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Forest Fire Control Model in Sungai Wain Protection Forest Ecosystem, East Kalimantan, Indonesia

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ABSTRACT

Sungai Wain Protected Forest Area (SWPF) occupies approximately 11,245 hectares of land, yearly fire-year outbreak inside and outside the area. One of the significant problems associated with this area is the optimal fire control measures. Therefore, this study examines the fire control model in Sungai Wain Protected Forest Ecosystem, East Kalimantan, Indonesia. The Fire Danger Rating System (FDRS) method and the Analytic Weather System measurement were used to determine several FDRS indexes, namely FFMC, DMC, DC, BUI, ISI, and FWI, to obtain the most significant relationship to the occurrence of fires. The analysis shows that FWI is very influential on fires with a correlation value of $Y = 82.907 + 32.814X$, where Y and X denote the level of fire intensity and parameter.

Furthermore, a structure model was used to analyze the present and future picture, which enabled the unified firefighting organization of protected forest management to carry out their jobs properly at low (0.4) moderate (2.67 and 2.403), high (9.368), and extreme index (16.023) FWI index values. This process is carried out with the help of a fire-care community team and the Forest and Land Fire Control Organization of East Kalimantan Province, and forest and land fire control organizations. The result showed that the city of Balikpapan could carry out its duties at the request of the Balikpapan Protected Forest Management Unit or fire with extreme intensity at SWPF. Furthermore, it also suggests locations where the fire is most likely to occur to equip early detection equipment, making it easier to anticipate and prevent fire in the SWPF area and its surroundings.

Keywords: Controlled Fire, Forest Fire, Forest Fire Incidence, Forest Zoning, Sustainable Forest

1. INTRODUCTION

Based on satellite studies, approximately 1.64 million hectares of forests and lands, including 670,000 ha (41%) of peatland, were burnt between 1 January and 31 October in seven Indonesian provinces. These findings reveal that the scale of fires in 2019 is relatively large, compared to that recorded in 2015, which reached 2.1 million hectares. The forest fire incident in East Kalimantan in 2015, 2016, 2017, 2018 and 2019 covered relatively 69,352.86 hectares, 43,136.78 hectares, 676.38 hectares, 27,893.20 hectares, and 68,524 hectares, respectively. This analysis indicates a decline in the forest ecosystem function in all the provinces [1].

However, it is also essential to understand that the role of forest fire varies among habitat types. For example, in tropical dry, boreal, and some coniferous

forests, it is an essential factor that aids in maintaining their structures and functions, including plants and animals' composition. On the contrary, in humid tropical forests, it tends to be harmful. Fire regimes usually change over time through natural causes and human intervention. In many forest areas, they have been substantially altered due to hundreds, and in some cases thousands, of years of human use. In Australia, for example, they have been in existence for thousands of years. They have profoundly affected the extent and distribution of "natural" eucalyptus, dry tropical, and rainforests. Therefore, understanding a particular forest's fire regime is essential for its development and implementing a sound fire management strategy.

The recurrence of fire cases in Indonesia shows that the implemented fire management efforts are still inadequate. This is based on the various information regarding the occurrence of this incidence every year in

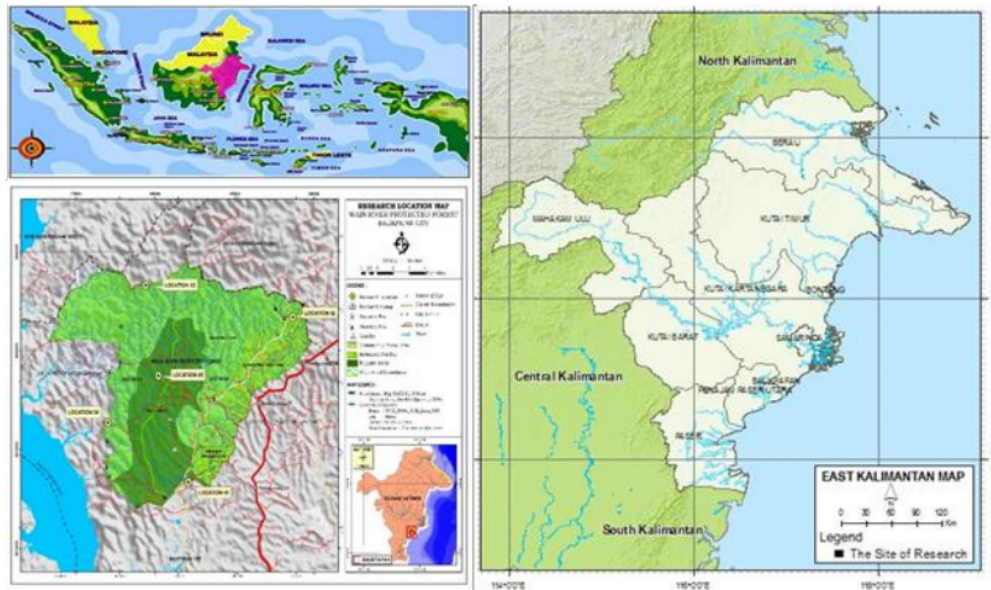


Figure 1 Wain river protected forest research area (SWPF)

different regions. This shows that there are still many unresolved problems. Coping systems involving forest communities that act as triggers and deterrents have increased rapidly in some areas. Currently, forest fires are regarded as natural disasters [2]. They are also referred to as organized crimes because one of the factors that cause them is human-made. Ninety per cent of forest fires are caused by human intention elements aimed at clearing lands for plantation [3].

