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Unraveling the Complexity of Forest Fire Cases in Riau Province: An Adaptive and Sustainable Policy Recommendation

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ABSTRACT

The increased burned land area from 1,219 hectares in 2022 to 2,632 hectares in 2023 indicates a significant escalation in environmental losses due to forest fires in Riau Province. The need for a quick and effective response from the government and the implementation of adaptive policies is crucial. This research has the potential to provide better policy guidance in dealing with forest fires in Riau Province to maintain environmental sustainability and the welfare of local communities. This research uses a qualitative approach with interviews, documentation, and field observation methods. The collected data was analyzed using Nvivo 12 Plus software. The main findings of this research show that forest fires in Riau Province are influenced by five dominant factors: land clearing with illegal burning, extreme weather, weak monitoring and law enforcement, land and ecosystem degradation, and lack of facilities and resources. Each of these factors contributes to increased fire frequency and intensity and negative impacts on the environment, public health, and regional economies. Stricter law enforcement and ecosystem restoration are considered crucial to overcome this problem. Increasing firefighting capacity, public education, early detection systems, and licensing arrangements are also needed to reduce the fire risk. Synergistic implementation of policies requires cooperation between government, society, and the private sector.

1. INTRODUCTION

Forest fires in Riau Province are a very urgent problem requiring immediate government and society attention [1]. Data for 2022 and 2023 shows that forest fires have caused significant harm to the environment, public health, and the regional economy. In 2022, as many as 1,219 hectares of land were burned, while in 2023, this number increased drastically to 2,632 hectares [2]. Severe haze conditions have also caused an increase in cases of respiratory problems and diseases related to air pollution in Riau Province [3]. In addition, the agricultural and tourism sectors also experience significant negative impacts due to reduced productivity and inconvenience for tourists [4]. Therefore, rapid and effective action is needed to contain these forest fires to protect the environment, public health, and regional economic sustainability [5].

Forest fires have extensive negative impacts, including environmental damage due to loss of flora and fauna habitat, loss of biodiversity, and land degradation [6]. Regarding public health, the resulting haze can cause respiratory problems, increase the risk of respiratory disease, and affect general physical well-being [7]. In addition, regional economies also suffer from reduced productivity in the agricultural and tourism sectors [8], and high recovery costs [9]. Thus, forest fires threaten the environment, public health, and the sustainability of the regional economy as a whole. This situation requires a government response to initiate effective forest fire mitigation policies and efforts to restore the environment and health of affected communities [10]. These steps are important to maintain regional economic sustainability and improve residents' quality of life, so adaptive policies are urgently needed.

Adaptive policy is a flexible and responsive strategy to changing environmental, social, and economic conditions to achieve long-term sustainable goals [11]. Some general adaptive policies in responding to forest fires include increasing monitoring and law enforcement against illegal forest burning [12], strengthening early warning systems [13], increasing capacity in forest fire management [14], promoting the use of technology and innovation for prevention and extinguishing fires [15], as well as the development of burnt land rehabilitation programs [16]. Apart from that, the above policy can also include steps to increase community participation in forest management and fire prevention and efforts to build inter-institutional and inter-sector collaboration for the holistic management of forest fires.

Besides the strategies already mentioned, governments worldwide have taken another route towards the mitigation of forest fires in the form of prescribed burning (or controlled burning), as it is called in Australia. This method is designed to lessen the large amounts of natural fuel, like dried leaves

and twigs, that can help wildfires spread more rapidly [17]. Policymakers in many countries have adopted ecosystem-based landscape management policies, including Canada, which strengthen buffer zones and restore natural ecosystems that are more resistant to fire [18]. Satellite-based monitoring technology is also increasingly harnessed to detect fires in real-time and accelerate firefighting responses [19]. This strategy's effectiveness hinges on the government's implementation capacity, such as the preparedness of human resources, availability of a budget, and coordination with stakeholders.

While several adaptive strategies have been adopted in several countries, success has consistently struggled due to practical constraints, such as regulatory compliance and poor law enforcement [20]. In such countries as Indonesia, the illegal burning method is still widely practiced due to low supervision and ineffective sanctions [21]. Technology, such as early warning systems and satellite monitoring, often fails due to infrastructure limits and a lack of technical capacity at local levels [22]. Complementarity in forest management through community participation thus is normally sub-optimal in fires in forest management, as mentioned above, and this is mainly due to limited education of the communities and no incentives to support community participation through forest management [23]. Thus, while adaptive policies are needed to provide flexible responses.

