

Optimizing Peatland Fire Mitigation Policy Through Technology and Innovation

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Abstract

Peatland fires are one of the biggest environmental problems in Indonesia with a wide impact on the environment and public health. Efforts to prevent and mitigate peatland fires are becoming increasingly important as the intensity of fires increases. Government policies, technological support, and community participation are key to preventing and reducing peatland fires. This study aims to examine the synergy between policies, technologies, and the role of communities in mitigating peatland fires. The method used is a qualitative approach, by collecting data from various relevant studies and previous literature. The data obtained are then analyzed to explore the relationship between these factors. The study results indicate that government policies have an important role in fire mitigation, although there are challenges in their implementation, such as low levels of compliance and coordination between institutions. Technology, especially in peatland monitoring and early warning systems, has made a significant contribution to fire prevention. However, obstacles in infrastructure and technology adoption remain obstacles that need to be overcome. Community participation and wider education are also needed to support the effectiveness of policies and technologies in fire prevention. In conclusion, a strong synergy between policies, technologies, and communities is essential to achieving sustainable peatland fire mitigation.

Keywords: Policy, Mitigation, Fire, Peatland, Technology, Innovation.

INTRODUCTION

Peatland fires have become an increasingly pressing issue in tropical countries, including Indonesia, where peatlands play an important role in the ecosystem and the lives of local communities. Peatlands, which are one of the most productive types of wetlands, have been significantly damaged by land clearing for plantations, agricultural activities, and unsustainable logging (Mishra et al., 2021). The process of draining peatlands has made the soil highly flammable, especially during

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the long dry season, resulting in widespread and difficult-to-control fires. The impact of these fires is not only limited to local areas but also affects air quality in regional areas, even across countries, with thick and prolonged smoke haze (Kirkland et al., 2023).



Figure 1. Peatlands

Peatland fires have a very significant impact on the environment, economy, and public health. The thick smoke produced by these fires causes various health problems, especially respiratory problems for communities around the affected areas. In addition, carbon emissions released from peat fires contribute significantly to global climate change (Phung et al., 2022). Peatlands store large amounts of carbon in their soil, and when burned, this carbon is released into the atmosphere in large quantities, exacerbating the greenhouse gas effect. The economic consequences are also very pronounced, both from direct losses in the form of damage to agricultural and plantation land, as well as the costs incurred to extinguish fires and restore land that has been burned (Volkova et al., 2021).

Despite efforts from various parties, including the government and non-governmental organizations, to reduce the risk of peatland fires, the challenges in mitigating these fires are still very large. Policies that have been implemented are often unable to effectively reduce the number and intensity of fires that occur each year. One of the main reasons is the lack of application of appropriate technology and limitations in the innovation needed to combat peatland fires. In an increasingly urgent situation, optimizing policies through the use of technology and innovation is very important to ensure that mitigation measures are not only temporary but can be sustainable in the long term (Puspitaloka et al., 2021).

Technological developments have offered various potential solutions to reduce the risk of peatland fires. Monitoring technology, such

as the use of satellites and drones, allows early detection of hotspots and areas that have the potential to burn. However, although this technology is available, its implementation in the field still faces various obstacles. Inadequate infrastructure, high costs, and limited access to this technology mean that its use is not yet optimal (Abdelmajeed & Juszczak, 2024). On the other hand, innovation in land management is also key to reducing the risk of fires. For example, appropriate water management techniques in peatlands can maintain soil moisture and prevent drying out which makes the land vulnerable to fire. Unfortunately, these innovative practices have not been widely adopted, and many still rely on traditional and less efficient land management methods (Taufik et al., 2022).



Figure 2. Peatland Fires

In addition, there are challenges in terms of coordination and synergy between the various parties involved in peatland fire mitigation. The government, private sector, and local communities often work separately, with policies that are not always aligned with each other. On the government side, although there are regulations governing land fire prevention, their implementation at the local level is still ineffective (Jefferson et al., 2020). Many regions still do not have adequate capacity to implement these policies, especially in terms of providing trained human resources and supporting infrastructure. The private sector, especially plantation companies, is often less involved in comprehensive fire mitigation efforts. They have a significant role considering the large amount of peatland used for industrial and plantation activities (Saleh et al., 2020).

