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Mapping of Fire Detection Using Visible Infrared Imaging Radiometer Suite Satellite Imagery to Reduce the Risk of Environmental Damage

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Abstract:

The frequency of fires increases and triggers environmental damage, so it needs detection to minimize negative impacts. Fire detection using S-NPP VIIRS satellite imagery. Based on the background, research was conducted with the title "Mapping of Fire Detection Using Visible Infrared Imaging Radiometer Suite Satellite Imagery to Reduce the Risk of Environmental Damage".

Research in Banjarbaru City, South Kalimantan Province. Hotspot data from S-NPP VIIRS satellite image recording in 2012-2021. Data analysis is descriptive qualitative (describes the distribution of hotspots) and quantitatively (maps the frequency and distribution of hotspots) as the first step in detecting fires to reduce the risk of environmental damage. The risk of environmental damage is known using a questionnaire.

The results of the study revealed that the highest number of hotspots and nominal and high confidence levels were in September (1370) and October (1050). The greater the number of hotspots with a nominal confidence level and high the potential for fires and environmental damage the higher. Environmental damage in the study area is quite high (>75%). Research findings show that fire detection results can be used as a strategy to reduce the risk of environmental damage and minimize negative impacts.

Keywords: mapping; fire detection; S-NPP VIIRS; environmental damage.

JEL Classification: Q51; Q54.

Introduction

Fire is a disaster that occurs in developed and developing countries so that it becomes a national and international problem (Kumalawati *et al.* 2021; Martell 2001) including in Indonesia (I Koren and Feingold 2011). Fires occur every year and their frequency is increasing in Indonesia, including South Kalimantan, especially during the dry season (Sepriando *et al.* 2019; Rosalina *et al.* 2019; Yulianti *et al.* 2013). Fires often occur in the dry season, namely from August to October or a transitional period (Fachmi Rasyid 2014; Kumalawati *et al.* 2019). In the dry season, rainfall is low and water levels begin to decline (Ismuhajaroh *et al.* 2022) especially in peat areas. Activities on peatlands for various purposes if carried out without paying attention to the environment will have a negative impact so that it will trigger a decrease in the existing water level (Juita *et al.* 2022). Water in this case is a water resource which is vital for all types of living things, humans, communities and countries, so monitoring water quality is important (Kusmambetov *et al.* 2022; Gariba *et al.* 2022). The reduced availability of water in our environment can trigger fires and have a negative impact on the environment which is positively related to sustainability issues (Jawabreh *et al.* 2022).

The impact of fires affects sea and air transportation systems (Cahyono *et al.* 2015), air quality, human health in Indonesia and other countries such as Malaysia, Singapore, Thailand and the Philippines (Sabani W *et al.* 2019) and triggers widespread environmental damage (Arum *et al.* 2021). Other impacts of fires that arise are also from the economic and social side (Saufina 2014; Kumalawati *et al.* 2019). Fire is an important environmental problem and occurs due to natural factors and uncontrolled human activities (Schweithelm and Glover 1999; Fachmi Rasyid 2014; Achmad *et al.* 2021). Fires make environmental conditions worse and are threatened because they can trigger environmental damage (Jayawardana 2016; Pasai 2020) such as air pollution which has an impact on other countries, especially Malaysia and Singapore (KLHK RI., 2020). Fires also result in forest degradation and deforestation costing the economy an estimated $1.62-2.7 billion (Luca Tacconi 2013). Forest degradation and deforestation caused by fires cause a decrease in environmental quality which in turn leads to disasters and triggers environmental pollution which in turn damages environmental ecosystems (Prawesthi 2016). Environmental information is one of the important priority issues to know (Yerkinbayeva *et al.* 2022).

The cause of fires is mostly due to human factors so it is very difficult to predict fire behavior, such as where and when it will start (Paveglio 2018). The human factor that causes fires is land clearing (Kumalawati *et al.* 2021). The frequency of fires every year continues to increase with a greater negative impact, so it is very necessary to detect fires. Fire detection can be done using remote sensing imagery. Fire detection using remote sensing imagery has been carried out since the late 1970s and early 1980s (Milne 1986; Matson and Dozier 1981). Fire detection in Indonesia including South Kalimantan is carried out by monitoring hotspots using Terra satellite imagery, Aqua sensor MODIS (Moderate Resolution Imaging Spectroradiometer) and Suomi NPP sensor VIIRS (Visible Infrared Imaging Radiometer Suite) (LAPAN 2016; Kaufman *et al.* 1998; Giglio *et al.* 1999; Justice *et al.* 2002; Prasasti *et al.* 2018; Kumalawati *et al.* 2021). The results of hotspot detection in South Kalimantan using S-NPP VIIRS satellite imagery can tell the number of hotspots every month (see Table 1).

