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Research Article

Analysis of Canal Blocking Distribution to Reduce Sabangau Tropical Peat Swamp Forest Fires

Petrisly Perkasa [1,*], Sulmin Gumiri [2], Wahyudi Wahyudi [3], Indrawan Permana[4]

[1] Department of Education and Technology, Faculty of Teacher Training and Education, University of Palangka Raya, Palangka Raya, 73111, Indonesia

[2] Department of Fisheries, Faculty of Agriculture, University of Palangka Raya, Palangka Raya, 73111, Indonesia

[3] Department of Forestry, Faculty of Agriculture University of Palangka Raya, Palangka Raya, 73111, Indonesia

[4] Department of Architecture, Faculty of Engineering, University of Palangka Raya, Palangka Raya, 73111, Indonesia

*Corresponding Author: Petrisly Perkasa, Email: petris.perkasa@ptb.upr.ac.id

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Abstract

The vast tropical peat swamp forest in Sabangau, Central Kalimantan, Indonesia, makes it difficult for officials to fight forest fires. Forest and tropical peatland fires are recurring events caused by anthropogenic activities around forests. This study aims to provide patterns of forest fires that have occurred over the past 11 years and produce predictive patterns for mitigation planning in 2023 and 2027. The method used is overlay, an analysis method carried out on several maps with mapping software. The results of this study show four factors cause forest fires, namely: The number of canals that penetrate the Sabangau Peat Forest Nature Laboratory of Palangka Raya University, the number of anthropogenic human activities, rainfall that is a small part of El Nino, and the limited ability of Peat Forest Nature Laboratory of Palangka Raya University area managers to maintain groundwater levels above (- 0.33 m). The overlap method stitches several theme maps together to create a new map. It is then geographically processed to describe various events and predictions of each causal factor.

1. Introduction

This study has the topic of the relationship between data on the distribution of canal barriers built at the research site, hotspots, rainfall, and groundwater level data on the incidence of forest fires at the Peat Forest Nature Laboratory (LAHG) of Palangka Raya University for the past 11 years. The Sabangau area is a watershed rich in biodiversity typical of tropical peatlands. The Sabangau River plays a significant role in climate change because it stores carbon, protects wildlife, and provides food needs for people in the region [1]. The Sabangau area is 80% peatland, contributing to biodiversity, climate regulation, and human welfare. Sabangau is one of the places that is still relatively protected where rare animals typical of Kalimantan, such as orangutans *(Pongo pygmaeus wurmbii)* dan macan dahan *(Neofelis diardi borneensis)* [2]. In addition, Sabangau is also a shelter for rare birds rarely seen and used as a sacred symbol for the Dayak tribe, namely the Tingang bird (*Rhinoplax vigil*) [3]. Environmental sustainability is also related to Dayak customs, proven to have significance for preserving forests and watersheds, especially in the upstream part where there is still little interaction between people and interests [4].

The Dayak believe that forests are necessary for survival and that peatland forests must be protected. However, Dayak communities still need guidance and assistance in sustainable forest management that considers the socio-economic function of peatlands, maintaining a balance between environmental protection and local community development [5]. Sabangau is also famous for its approximately 198.515 km long river, which divides the Katingan district, Pulang Pisau Regency, and Palangka Raya City, whose area is a peatland ecosystem. Sabangau is also the primary source for hydrological function on the island of Kalimantan because it is a carbon sink and producer of typical blackwater fish, providing many benefits for fishermen and the community as a good source of protein [6]. The high need for the consumption of blackwater fish causes overfishing, so fishermen and canal users enter the forest more [7]. Almost half of Sabangau's territory has been degraded. Sabangau has nearly 50,000 inhabitants whose livelihoods depend on the resources available in the region. Currently, around 6-7% of local people fall into the poor category and survive by fishing and forest products [8].

Social and environmental challenges are common in the Sabangau region of Central Kalimantan, Indonesia. These include the loss of peatland wetland forests due to forest fires, the reduction of fish populations on peatlands, and the associated socio-cultural difficulties, such as the possible cessation of fishery-based livelihoods [9]. In addition, indigenous communities have historically and persistently been marginalized. To solve these complex and interconnected problems, an interdisciplinary strategy that emphasizes interdependence and incorporates diverse worldviews is needed [10]. Sabangau is a tropical peat swamp forest site of legal and illegal logging operations from 1970 to 2006. The logging industry created a network of canals to transport logs, leading to excessive drainage on peatlands [11]. Tropical peat swamp forests are degraded due to logging and draining activities, which usually lead to land use change and fires [12].

Forest fires are increasingly crucial in the deforestation and degradation of tropical peatlands in Sabangau. A relationship was identified between the frequency of fires after draining peatlands [13]. Severe forest fires greatly decrease the diversity, number of individuals, and number of plant species. Ash accumulation in peat forest fires directly impacts increasing pH, organic matter, humic acid content, hydrophobicity, N-available, and K-available [14]. Rehydration through canal closure techniques is the first step in restoring degraded peatlands [15]. Using canal dividers raises the groundwater level so peat becomes wet [16].

The wetting program, which aims to restore the hydrological condition of peatlands to conditions similar to their natural conditions, includes canal closure, tree planting, economic improvement of surrounding communities, and construction of deep wells for fire suppression activities [17]. In addition to peat restoration, another alternative to protection is ecotourism techniques to utilize resources in protected areas in developing countries due to their status as intermediaries between rural economic progress and nature conservation [18]. In addition, community forest management has been identified as a win-win option in reducing forest fires while improving the welfare of rural communities in developing countries [19]. The problem in this study is why forest fires still occur frequently in the dry season. The leading cause of forest fires in Sabangau's tropical peatland environment is primarily the interaction between humans (social systems) and nature (ecological systems) [20].

