several species of plants and animals in that area. The loss of these species also threatens the existence of species that have a high conservation status of rarity so that some species are threatened with extinction. Several species of important and rare value generally grow in forest areas with dense vegetation, so if an opened area occurs in an ecosystem it will threaten the extinction of these species. Lore Lindu National Park is a nature conservation area that is home to several protected and endangered species. There are endemic species such as tarsier, anoa, maleo, Sulawesi hornbill, and several other exotic flora. Forest and land fires are a threat to the existence of these species, so efforts to protect and preserve these species in their ecosystems need to be increased, especially in certain seasons and in certain types of land cover.

CONCLUSION

The 55 hotspots in LLNP were recorded from 2017 to 2021. The most hotspots were in 2019, with a total of 16 hotspots. The hotspot pattern fluctuates yearly, with hotspot conditions increasing from July to October. The number of hotspots each year is influenced by conditions of rainfall intensity. The two variables show a non-directional correlation, meaning that the higher the rainfall, the lower the hotspot. The distribution pattern of hotspots is more common in Poso Regency, with an average rainfall intensity lower than the average rainfall intensity in Sigi Regency. The distribution of hotspots by type of land cover shows that the number of hotspots is more in the secondary dry land forest area, as many as 29 points. The condition of hotspot distribution based on land cover occurs around the settlements in LLNP and is indicated to occur artificially by humans. Rainfall and land cover can be used as factors that affect the presence of hotspots in LLNP. However, in addition to rainfall, it is necessary to correlate it with other climatic factors such as humidity and temperature for a more comprehensive study result. This research is limited to spatial analysis of the relationship between hotspot data and land cover. The next recommendation is to analyse how socio-economic factors affect the needs of the community to get their needs in the forest, which has the potential for land clearing activities in the area.

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REFERENCES

Aflahah E, Hidayati R, Hidayat R, Alfahmi F. 2019. Pendugaan hotspot sebagai indikator kebakaran hutan di Kalimantan berdasarkan faktor iklim [Hotspot asummption as a forest fire indicator in Kalimantan based on climate factor]. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (Journal of Natural Resources and Environmental Management). Bogor, ID, 9(2), pp. 405-418. doi: 10.29244/jpsl.9.2.405-418.

Ananda FR, Purnomo EP, Fathani AT, Salsabila L. 2022. Strategi pemerintah daerah dalam mengatasi kebakaran hutan dan lahan di Kabupaten Kotawaringin Barat [Regional government strategy in dealing with forest and land fires in West Kotawaringin Regency]. Jurnal Ilmu Sosial Dan Humaniora, 11(2), 1 73-181.

Badri M, Lubis DP, Susanto D, Suharjito D. 2018. Sistem komunikasi peringatan dini pencegahan kebakaran hutan dan lahan di Provinsi Riau [Early warning communication system for preventing forest and land fires in Riau Province]. Jurnal PIKOM (Penelitian Komunikasi Dan Pembangunan), 19(1), 1-16.

Cochrane M. 2013. Current fire regimes, impacts and likely changes-V: Tropical South America. In: J. G. Goldammer (ed.) Vegetation fires and global change: Challenges for concerted International action. A white paper directed to the United Nations and international organiz. Germany: Kessel House.

Dini NLK, Jauhari A, Rachmawati N. 2022. Prediksi nilai karbon yang hilang akibat kebakaran hutan dan lahan di Kota Banjarbaru [Prediction of the value of carbon lost due to forest and land fires in Banjarbaru City]. Jurnal Sylva Scienteae, 5(3), 372-378.

Endrawati, Purwanto J, Nugroho S, Agung R. 2017. Identifikasi areal bekas kebakaran hutan dan lahan menggunakan analisis semi otomatis citra satelit landsat [Identification of areas where forest and land fires have occurred using semi-automatic analysis of Landsat satellite images]. Seminar Nasional Geomatika 2017: Inovasi Teknologi Penyediaan Informasi Geospasial Untuk Pembangunan Berkelanjutan, 273-282.

Fitria P, Jauhari A, Rianawati F. 2021. Analisis tingkat kerawanan kebakaran hutan dan lahan berbasis penginderaan jauh di Kecamatan Karang Intan [Analysis of the level of vulnerability to forest and land fires based on remote sensing in Karang Intan District]. Jurnal Sylva Scienteae, 4(6), 1110-1120.

Giglio L, Schroeder W, Justice CO. 2016. The collection 6 MODIS active fire detection algorithm and fire products. Remote Sensing of Environment, 178, 31-41. doi: 10.1016/j.rse.2016.02.054

Hadiyani F, Nurhayati A. 2022. Hotspot analysis in 2015 and 2019 at Ogan Komering Ilir district South Sumatra Province. IOP Conf. Series: Earth and Environmental Science, 959 012056

Harrison ME, Page SE, Limin SH. 2009. The global impact of Indonesian forest fires. Biologist, 56(3), 156-163.

Indradjad A, Purwanto J, Sunarmodo W. 2019. Analisis tingkat akurasi titik hotspot dari S-NPP VIIRS dan TERRA/AQUA MODIS terhadap kejadian kebakaran [Analysis of the accuracy level of hotspot points from S-NPP VIIRS and TERRA/AQUA MODIS regarding fire events]. Jurnal Penginderaan Jauh Dan Pengolahan Data Citra Digital, 16(1), 53-60.

Jaya INS, Purnama ES, Arianti I, Jaruntorn B. 2007. Forest Fire Risk Assessment Model and Post-Fire Evaluation Using Remote Sensing and GIS: A Case Study in Riau, West Kalimantan And East Kalimantan Provinces, Indonesia. The Forest Restoration and Rehabilitation Training Course and Workshop, Viiki Tropical Resources Institute (VITRI), University of Helsinki, Finland.