Table 1. Number of Hotspots Each Month Based on S-NPP VIIRS Province of South Kalimantan 2012-2021

Mounth	Number of Hotpots
January	688
February	474
March	446
April	434
May	778
June	969
July	2864
August	11980
September	45112
October	35703
November	7588
December	749
Number of Hotspots	107.785

*Source:*https://earthdata.nasa.gov/earth-observationdata/near-real-time/firms/viirs-i-band-active-fire-data; Processing and Analysis Results, 2022.

Fires often occur in the dry season, namely from August to October or a transitional period (Fachmi Rasyid 2014; Kumalawati *et al.* 2019). The number of hotspots in South Kalimantan based on the results of the S-NPP VIIRS satellite image recording from 2012-2021 is 107,785 which is increasing every month, especially from August to October. The highest hotspot occurred in September (45,112). The high distribution of hotspots in most regencies/cities in South Kalimantan Province, so it is necessary to detect the distribution of hotspots in each area, especially in Banjarbaru City. The city of Banjarbaru has a fairly high distribution of hotspots and is the location of the Syamsudinnoor international airport. The location around the airport has a high risk of fire, so it is feared that it will interfere with flights. Seeing this, it is necessary to detect the distribution of hotspots in Banjarbaru City in more detail to reduce the risk of fire around the airport location and reduce the risk of environmental damage. The location around the airport is densely populated, so early detection of potential fires is very important to minimize the impact of casualties, property and reduce the risk of greater environmental damage. The risk of greater environmental damage can be minimized so that it can support the success of sustainable development (Thao and Bakucz 2022).

The S-NPP VIIRS satellite image will provide an overview of the frequency, distribution and distribution of hotspots in the research area. Not all hotspots can appear as fires. Hotspots that have a high level of confidence can turn into fires and cause fires (Giglio *et al.* 1999; Giglio 2007). The higher the level of confidence in the hotspot, the higher the potential for fires to occur. Mapping of potential fires can be used as an initial step in fire detection so that it is expected to reduce the risk of greater fires in the future (Adam *et al.* 2019; Choommanivong *et al.* 2019) and minimize the negative impacts that may arise from fires. Based on the above background, it is very necessary to do research on "Mapping of fire detection using Visible Infrared Imaging Radiometer Suite Satellite Imagery to reduce the Risk of Environmental Damage".

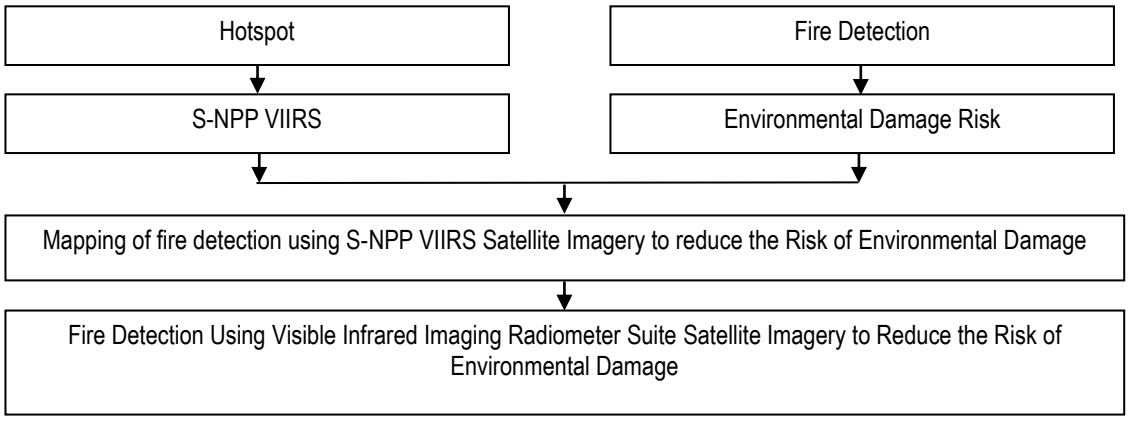
3. Literature Review

Fire is a natural disaster and fire information can be obtained from social media, where social media has long been developing around the world (Faisal *et al.* 2022). Fire is a disaster that occurs in both developing and developed countries. Fires in developing countries such as Indonesia are of global concern (Adiningsih *et al.* 2005). Fire in Indonesia is a disaster that occurs every year and the frequency is increasing, it is not a new thing (S.H. Sitorus and Hidayat 2020). The biggest fires occurred in 2015 in Indonesia including South Kalimantan (Kumalawati *et al.* 2021). Fires in South Kalimantan are mostly caused by human activities (Page *et al.* 2002; Adinugroho *et al.* 2005; Wooster *et al.* 2011; Fachmi Rasyid 2014; Rezainy *et al.* 2020) and occurs during the dry season (Barber and Schwiehelm 2000; Bowen *et al.* 2001; Bahri 2002; Mapilata *et al.* 2013; Wibowo 2019; Mubarak *et al.* 2019). Fires can trigger environmental damage so it is necessary to have mitigation and adaptation to reduce the risk of environmental damage and the negative impacts that may arise (Gellert 1998; Stole *et al.* 2003; Flanningan *et al.* 2006; Caciuc 2014; Herawati and Santoso 2011; Cahyono *et al.* 2015).