Forest fires in Sabangau caused massive haze to spread across most of central-west Kalimantan. Fog impacts several aspects, such as public health, social, economic, and environmental [21]. However, people do not always understand how complicated these socio-ecological factors are. It also opens up research opportunities that can be developed by combining socio-economic, ecological, and spatial data analysis as decision-support tools [22]. The main outside forces changing land cover due to forest fires are access to forests, commodity prices, and rainfall patterns [23]. Frequent forest fires cause climate change in Central Kalimantan. Climate change is a seasonal shift and changes in the order of people's lives, making it difficult to recover quickly [24]. But in recent years, such fires have become more frequent. The most severe fires are attributed to ENSO's El Niño phase, which causes prolonged drought, particularly in southern Sumatra and Kalimantan peatland areas. Over the past 20 years, rapid land-use change, exacerbated by climate variability, has increased the frequency of wildfires [25]. The novelty of this study is to look at forest fire patterns from spatial analysis, which is supported by data from rainfall groundwater levels. The amount of rainfall during the dry season in a given year is an important climatic factor influencing the incidence of forest fires. Extremely dry conditions during drought years increase vulnerability to fires.

This study aims to provide patterns of forest fires that have occurred for 11 years and how to prevent them with a spatial approach due to the problematic access location. This research seeks to contribute to the world about forest fires still lacking in tropical peatlands. The results of this study can add a reference for the world in preventing forest fires, especially in tropical peat areas that have access to surrounding communities that use canals as a source of life.

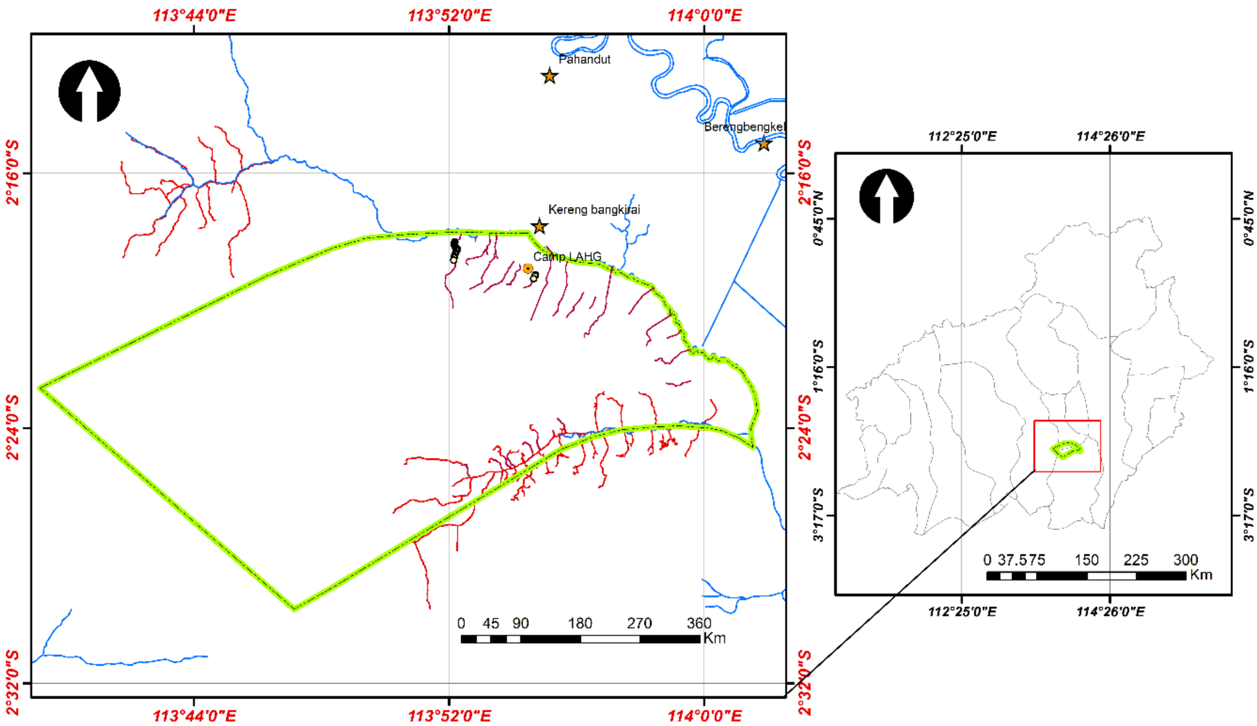
2. Materials and Methods

The research was conducted at the Peat Forest Nature Laboratory (LAHG) of Palangka Raya University, located in a watershed called Sabangau. The city of Palangka Raya, the capital of Central Kalimantan, Republic of Indonesia, administratively enters the location of this research. The materials used using forest and land fire hotspot data from the Visible Independent Imaging Radiometer Suite (VIIRS) on the Suomi National Polar-orbiting Partnership (S-NPP) satellite incorporate fire-sensitive channels, including a 4 μm high saturation temperature dual-gain channel, enabling active fire detection and characterization. The functional flame product, based on the 750 m medium-resolution VIIRS "M" band, is one of the standard operational products produced by the NASA/NOAA Suomi National Polar-orbiting Partnership (S-NPP)

This product is based on the previous version of the "Collection 4" algorithm used to process Moderate Resolution Imaging Spectroradiometer (MODIS) data [26]. Estimates of rainfall and number of rainy days are performed using the Global Precipitation Measurement (GPM) satellite, which is part of NASA's systematic earth mission program and will interact with a constellation of satellites to provide comprehensive global coverage, becoming an alternative approach to collecting rainfall data in hard-to-reach areas [27, 28]. Groundwater level data with the Piezometer retrieval technique determines how much pressure a liquid releases using a 4-inch PVC pipe of about 3 meters at the research location [29]. Data on the distribution of canal blocking at the research site.

The study was conducted by collecting secondary data from 2012 until 2022. The overlay method analyses the secondary data on several maps with mapping software [30]. The survey of canal blocking in Sabangau requires a lot of manpower, high costs, and a long time to complete. Geospatial technologies, such as Remote Sensing and Geographic Information Systems, offer alternative ways to access Sabangau forest areas, especially those that are difficult to reach for specific purposes or outcomes [31].

Through this analysis technique, the distribution of the location of the canal bulkhead is compared with data on forest and land fire hotspots, rain deposits and groundwater levels from field observations. The quantitative data will be analyzed comparatively, reaching the same phenomenon in different groups of subjects. Figure 1 below is the location of the Peat Forest Nature Laboratory (LAHG) of Palangka Raya University in the province of Central Kalimantan, Indonesia.



