Forest and Land Fire Disaster Risk Assessment Using Geographic Information Systems in South Arut Sub-district, Kotawaringin Barat Regency, Central Kalimantan Province

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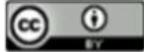*Corresponding author e-mail: taraprakoso440@gmail.com

Abstract

Kotawaringin Barat Regency, located in Central Kalimantan Province, consists of six sub-districts: Kumai, South Arut, North Arut, Pangkalan Lada, Pangkalan Banteng, and Kotawaringin Lama — all of which have the potential to experience natural disasters, one of which is forest and land fires. In recent years, there have been numerous incidents of forest and land fires in the region. In 2022, there were approximately 75 incidents; in 2023, around 201 incidents; and in 2024, about 36 incidents — most of which occurred in South Arut and Kumai Sub-districts. Due to the concentration of fire incidents in these two sub-districts, this study focuses on South Arut Sub-district. The assessment of forest and land fire risk was carried out using spatial analysis methods. The weights for hazard, vulnerability, and capacity were determined using secondary data processed with formulas based on BNPB Regulation No. 2 of 2012 concerning disaster risk assessment, utilizing Microsoft Excel. The results of the risk assessment in South Arut show that the area is predominantly categorized as high-risk, with 8 villages/urban wards (83.8% of the total area). The moderate-risk classification includes 6 villages/urban wards (13.3%), and the low-risk classification also covers 6 villages/urban wards (2.9%). The high disaster risk is primarily due to the high percentage of hazard and vulnerability, while the capacity remains at a moderate level. Therefore, it is necessary to increase the local capacity in facing forest and land fire disasters to reduce the overall risk.

Keywords: Forest and Land Fires; South Arut Sub-district; Risk

1. Introduction

Kalimantan is a region highly sensitive to forest and land fire disasters. During extreme dry seasons caused by the El Niño phenomenon, many areas in Kalimantan experience a significant drop in air humidity. In addition, human activities — whether intentional or due to negligence — contribute to the occurrence of forest and land fires (Tacconi, 2003). Central Kalimantan is one of the regions highly prone to natural disasters, particularly related to environmental degradation. One of the major environmental issues is forest and land fires, which frequently occur across all regencies and sub-districts in Central Kalimantan, especially during the dry season. These fires have severe impacts on human life in terms of the environment, public health, culture, and the economy, not only in Kalimantan but also in neighboring countries such as Malaysia, Singapore, and Brunei Darussalam.

Kotawaringin Barat Regency in Central Kalimantan Province consists of six sub-districts: Kumai, South Arut, North Arut, Pangkalan Lada, Pangkalan Banteng, and Kotawaringin Lama — all of which are disaster-prone areas, including susceptibility to forest and land fires. In recent years, numerous fire incidents have occurred in Kotawaringin Barat. In 2022, there were approximately 75 incidents, followed by 201 incidents in 2023, and about 36 incidents in 2024. Most of these occurred in the South Arut and Kumai sub-districts (BPBD Kobar, 2024). Given the concentration of fire incidents in these two areas, this study focuses on South Arut Sub-district as the study area (Figure 1).

South Arut Sub-district covers an area of approximately 2,400 km² and consists of seven urban wards (Kelurahan Baru, Kelurahan Madurejo, Kelurahan Mendawai, Kelurahan Mendawai

Seberang, Kelurahan Raja, Kelurahan Raja Seberang, and Kelurahan Sidorejo) and thirteen villages (Desa Kenambui, Desa Kumpai Batu Atas, Desa Kumpai Batu Bawah, Desa Mendang Sari, Desa Natai Baru, Desa Natai Raya, Desa Pasir Panjang, Desa Rangda, Desa Runtu, Desa Sulung, Desa Tanjung Putri, Desa Tanjung Terantang, and Desa Umpang) (BPS Kobar, 2024). On average, the fires in South Arut occur during the dry season (BMKG Kobar, 2019).