Other negative impacts caused by fires in the form of smoke crossing Indonesian borders such as Singapore and Malaysia, threatened animal habitats, forest damage, burned soil resulting in reduced quality so that it is easier for erosion and potential flooding (Saragih 2017). All these negative impacts trigger a decrease in environmental quality and increase environmental damage so that awareness and real action are needed from all elements of society, both the government of each country and citizens to be responsible for managing and preserving the environment. The responsibility to manage and preserve the environment is a reflection of the sustainability of life in the present and in the future. The protection and improvement of the human environment is a big problem that will affect the welfare of society and economic development in every region. Seeing this, it is very necessary to prevent fires from an early stage to minimize negative impacts.

Fire prevention is very necessary considering the many negative impacts that may arise due to fires (Kumalawati *et al.* 2021), such as decreasing environmental quality (Saragih 2017). Fire prevention can be done by detecting the distribution of hotspots using remote sensing technology (Clark and Boblle 2007). In addition, detection of hotspot distribution is very important to know the potential for fires in each area (Mapilata *et al.* 2013; Samsuri *et al.* 2012) so that it is expected to reduce the risk of greater environmental damage and minimize negative impacts. The distribution and frequency of hotspots can be determined using remote sensing imagery of S-NPP VIIRS (Justice *et al.* 2002; Giglio *et al.* 2003; Kumalawati *et al.* 2021). Not all hotspots can become fires (Prasasti *et al.* 2012), hotspots that have high accuracy have a greater potential for fires to occur, so field checks are necessary (Fathurrakhman 2007). Hotspots from the S-NPP VIIRS satellite image recording are used as an approach for early detection of fires. After early detection of fires is expected to reduce the risk of fires that may occur and minimize the risk of greater environmental damage in the future (see Figure 1).

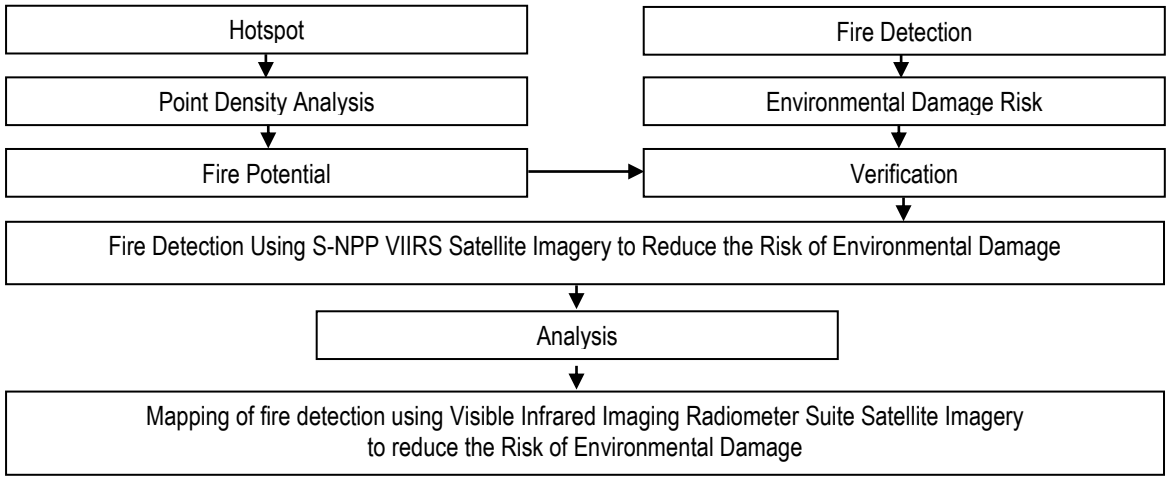
Figure 1. Mapping of fire detection using Visible Infrared Imaging Radiometer Suite Satellite Imagery to reduce the Risk of Environmental Damage



4. Methodology

This research uses a survey approach and is a qualitative and quantitative research. Data collection methods used are field research and literature. The data taken is hotspot data from SNPP VIIRS satellite imagery from 2012-2021. Data analysis was carried out descriptively qualitatively and quantitatively. Qualitative descriptive analysis was conducted to describe the distribution of hotspots in each district/city in South Kalimantan, especially Banjarbaru City. Quantitative analysis to map the frequency and distribution of hotspots in the research area as a first step in fire detection so that it is expected to reduce the risk of environmental damage in the future. The risk of environmental damage uses primary data, namely a questionnaire. 100 questionnaires will be distributed to respondents. Respondents are people who live in areas that have a high potential for fires. Methods in research are generally described in stages according to the flow chart (see Figure 2).