Local communities, most of whom depend on peatland for their daily lives, also play an important role in these mitigation efforts. Without community involvement, the policies made will be difficult to implement effectively. Therefore, active community participation in maintaining peatland and preventing fires is needed. However, there are still

limitations in terms of education and socialization regarding the importance of protecting peatlands from fires. Many people still rely on the practice of burning land to clear agricultural land, which, although it has been banned, is still widely practiced because it is considered a fast and cheap method (Wiesner & Dargusch, 2022).

In this context, optimizing peatland fire mitigation policies through technology and innovation is a must. Traditional approaches that have been used in fire prevention have proven to be ineffective in facing increasingly complex challenges. Technological innovation is not only needed to detect and extinguish fires but also to manage land sustainably so that it is not vulnerable to fire. The use of sophisticated technology, supported by appropriate policies, can provide long-term solutions to the problem of peatland fires. However, to achieve this, synergy is needed between various parties, from the government, and the private sector, to local communities, to ensure that fire mitigation efforts can be implemented more effectively and efficiently (Martynyuk et al., 2021).

Therefore, this study aims to examine how technology and innovation can be used optimally in peatland fire mitigation policies. By combining appropriate policies with the use of modern technology, it is hoped that a more effective approach can be created to overcome the problem of peatland fires. This study will also explore the challenges faced in implementing technology in the field, as well as how policies can be optimized to support the wider use of these innovations.

LITERATURE REVIEW

Peatlands

Peat is a wetland ecosystem characterized by the accumulation of organic matter over a long period of time. This accumulation occurs because decomposition is relatively slow compared to the rate of accumulation of organic matter. Peat is formed from piles of dead vegetation remains, both rotten and unmodified. These piles will continue to increase because the degradation process is hampered by anaerobic conditions and/or other environmental conditions that cause the growth rate of decomposing organisms to decrease (Szajdak et al., 2020). This is quite in line with Government Regulation of the Republic of Indonesia No. 57 of 2016 in article 1 which also states that peat is an organic material that is formed naturally from plant remains that are not perfectly decomposed and accumulate in swamps. In addition, in more detail, the Draft Indonesian National Standard defines peatland as a land consisting of water-saturated soil, formed from deposits originating from the accumulation of remains (residues) of past plant tissue that have rotted, with a thickness of more than 50 cm (Drollinger et al., 2020).

Hardowigeno stated that peatland is soil formed from piles of dead soil remains, both rotten and unmodified. The pile continues to grow because the decomposition process is hampered by anaerobic conditions and/or other environmental conditions that cause low levels of decomposing biota development. Peat soil formation is a deposition and

transportation process that is different from the general mineral soil formation process which is a pedogenic process (Broda & Hill, 2021).

Soil Survey Staff stated that peat soil is generally dark brown to blackish, although the original material is gray, brown, or reddish, but after decomposition dark-colored humic compounds will appear. Peat is usually associated with natural materials that have high compressibility. The material consists mainly of plant tissue that is dark brown to black, and because it comes from plants that are decomposing, it will have a distinctive odor (Alexandrovskiy et al., 2022).

Peatland management in Indonesia has been regulated in Government Regulation of the Republic of Indonesia No. 57 of 2016 concerning the Protection and Management of Peat Ecosystems. This regulation is based on and refers to Article 5 paragraph 2 of the 1945 Constitution of the Republic of Indonesia and Law No. 32 of 2009 concerning the Protection and Management of the Environment (Zulkarnaini et al., 2024).

The article states that the protection and management of peat ecosystems is defined as a systematic and integrated effort carried out to preserve the function of peat ecosystems and prevent damage to peat ecosystems which includes planning, utilization, control, maintenance, supervision, and law enforcement (Yuwati et al., 2021).