(a) (b)

Figure 1. Map of the Research Location. (a) Map of the location of Peat Forest Nature Laboratory (LAHG) of Palangka Raya University. (b) Map of Central Kalimantan Province

3. Results and Discussions

The study aimed to identify patterns of wildfires over 11 years to develop spatial-based preventive measures in hard-to-access locations. The dynamics of constructing canal barriers at LAHG Sebangau for peat wetting to reduce the risk of forest fires started from 2012 to 2022, with 263 canal dividers. Canal dividers were built on canals that release water rapidly from the forest. The closure of this canal intends to close the passage of water out of the forest so that peat does not dry out. The main material of the canal bulkhead consists of Galam wood (*Melaleuca leucadendra*). Canal-blocking buildings in peat swamp forests can be seen in Figure 2.

Figure 2. Construction of canal barriers in tropical peat swamp forests

Galam wood is not durable in water, so damage occurs in the first and second years [32]. Damage to canal barriers also occurs due to the many human socio-economic activities (anthropogenic) in the canals that penetrate the forest at the research site. The pattern of construction of canal bulkheads in this study was not the same between years; most were built in 2012, as many as 139 canal partitions, and at least in 2019, as many as four canal blocks. The distance between the canal dividers was 25 m and 200 m; the length varied, and no one was the same for each blocked channel. In previous studies, the distance between canals was ideally 50 m with a wetting radius of 170 m [33]. This study can also be used as a reference for calculating the impact of increased moisture on degraded peat soils after constructing canal bulkheads using high-frequency multitemporal radar satellite images [34].

The construction of canal bulkheads at the research site was not built before the drought pattern, so it was less effective for wetting. The canal bulkhead was constructed in the early years of the wet season. Development patterns were located in 2012 and 2016, while drought patterns came faster due to global climate change, which is once every four years [35]. According to the analysis of this study, the construction of bulkheads should be in a pattern, namely in 2014, 2018, and 2022.

Canal blockages positively affect groundwater levels in the driest month above fire-prone critical points. Conversely, locations that do not have restrictions beyond the required fire-prone water level [36]. Canal blocking is a joint community work because it can increase income when involved in its construction.

Canal barriers can be designed to support ecotourism around the Sebangau River, such as there is a gazebo to rest when tourists enter the forest. The development of the number of canal blockings in 11 years can be seen in Figure 3.

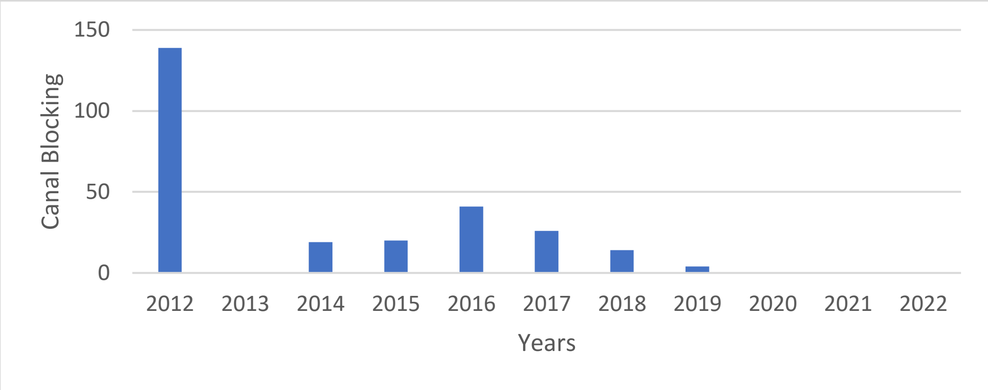


Figure 3. Growth in the Number of Canal Barriers in 11 Years

The number of hotspot attacks at the study site for 11 years amounted to 1867 hotspots, with the highest number in 2014 as many as 336 hotspots, in 2015 as many as 1425 hotspots, and in 2019 as many as 102 hotspots. In 2014 and 2015, there was a drought and more intense and prolonged fires in Indonesia due to El Niño type Pacific northeast [37] caused forest fires everywhere, which caused an increase in Particle Matter Size 10 (PM 10) and the Pollution Standard Index (PSI) of El Niño was extreme [38]. Based on the analysis of this study, the incidence of drought at the LAHG location of Palangka Raya University is a repeat of every four years, namely 2015 and 2019, and predictions for 2023. The results of this study can be applied to drought early warning and forest fire management in 2027. The number of hotspots in 11 years at the study site can be seen in Figure 4.

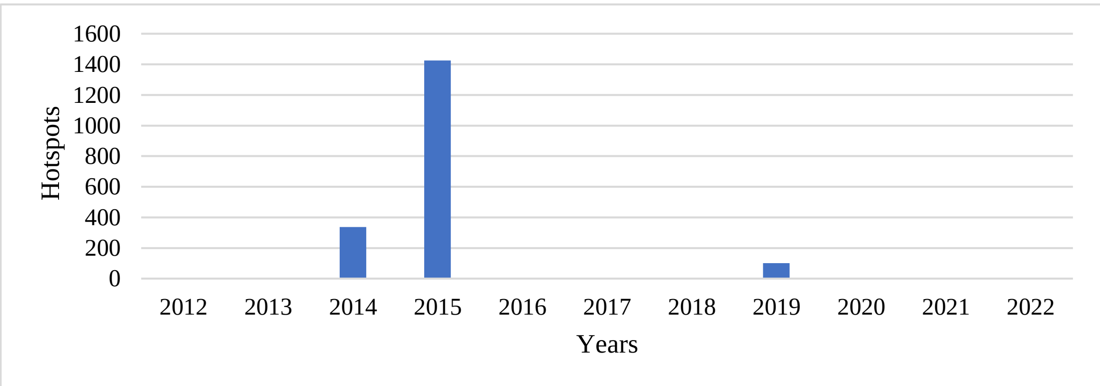


Figure 4. Number of hotspots in 11 years at the study site

When analyzed, The hotspots that occurred for 11 years at the study site showed a similar pattern: forest fires started from the banks of the Sabangau River and then spread to the LAHG site. The pattern of forest fires became three central forest fire locations: the north facing the Sabangau river, the southwest behind the LAHG camp, which penetrated the Bakung tributary, and the southeast direction, which resembled an eagle's head [39, 40]. The results of this analysis can be used as boundary zones that effectively show the distribution of hotspots temporally and spatially. Based on this, strategies can be formulated to prevent forest fires at the village level. The pattern of forest fires over 11 years at the study site can be seen in Figure 5.