Figure 2. Research Flowchart



The identification of potential fires uses the semi-automatic analysis method of S-NPP VIIRS satellite imagery because the method developed is a combination of digital and visual detection methods. Digital detection is carried out on hotspot analysis and hotspot density analysis methods, while visual detection is done by digitizing on screen which is strongly influenced by the ability of the human eye senses with the help of S-NPP VIIRS satellite imagery. Point density analysis is very easy and fast to determine a potential fire. Potentially burnt areas have clustered hotspots with high accuracy. The distribution of hot spots that are repeated and clustered at that location is a sign of a fire (LAPAN 2016). Follow up analysis is an analysis by overlapping the thematic maps needed to add information obtained, such as administrative boundaries. The results of the delineation of the potential for fire are used as the basis for field checks to verify the results of the delineation of the potential for burning with the actual conditions in the field. Furthermore, from the results of verification of the potential for burning with actual conditions in the field and a questionnaire, a Fire Detection Map will be obtained using S-NPP VIIRS Satellite Imagery to reduce the Risk of Environmental Damage.

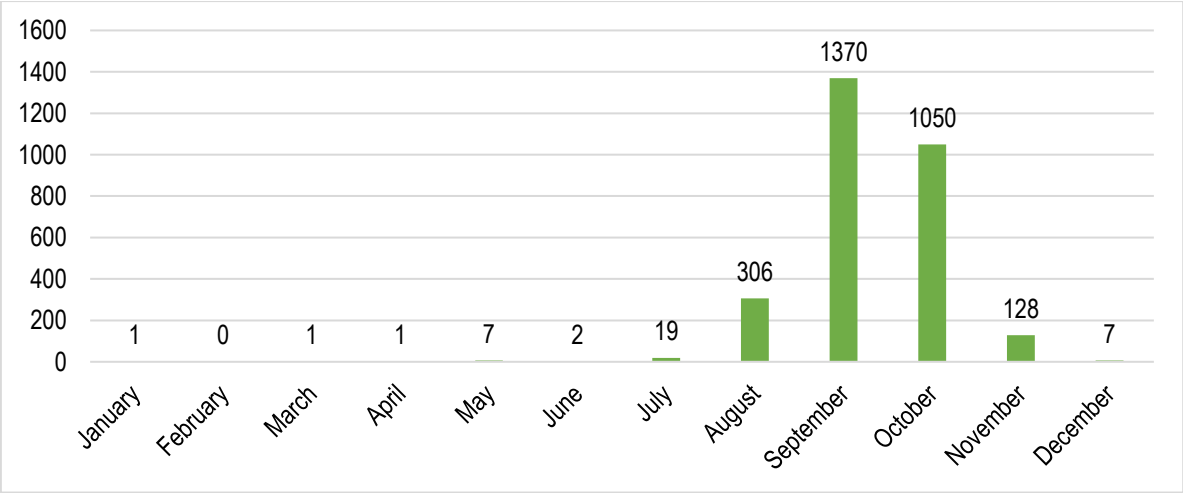
5. Result and Discussion

5.1. Number of Hotspots Each Month based on S-NPP VIIRS

Fire is a disaster and a serious problem that until now has been difficult to overcome. The high risk and loss due to fires prompts the need for serious efforts to carry out fire prevention and control measures. Fire prevention and control can be done with a fire detection and early warning system approach that can be done by analyzing hotspot data through remote sensing using the S-NPP VIIRS satellite (Endrawati *et al.* 2018). Utilization of remote sensing technology can be done with two approaches, namely digitally and visual interpretation (Suwarsono, 2012). In this study, the analysis of fire potential uses a visual interpretation approach using semi-automatic analysis of S-NNP VIIRS satellite imagery and field observations. The results of early detection based on hotspot recording results from S-NPP VIIRS satellite imagery can be used as an approach in reducing the risk of greater environmental damage in the future. Hotspots in the study were processed from 2012-2021 in the form of daily and monthly data. The results of fire detection seen from the number of hotspots in the research area are.

Fire is an event whose behavior is difficult to predict (Kusuma *et al.* 2021). Fires have become an annual phenomenon and occur every year during the dry season (Baroroh 2021) including in Banjarbaru City, South Kalimantan Province. Fires can be detected by looking at the number of hotspots in the area. Hotspots are used for monitoring fires that occur every year (Arimurti 2021). Fire monitoring can be done using S-NPP VIIRS satellite imagery. Based on the results of recording and processing satellite imagery of S-NPP VIIRS from 2012-2021 in Banjarbaru City, South Kalimantan during January to July, the number of hotspots is very small (see Figure 3). Hotspots in Banjarbaru City in August began to experience a significant increase until October because that month entered the dry season. From November to December the number of hotspots began to decline again.