The distribution of peat land in Indonesia is as shown in the following table:

Table 1. Distribution of Peat Hydrological Units Nationally

Province	Peat Hydrological Unit	Administrative Boundaries of the Region			Total Area (Ha)
		District/City	Cross-district/city	Cross Province	
Aceh	37	189,274	136,050	12,840	338,164
Bangka Belitung	17	72,381	25,531	0	97,913
Bengkulu	3	8,943	0	5,326	14,269
Jambi	14	175,859	526,127	202,127	904,423
Riau Islands	5	16,284	0	0	16,284
Lampung	7	44,479	53,118	0	97,597
Riau	59	1,503,404	3,664,911	187,058	5,355,374
West Sumatera	14	129,974	16,256	7,629	153,859
South Sumatera	36	1,400,010	583,177	118,574	2,101,761
North Sumatera	27	121,544	286,787	116,555	524,885
Total Sumatera	207	3,662,152	5,291,957	650,420	9,604,529
West Kalimantan	124	2,028,147	760,339	12,961	2,801,447
South Kalimantan	4	0	191,021	47,444	238,465
Central Kalimantan	35	769,751	3,829,367	75,988	4,675,105
East Kalimantan	16	147,162	195,188	0	342,350
North Kalimantan	13	189,597	157,854	0	347,451
Total Kalimantan	190	3,134,656	5,133,770	136,392	8,404,818
West Sulawesi	2	0	0	42,476	42,476
Central Sulawesi	3	12,345	0	8,469	20,814
Total Sulawesi	5	12,345	0	50,945	63,290
Papua	250	3,200,949	1,896,328	0	5,097,276
West Papua	216	1,289,714	208,176	0	1,497,891
Total Papua	465	4,490,663	2,104,504	0	6,595,167
Indonesia	865	11,299,816	12,530,231	837,757	24,667,804

Due to the content in peatlands, peatlands are known as fragile or vulnerable lands to unfavorable changes in characteristics/properties. Therefore, it is necessary to have a further understanding of the characteristics of peatlands that can be studied through the physical and chemical properties of peatlands to prevent damage to peatlands (Rowland et al., 2021). Some of the physical and chemical properties of peatlands that need to be known include:

a. Physical Properties of Peatlands

1). Peat Maturity

Peat maturity greatly determines the level of peatland productivity, because it greatly influences the level of peat soil fertility, and the availability of nutrients as seen from the level of organic material weathering (Wilpert, 2022).

2). Water Content

Peatlands can absorb and store water much higher than mineral soil because they have organic material in them (Wang et al., 2021).

3). Bulk Density

Bulk density or volume weight is a physical property of soil that indicates the weight of the solid mass in a volume of peat. This unit is often analyzed to assess porosity, bearing capacity, and potential water storage capacity (Paul et al., 2021).

4). Bearing Capacity

The condition of plants that are not upright (tilting) which is often found in peatlands is an indication of the low load-bearing capacity of peat soil, where the lower the level of maturity, the peat soil will be loose and its bearing capacity will be lower (Lewis et al., 2020).

5). Land Surface Subsidence

Subsidence can occur when peat land has experienced drainage (flow out of the peat body), shrinkage due to reduced water, and weathering or decomposition (Dhandapani et al., 2023).

6). Irreversible

Drying Peat with a water content of <100% by weight has generally undergone an irreversible drying process. In this condition, peat becomes flammable and easily washed away by water flow (Falatehan & Sari, 2020).

b. Chemical Properties of Peatlands

1). Soil Acidity

The acidity of tropical peat soils is generally high, ranging between pH 3-5, which is caused by poor conditions for the regulation and hydrolysis of organic acids. These organic acids play a significant role in the low pH of peatlands (Stirling et al., 2020).

2). Cation Exchange Capacity

This capacity in peatlands is very high, ranging from 100-300 me/100g based on absolute dry weight. This high value is caused by the negative charge depending on the pH, which

mostly comes from the carboxylate and phenolic groups contained in peatlands (Shtang et al., 2024).

3). Organic Acid Content

Tropical peat soils in Indonesia have higher lignin content, resulting in organic acids such as phenolic acids that can cause chemical mechanisms. Several studies have shown that phenolic acids are toxic to plants and can be categorized as the main source of carbon release (Busman et al., 2023).