In 1995, the Sungai Wain Protected Forest (SWPF) had an area of 9,500 hectares, which was later increased to 11,245 hectares, according to the Decree of the Minister of Forestry No. 3922 concerning the Designation of Sungai Wain Protected Forest. An additional 1,463 hectares (13%) were added to the western part of the SWPF. However, 41.6% or relatively 4,677.92 hectares were damaged by forest fires in 1998. The areas that have experienced more than one fire event are represented using a light yellow colour. In contrast, those that have been primarily affected are located in Central and East Kalimantan. In the non-El Niño season, an average of approximately 1.3 Mha experienced fire incidents within one year (1.7% of the mainland located in Kalimantan). However, this was further increased to an average of 3.7 Mha (5.1% of the Kalimantan land area). During the severe fire outbreak in 1997, relatively 4.6 Mha was affected. Ecosystem changes caused by fire incidents significantly affect its habitats. The dynamics and stability of scrub and forest are of particular concern to managers, ecologists, foresters, range specialists, and users of landscape economies, specifically in systems sensitive to tipping

points mediated by the disruption of alternative structural types. The composition, density, and structure of plant communities after a disturbance tend to be resilient whenever it encounters subsequent changes and refuses to return to pre-disturbance conditions due to changes in ecosystem dynamics [4].

One of the pressures usually encountered by SWPF is forest fires yearly, which is common in several other provinces. In 1998, SWPF had an area of 9,783 hectares. However, after the forest fire incident, only 39% or 3,841 hectares remained as natural forests. In comparison, 41.6% or 4,071 hectares were damaged, and approximately 17.4% changed; this was due to the encroachment (land occupation) of 1,703 hectares. Presently, this condition tends to change because land use by the surrounding community is considered uncontrollable, particularly when carrying out certain activities such as clearing of arable lands, logging timber, collecting non-timber forest products, and others. All these activities have an economic motive [5].

The effect of fire on forest ecosystems is highly dependent on its scale (from a single tree exposed to thousands of hectares or more, e.g., canopy vs. surface fires) and severity (e.g., tree fires that usually burned out) according to [6,7]. Severe fires due to stand replacement affect all forest ecosystem components, including nutrient cycling, tree species composition, and regrowth [6,8]. The influence of the dry season in the City of Balikpapan dramatically affects the rate of fire incidence. El Niño also has a significant effect on fire activity [9].

No research has been carried out on forest fire control in Sungai Wain Protection Forest, including creating a model using the Vensim dynamic system program. The results obtained from this research are expected to serve as a guide to the managers of the SWPF, the neighbouring communities, and the Balikpapan City Government to make improvements. Community groups approved by the government are part of forest fire controllers and Sungai Wain Protected Forest guards.

2. MATERIALS AND METHODS

This research was carried out in the SWPF stipulated by the Minister of Forestry Decree No. 3922 concerning the Sungai Wain Protected Forest area with 11,245 hectares. Initially, it was previously regulated by the Minister of Forestry Decree No. 416/KPTS-II/1995 dated 10 August 1995 with an area of 9,783 hectares. The research locations are the northern and western parts bordering Kutai Kartanegara Regency's administrative area and the Singlurus Company's land. The southern and eastern parts of Inhutani are bound by the Kariangau Industrial Estate, Balikpapan City, and the smallholder plantation areas in North Balikpapan Regency. This research was carried out from February 2019 to the same month in 2020. The objective of this study was to develop a model to control forest fires in protected areas.

2.1 Procedure

This study is categorized as descriptive research to create a systematic, factual and accurate picture of the research object's facts and characteristics. In addition, primary and secondary data were collected. Primary data was obtained from interviewing the respondents, and direct measurements or observations were carried out in the field. Secondary data was obtained through reports, literature, and internet site searches on various sources and information from related agencies.

In this study, the primary data collected includes rainfall, atmospheric temperature, humidity, and wind speed. Secondary data collected consists of the number of human resources, vehicles, and the fire location's extent. The data collection techniques used to obtain, analyze, and solve the research problems include an interview described as a dialogue conducted to get information from the source.

Questionnaires are some written questions in the form of reports regarding personal or known matters, which are also used to obtain information from respondents. It is divided into an open questionnaire, allowing respondents to answer the questions in their sentences. The answers have been provided; therefore, the respondents only need to choose from the options.

Observation is a way of collecting data directly by using all the sense organs.

2.2 Data Analysis

The variables used in this research were analyzed according to scientific principles using a fire hazard rating system (SPBK) or a fire danger rating system (FDRS), which is a safety standard for the early detection or warning signal about the possibility of a fire. This system was developed based on indicators that influence a fire outbreak, namely fuel humidity and drought level.

6 The variables, which include atmospheric temperature ($^{\circ}\text{C}$), humidity (%), wind speed (km h^{-1}), and rainfall (mm), were measured using automatic weather systems (AWS) for scientific purposes. The data were further processed using a Fire Danger Rating System (FDRS) program. This data processing produced FFM, DMC, DC, ISI, BUI, and FWI, which are indices of fire hazard warnings and describe forest and land potentials to burn in extreme weather conditions. In this study, an analysis of the relationship between fire incidence and each SPBK code is generated to determine the correlations that have a strong influence on this phenomenon. Furthermore, it was paired with fires occurrences from 2015 to 2019 in the protected forest area of the Wain River. A linear regression formula was applied to obtain the correlation or relationship between fire incidence and the area. This simple equation is a model that describes the relationship between an independent variable or predictor (X) and a dependent variable or response (Y). It is usually expressed in a straight line to determine the correlation or relationship between variables X and Y. To discover the relationship between the FWI index and the fire area, use the SPSS version 24 tool program, or the equation which is stated as follows:

$$Y = a + bX$$

Which:

Y = dependent variable

X = independent variable

a = Constant

b = Regression coefficient (slope)

Dynamic System Modeling Stage is carried out in several stages [10], namely:

2.2.1. Concept Creation

The initial stage is to identify the problem, discover the person responsible for handling it and the reason behind its occurrence. After which, each event is studied to find a pattern. Based on this pattern, problems are formulated, and they are called mental models. These

are described using a diagrammatic model known as a causal loop diagram (CLD), which discloses the cause and effect of the relationship between different variables in a system using a particular image language. The arrows representing the relationship intertwines to form a causal loop, where the arrowheads reveal the causes and effects.