Figure 3. Number of Hotspots Each Month Based on S-NPP VIIRS, Banjarbaru City, 2012-2021



The number of hotspots recorded by satellite imagery of S-NPP VIIRS Banjarbaru City, South Kalimantan Province from 2012-2021 was mostly found in August, September and October. The highest number of hotspots was in 2015 because of the effect of El Nino which will have an impact on decreasing rainfall if it occurs in July to November outside of that month the effect of El Nino is not too significant (Ariyadi 2017; Kumalawati *et al.* 2019). In 2015 in Banjarbaru City the highest number of hotspots was from August to October, where November began to decline. In 2015 the fire that occurred was one of the largest fires in Indonesia (Herdian *et al.* 2021) including in Banjarbaru City, South Kalimantan. In 2018 and 2019 the number of Hotspots in Banjarbaru City increased again from August to October, this was also due to the influence of El Nino. In 2018 and 2019 the effect of El Nino was not as large as in 2015 so the number of hotspots was not as high as in 2015 (see Table 2 and Figure 4).

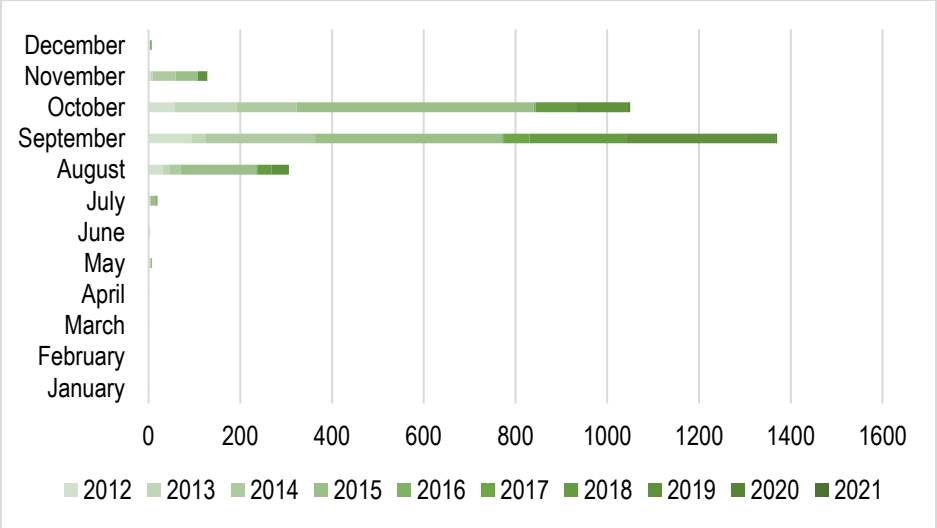
Based on the results of processing and field checks, it shows that every September to October the incidence of fires is quite high in Banjarbaru City. The highest number of hotspots from 2012-2021 is also found every September to October, so that in that month the community must be more alert and ready to face the possibility of fires that could occur. The results of this research on fires are very useful for educating the public about the parameters of the occurrence of fires so that they can carry out disaster mitigation earlier and reduce the risk of greater environmental damage in the future.

Table 2. Number of Hotspots Each Year in The City of Banjarbaru, South Kalimantan, 2012-2021

Month	Years									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
January	1	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0
March	1	0	0	0	0	0	0	0	0	0
April	1	0	0	0	0	0	0	0	0	0
May	4	0	0	1	0	0	0	2	0	0
June	0	0	0	0	0	0	2	0	0	0
July	3	1	0	11	0	0	2	2	0	0
August	31	14	25	164	1	2	31	38	0	0
September	93	31	239	408	4	56	212	323	4	0
October	56	136	131	517	3	1	88	113	5	0
November	5	4	50	49	0	0	0	20	0	0
December	1	2	0	1	0	0	0	3	0	0
Number of Hotspots	**196**	**188**	**445**	**1151**	**8**	**59**	**335**	**501**	**9**	**0**

Source: https://earthdata.nasa.gov/earth-observationdata/near-real-time/firms/viirs-i-band-active-fire-data; Processing and Analysis Results, 2022

Figure 4. Number of Hotspots Each Year in The City of Banjarbaru, South Kalimantan, 2012-2021



5.2. Number of Hotspots based on the Confidence Level of the Recording Results of S-NPP VIIRS.

Fire is one of the environmental problems in economic and ecological terms that harms the community (Pratiwi *et al.* 2021).

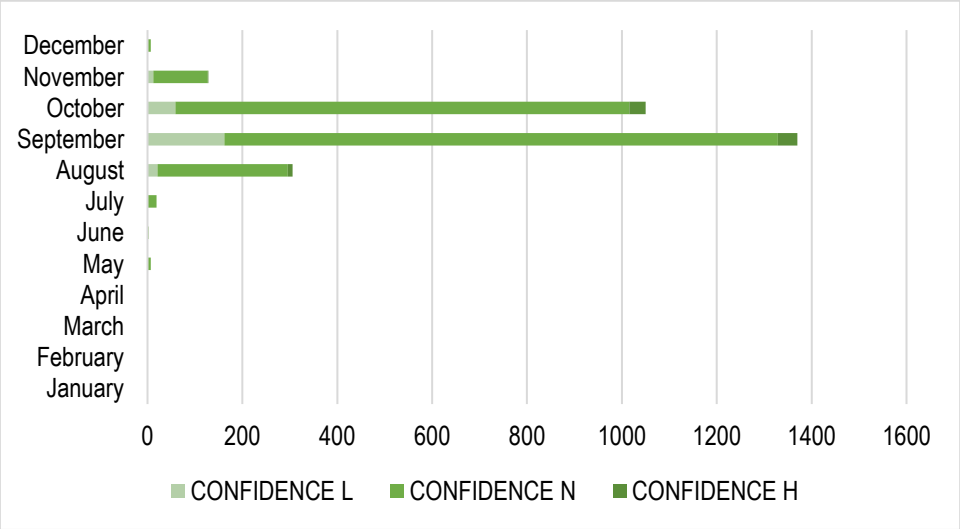
Table 3. Number of Hotspots by Confidence Level in The City of Banjarbaru, South Kalimantan, 2012-2021