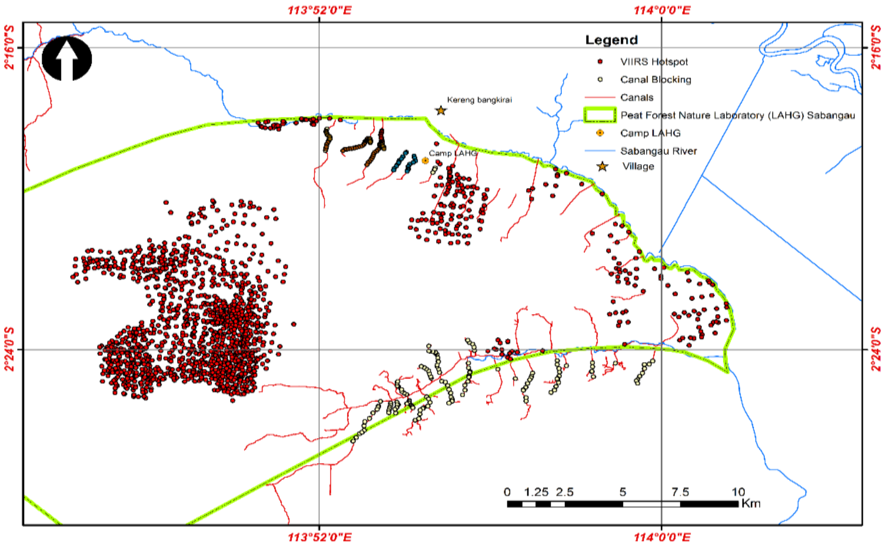
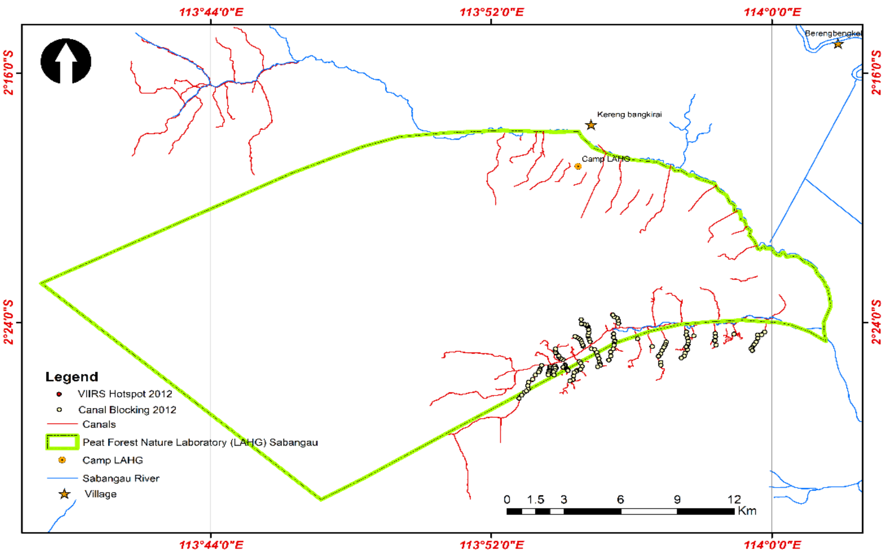