4). Availability of Macro Nutrients

Peatlands generally have the availability of N, P, K, Ca, and Mg. where Most of the total N, P, and K elements in peat are in organic form (Dhandapani et al., 2021).

5). Availability of Micro Nutrients

In addition to macronutrients, peatlands also have microelements such as Cu, Zn, Fe, Mn, B, and Mo. However, these levels are generally very low and deficiencies often occur (Manasypov et al., 2021).

6). Ash Content

Ash content is one of the characteristics of the level of peat soil fertility. The thicker the peat, the lower the ash and base content (Iskandar et al., 2020).

In addition, peat characteristics can also be distinguished based on their level of maturity, so that peat is grouped into 3 types, namely:

- a. Sapric peat (mature) is peat that has advanced to decay and its original material is not recognized, is dark brown to black, and when squeezed the fiber content is <15% (Schaney et al., 2021).
- b. Hemic peat (semi-mature) is semi-decadent peat, some of its original material can still be recognized, is brown, and when squeezed the fiber content is 15 - 75%.
- c. Fabric peat (raw) is peat that has not yet decayed, its original material can still be recognized, is brown, and when squeezed >75% of its fiber remains (Khanday et al., 2021).

Land Fire

Forest and land fires commonly referred to as karhutla consist of 2 different definitions. According to Hatta, forest fires are fires that occur in forest areas, while land fires are fires that occur outside forest areas, both can occur intentionally or unintentionally (Pivello et al., 2021). In Indonesia, almost 99% of forest and land fires are caused by human activities, both intentionally and unintentionally (elements of negligence). Some of them are caused by land conversion, illegal farming, and agriculture, while natural factors only contribute 1% (Hamim et al., 2023).

Meanwhile, fire dynamics is defined as the study of how chemical reactions, material science, and mechanical engineering from fluid mechanics and heat transfer interact in influencing fire behavior. In other words, fire dynamics can also be defined as a study that studies how fires start, spread, and develop (Chen et al., 2023).

Forest and land fires often occur in peatland areas. Fires are not only caused by human activities and extreme climate conditions, fires are also caused by the biophysical conditions of degraded land. Fires in peatland areas will get worse when the fire starts to spread from above the surface to below the surface (ground fire) and starts to burn organic material that has accumulated in the soil. Given that fires occur underground and only the smoke from the fire appears on the surface, this often causes great difficulty in extinguishing the fire (Goldstein et al., 2020).

Peatlands have multifunctional functions, namely hydrological, production, and ecological functions that are very vital for human survival. Unfortunately, peatlands are land that is susceptible to changes in characteristics so it can experience a decrease in land quality, in terms of chemical, physical, and biological properties (Juutinen et al., 2020).

In natural conditions, peat is saturated with water. However, in degraded peat conditions, peat water will easily flow out, so that the peat becomes dry. Degraded peatlands are land that has experienced a decrease in these three functions due to human activities (Sinclair et al., 2020). There are 5 (five) indicators used to assess whether peatlands have been degraded or not, which include:

- a. There has been tree felling;
- b. There is a logging road;
- c. There are traces of fire;
- d. Dryland conditions/not flooded; and
- e. There are traces of mining.

This was also conveyed by Masganti, where degraded peatlands can be seen from the appearance of the land surface and can be characterized by the ground cover plants being shrubs, and/or the land being open land from a former mine. This land has higher levels of total N, available P, and basic elements and ash content (De la Barreda-Bautista et al., 2022). Organic materials in dry conditions and during long dry seasons will later be very flammable, thus creating a large potential for fires on peatlands. This is supported by the results of a study that states that the level of fire vulnerability on peatlands is much higher than fires on mineral soils (Flanagan et al., 2020).