The fires in Kalimantan are also exacerbated by the region's dominant soil type — organic or peat soil — which is highly flammable (D. Muharrama, 2023). The character of forest and land fires in Kotawaringin Barat Regency is particularly unique, as most of them occur on peatlands, which have high potential to produce thick smoke (BPBD Kobar, 2024).
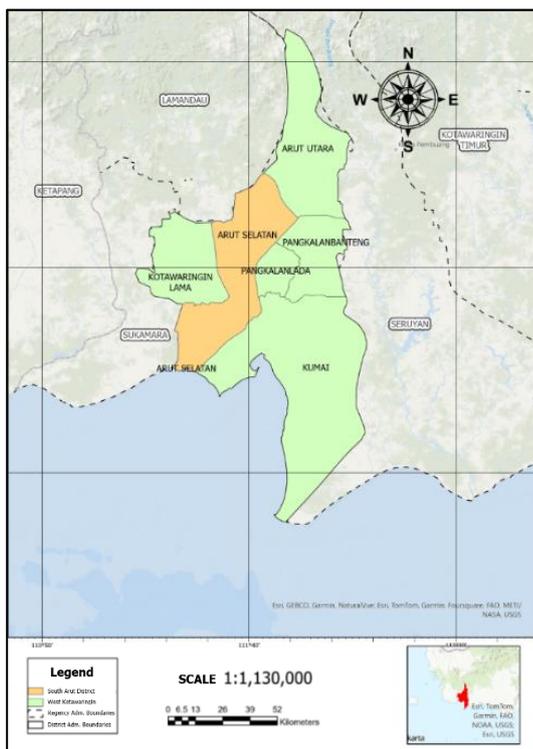

Fig. 1 Administrative Map of South Arut Sub-district

2. Method

Previous studies [(D. Muharrama, 2023); (Harun All Rosit, 2023)] have shown that forest and land fire risk assessment can be conducted using spatial analysis methods. The weights for hazard, vulnerability, and capacity are derived from secondary data, processed using formulas in accordance with the Regulation of the Head of BNPB No. 2 of 2012 concerning disaster risk assessment, with the aid of Microsoft Excel. Once the weights for hazard, vulnerability, and capacity are determined, the next step is to overlay these weight values using a formula such as the example in Equation 1 below.

$$R = H \times \frac{V}{C}$$ (BNPB

(2012) 'Peraturan Badan Nasional Penanggulangan Bencana No 02 Tahun 2012 Tentang Pedoman Umum Pengkajian Risiko Bencana,' n.d.)

Explanation
- **R**: Disaster Risk
- **H**: The frequency (likelihood) of a specific disaster occurring with a certain intensity at a specific location
- **V**: The expected loss (impact) in a given area if a specific disaster occurs at a certain intensity
- **C**: The available capacity in that area to recover from the specific disaster

Once the weighted values for disaster risk (R) of forest and land fires have been calculated, the next step is to visualize the results using ArcGIS, producing a risk map of forest and land fires.

2.1. Study Area

The study area focuses on South Arut Sub-district, Kotawaringin Barat Regency, which consists of seven urban wards (Kelurahan Baru, Kelurahan Madurejo, Kelurahan Mendawai, Kelurahan Mendawai Seberang, Kelurahan Raja, Kelurahan Raja Seberang, and Kelurahan Sidorejo) and thirteen villages (Desa Kenambui, Desa Kumpai Batu Atas, Desa Kumpai Batu Bawah, Desa Mendang Sari, Desa Natai Baru, Desa Natai Raya, Desa Pasir Panjang, Desa Rangda, Desa Runtu, Desa Sulung, Desa Tanjung Putri, Desa Tanjung Terantang, and Desa Umpang). South Arut Sub-district covers an area of approximately 2,400 km², stretching from 2º42′24.84″ S to 111º38′51.38″ E (Central Bureau of Statistics, 2021).

The boundaries of South Arut Sub-district are as follows: to the north, it borders North Arut Sub-district; to the east, it is adjacent to the sub-districts of Kumai, Pangkalan Lada, and Pangkalan Banteng; to the west, it borders Kotawaringin Lama Sub-district; and to the south, it is bordered by Kumai Sub-district and the Java Sea (Central Bureau of Statistics, 2021).