2.2.2. Model Making

After the CLD is formed, a computer model called a stock-flow diagram (SFD) is developed. SFD is broadly translated using computer symbols following the selected software, namely Vensim. They include symbols that describe stock (level), flow (rate), auxiliary, and constants.

2.2.3. Data Input

To analyze a model, both primary and secondary data obtained from field observations are input into the SFD. The method of entering information into the model is highly dependent on the type of data. It is entered into the model as stock, flow, auxiliary, and also constant.

2.2.4. Model Simulation

Based on the SFD, which already contains data, simulation is carried out to obtain results. However, before this is performed, the simulation specifications are first determined and include the integration method, time range, and step. Simulation is the dynamic process of model behaviour, and the output consists of a time behaviour graph and a time table.

2.2.5. Model Validation

Model verification is performed to check the model's suitability developed according to the applicable principles and evaluate some errors during modelling. Meanwhile, validation is the final stage in modelling, which involves checking the model by reviewing its output following the entire system. In other words, it is valid when it displays things that match reality.

The various modelling approaches and methodologies were applied to multiple components of a forest fire management system. However, operations research methods have significantly contributed to this field by focusing on narrowly defined static problems. In addition, one advantage of using System Dynamics over traditional operations research methods is the ability to model the long-term dynamics of various policies and decisions. This provides a broader view of the problem, yielding insights that are systemic rather than statistically significant.

The regression analysis results determine that the FWI Index is influential in the settlement of fire hazard and potential estimates. The Canadian Fire Weather Index System (FWI) is designed to provide a uniform numerical rating of relative fire potential by dynamically combining information from local temperature, wind speed, relative humidity, and rainfall values [11]. Furthermore, assuming the daily time series for each of these variables is available, the system can process actual observations or simulated forecasts in the future. This system relies on six components that convert the input data into an intermediate sum to estimate the final aggregate index. However, three parts describe the state of the fuel (litter and an organic layer, from the surface to more profound levels), while the others are related to fire behaviour (rate of spread, intensity). The final FWI index is a standardized aggregate numerical ranking of fire intensity that considers other components. In addition, it takes into account the behaviour of reference fuel types (mature pine stands), regardless of other factors that tend to affect fire hazards such as topography and the actual or future fuel details; therefore, this system supports harmonized comparisons between different regions, and time intervals in a particular area, to highlight the role of climatic variations in weather-induced fire hazard components.

3. RESULTS AND DISCUSSION

Fire Weather Index (FWI) is a general fire hazard rating indicator. This code is used for estimating the difficulty of fire control. The results showed that the magnitude of the correlation value (R) was 0.916, and the effect of the independent variable on the dependent variable is called the determination of R squared. Based on this output, the coefficient of determination (R^2) is 0.84, which means that the effect of the independent variable (FWI Index) on the dependent variable (fire area) is 83.9%, while other factors besides variable X influence the rest.

ANOVA shows the significant (significant) effect of the FWI (X) on the Fire (Y). Following this output, it is obvious that F count = 15.636 with a significance or probability level of $0.029 < 0.05$; therefore, the regression model is used to predict the fire area's variable. Subsequently, the constant (a) is 82.907, while the average index value (b) is 32.814, the model or regression equation is written as $Y = a + bX$ or $82.907 + 32.814X$

Weather and climatic factors that influence forest and land fires are humidity, determine the water content or fuel moisture, and the occurrence of fires [12]. Atmospheric temperature affects the drought region, particularly during the dry season. Rainfall affects humidity and the water content or fuel moisture. The

wind helps to dry the fuel and determines the direction of fire spread.

However, the weather has an influential impact on fire incidence. According to [13], research using the historical relationship between weather and fire hazard and two GCMs to predict Canada's prospective areas is likely to experience fire incidence. The results showed an increase of 74 to 118% of sites is expected to encounter this phenomenon by the end of this century. Change in the fire regime inflicted on sustainable forests management in Canada. They found that estimates regarding future fire activities in this century are less than that of the historical (pre-industrial) recorded in many locations worldwide. It was suggested that boreal forest management is potentially utilized to re-create forest-age structures from fire-dominated pre-industrial landscapes [14].

Conversely, other factors such as ignition agents, duration of fire season, and management policies are likely to influence climate change on fire activities greatly. However, this does not describe vegetation changes, which severely affect lightning ignition and burnt areas. The increased potential is due to the low humidity of the fuel. The distribution of temperature, humidity, rainfall and wind speed are shown in Figure 2.

Fine Fuel Moisture Code (FFMC) is a numerical rating of litter's moisture content and other fine fuels. This code is an indicator of the relative ease of ignition. The magnitude of the FFMC index and fire variables' relationship shows that (R) is 0.861. This measures the percentage influence of the independent variable on the dependent variable, and this is called determination obtained by R squared. Based on this output, the

coefficient of determination (R^2) is 0.741, which implies that the effect of FFMC Index (independent variable) on fire (dependent variable) is 74.1%. At the same time, the rest include other factors besides the X variable.

The output results (ANOVA) shows the significant effect of the FFMC index (X) on the Fire variable (Y). Following this output, it was discovered that F count = 8,596 with a significant level or probability of $0.061 > 0.05$; therefore, the regression model was not used to predict the fire area variable. The result of the correlation equation between the FFMC index and the fire area shows that in column B the constant (a) is -10009.432, while the average index value (b) is 17.661; therefore, the model or regression equation is stated as follows $Y = a + bX$ or $-10009 + 17.661X$.

Duff Moisture Code (DMC) is a numerical rating of the average moisture content of a medium-depth, non-dense organic soil layer. This code indicates the fuel consumption in moderate duff layers and medium-size woody materials. The value of the correlation or relationship (R) is 0.800, and the percentage influence of the independent variable on the dependent variable is called determination obtained by R squared. Following this output, the coefficient of determination (R^2) is 0.809, which implies that the influence of the DMC index (independent variable) on the fire area (dependent variable) is 80.9%. In contrast, other factors influence the rest in the X variable.