METHOD

The method used in this study is a qualitative approach, which is considered the most appropriate for gaining an in-depth understanding of the phenomenon being studied. Through this approach, researchers attempt to obtain research data from various relevant sources, including research results and previous studies that support the topic being discussed. A qualitative approach allows researchers to understand the context and dynamics that exist in the peatland fire phenomenon and the impact of the mitigation policies implemented. After the research data has been collected, the next process is to process the information to find significant findings. This data processing will involve an in-depth analysis of the information obtained, to explore the relationship between policy,

technology, and the role of the community in peatland fire mitigation. Thus, the results of the study are expected to provide a significant contribution to the development of more effective and sustainable mitigation strategies.

RESULT AND DISCUSSION

The Role of Policy in Peatland Fire Prevention and Mitigation

The role of policy in preventing and mitigating peatland fires is crucial considering the complexity and impacts of these fires, which are not only local but also extend to the regional level. The Indonesian government, as one of the countries with a significant area of peatland, has implemented various policies to prevent and overcome peatland fires. These policies include strict regulations on the use of peatland, a ban on land burning, and a peatland ecosystem restoration program. One of the greatest achievements of government policies is the establishment of the Peatland Restoration Agency (BRG) which focuses on the rehabilitation and protection of peatlands. In addition, the government's efforts to increase the involvement of various parties, from local governments, and local communities, to the private sector, show that there is a strong commitment to overcoming the problem of peatland fires. However, although many policies have been issued, the effectiveness of these policies still faces many challenges, especially in terms of implementation in the field. Existing policies often cannot be implemented optimally due to limited resources, lack of capacity at the local level, and low public awareness of the importance of protecting peatlands.

The main obstacle in implementing peatland fire prevention and mitigation policies is the level of compliance with existing regulations. Although the government has issued a ban on land burning, there are still many violations in the field. In many areas, local communities and the private sector still use the burning method as a quick and cheap way to clear land. This is due to several factors, including the lack of more efficient alternatives and the lack of strict law enforcement in the field. At the community level, the traditional practice of burning land for small-scale agriculture remains a major challenge. Although there are regulations prohibiting it, many communities do not yet have access to more environmentally friendly land management technologies, so they continue to rely on the methods they have used for years. In the private sector, especially plantation companies, despite efforts to comply with regulations, there are still some who are less committed to implementing responsible land management practices. This shows that existing regulations are not strong enough or effective in encouraging comprehensive compliance, both at the individual and institutional levels.

Coordination between institutions is an important aspect in ensuring that peatland fire prevention and mitigation policies can be implemented effectively. Peatland fires do not only require intervention from one institution, but require close cooperation between various agencies, including the central government, local governments, law

enforcement agencies, and the private sector. Without good coordination, policies issued at the central level often cannot be implemented properly at the regional level. For example, the peatland restoration program initiated by BRG often faces obstacles when it has to be implemented in areas that have inconsistent local policies. In addition, cross-sector coordination between government agencies that handle forestry, plantations, and the environment often still overlaps, which makes the implementation of fire prevention policies less effective. Another challenge is the difference in interests between various parties, where certain sectors, especially the private sector, maybe more oriented towards economic gain than environmental sustainability, thus hampering the implementation of more proactive policies in preventing land fires.

To ensure that peatland fire prevention and mitigation policies can run optimally, periodic evaluation and monitoring of these policies are essential. Evaluation allows the government to know the extent to which the policies implemented have achieved their intended goals and identify areas that need improvement. Without regular evaluation, it is difficult to know whether the policies are only effective on paper or have a positive impact on the ground. In addition, strict supervision is also needed to ensure compliance with existing regulations. A good supervision mechanism must involve continuous monitoring, both through technology and through direct interaction with the community and business actors. The use of monitoring technology, such as the use of satellites and drones, can help detect hotspots and areas prone to fires more quickly and accurately. However, this technology must be supported by a well-coordinated monitoring system between various related institutions to be used effectively. Without strict supervision, violations of peatland fire regulations will be difficult to prevent, and even well-designed policies will not be able to have a significant impact.

It can be said that the role of policy in preventing and mitigating peatland fires is very important, but the success of this policy depends on many factors. The effectiveness of the policy must be measured by the extent to which the policy can be implemented well in the field, while compliance with regulations and coordination between institutions must be improved so that the policy can run according to plan. In addition, periodic evaluation and supervision are very important to ensure that existing policies continue to develop and can overcome the increasingly complex challenges related to peatland fires. With good synergy between the right policy, effective implementation, and strict supervision, it is hoped that peatland fires can be prevented more optimally in the future.