2.2. Study Framework

This chapter outlines the study framework, which involves three main stages as follows:

a. The first stage is data collection, which involves gathering relevant and necessary data for this research. The data were obtained from various local government agencies (OPD) in Kotawaringin Barat Regency, such as the Regional Disaster Management Agency (BPBD), the Regional Development Planning Agency (BAPPEDA), the Agency for National Unity and Politics (Kesbangpol), and other supporting departments related to this study.

b. The second stage includes data processing using Microsoft Excel to determine the category values for each village/urban ward, classified into three levels: low, medium, and high.

c. The third stage, following the calculations resulting in values for vulnerability, capacity, and risk of forest and land fires, is data visualization using Geographic Information System (GIS) software.

2.3. Data Collection and Analysis

At this stage, secondary data collection was carried out. The secondary data were obtained from stakeholders involved in forest and land fire-related issues, such as the Meteorology, Climatology, and

Geophysics Agency (BMKG) of Kotawaringin Barat, the Central Statistics Agency (BPS) of Kotawaringin Barat, the Regional Disaster Management Agency (BPBD) of Kotawaringin Barat, the Public Works Department of Kotawaringin Barat, and the South Arut Sub-district office (Figure 2).

The collected data from these institutions were then used to assess the disaster risk of forest and land fires occurring in South Arut Sub-district, Kotawaringin Barat Regency.
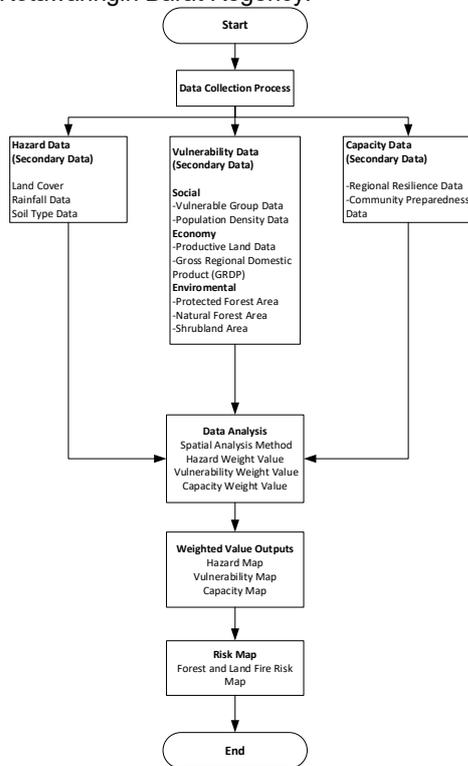

Fig. 2 Research Plan Flowchart

2.4. Classification Modelling

S Previous studies [(D. Muharrama, 2023); (Harun All Rosit, 2023)] have demonstrated that disaster risk analysis for forest and land fires can be effectively conducted using a spatial approach with Geographic Information Systems (GIS). In general, the method used aligns with the Regulation of the Head of BNPB No. 2 of 2012 concerning disaster risk assessment, which outlines the principles of assessment, assessment methods, risk index calculation methods, and guidelines for implementation.

The assessment process utilizes spatial analysis through GIS to maximize effectiveness and efficiency in evaluating regional conditions. The risk index is calculated using the following equation: Equation (1)

3. DISCUSSION

3.1. Hazard Level of Forest and Land Fire Disaster

The hazard level of forest and land fire disasters in South Arut Sub-district is classified into three categories: low, medium, and high for each village and urban ward. The following are the results of the hazard level analysis of forest and land fire disasters in South Arut Sub-district.
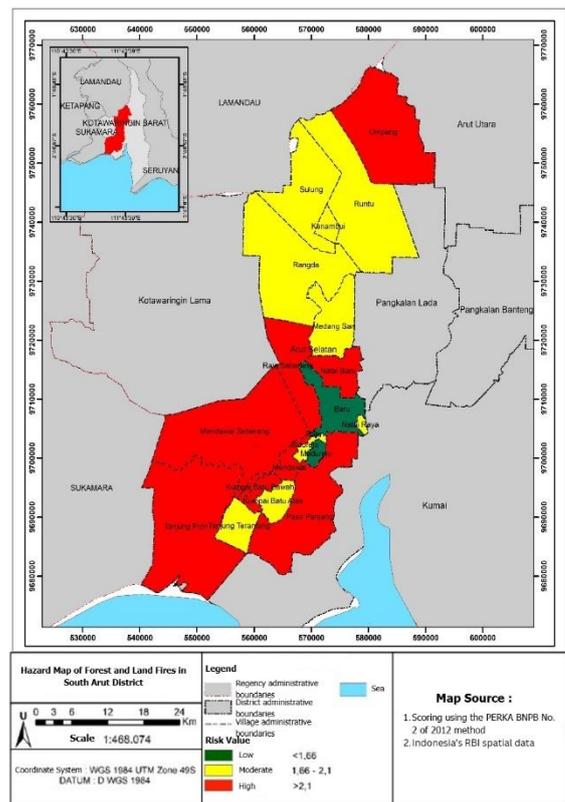