In the ANOVA section, it shows that the real (significant) influence of the DMC (X) is on the Fire variable (Y). Based on this output, it is shown that the F count = 12.691 with a significance level or probability of $0.038 < 0.05$; therefore, the regression model is used

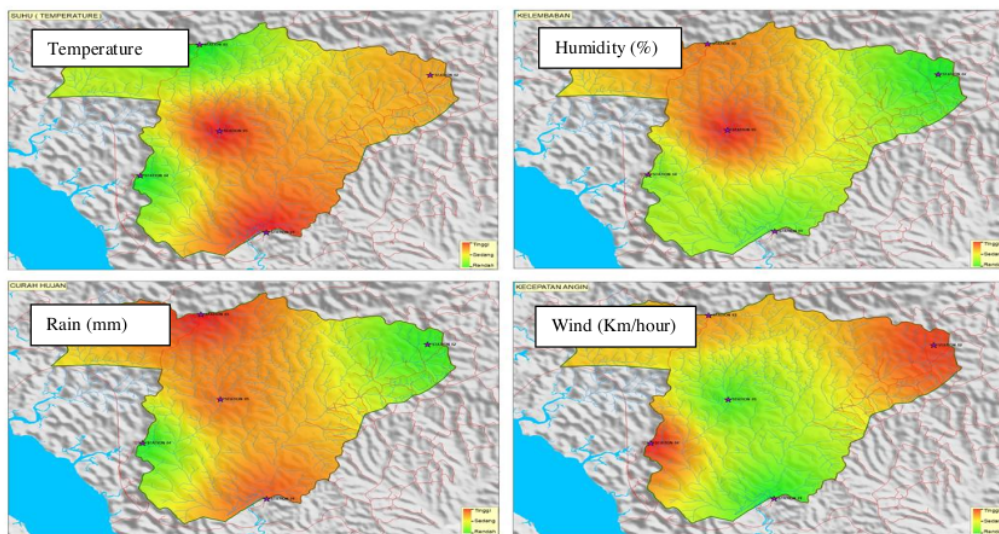


Figure 2 The distribution of temperature, rainfall, humidity and wind speed

to predict the fire area. Furthermore, the equation in column B, shows that the constant value (a) is 51.079, while the average index value (b) is 11.397, the model regression equation is stated as $Y = a + bX$ or $51.079 + 11.397X$.

Drought Code (DC) is a numerical ranking of the organic layer's average moisture content relatively 10 to 20 cm beneath the soil surface. This code is a useful indicator of seasonal drought and a potential for the occurrence of haze. The magnitude of the correlation or relationship value (R) is 0.298. This illustrates the independent variable's percentage influence on the dependent variable called determination, R squared's outcome. Based on this output, the coefficient of determination (R²) is 0.89, which implies that the influence of the Free DC index (independent variable) on fire (dependent variable) is 89%, while other factors besides the X variable influence the rest.

The ANOVA section shows the significant effect of DC (X) on the Fire variable (Y). Following this output, it is obvious that the F count = 0.293 with a significance level or probability of 0.626 > 0.05. Therefore the regression model was not used to predict the fire area variable. The equation in column B shows that constant (a) is 151.260, while the average index value (b) is 0.499, the model or regression equation is reported as follows $Y = a + bX$ or $151.260 + 0.499X$

Initial Spread Index (ISI) is a numerical rating of the fire spread caused by fine fuels (grasses). The ISI is a useful indicator for the difficulties encountered during fire control. The magnitude of the correlation or relationship value (R) is 0.953. The percentage influence of the independent variable on the dependent variable is called determination obtained from R squared. Following this output, the coefficient of determination (R²) is 0.914, which implies that the influence of the ISI index (independent variable) on the Fire Area (dependent variable) is 91.4%, while other factors besides the X variable influence the rest.

The value of the ANOVA illustrates the real (significant) influence of the DC (X) on the Fire variable (Y). Relating to this output, it is obvious that the F count = 31.954 with a significance level or probability of 0.011 < 0.05; therefore, the regression model is used to predict the fire area. Based on the results, Constant (a) is -36,356, while the mean index value (b) is 127.235, the model or regression equation is reported as $Y = a + bX$ or $-36.356 + 127.235X$

Build Up Index (BUI) is a numerical ranking of the consumed fuel level and a combination of DMC (Duff Moisture Code) and DC (Drought Code). The magnitude of the correlation or relationship value (R) is 0.89. It illustrates the independent variable's percentage influence on the dependent variable, referred to as determination realized from R squared. Based on this

output, the coefficient of determination (R²) is 0.794, which implies that the influence of the BUI index (independent variable) on fire (dependent variable) is 79.4%, while other factors besides the X variable influence the rest.

This shows the magnitude of the real (significant) influence of the DC (X) on the Fire variable (Y). Following this output, it is obvious that the F count = 11.575 with a significance level or probability of 0.042 < 0.05; therefore, the regression model is used to predict the fire area. The magnitude of the constant (a) is 40,812, while the average index value (b) is 7.494, the model or regression equation is stated as follows $Y = a + bX$ or $40.812 + 7.494X$.

3.1. Research Location One

Based on tabulations, the simulation results of the fire control model in the first research location is FFMC 73.7 (extreme), DC 164.76 (moderate), ISI 1.6 (moderate), FWI 2.403 (moderate), and an intensity factor of 0.5. Location one is adjacent to the residential areas and included in the Balikpapan Botanical Gardens. Initially, the fire was started when members of the community deliberately threw away their cigarettes, thereby igniting the forest fuel due to the extreme content of the FFMC index of 73.7. The SPBK code (FFMC, DMC, DC, ISI, BUI, and FWI) is used as a fire hazard warning because it describes forest and land's potential to get burnt due to extreme weather conditions [15]. In tropical forests, most fire incidents have low to moderate fire intensity [16].