Technological Innovation for Peatland Fire Prevention

Technological innovation plays a key role in peatland fire prevention efforts, especially given the scale and complexity of this environmental challenge. Monitoring technology has developed rapidly and provides practical solutions for detecting and managing peatlands in real-time. One technology that is now widely used is satellites, which can

detect hotspots in various areas that are prone to fire. The use of satellites allows for extensive monitoring in a relatively short time so that relevant authorities can immediately find out if there is an increase in temperature in a peat area. In addition, drone technology is also increasingly being applied in land monitoring. Drones can fly low and capture detailed images of the surface conditions of peatlands, providing more accurate data on changes in soil and vegetation conditions. Drones are also more flexible in reaching areas that are difficult to access, ensuring that the entire peatland area can be closely monitored. Innovations in monitoring technology provide great opportunities to prevent fires early on because the data generated can be used to identify fire-prone areas and organize preventive measures before fires occur.



Figure 3. Innovation in Forest Fire Prevention in Peat Lands

In addition to monitoring technology, sensors, and technology-based data processing also play an important role in peatland fire prevention. Sensors installed in the ground can measure humidity, temperature, and oxygen levels in peatlands, providing much-needed information to predict the potential for fires. The data generated from these sensors is then processed using algorithms and predictive models that can project fire risk based on weather conditions and changes in the land. Processing weather data such as rainfall levels, wind, and air temperature is also very important in providing an overview of the possibility of fires. This technology allows authorities to plan more proactive actions, for example by increasing irrigation in areas showing signs of excessive drought. These sensors can be monitored in real-time so that responses to changing conditions can be carried out quickly and appropriately. With accurate data, mitigation policies and field actions can be more effective, minimizing the risk of greater fires in the future.

Technology-based early warning systems are also a significant step in preventing peatland fires. Using advanced technologies such as satellites, sensors, and communication networks, these systems can detect fire threats in real-time and provide warnings to authorities and local communities. Early warning systems work by analyzing various

parameters, such as increasing temperatures, decreasing soil moisture, and the presence of hotspots, to signal that land conditions are at risk of fire. This early warning allows for faster preventive action, either in the form of extinguishing small fires that have just emerged or by taking preventive measures such as wetting the surrounding area. This technology can also be integrated with application-based information systems, where local communities can get direct notifications if there is a fire threat in their area. A quick response is essential in peatland fire situations because they can easily spread if not handled immediately. Further development of this system could include the use of artificial intelligence to improve the accuracy of fire predictions and formulate better intervention strategies.

In addition to monitoring and early warning, water management in peatlands is also key to fire prevention, where water storage and distribution technology plays a vital role. Dry peatlands are highly susceptible to fire, so maintaining soil moisture is a key strategy in fire mitigation. Water storage technology has been developed to support efficient peatland irrigation, either through the construction of canals that can hold large amounts of water, or using techniques such as infiltration wells. This technology is designed to store water during the rainy season and distribute it to peatlands when conditions are dry. This way, soil moisture can be maintained at a safe level, reducing the risk of fire. In addition, technology-based irrigation systems that are automatically controlled can also be implemented to ensure optimal water distribution in peatland areas. Another innovation that is being developed is gravity-based water management technology, where water from natural sources is channeled to peatlands without the need for pumps, making it more energy and cost-efficient.

With increasingly sophisticated technological innovations in various aspects of peatland fire prevention, challenges that were previously difficult to overcome can now be handled better. Monitoring technology, sensors and data processing, early warning systems, and water management all work synergistically to prevent fires more effectively. However, for this technology to run optimally, commitment is needed from various parties, from the government, and research institutions, to the community, to continue to develop and adopt these innovations in fire mitigation efforts. With the application of the right technology, it is hoped that peatlands can be managed more sustainably, reducing the frequency and scale of fires that can damage the environment and cause major economic losses.