Figure 3. Forest and Land Fire Hazard Map of South Arut Sub-district

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The parameters used to generate the hazard map include land cover, climate, and soil type. The land cover data were sourced from the Public Works Department of Kotawaringin Barat Regency and consist of various categories such as residential areas, dense forests, fields/gardens, shrub forests, plantations, and mixed-crop gardens. Each of these land cover types contributes differently to the level of fire hazard.

Each parameter is assigned a weight value based on the Regulation of the Head of BNPB No. 2 of 2012. Climate data were obtained from the annual weather records provided by BMKG Kotawaringin Barat and converted into weighted values according to the same regulation. Soil type data, sourced from the Public Works Department of Kotawaringin Barat Regency, include organic, non-organic, and semi-organic soils, all classified and weighted in accordance with the Regulation of the Head of BNPB No. 2 of 2012.

Among the villages and urban wards in South Arut Sub-district, three urban wards fall under the low hazard classification: Kelurahan Baru, Kelurahan Madurejo, and Kelurahan Raja, with a total area of 36 km², accounting for 1.5% of the total area of South Arut Sub-district. The moderate hazard classification includes nine villages/urban wards: Desa Kenambui, Desa Kumpai Batu Atas, Desa Medang Sari, Desa Natai Raya, Desa Rangda, Desa Runtu, Kelurahan Sidorejo, Desa Sulung, and Desa Tanjung Terantang, with a total area of 938.45 km², representing 39.1% of the total sub-district area. The high hazard classification consists of eight

villages/urban wards: Desa Kumpai Batu Bawah, Kelurahan Mendawai, Kelurahan Mendawai Seberang, Desa Natai Baru, Desa Pasir Panjang, Kelurahan Raja Seberang, Desa Tanjung Putri, and Desa Umpang, covering a total area of 1,425.55 km², or 59.4% of the total area of South Arut Sub-district (Table 1).

Table 1. Hazard Assessment of Forest and Land Fires in South Arut Sub-district

Village / Urban Ward	Classification (Km2)		
	Low	Medium	High
Baru	8,5		
Kenambui		150	
Kumpai Batu Atas		30	
Kumpai Batu Bawah			18,25
Madurejo	26		
Medang Sari		9	
Mendawai			26
Mendawai Seberang			469
Natai Baru			7,3
Natai Raya		6,2	
Pasir Panjang			162
Raja Seberang			115
Raja	1,5		
Rangda		51	
Runtu		504	
Sidorejo		6	
Sulung		170	
Tanjung Putri			19
Tanjung Terantang		12,25	
Umpang			609

3.2. Vulnerability Level of Forest and Land Fire Disasters

The vulnerability to forest and land fires in South Arut Sub-district is composed of several parameters, namely economic vulnerability, environmental vulnerability, and social vulnerability.

a. Economic Vulnerability

The economic vulnerability map is constructed based on two indicators: Gross Regional Domestic Product (GRDP), sourced from the Central Statistics Agency (BPS) of Kotawaringin Barat Regency, and the extent of productive land in Kotawaringin Barat Regency, also sourced from BPS Kotawaringin Barat.