Month	Confidence		
	L	N	H
January	0	1	0
February	0	0	0
March	0	1	0
April	0	1	0
May	0	7	0
June	0	2	0
July	0	19	0
August	21	275	10
September	162	1167	41
October	59	957	34
November	12	115	1
December	0	7	0

Source: https://earthdata.nasa.gov/earth-observationdata/near-real-time/firms/viirs-i-band-active-fire-data; Processing and Analysis Results, 2022

The worst fires in Indonesia in 2015 included Kalimantan (BNPB 2019). Fires generally occur in August and September, coinciding with the dry season in most parts of Indonesia (Misfaul *et al.* 2018) including South Kalimantan. The dry season has very low rainfall, which makes it more flammable (Itsnaini *et al.* 2017). Hotspots in Banjarbaru City based on the recording of S-NPP VIRRS satellite imagery from 2012-2021 seen from the level of confidence that the most hotspots are in August, September, and October. The Nominal confidence level found the highest number of hotspots were also in August, September, and October (see Table 3, Figure 5).

Figure 5. Number of Hotspots by Confidence Level in Banjarbaru City, South Kalimantan 2012-2021



The highest number of hotspots based on confidence level was found in 2015 in August, September, and October. The year 2016 started to decline then increased again in 2018 and 2019 in the same month, this was due to the influence of El Nino (see Table 4). The influence of El Nino in 2018 and 2019 is not as big as it was in 2015. The number of hotspots from 2012-2021 based on the level of confidence is mostly found every year in August, September, and October because those months are in the dry season. Hotspots with nominal and high confidence levels have a high fire potential as well. The potential for fires is high in Banjarbaru City, South Kalimantan Province every year in August, September, and October so that in these months the community must be more alert and ready to deal with fire disasters. Based on the results of the mapping of potential fires, it can be an early detection of fires so that it is expected to reduce the risk of environmental damage in the future.

Table 4. Number of Hotspot by Confidence Levels Every Year in Banjarbaru City, South Kalimantan 2012-2021

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2012	L	0	0	0	0	0	0	0	0	14	9	0	0
	N	1	0	1	1	4	0	3	30	78	46	5	1
	H	0	0	0	0	0	0	0	1	1	1	0	0
2013	L	0	0	0	0	0	0	0	0	0	4	1	0
	N	0	0	0	0	0	0	1	14	31	128	3	2
	H	0	0	0	0	0	0	0	0	0	4	0	0
2014	L	0	0	0	0	0	0	0	0	27	5	7	0
	N	0	0	0	0	0	0	0	23	206	125	42	0
	H	0	0	0	0	0	0	0	2	6	1	1	0
2015	L	0	0	0	0	0	0	0	17	61	22	2	0
	N	0	0	0	0	1	0	11	141	342	472	47	1
	H	0	0	0	0	0	0	0	6	5	23	0	0
2016	L	0	0	0	0	0	0	0	0	0	0	0	0
	N	0	0	0	0	0	0	0	1	4	3	0	0
	H	0	0	0	0	0	0	0	0	0	0	0	0
2017	L	0	0	0	0	0	0	0	0	0	0	0	0
	N	0	0	0	0	0	0	0	2	47	1	0	0
	H	0	0	0	0	0	0	0	0	9	0	0	0

Month		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2018	L	0	0	0	0	0	0	0	2	28	11	0	0
	N	0	0	0	0	0	2	2	29	176	77	0	0
	H	0	0	0	0	0	0	0	0	8	0	0	0
2019	L	0	0	0	0	0	0	0	2	31	8	2	0
	N	0	0	0	0	2	0	2	35	280	100	18	3
	H	0	0	0	0	0	0	0	1	12	5	0	0
2020	L	0	0	0	0	0	0	0	0	1	0	0	0
	N	0	0	0	0	0	0	0	0	3	5	0	0
	H	0	0	0	0	0	0	0	0	0	0	0	0
2021	L	0	0	0	0	0	0	0	0	0	0	0	0
	N	0	0	0	0	0	0	0	0	0	0	0	0
	H	0	0	0	0	0	0	0	0	0	0	0	0
HOTSPOT		1	0	1	1	7	2	19	306	1370	1050	128	7