Conversely, whenever a fire broke out at location 1, members of the community usually try to contact the nearest fire department to report the incident. They usually succeeded in providing useful information. The officers and firefighters respond immediately by heading to the location according to the information provided. The pressure exerted by the firefighting team affected the fire intensity; however, they were unable to resolve this issue within one day. Therefore, it continued for several days.

Furthermore, during a fire incident, supposing the DC value system model is 164.76. It means that the smoke is moderate and does not have a massive impact on the Sungai Wain protected forest community and animals. In this study, the fire characteristics were moderate, the canopy was slightly burnt, litters were removed, and the fire was controlled.

On the first day, the firefighters were able to control the fire because its intensity was below zero, meaning that the fire was controllable, as shown in Table 1.

At the time of this study, the least average annual rainfall in location 1 was 0.4 millimeters; however, this was insignificant to the fire's magnitude or rate. This

Table 1. Fire intensity and fire control

Time (Day)	0	00.05	1	01.05	2	02.05	3	03.05	4	04.05	5
Fire extinguisher intensity :	64	445.309	5119	63784.2	802077	1,01E+11	1,27E+13	1,60E+14	2,01E+15	2,54E+16	3,19E+17
Fire intensity :	36	39.05.00	-616.839	-1531.71	-20302.6	-256964	-3,24E+11	-4,07E+11	-5,13E+13	-6,46E+14	-8,13E+15

was due to the local people’s level of awareness regarding the protection of the SWPF. Following several studies carried out on climatic factors, it was reported that rainfall indirectly affects forest and land fires. Precipitation is an essential factor that influences the humidity of the fuel. According to [17], it is used to determine the accumulation of grass fuel. In Indonesia, fire incidents are generally related to drought, which occurs from the middle to the end of the dry season. In addition, there is a significant relationship between fire area (ha), rainfall (mm), and frequency.

The graph of energy intensity plotted against fire behaviour in the Sungai Wain protected forest ecosystem shows moderate intensity. The firefighters extinguished the fire more quickly at research location one. Based on the results from the regression analysis of the FWI index value as the X variable lever model and fire area Y, the following equation is used to estimate the size of the fire area at study site 1, $Y = 82.907 + 32.84 (X)$. The fire area’s value is 1.07 hectares, and the fire control model shows that the fire department was able to control the fire within one day. However, the intensity is worth opposing. This means that the fire intensity could not suppress the SWPF ecosystem because the fire fighting energy is greater than the intensity. It is estimated that several types of plants got burnt at this location.

The ISI value is 3.8, and this figure shows that the fire tends to be overcome before using a fire extinguisher. The fire control parameter tries to suppress the intensity factor. However, when a fire occurs, the intensity shows a positive behaviour, such as the burning of some plants in the research location.

According to the graph, fire behaviour was overcome by using a fire extinguisher. Several plants, among others, were discovered in this location are ironwood (*Eusideroxylon zwageri*), bengkirai (*Shorea laevis*), meranti (*Shorea spp*), lai (*Durio kutejensis*), earth peg (*Eurycoma longifolia*), nibung (*Oncosperm tigilarium*), yellow root (*Coscinium fenestratum* and *Fibraurea tinctoria*), orchids black (*Coelogyne spp*), semar bag (*Nepenthes spp*), gaharu (*Aquilaria microcarpa*), pait-pait wood (*Quasia indica*), barito tab (*Ficus del Aptoidea*), and rattan (*Calamus spp*). The graph of escalation plotted between fire intensity and control is shown in Figure 3.

Research location 1 is directly adjacent to community settlements and plantations around the Sungai Wain protected forest. This site provides many benefits; apart from the water, several sources of non-timber forest products (NTFP) are realized from SWPF. Forest resources have many functions and provide numerous services to humans [18]. One of the obstacles that need to be considered is the marketing factor. This includes the transaction process of commodity selling prices, costly and expensive transportation due to mountainous areas [19]. Non-timber forest products offer more significant benefits for residents, particularly those residing near the forests because it provides various necessities of life such as food, medicine, clothing, and household tools according to the research was done by [20,21]. In addition, it also encourages community participation in forest conservation programs [22]. Relatively minor damage using a single hoist at the ground surface is caused by slipping the topsoil and remaining stands [23].

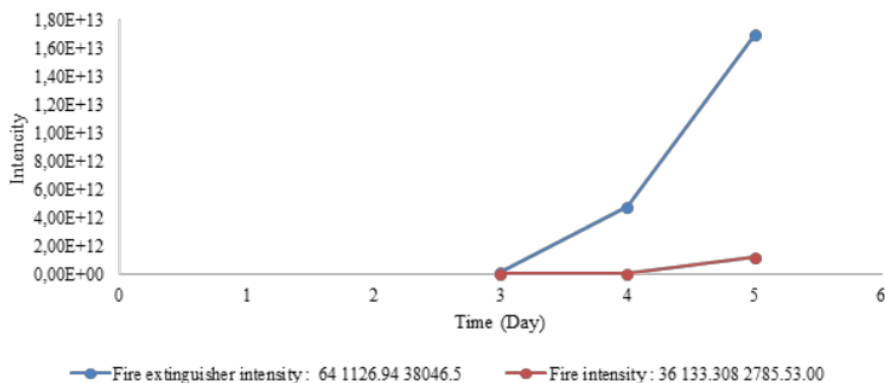


Figure 3 Graph of escalation between fire intensity and fire control

3.2. Research Location Two

Based on this analysis, the fire intensity at location two and the fire control simulation scenario model show extreme activities because the average impact of the accumulated FPMC index is 82.3 (high). The FPMC 81-83 threshold indicates the point at which the most exposed refined fuels in the landscape have the potential to burn, which is when DC is 453.3 (extreme), ISI 4.8 (High), FWI 16,023 (extreme), and an intensity factor of 0.7. The fire incident's initial simulation model in location 2 started with the community deliberately burning the forests to expand the area by 1,400 hectares designated by the government for plantation activities. The fires occurred at high speed because the value of the FPMC index is 82.3. This causes its rapid spread to the plantation and can enter SWPF primary and secondary forests. Society could not control the fire, irrespective of the self-awareness effort to use simple tools such as leaves and water; therefore, they tried to contact the Community Fire Care Team (KKP), which was not far from location two. The KKP wanted to overcome it; however, their efforts did not go well. Therefore, they collaborated with the Sungai Wain Protected Forest Unit (KHL). Maximum effort was made by the fire department team together with the East Kalimantan Province Fire Control Management Team, the East Kalimantan Provincial BPBD, the Balikpapan City Fire Control Task Force Organization, the Indonesian National Army and Police (TNI/POLRI), Basarnas, BPBD Balikpapan City.