Fig.4 Economic Vulnerability Map of Forest and Land Fires in South Arut Sub-district

A total of 17 villages/urban wards fall under the low economic vulnerability category, namely: Kelurahan Baru, Desa Kenambui, Desa Kumpai Batu Atas, Desa Kumpai Batu Bawah, Kelurahan Madurejo, Desa Medang Sari, Kelurahan Mendawai, Desa Natai Baru, Desa Natai Raya, Desa Pasir Panjang, Kelurahan Raja Seberang, Kelurahan Raja, Desa Rangda, Kelurahan Sidorejo, Desa Sulung, Desa Tanjung Putri, and Desa Tanjung Terantang. Meanwhile, 3 villages/urban wards are classified as having high economic vulnerability: Kelurahan Mendawai Seberang, Desa Runtu, and Desa Umpang (Fig. 4).

b. Enviromental Vulnerability

The environmental vulnerability map is constructed using data on the area of protected forests, fields, large-scale plantations, mixed-crop gardens, and monoculture plantations; natural forest area (including secondary and primary forests); and shrubland (including alang-alang grassland and bushes). All of these data were derived from the RBI (Base Map) of Kotawaringin Barat Regency.

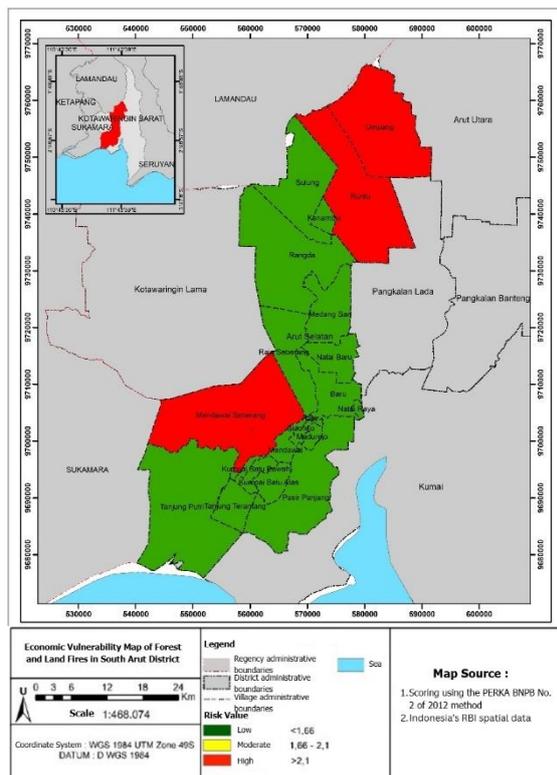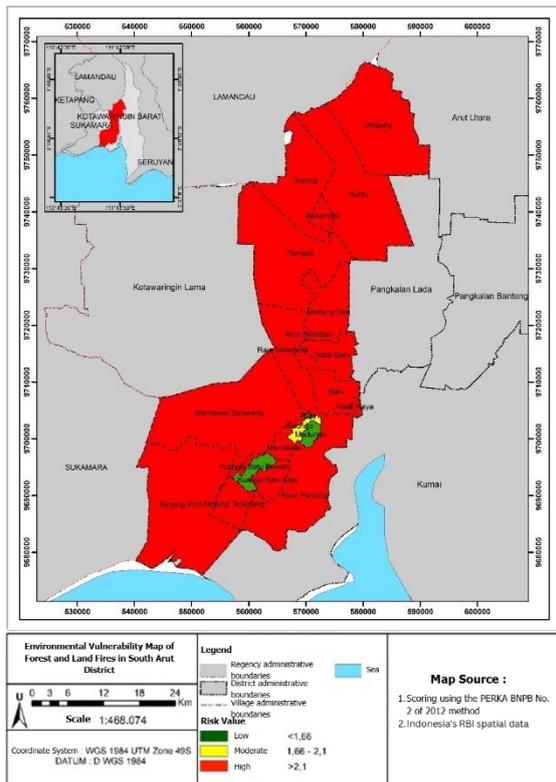**Fig. 5** Environmental Vulnerability Map of Forest and Land Fires in South Arut Sub-district