Optimizing Technology Implementation in Mitigation Policies

Optimizing the implementation of technology in peatland fire mitigation policies is a crucial step in strengthening efforts to prevent and control fires that often occur in the area. One of the main challenges is how existing technology can be integrated with applicable policies. To achieve this, a systematic approach is needed, where monitoring, early warning, and land management technologies are adopted and integrated

with mitigation policies implemented by the government. Integrating technology into policies does not only mean providing sophisticated tools and infrastructure, but also ensuring that every technology used contributes directly to preventing peatland fires. One important step is to formulate policies that facilitate the use of technology sustainably, such as creating regulations that support the use of drones, satellites, and sensors in the field. In addition, it is important to develop protocols and operational standards that require the use of this technology as part of systematic mitigation efforts. Policies that optimally integrate technology must also consider steps to improve coordination between institutions in the use of data and technology so that the results of fire monitoring and detection can be immediately followed up by related parties.

The role of the government in facilitating the use of technology is also vital in accelerating implementation in the field. The government needs to be the driving force in providing technological infrastructure, such as communication networks that support early warning systems, as well as technological tools needed to monitor and manage peatlands effectively. In addition, the government also needs to provide training to field officers, ensuring that they have adequate skills to operate and utilize the technology. In many cases, sophisticated technology is often not used optimally due to a lack of understanding or skills at the operational level. Therefore, well-planned technical training is an important element in effective mitigation policies. The government must also play a role in providing incentives to the private sector and communities to adopt technologies that support land fire prevention. For example, through subsidies for the purchase of technological equipment or support in the development of technological infrastructure in fire-prone areas. With encouragement from the government, both in the form of regulations and material support, it is hoped that the implementation of technology in the field can take place more quickly and efficiently.

However, on the other hand, the implementation of technology in peatland fire mitigation policies also faces various obstacles that need to be overcome. One of the biggest obstacles is the limited infrastructure in many fire-prone areas, where access to technology is often limited. Inadequate communication networks can hamper the transmission of real-time data which is very important in early warning systems, while limited access to electricity in some areas also poses a challenge to the operation of technological equipment. In addition, the high costs associated with adopting advanced technology are often an obstacle for many parties, especially in terms of procuring tools such as drones, satellites, or sensors that require large investments. The government and related institutions need to find innovative solutions to overcome these obstacles, such as through collaboration with the private sector or international institutions that can support funding for mitigation technology. Not only that, the gap in workforce skills in the field is also a serious obstacle. Many field officers may not be familiar with the latest technology, so there needs to be an increase in capacity in terms of

operating and maintaining technology. Without adequate skills, the advanced technology used will not provide maximum results.

Expanding local technology capacity is also an important issue in efforts to optimize the implementation of technology in peatland fire mitigation policies. Empowering local technologies, especially those designed and developed according to the characteristics of Indonesian peatlands, can be a more sustainable long-term solution. Local technologies are often more adaptive to local environmental conditions and can be operated at a lower cost than imported technologies. Empowering local technologies must also be accompanied by efforts to improve the capacity of local human resources in managing and utilizing these technologies. Continuous training and education are essential to ensure that local workers have the capacity needed to manage these technologies independently. In addition, collaboration between research institutions, universities, and local communities must be strengthened to create technological innovations that are tailored to local needs. By expanding the capacity of local technologies, peatland fire mitigation efforts can be carried out more efficiently and sustainably, as well as encouraging regional independence in managing potential fire risks.

Optimizing the implementation of technology in peatland fire mitigation policies requires an integrated approach, where technology, regulations, human resources, and infrastructure support each other. The government needs to play an active role in encouraging the use of technology and overcoming existing obstacles while continuing to improve local capacity so that peatland fire mitigation efforts can run sustainably and effectively. Thus, technology can be a tool that not only helps in fire prevention but also ensures better peatland management for the future.