Kementerian Lingkungan Hidup dan Kehutanan. 2016. Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor P.32/MenLHK/Setjen/Kum.1/3/2016 tentang Pengendalian Kebakaran Hutan dan Lahan [Regulation of the Minister of Environment and Forestry Number P.32/MenLHK/Setjen/Kum.1/3/2016 concerning Control of Forest and Land Fires]. Jakarta: Kementerian Lingkungan Hidup dan Kehutanan.

Mulyono D. 2016. Analisis Karakteristik Curah Hujan Di Wilayah Kabupaten Garut Selatan [Analysis of Rainfall Characteristics in the South Garut Regency Area]. Jurnal Konstruksi 12(1), 1-9. doi: 10.33364/konstruksi/v.12-1.274.

Muzaki A, Pratiwi R, Az Zahro SR. 2021. Pengendalian kebakaran hutan melalui penguatan peran polisi kehutanan untuk mewujudkan sustainable development goals [Controlling forest fires through strengthening the role of forestry police to realize sustainable development goals]. LITRA: Jurnal

Hukum Lingkungan, Tata Ruang, Dan Agraria, 1(1), 22-44. doi: 10.23920/litra.v1i1.579.

Prabowo MR, Koesmaryono Y, Faqih A, Sopaheluwakan A. 2020. Karakteristik spasial dan temporal hotspot di Pulau Sumatera [Spatial and temporal characteristics of hotspots on Sumatra Island]. Jurnal Meteorologi dan Geofisika, 21(1), 9-19. doi: 10.31172/jmg.v21i1.674.

Prawaka F, Zakaria A, Tugiono S. 2016. Analisis data curah hujan yang hilang dengan menggunakan metode normal ratio, inversed square distance, dan rata-rata aljabar (studi kasus curah hujan beberapa stasiun hujan daerah Bandar Lampung [Analysis of missing rainfall data using the normal ratio, inverse square distance, and algebraic average methods (case study of rainfall at several rainfall stations in the Bandar Lampung area)]. Jurnal Rekayasa Sipil Dan Desain, 4(3), 397-406.

Putra EI, Husni RF. 2021. Hubungan curah hujan dan titik panas (hotspot) kebakaran di Hutan Lindung Gambut (HLG) Londerang, Provinsi Jambi [Relationship between rainfall and fire hotspots in Londerang Peat Protection Forest (HLG), Jambi Province]. Journal Silvikultur Tropika, 12(3), 129-134.

Rasyid, Fachmi. 2014. Permasalahan dan Dampak Kebakaran Hutan [Issues and Impacts of Forest Fires]. Jurnal Lingkar Widyaiswara, 1(4), 47-59.

Saharjo BH, Nasution MRA. 2021. Pola sebaran titik panas (hotspot) sebagai indikator terjadinya kebakaran hutan dan lahan di Kabupaten Aceh Barat [Hotspot distribution patterns as an indicator of forest and land fires in West Aceh District]. Journal Silvikultur Tropika, 12(2), 60-66. doi: 10.29244/j-siltrop.12.2.60-66.

Saputra MR, Arisanty D, Adyatma S. 2021. Tingkat kerawanan kebakaran hutan dan lahan di Banjarbaru Provinsi Kalimantan Selatan [Land and forest fire vulnerability in Banjarbaru, South Kalimantan Province]. Jambura Geoscience Review, 3(2), 57-64. doi: 10.34312/jgeosrev.v3i2.5648

Sinaga RP, Darmawan A. 2014. Perubahan tutupan lahan di Resort Pugung Tampak Taman Nasional Bukit Barisan Selatan (TNBBS) [Land cover change in the Pugung Resort of Bukit Barisan Selatan National Park (TNBBS)]. Jurnal Sylva Lestari, 2(1), 77-86.

Syaufina L. 2008. Kebakaran Hutan dan Lahan di Indonesia: Perilaku Api, Penyebab, dan Dampak Kebakaran [Forest and Land Fires in Indonesia: Fire Behaviour, Causes, and Impacts]. Malang: Bayumedia Publishing.

Syaufina L, Hafni DAF. 2018. Variabilitas iklim dan kejadian kebakaran hutan dan lahan gambut di Kabupaten Bengkalis, Provinsi Riau [Climate variability and the incidence of forest and peatland fires in Bengkalis Regency, Riau Province]. Jurnal Silvikultur Tropika 9(1): 60-68.

Syaufina L, Sukmana A. 2008. Tinjauan Penyebab Utama Kebakaran Hutan Di Daerah Tangkapan Air Danau Toba. In Pusat Penelitian dan Pengembangan Hutan Konservasi Alam. Pusat Penelitian dan Pengembangan Hutan Konservasi Alam [Review of the Main Causes of Forest Fires in the Lake Toba Catchment Area. In Centre for Research and Development of Nature Conservation Forests. Centre for Research and Development of Nature Conservation Forests]. https://www.academia.edu/download/34834904/Fire_causes_at_catchment_area_of_Toba_Lake.pdf

Utomo AW, Suprayogi A, Sasmito B. 2017. Analisis hubungan variasi Land Surface Temperature dengan kelas tutupan lahan menggunakan data citra satelit landsat (Studi kasus: Kabupaten Pati) [Analysing the relationship between Land Surface Temperature variation and land cover class using landsat satellite image data (Case study: Pati District)]. Jurnal Geodesi Undip, 6(2), 71-80.

Yusuf A, Hapsoh, Siregar SH, Nurrochmat DR. 2019. Analisis kebakaran hutan dan lahan di Provinsi Riau [Analysis of forest and land fires in Riau Province]. Dinamika Lingkungan Indonesia, 6(2), 67-84. doi: 10.31258/dli.6.2.p.67-84.