Fig. 6 Vulnerability Map of Forest and Land Fires in South Arut Sub-district

A total of 16 villages/urban wards fall into the high environmental vulnerability classification, namely: Kelurahan Baru, Desa Kenambui, Desa Kumpai Batu Atas, Desa Medang Sari, Kelurahan Mendawai, Kelurahan Mendawai Seberang, Desa Natai Baru, Desa Natai Raya, Desa Pasir Panjang, Kelurahan Raja Seberang, Desa Rangda, Desa Runtu, Desa Sulung, Desa Tanjung Putri, Desa Tanjung Terantang, and Desa Umbang, with a combined percentage of 97.8% of the total area. Meanwhile, 3 villages/urban wards are classified as having low environmental vulnerability: Desa Kumpai Batu Bawah, Kelurahan Madurejo, and Kelurahan Sidorejo, accounting for 1.9% of the total area. The moderate category includes only Kelurahan Raja, with approximately 0.3%.

Areas with high vulnerability are predominantly covered with vegetation such as protected forests, natural forests, and shrublands. In contrast, areas categorized as low to moderate vulnerability are mostly residential zones (Fig. 5).

c. Social Vulnerability

The social vulnerability map is based on population density and the number of people in vulnerable age groups, obtained from data provided by the Central Statistics Agency (BPS) of Kotawaringin Barat Regency.
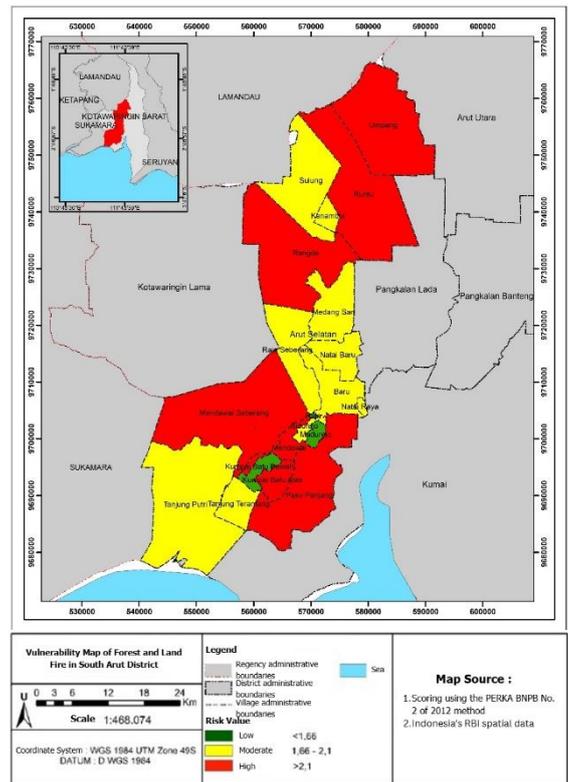
Based on the Social Vulnerability Map, 17 villages/urban wards fall into the high vulnerability classification, including: Kelurahan Baru, Desa Kumpai Batu Atas, Desa Kumpai Batu Bawah, Kelurahan Madurejo, Desa Medang Sari, Kelurahan Mendawai, Kelurahan Mendawai Seberang, Desa Natai Baru, Desa Natai Raya, Desa Pasir Panjang, Kelurahan Raja Seberang, Kelurahan Raja, Desa Rangda, Desa Runtu, Kelurahan Sidorejo, Desa Tanjung Terantang, and Desa Umpang (Fig. 6).

These areas represent 92.7% of the total population, equivalent to 114,760 people/km² out of a total population of 123,706 people/km² in South Arut Sub-district. Meanwhile, the moderate classification includes three villages: Desa Kenambui, Desa Sulung, and Desa Tanjung Putri, accounting for 7.3% or 2,258 people/km².