Synergy of Policy, Technology, and Society in Peatland Fire Mitigation

The synergy between policy, technology, and society plays a key role in mitigating peatland fires, which often pose a serious threat to the environment and socio-economic life in many areas. In this case, community involvement in policy implementation is an important element that cannot be ignored. Communities living around peatland areas have valuable local knowledge and play a direct role in maintaining the ecosystem. When peatland fire mitigation policies are implemented, the role of the community is not only limited to compliance with regulations but also in supporting and utilizing technology introduced by the government. In some cases, the lack of community involvement can be an obstacle to the success of the policy, because, without their active support, various policies and technological innovations will not be able to run effectively. Therefore, steps that encourage active community participation in every phase of policy implementation need to be intensified, including providing space for them to contribute to decision-making related to peatland management.

One effective approach to increasing community involvement is through comprehensive education programs and awareness campaigns. Communities who understand the importance of maintaining peatland ecosystems and the dangers of fires that can occur tend to be more proactive in supporting government policies. Systematic educational programs can help communities understand the negative impacts of illegal land-burning practices and the importance of maintaining peatland moisture. Through education, communities can also better understand how technology can be used to detect and prevent land fires, and how they can play a role in using this technology. For example, communities can be involved in managing data from field sensors or monitoring hotspots through satellite-based technology. In addition, awareness campaigns involving social media, radio, or face-to-face meetings can broaden the reach of important messages related to peatland fire mitigation. By increasing public awareness, it is hoped that a new culture will be formed that supports peatland conservation efforts through collaboration between government policies, technology, and local community practices.

Collaboration between the government and the private sector is also an important element in this synergy. The government cannot work alone in providing technology and resources for peatland fire mitigation. The private sector has great potential in terms of providing innovative technology and continuous research and development. Technology companies can provide sophisticated tools, such as monitoring sensors, early warning systems, and drones designed to monitor peatlands in real-time. On the other hand, the government can provide regulations that facilitate the use of this technology, as well as create incentives for the private sector to continue to innovate in creating appropriate solutions. In addition, this collaboration can also strengthen support in providing funds for peatland fire mitigation projects, including the research and development needed to create technology that is more adaptive to local conditions. With good synergy between the government and the private sector, technology implementation can be carried out more quickly and effectively, so that peatland fires can be prevented and minimized before they occur massively.

Ultimately, the success of peatland fire mitigation requires an integrated approach that involves all elements: strong policies, appropriate technology, and active community participation. The policies implemented must be able to adapt to existing technological advances, where technology becomes a tool that not only supports but also strengthens fire mitigation efforts. On the other hand, technology must be accessible and utilized by all stakeholders, including communities living around peatlands. To achieve this, there needs to be good synchronization between various government institutions, the private sector, and the community. The community, as the main actors in the field, must be given access to technology and adequate knowledge to be able to utilize it effectively. This integrated approach also needs to include periodic evaluation and adjustment of policies, so that all fire mitigation

efforts can run following the latest developments in both technology and existing social dynamics.

With an integrated approach, policies, technology, and communities do not just work alone but strengthen each other in creating a safer environment from the threat of peatland fires. Technology becomes the main instrument that supports government policies, while communities play a role as agents of change in the field. In the long term, this synergy that is built will help achieve sustainable success in mitigating peatland fires, creating a more sustainable environment, and reducing negative impacts on the social and economic lives of affected communities. This synergy mechanism must continue to be strengthened through inclusive cooperation between all parties involved, as well as periodic evaluations to ensure that the policies and technologies implemented continue to be relevant and effective in facing the challenges of peatland fires in the future.

CONCLUSION

Peatland fire mitigation requires strong synergy between policy, technology, and community participation. Existing policies provide an important basis for prevention and mitigation, but their effectiveness is still limited by implementation challenges, such as community compliance, inter-agency coordination, and periodic evaluation. By actively involving the community, policies can be implemented more effectively, especially through education programs and awareness campaigns that promote understanding of the importance of maintaining peatland ecosystems. Technology plays a vital role in supporting these policies, especially through monitoring, early warning systems, and water management in peatlands. However, the implementation of this technology also faces challenges, including limited infrastructure and human resource readiness. Therefore, greater support is needed from the government and the private sector in providing technology and building local capacity. With good integration between policy, technology, and the community, peatland fire mitigation can be more effective and sustainable in the future.

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