The smoke disturbed the community, particularly road users unable to see ahead because of the thick smog around the SWPF. This is because the value of the DC index is 453.3, which is at the disaster level. This is immediately conveyed to the Balikpapan City Government to issue a decree. The fire intensity at location two is difficult to extinguish because the FWI index of 16,023 is an extreme value, as shown in Figure

8. The following types of plants namely white dragon fruit (*Hylocereus undatus*), dragon fruit with red meat (*Hylocereus*), aren (*Arenga pinnata*), rice (*Oryza sativa*), corn (*Zea mays*), banana (*Musa paradisiaca*), ginger (*Zingiber officinale*), salak (*Salacca zalacca*), coconut (*Cocos nucifera*), and lahung (*Durio dulcis*) were presumed to be burnt. The level of fire characteristics is extreme, and the impact is in the form of canopy fires, causing damages to remaining stands, open grounds and killing all understorey. The escalation between the control factors and fire intensity is shown in Figure 4.

Figure 4 shows that the fire extinguisher was unable to control the fire intensity until the sixth day. Therefore, it was only able to imperfectly extinguish the fire because the forest fuel ecosystem ignited it. The graph shows that the fire intensity was greater than that of the firefighting on the sixth day, thereby causing it to continue. Supposing, the government fails to increase the fire extinguishing energy's capacity to fire in SWPF.

The condition of location 2 shows that the value of the ISI index is 4.8, and this affected the FPMC and FWI indices. Supposing this location offers huge fire rates, based on the regression results, is influenced by the index. The ISI index determines the effect of FPMC and wind speed on the rate of fire propagation [24]. DC represents the rate of water content at a soil depth in the solid organic layer and is a good indicator of the effect of seasonal drought on coarse fuel. BUI combines the DMC and DC rates of fuel moisture to represent a dry and flammable fuel fraction [25]. FWI combines ISI and BUI, a relative measure of a single fire's potential intensity spread in an area [24]. The FWI value ranges from 0 to 50. This model's main disadvantage is that it provides an overview of the currently available dead fuel components. The sufficient fuel's humidity level is controlled by the surrounding weather conditions, including atmospheric temperature, humidity, wind,

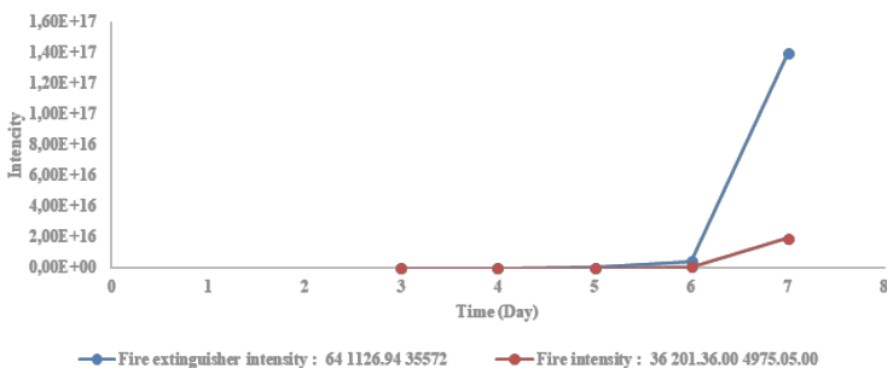


Figure 4 Graph of escalation between fire intensity and fire control



Figure 5 Fire incidents in Sungai Wain and its surrounding protected forest

solar radiation, and rainfall.

The people residing around the SWPF usually use fire to prepare their lands for cultivation because it is an essential tool. Therefore, humans are responsible for the majority of forest fires in the tropics. The direct causes are used as weapons during the land tenure or disputes, including accidental, escaped, or related fires resource extraction [26]. Land development strategies, such as pulp or oil palm plantations, use fire for tillage and significantly contributed to its incidents in recent years [27]. In addition, small farmers use fire to prepare their lands for cultivating crops. This process often extends to the surrounding forest, particularly during the El Niño years. Arson is the leading cause of fires incidence in many areas rich in resources. The land is scarce for agricultural purposes and conflicts concerning ownership or access rights [28]. This incident is prevalent in natural forests and when people have acquired land for large-scale plantations, such as oil palm [27].

The fire behaviour's energy intensity in the Sungai Wain protected forest ecosystem shows extreme intensity; therefore, initially, the firefighters had difficulty extinguishing the fire. However,

management's ability to utilize the fire-care community (MPA) made it possible for the fire to be extinguished or controlled. The fire area at location 2 is estimated as 1.68 hectares per day; the fire control model results show that in 2 days, the fire is suppressed below zero. The behaviour of the firefighter is shown in Figure 5.

The Wain river's protected forest has several biodiversities destroyed by the fire incident's impact, particularly its flora and fauna habitat. Plant and animals' death led to forest destruction, causing a decrease in these species' survival rates. Based on the ISI index value, which is relatively high, in 2015, the impact of fire in the form of smoke was encountered in Jalan Soekarno Hatta Balikpapan-Samarinda, located around the protected forest of the Wain river. Fires are one of the leading causes of forest destruction and the disruption of its sustainability. It has a considerable impact both ecologically and economically. This often occurs in Kalimantan and Sumatra, although it harms the environment, namely the provision of forest and land resources, the economy, and other losses due to smoke (pollution) usually encountered when moving to nearby countries, Malaysia and Singapore [29].