Figure 5. 11-year pattern of forest fires at the study site



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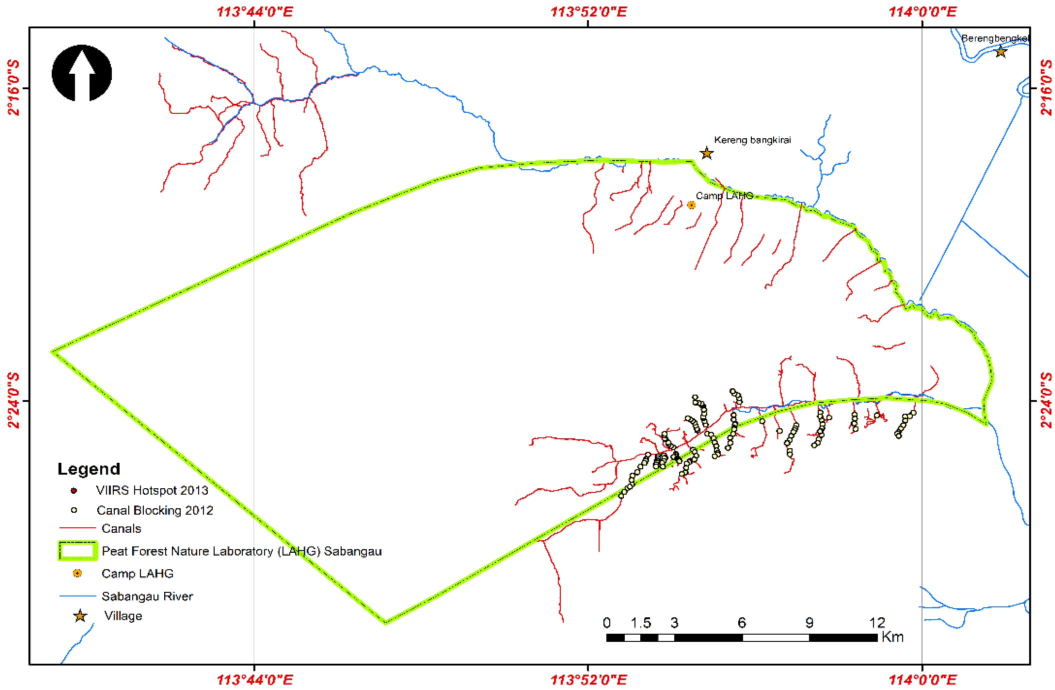
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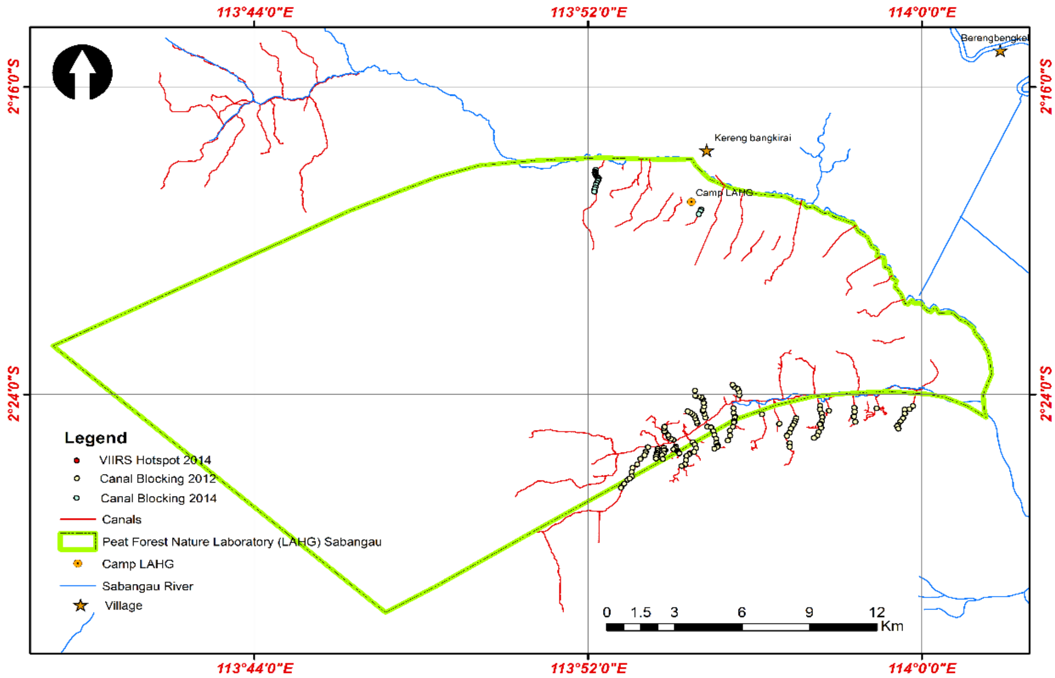
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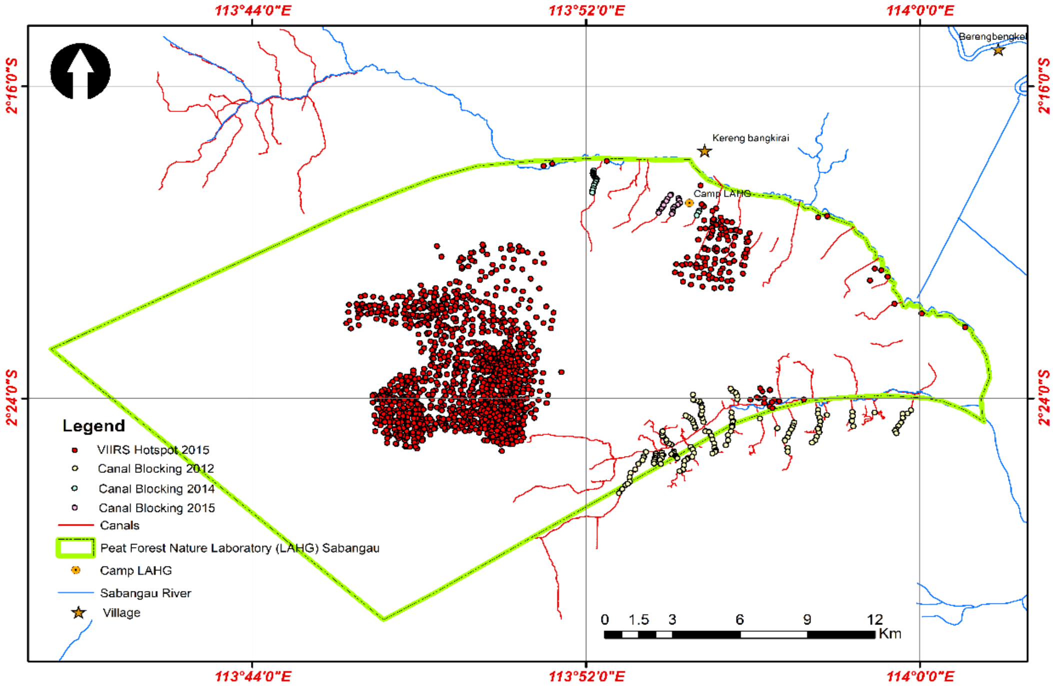
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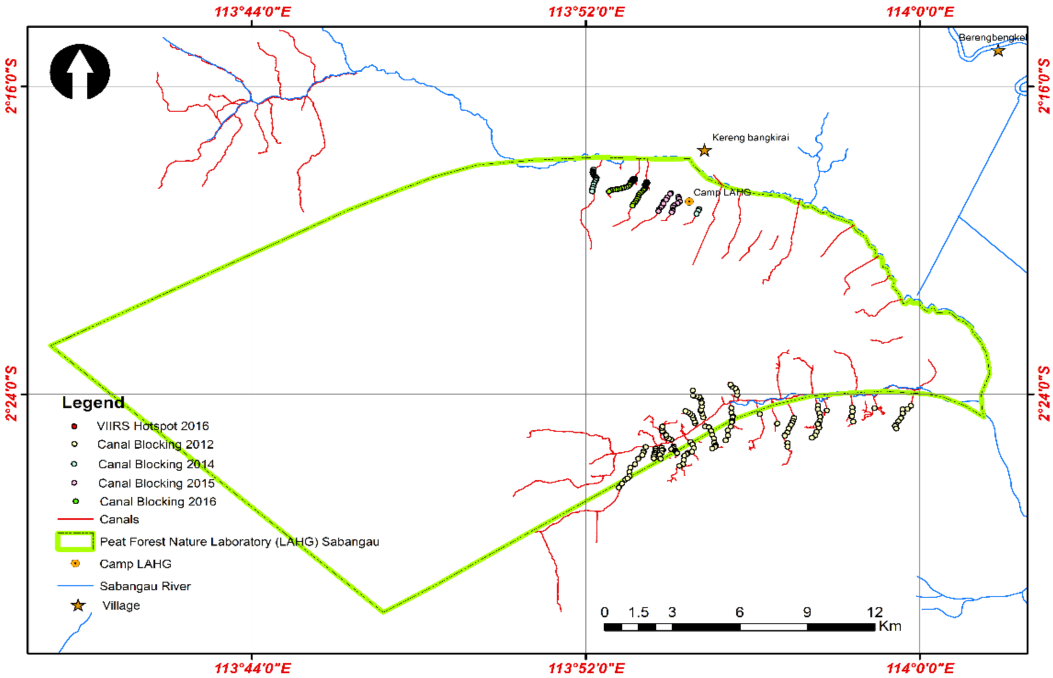