Based on the results of the three vulnerability indicators—economic, environmental, and social—a comprehensive Forest and Land Fire Vulnerability Map of South Arut Sub-district is presented as follows:

Fig. 7 Social Vulnerability Map of Forest and Land Fire South Arut Sub-district

A total of 7 villages/urban wards fall under the high vulnerability classification, namely: Desa Kumpai Batu Atas, Kelurahan Mendawai, Kelurahan Mendawai Seberang, Desa Pasir Panjang, Desa Rangda, Desa Runtu, and Desa Umpang, with a total area of 1,851 km², accounting for 77.2% of the total area of South Arut Sub-district (Fig. 7)

Table 2. Forest and Land Fire Vulnerability Assessment of South Arut Sub-district

Village / Urban Ward	Classification (Km2)		
	Low	Sedang	Low
Baru	8,5		
Kenambui		150	
Kumpai Batu Atas		30	
Kumpai Batu Bawah	18,25		
Madurejo	26		
Medang Sari	9		
Mendawai			26
Mendawai Seberang			469
Natai Baru		7,3	
Natai Raya	6,2		
Pasir Panjang			162
Raja Seberang		115	
Raja	1,5		
Rangda			51

Village / Urban Ward	Classification (Km2)		
	Low	Sedang	Low
Runtu			504
Sidorejo		6	
Sulung			170
Tanjung Putri			19
Tanjung Terantang		12,25	
Umpang			609

The moderate vulnerability classification includes 10 villages/urban wards, namely: Kelurahan Baru, Desa Kenambui, Desa Medang Sari, Desa Natai Raya, Desa Natai Baru, Kelurahan Raja Seberang, Kelurahan Sidorejo, and Desa Sulung. Desa Tanjung Putri and Desa Tanjung Terantang fall into the moderate vulnerability classification, with a combined area of 495.25 km², accounting for 20.7% of the total area of South Arut Sub-district. Meanwhile, the low vulnerability classification includes three villages/urban wards: Desa Kumpai Raja, with a total area of 45.7 km², representing 2.1% of the total area of South Arut Sub-district.

3.3. Capacity Level of Forest and Land Fire Disaster

Fig. 8 Forest and Land Fire Capacity Map of South Arut Sub-district

fire disasters in South Arut Sub-district is determined based on two indicators: Preparedness Score and Community Resilience Score, both obtained from the Regional Disaster Management Agency (BPBD) of Kotawaringin Barat Regency. The capacity levels are then classified into low, moderate, and high for each village/urban ward (Fig. 8).

Based on the Capacity Map, the high-capacity classification includes four villages/urban wards: Kelurahan Baru, Desa Kumpai Batu Bawah, Desa Natai Baru, and Kelurahan Raja Seberang, representing 20% of the total number of villages/urban wards in South Arut Sub-district

The moderate capacity classification includes 10 villages/urban wards: Desa Kumpai Batu

Atas, Kelurahan Madurejo, Desa Medang Sari, Kelurahan Mendawai, Kelurahan Mendawai Seberang, Desa Natai Raya, Desa Pasir Panjang, Kelurahan Sidorejo, Desa Tanjung Putri, and Desa Tanjung Terantang, accounting for 50% of the total number of villages/urban wards in South Arut Sub-district.

The low-capacity classification includes 6 villages/urban wards: Desa Kenambui, Kelurahan Raja, Desa Rangda, Desa Runtu, Desa Sulung, and Desa Umpang, representing 30% of the total.

Table 3. Forest and Land Fire Capacity Assessment of South Arut Sub-district

Village / Urban Ward	Classification (Km2)		
	Low	Sedang	Low
Baru		8,5	
Kenambui		150	
Kumpai Batu Atas			30
Kumpai Batu Bawah	18,25		
Madurejo	26		
Medang Sari		9	
Mendawai			26
Mendawai Seberang			469
Natai Baru		7,3	
Natai Raya		6,2	
Pasir Panjang			162
Raja Seberang		115	
Raja	1,5		
Rangda			51
Runtu			504
Sidorejo		6	
Sulung		170	
Tanjung Putri		19	
Tanjung Terantang		12,25	
Umpang			609

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3.4. Risk Level of Forest and Land Fire Disaster

The risk level of forest and land fire disasters in South Arut Sub-district is determined using the formula outlined in the Regulation of the Head of BNPB No. 2 of 2012.