*Source:*https://earthdata.nasa.gov/earth-observationdata/near-real-time/firms/viirs-i-band-active-fire-data;
Processing and Analysis Results, 2022

5.3. Risk of Environmental Damage Due to Fire

Fire is a hazard that threatens the safety of human life or property if the fire is not controlled, and triggers increased environmental damage. Fire disasters cannot be predicted when they occur and their causes, what can be done is with early preparation and warning (Januandri *et al.* 2017). Losses and casualties can be minimized by increasing community capacity. Disaster risk is the potential loss caused by a disaster in an area within a certain period of time (Isa *et al.* 2014). Fires can cause environmental damage and the negative impact is quite large, including smoke pollution that disturbs the environment, not only in Indonesia but also in neighboring countries (Page 2002; Saharjo 2016; Wasis *et al.* 2018).

Ecologically forest and land fires can reduce the quantity and quality of biological natural resources and ecosystems that function as life supports, among others by reducing the diversity of flora and fauna species, decreasing soil quality, changing hydrological functions and global warming (Saharjo and Wasis 2019). Fires also cause subsidence, decreased environmental service functions, death of soil microorganisms, loss of forest vegetation, water management functions, carbon sequestration, wood, erosion, river sedimentation and river pollution (Wasis *et al.* 2018b, Wasis 2018).

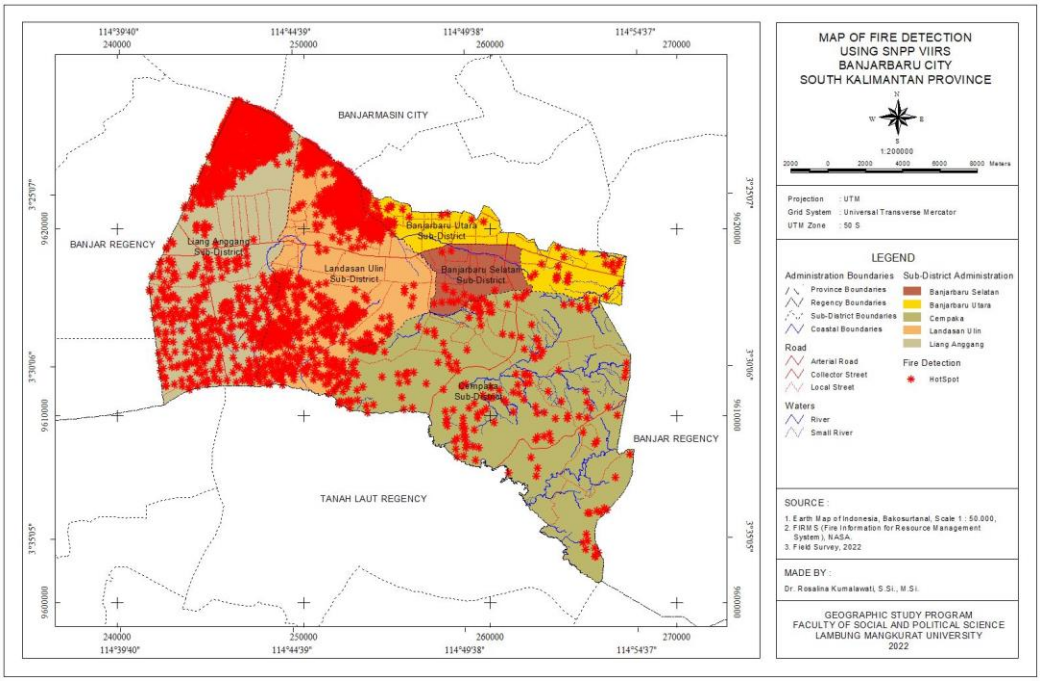
Table 5. Environmental Damage Due to Fire in the Research Area

No.	Environmental Damage Due to Fire	Answer	Total	Percentage (%)
1	Increased air pollution due to smoke pollution from fires	Yes	85	85
		No	15	15
2	Reduced diversity of flora and fauna species	Yes	80	80
		No	20	20
3	Soil quality is getting worse	Yes	90	90
		No	10	10
4	The decline in hydrological functions, and water management	Yes	82	82
		No	18	18
5	Global Warming (Temperature is getting hotter)	Yes	78	78
		No	22	22
6	Land subsidence	Yes	75	75
		No	25	25
7	Environmental pollution causing a decrease in environmental function	Yes	75	75
		No	25	25
8	Death of soil microorganisms	Yes	95	95
		No	5	5
9	Loss of vegetation/wood	Yes	93	93
		No	7	7
10	Loss of carbon sequestration	Yes	78	78
		No	22	22
11	Increased erosion, river sediment and pollution	Yes	90	90
		No	10	10

Source: Primary Data Processing and Analysis, 2022

The wider the fire area and the increasing frequency, the greater the negative impact will result in increasing the potential for environmental damage (see Table 5). Environmental damage in the research area based on the results of interviews is quite high. Most of the community said that fire could trigger environmental damage (>75%) and only 26% said no. Seeing this, it can be seen that the negative impact caused by fire is quite large and very detrimental to the community. The negative impact of fires that trigger environmental damage can be minimized by knowing the distribution of the number of hotspots early in each area, especially based on the level of confidence.