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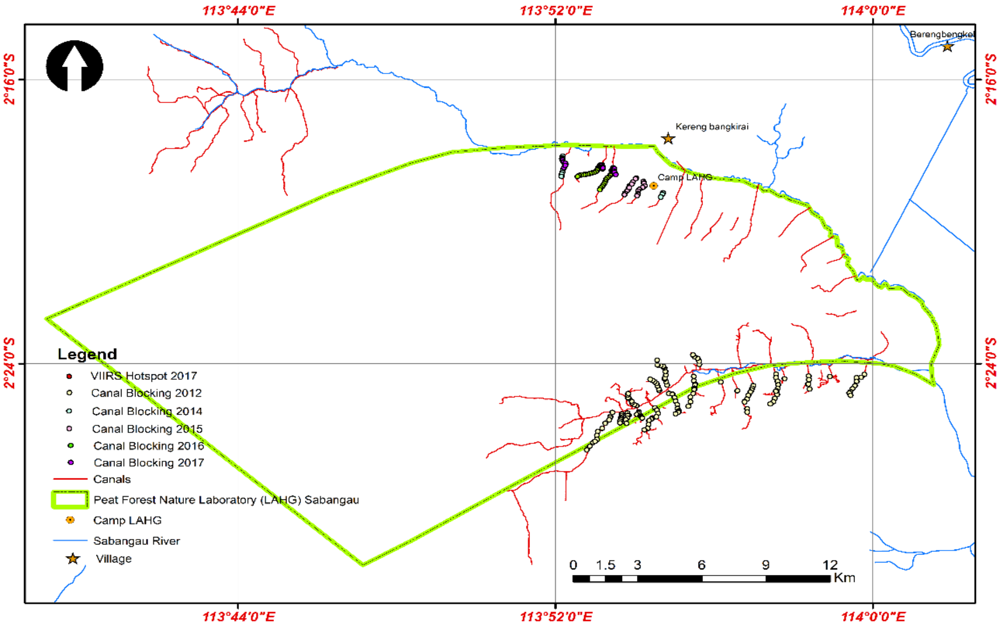
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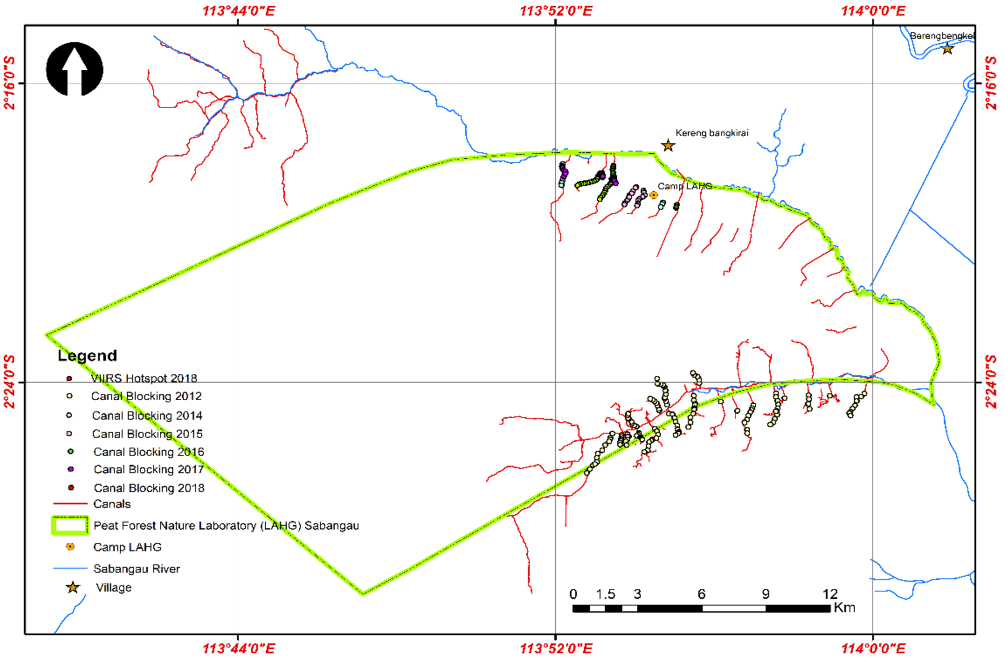
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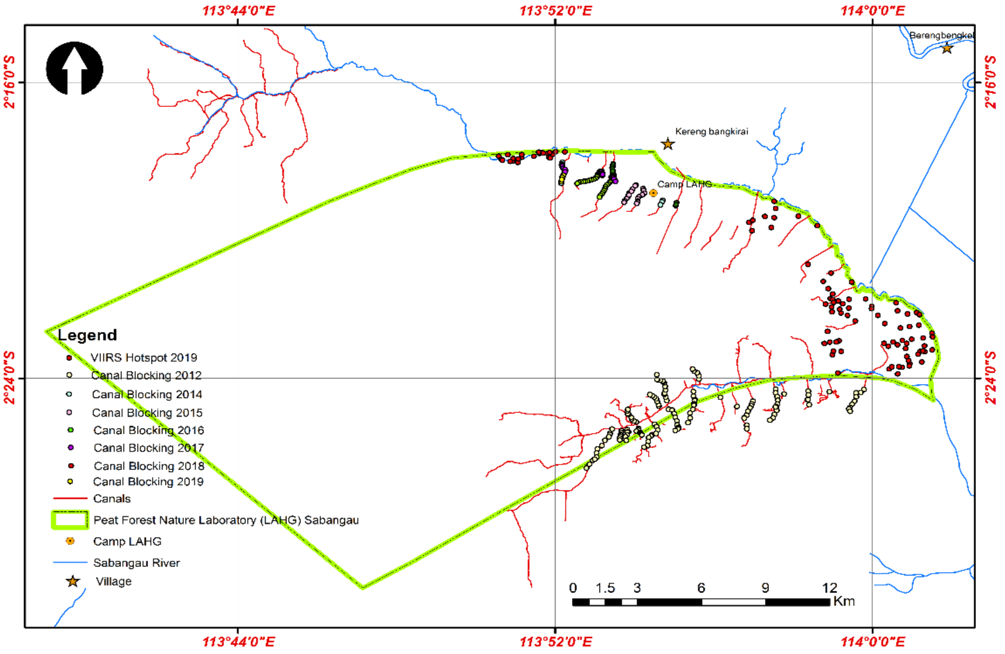
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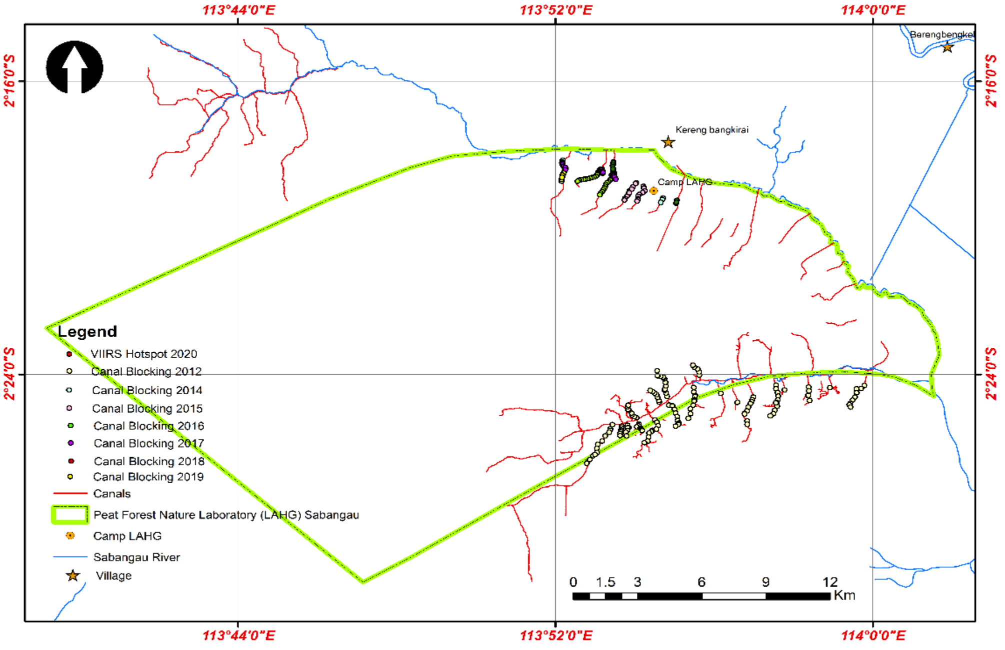
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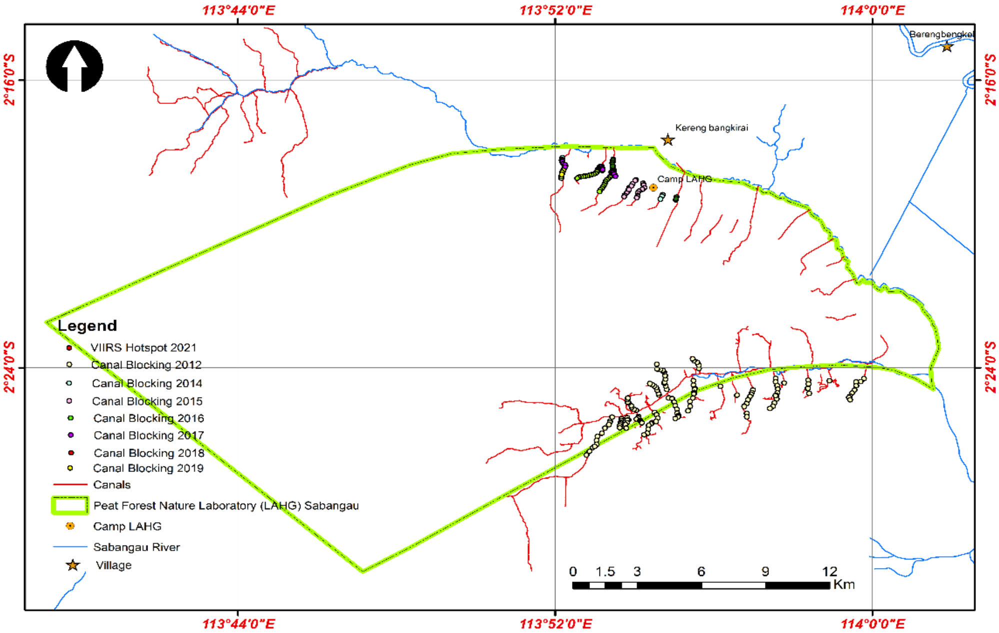