3.3. Research Location Three

Following the results obtained at location three, the fire control simulation scenario model shows moderate activity since the average accumulated impact of the FPMC index is 71.7 (high), DC 116.3 (low), ISI 1.8 (moderate), FWI 2.67 (moderate), and an intensity factor of 0.5. This study location is adjacent to the mine area of Singlurus and Inhutani companies. The fire incident that occurred was assumed to be caused by the community trying to enter the SWPF from the northern part. They accidentally dropped cigarette butts, and the forest quickly caught fire because of the high value of the FPMC index, which was 71.7. The setting parameter tries to suppress the intensity factor; however, it shows a positive behaviour at the initial stage when a fire occurs. This is displayed by the ability to burn several plants, including ironwood (*Eusideroxylon zwageri*), bengkirai (*Shorea laevis*), meranti (*Shorea* spp), earth peg (*Eurycoma longifolia*), nibung (*Oncosperm tigararium*), yellow root (*Coscinium fenestratum* and *Fibraurea tinctoria*), black orchid (*Coelogyne* spp), semar bag (*Nephentes* spp), gaharu (*Aquilaria microcarpa*), pait-pait wood (*Quasia indica*), barito tab (*Ficus del Aptoidea*), and rattan (*Calamus* spp) in a particular location. The simulation results are shown in Figure 8. The graph shows a positive behaviour, irrespective of the fact that the fire intensity could not withstand the rate of control. The effect of the FWI index value of 2.67 and fire intensity of 0.5 is moderate, meaning that the fire is slightly controlled, and the system behaviour is shown in Figure 6.

Irrespective of the fact that research location 3 is adjacent to a coal mining area, the source of fire is not expected to be generated from its activities. In the context of prevention and control, the National Coordination Team for management of forest and land fires (2017) stated that the fire incidents in the coal seam were caused by outcrops of flammable lignite, spreading to both forests areas and other land uses.

During extinguishing the fire, the top order is prevention and, at the same time, cutting off the connection or contact between the burning coal seam and the atmosphere.

The scenario and data tabulation results show that fire incidents in the Sungai Wain protected forest ecosystems is moderate intensity. The model scenario provides a directive that shows the firefighters had no difficulty in extinguishing the fire. Based on the linear regression equation, the fire area at location three is 0.4 hectares per day; the fire control model shows that firefighters can control it for one day. However, there is a need to considered the magnitude of the incident on the flora and fauna ecosystem in SWPF. The impact of this fire is felt by the ecosystem in the protected forest of the Wain river. For example, the incident that occurred between 1982 to 1983 in Kutai National Park (East Kalimantan) led to the death of several reptiles and amphibians [30] and the loss of fruit trees, thereby causing a decline in the population of fruit-eating birds such as hornbills, plummet [31].

Figure 8 shows that the fire intensity is moderate; therefore, the firefighting team can perform their jobs effectively. The graph indicates that the fire control is greater than the fire intensity, which led to the fire being extinguished earlier. The firefighting team was able to control the fire within three days; however, the incident did not affect a larger area of the forest ecosystem compared to the second study site.

The community does not use the third research location, and the number of shrubs and trees are left abandoned, thereby posing as a potential source of the fire. This is due to the accumulation of fuel from dead trees in the area. A similar incident also occurred in Portugal. Fuel was accumulated over time through other means. The reforestation of pine plantations on public lands [32] and direct investment in eucalyptus by pulp and paper companies and private non-industrial landowners [33] significantly increased Portugal's total

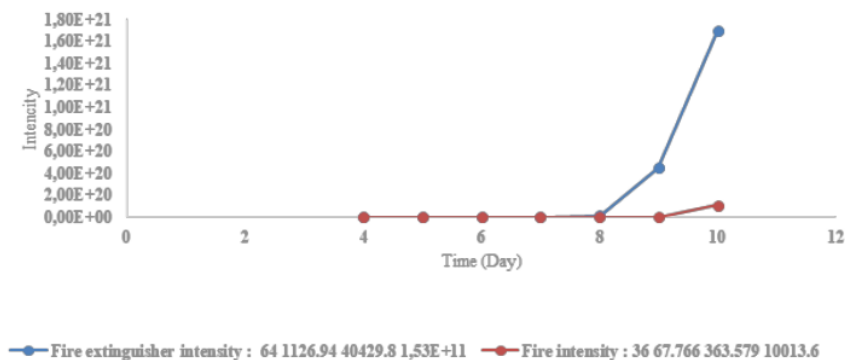


Figure 6 Graph of percentage of fire intensity and fire control

forest area this period. Therefore, an increase in forest areas also positively affected the accumulation of fuel in the 20th century. Presently, rural areas and forests are severely abandoned due to a lack of agricultural activities and emigration flow to coastal cities, which started around the second half of the 20th century [34]. Traditional farming practices before this period kept fuel levels reasonably stable through the integration of agriculture and livestock grazing with fuel management. However, as agriculture became abandoned, scrub and the mixed forest began to dominate the landscape resulting in a 20-40% increase in fuel accumulation [34].

3.4. The Fourth Research Location

The simulation results of fire control level and intensity at location four with control simulation scenario models show high activity, the average accumulated impact of the FPMC, DC, ISI, and FWI index values are 83.5 (extreme), 247.5 (medium), 3.8 (moderate), and 9,358 (high), with intensity factor of 0.6. Fires occurred in study locations four, with the incidents adjacent to the Kariangau industrial area and the East Kalimantan Institute. The fire incident is suspected to be the fire source for people trying to expand the industrial business area. The climatic conditions in the Sungai Wain protected forest ecosystem; the FPMC with an extreme index indicated that it was very dangerous, and the FWI index was also high. There are several plants in one location, including ironwood (*Eusideroxylon zwageri*), bengkirai (*Shorea laevis*), meranti (*Shorea spp*), earth peg (*Eurycoma longifolia*), nibung (*Oncosperm tigarium*), yellow root (*Cosciniun fenestratum and Fibraurea tinctoria*), black orchids (*Coelogyne spp*), semar bags (*Nepenthes spp*), gaharu (*Aquilaria microcarpa*), pait-pait wood (*Quasia indica*), barito tab (*Ficus del Aptoidea*) and rattan (*Calamus spp*).