Figure 6. Map of Fire Detection Using SNPP-VIIRS Banjarbaru City, South Kalimantan Province



The greater the number of hotspots with nominal and high confidence levels, the higher the potential for fires in the area. The results of fire detection seen from the potential for fires in each area can be used as a strategy in reducing the risk of environmental damage (see Figure 6). The community will also become more alert and resilient in the face of possible disasters that may occur in their area at any time. In addition, the community can mitigate and adapt to disasters from an early age so as to minimize the loss of life and property which is much larger.

Conclusion

1. The highest number of hotspots from 2012-2021 in Banjarbaru City was in September as many as 1370 and October as many as 1050.
2. The highest number of hotspots based on the level of confidence in Banjarbaru City is also in September and October, the more hotspots with nominal and high confidence levels, the higher the potential for fires, so the potential for environmental damage is also high.
3. Environmental damage in the research area is quite high, most people say that fires can trigger environmental damage (> 75%) and only 26% say no.
4. The results of fire detection seen from the potential for fires in each area can be used as a strategy in reducing the risk of environmental damage so that negative impacts can be minimized.

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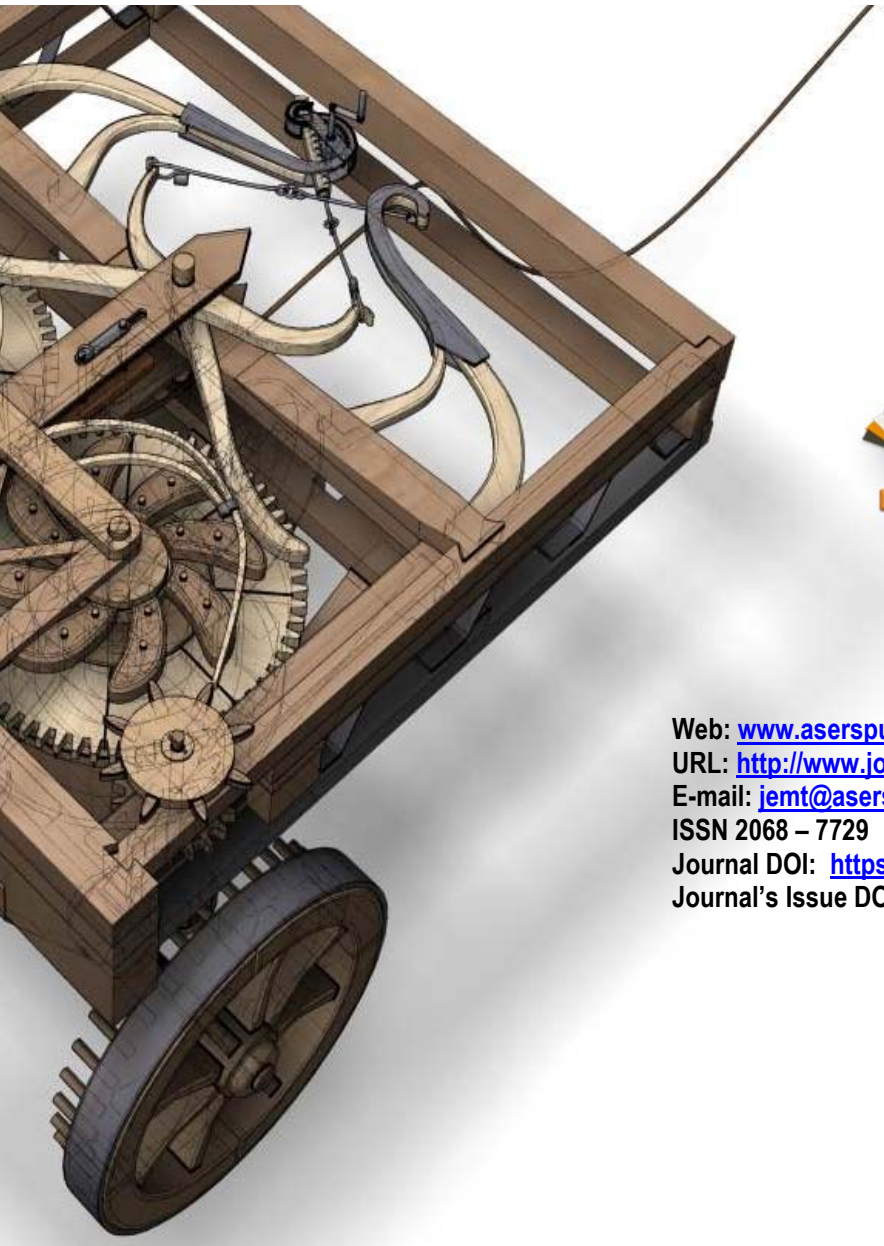

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