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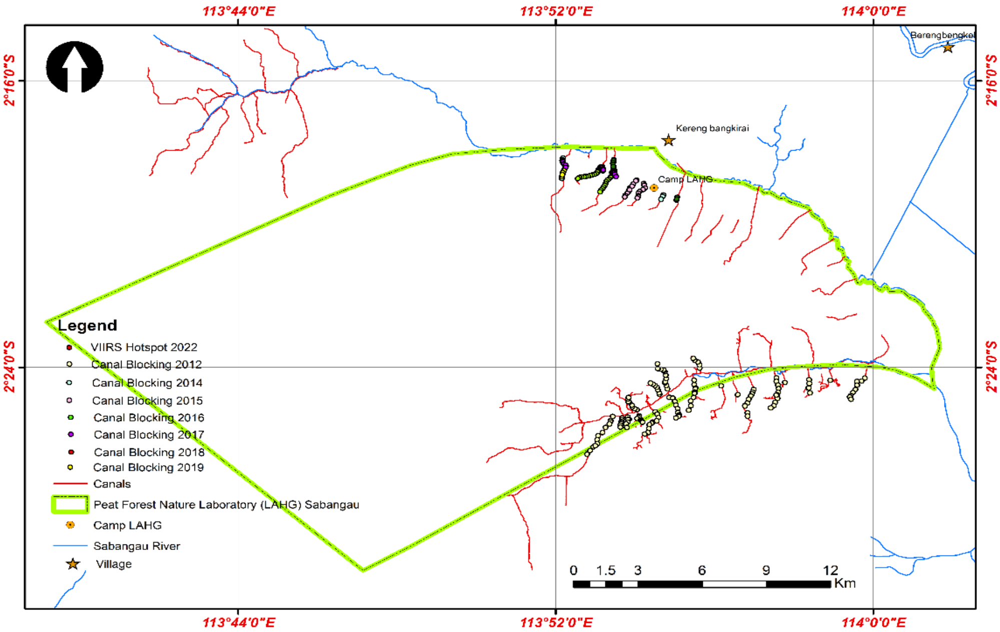