Adaptive policy is, theoretically, a flexible, responsive, and learning-based way to approach changing environmental, social, and economic dynamics. This idea is aligned with a living policy, as policies are used, monitored, and evaluated regularly to adjust the strategy to suit developing conditions. Adaptive policies for forest fires, such as prevention, mitigation, and recovery measures approach, based on scientific data, technological innovation, and multi-stakeholder involvement from the government, society, and the private sector. Additionally, it explores the importance of feedback loops (Feedback systems) where policies deployed are feedbacked by identifying policies that increase the risk and impact of forest fires.

Riau Province is one of the regions in Indonesia (located on the island of Sumatra). This area experiences high-intensity forest and land fires caused by a combination of natural factors and human activities. In this area, the most dominant type of fire is peatland fires, which are often the result of land clearing practices or illegal burning due to oil palm plantation land clearing in particular and for the forestry industry. Fires on peatlands are harder to fight because they can burrow into the rich layer of organic material below ground, and the smoke is dense and lingers. These fires have devastated a vast area and led to environmental degradation in terms of loss of biodiversity and ecosystem function, a public health crisis from air pollution, which exacerbates respiratory diseases, and large losses in agriculture, tourism, and trade. In addition, the smoke's haze affects other regions in the country and neighboring countries like Malaysia and Singapore, making forest fires in the province of Riau an environmental issue on a national and international scale.

The analysis has two principal investigative questions. First, what aspects affect the surge of forest fire cases in the Riau Province? The second question would be how adaptive and sustainable policy design arrangements can be implemented to reduce the risk of forest fires in the province of Riau by taking into account the complexity of the factors involved and the involvement of stakeholders. This study aims to bridge the gap caused by previous studies, which remained inconclusive in determining the dominant factors that caused forest fires in Riau and the lack of an adaptive and sustainable policy approach.

2. METHOD

This study uses a qualitative method, collecting data through in-depth interviews, documentation studies, and field observations to understand the factors causing forest fires in Riau Province and the effectiveness of the existing policy. Interviews were conducted using a purposive sampling technique, confirming that the informants were relevant to the research. The primary informants were 20 various stakeholders ranging from government representatives of the Riau Province Environment and Forestry Office, the Regional Disaster Management Agency (BPBD) members of the Regional People's Representative Council (DPRD) Riau Province in the field of the environment, Forestry Police, the private sector (especially companies operating in the plantation and forestry) and local communities directly affected by forest fires. Interviews were carried out semi-structured with the possibility of exploring further policies, forest management practices, and challenges experienced in forest fire mitigation.

Furthermore, documentation studies were conducted through documents, such as government policies, official reports by the relevant agencies, statistical data regarding forest fires in previous years, and relevant academic studies to provide a broader scope of the context surrounding the phenomenon of forest fires across Riau. Direct observations of ecological conditions in the field, land clearing patterns, and stakeholders' responses to fires were made at some places characterized by widespread forest fires. This research applies thematic analysis techniques to analyze data with an inductive approach to find out the main patterns of the factors causing forest fires and the effectiveness of the policies that have been implemented.

Data were analyzed through Nvivo 12 Plus, which helped in a more aesthetical qualitative analysis process. The analysis process starts with transcribing all data collected through interviews, field observations, and documentation. Afterward, the data was imported to Nvivo 12 Plus software for systematic data analysis after the completion of the transcript. Researchers use the Cases Classification feature in Nvivo to classify the data sources according to cases that are units of analysis. Following this, thematic codes were applied to the data to help researchers identify patterns, relationships, and key findings relevant to factors that influence forest fires.

3. RESULTS AND DISCUSSION

3.1 Factors influencing the high increase in forest fire incidents in Riau Province

According to the National Disaster Management Agency, the number of cases of forest and land fires in Riau Province has significantly increased in the last few years, whereby the cases in 2023 reached 344, while in 2022, it reached 334 from 88 cases in 2021 [24]. This spike in cases emphasizes how urgent the problem of forest fires is, which needs to be addressed seriously.