Figure 7 shows that the fire's intensity is extreme; therefore, the fire fighting team found it difficult to extinguish. The graphical behaviour also indicated that

the team could not control the fire intensity; thus, it continued burning until the seventh day. On the eighth day, they were able to control the intensity; therefore, the total time spent in maintaining the fire was seven days, as shown in Figure 9. Research location 4 is different from 2, where the firefighting team was unable to complete its task until the sixth day. However, at location four, they were able to control the fire on the seventh day.

Location four, firefighters have no difficulty in extinguishing the fire, as shown in table 4. On the first day, the firefighters were able to control the fire, as illustrated in Figure 7, using good initial energy, thereby preventing it from growing. Based on the regression equation results at location four, the fire area is calculated based on the FWI year index value of 2.403 to obtain 0.44 hectares. Furthermore, the burned area's magnitude is determined based on fire control models at location four, not more than one day. Several factors influence fires' occurrence; therefore, a dynamic system that aims to provide information on its real existence in the field is designed to analyze the problem.

3.5. Research Location Five

The measurement results showed that the FPMC, DC, ISI, and FWI index values were 55.3 (moderate), 359.6 (high), 0.5 (moderate), and 0.4 (low). At the FWI, there is no combustion due to the low, while the FPMC and DMC are described as fine and coarse fuel conditions with potential ignitions. Therefore, even though the FPMC and DMC conditions are high, there is no trigger in activity because Indonesia's fires were deliberate. However, research location 5 is situated in the middle and difficult to access in a fire outbreak. This area does not have early detection; therefore, it needs special daily care.

It is concluded that based on the simulation results of the fire control model, the simulation index based on research data at location 1 shows that the FPMC index value, DC, ISI, and FWI were 73.7 (high), 164.76

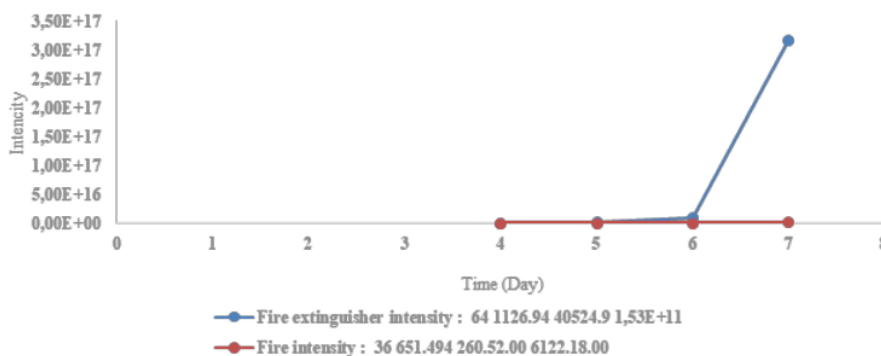


Figure 7 Graph of percentage of fire intensity and fire control

(moderate), 1.6 (moderate), and 2.403 (moderate). It is estimated that the area of land burned is 1.07 hectares per day. For location two, the average FFMC, DC, ISI, and FWI index values were 82.3 (high), 453.3 (extreme), 4.8 (High), and 16.023 (extreme), respectively. The fires of the Sungai Wain protected forest ecosystem in location two showed extreme intensity. Meanwhile, the fire data in study location two, which covers 1.68 hectares per year, from several research locations, shows that the highest number of fires comes from the agricultural community. Furthermore, based on the simulation results of fire control scenarios, firefighters have difficulty extinguishing the fire. For location three, the FFMC, DC, ISI, and FWI mean index values were 71.7 (high), 116.3 (low), 1.8 (moderate), and 2.67 (moderate), respectively. The fire in the Sungai Wain protected forest ecosystem showed moderate intensity; therefore, firefighters had no difficulty during the extinguishing process. Fires in the third study area reached 0.4 hectares per day; hence location four have an average FFMC, DC, ISI and FWI index values of 73.7 (high), 164.76 (moderate), 1.6 (low), and 2.403 (low). Firefighters at this location had no trouble putting out the fire. For location 5, no fire scenario was made because the DC and FWI numbers were low; therefore, the analysis showed that, in the absence of fires that occurred in location 5, the DC and FWI indices were relatively low, meaning that the fuel in the forest was in a low humidity position; hence they were unable to burn properly.

4. CONCLUSION

There are many tasks from the East Kalimantan provincial government that need to be carried out in fire control in SWPF, especially at research location 3, which is quite far away without firebreaks. Therefore, a budget is needed to provide a sense of security to the ecosystem and grant access to vehicles. In SWPF, the budget is essential to maintain its sustainability; therefore, increasing the Suppression Budget is synonymous with a rise in the extinguishing resources used to increase firefighting capability, thereby lowering the average duration and reducing forest burning. The model informs the effect of more extinguishing resources on fire duration. Time decreases with an increase in extinguishing expenditure. In a fire control model, the total cost of fires and suppression decreases at a low rate [35]. With more resources (e.g. firefighters), response time is reduced, reducing the likelihood that the fire escapes the initial attack, thereby lowering damages and suppression costs [36].

There are many different challenges to policy implementation, and the majority is bureaucratic. One of the shortcomings of democracy and checks and balances is the slowness in implementing new policies (or laws).

Another challenge is the number of stakeholders investing minor issues with many complicating bureaucratic issues, thereby extending the time needed to approve policy changes. The difficulty in supporting the People's Representative Council's budget is part of a fire control problem, and conservation of the Wain river protected forest. The Wain river protected forest has a large economic resource for serving the community and companies' water needs in the City of Balikpapan [37]. Therefore, it is only natural that the people's representatives who sit in the parliament think of ways to realize the fire control budget.

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