(k)

Figure 6. Map of the number of canal blockages and hotspots in 11 years. (a) Year 2012. (b) Year 2013. (c) Year 2014. (d) Year 2015. (e) Year 2016. (f) Year 2017. (g) Year 2018. (h) Year 2019. (i) Year 2020. (j) Year 2021. (k) Year 2022

In previous research, the El Niño phenomenon occurred in large forest fires in central and southern Kalimantan, repeating 16 years (1997-1998 and 1982-1983). These forest fires were before the MODIS era [41]. In the MODIS era, several large forest and land fires in Indonesia, such as in 2002, 2006, 2009, 2015, and 2019, were impacts related to the El Nino phenomenon of ENSO and IOD [42].

When analyzed precipitation in 11 years at the study site, a low pattern was obtained in 2015 and 2019 [43]. The average precipitation is 83.36 mm/year. The El Niño phenomenon that influences rainfall causes short-term climate factors in a 4-year pattern that strongly controls the magnitude of human-caused forest fire activity yearly throughout Borneo Island. In Figure 5 below is the average precipitation in 11 years.

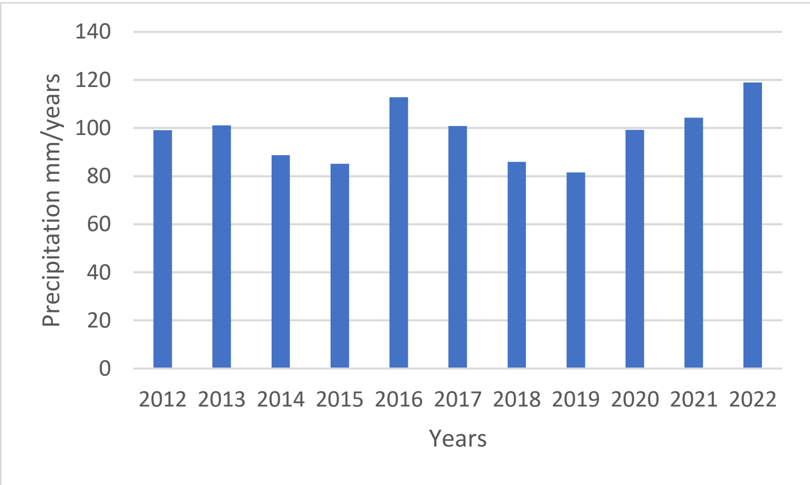

Figure 7. Average Precipitation in 11 years

Forest area management in LAHG Sabangau has been trying to find ways to reduce fire risk by looking at the groundwater level. Data on groundwater levels have been well recorded for 11 years. Analysis of groundwater level formed a low pattern; in 2015 and 2019, the average groundwater level in hazardous conditions was (-0.33 m) [44].

Therefore, the condition of the groundwater level must be kept less than that depth. Otherwise, forest fires may occur. The condition of high groundwater levels has similarities with rainfall patterns, which are repeated every four years. These two analytical factors (rainfall and groundwater level) can predict strategies to prevent forest fires in 2023 and 2027. This analysis shows that most areas in LAHG are highly vulnerable to fires and rainfall patterns in the dry season [45]. Figure 6 below shows the groundwater level pattern at the study site.

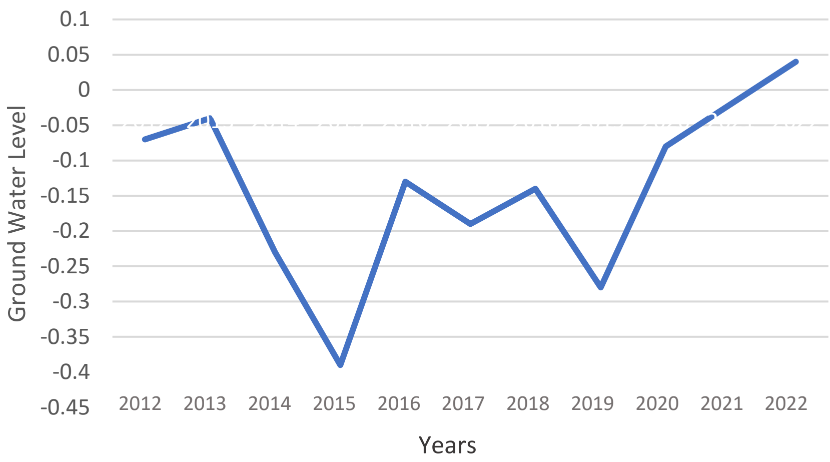

Figure 8. Average groundwater level for 11 years

The Sabangau LAHG area is dominated by canalized peatlands, which causes groundwater to flow laterally into the canal and empties into the Sabangau River. This condition causes the peat around the study site to become dry. In the dry season, where rainfall is lower, peat water conditions are further away from the surface, and peat becomes very dry. These conditions caused forest fires to increase to maximum intensity in 2015 and 2019 [46]. The groundwater level in that year was close to (-0.40 m), meaning that this analysis made lessons to improve the mitigation of forest fires by looking at the pattern of groundwater that continued to fall and was supported by little rainfall; routine patrols were carried out at three fire-prone points.

5. Conclusions

Forest fires at the Peat Forest Nature Laboratory (LAHG) of Palangka Raya University can be predicted by the map overlay method, a thematic map overlay in the form of heat spot distribution, rainfall, and groundwater level. Monitoring groundwater levels becomes an early warning system when groundwater levels drop to (– 0.33 m). Based on this, LAHG managers increased forest patrols and became aware of fire hazards. Canal blocking is one solution to protect the LAHG area. However, the life of canal bulkheads is still short, so two approaches need to be taken, namely in material engineering for construction and ecotourism. Suggestions for future research analyze LAHG areas with different anthropogenic pressures, such as various community activities such as overfishing and hunting in canals, forests, and banks of the Sabangau River.

Declaration of Competing Interest: The authors declare that they have no known competing of interest.

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