Based on the Risk Map, the high-risk classification includes eight villages/urban wards: Kelurahan Mendawai, Kelurahan Mendawai Seberang, Desa Pasir Panjang, Desa Rangda, Desa Runtu, Desa Sulung, Desa Tanjung Putri, and Desa Umpang, covering an area of 2,010 km² or 83.8% of the total area of South Arut Sub-district.
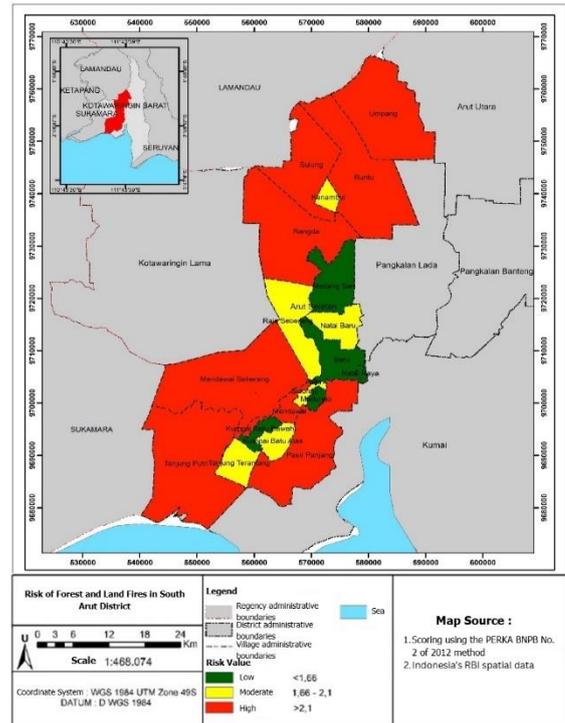
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Fig. 9 Forest and Land Fire Risk Map of South Arut Sub-district

Medium classification consists of 6 villages/sub-districts, namely Kenambui Village, Kumpai Batu Atas Village, Medang Sari Village, Natai Baru Village, Sidorejo Village and Tanjung Terantang Village. Percentage 13.3% with an area of 320.55 km2 of the total area of Arut Selatan District. While the low classification consists of 6 villages/sub-districts, namely Baru Village, Kumpai Batu Bawah Village, Madurejo Village, Natai Raya Village and Raja Village/ Percentage 2.9% with an area of 69.45 km². (Fig. 9).

Table 4. Forest and Land Fire Risk Assessment of South Arut Sub-district

Village / Urban Ward	Classification (Km2)		
	Low	Sedang	Low
Baru			2,5
Kenambui	1,5		
Kumpai Batu Atas		2	
Kumpai Batu Bawah			2,5
Madurejo		2	
Medang Sari		2	
Mendawai		2	
Mendawai Seberang		2	
Natai Baru			2,5
Natai Raya		2	

Village / Urban Ward	Classification (Km2)		
	Low	Sedang	Low
Pasir Panjang		2	
Raja Seberang			2,5
Raja	1,5		
Rangda	1,5		
Runtu	1,5		
Sidorejo		2	
Sulung	1,5		
Tanjung Putri		2	
Tanjung Terantang		2	
Umpang	1,5		

4. CONCLUSION

The hazard level of forest and land fires in South Arut Sub-district is predominantly in the high classification, with 7 villages/urban wards, accounting for 59.4% of the total area. The vulnerability level is also dominated by the high classification, covering 7 villages/urban wards or 77.2%. Meanwhile, the capacity level is mostly in the moderate classification, with 10 villages/urban wards, representing 50% of the total.

The risk level of forest and land fire disasters in South Arut Sub-district is primarily in the high-risk classification, with 8 villages/urban wards making up 83.8% of the total area. The moderate risk classification includes 6 villages/urban wards (13.3%), and the low risk classification also consists of 6 villages/urban wards (2.9%).

The high level of disaster risk is caused by the still-elevated percentages of hazard and vulnerability, while capacity remains at a moderate level. Therefore, it is necessary to enhance local capacity in dealing with forest and land fire disasters in order to reduce the risk.

The local government, from the regency level down to the villages and urban wards, must be committed to increasing disaster management capacity, especially for forest and land fires. An effective mitigation strategy should be implemented, involving all vertical institutions such as the military, police, and relevant agencies, in order to raise capacity levels and reduce hazard and vulnerability percentages.

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