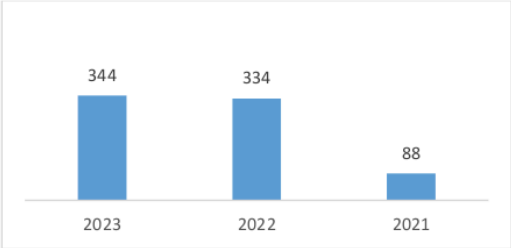

Figure 1. Number of forest fire cases in Riau Province 2021-2023

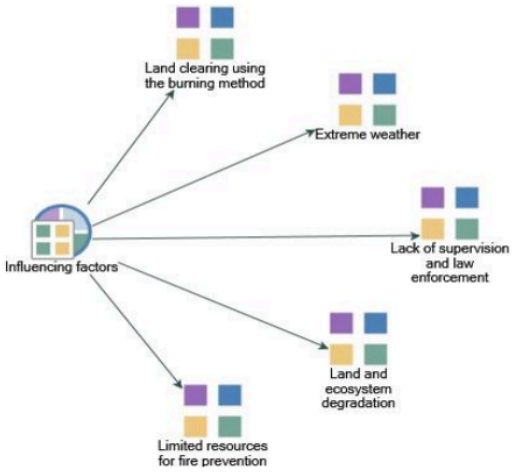

Figure 2. Dominant factors influencing the high incidence of forest fires in Riau Province

Due to the increasing cases depicted in Figure 1, it is necessary to comprehend the fundamental drivers of these forest fires. Forest fire incidents in Riau Province have experienced a very high increase due to interrelated factors. Figure 2 maps these factors.

Land clearing by burning type is unlawful, and clearing forests for agricultural or plantation purposes still often happens. Despite its highly detrimental environmental impact, this method is often selected because it is cheaper and more efficient in preparing land [25]. The continuation of this practice has led to an increase in the frequency and intensity of forest fires in Riau Province, worsening the environmental and public health impacts.

Figure 3. One sample of forest fire incidents in Riau Province

Figure 3 shows one of the empirical data that can be used to represent fire cases in Riau Province [26].

Another factor is extreme weather. The long dry season and high temperatures in Riau Province have made it easier for fires to spread and harder for authorities to control them [27]. This intense heat led to the formation of hotspots in some locations, which then moved around quickly because of the arid flora and rising heat. These hotspots make forest fires more intense, last longer, and are more challenging to extinguish, all with more severe environmental and public health consequences.

This is also due to the absence of supervision of land-burning activities and weak law enforcement against forest fire offenders, which significantly contribute to the rising number of fire incidents. The lack of proper monitoring means that those engaged in illegal burning face fewer repercussions, and inconsistent or less strong enforcement of the law means those continuing to do so do not fear being caught [28]. As a result, forest fires often cannot be prevented or controlled promptly, exacerbating the frequency and impact of fires and complicating mitigation and rehabilitation efforts.

In addition, land and ecosystem degradation in Riau Province facilitates the spread of fire because the remaining vegetation becomes more susceptible to burning [29]. This damage makes forests less resistant to future fire events: flammable material within the flames increases while the ecosystem's natural resistance to fire decreases. Lack of vegetation cover and more habitat destruction means fires easily spread to broader areas, and the intensity of the fire can be as high as destroying more forest areas and existing ecosystems.

Conversely, a shortage of proper personnel and equipment, such as facilities and other resources in Riau Province, affects the effectiveness of early detection and the rapid containment of forest fires. These constraints contribute to the fact that fires are responded to overly late, allowing them to spread and eventually become even more destructive. The lack of adequate resource support renders extinguishing efforts ineffective, aggravating the impacts of fire on the environment and public health and delaying the process of rehabilitation [30].

The dominant factors above affect the environment, public health, and the region's economic sustainability. Forest fires significantly impact the ecosystem, causing the loss of biodiversity and lowering soil quality. Large swathes of free-burning vegetation are having adverse effects on the ecosystem as countless species of flora and fauna lose their natural habitat [31]. Additionally, smoke and particles from fires contaminate the air, disrupting air quality and causing a decline in soil health essential for future plant growth [32].

Forest fires' smoke raises air pollution, aggravating respiratory diseases like asthma, bronchitis, and respiratory infections. This complicates public health, particularly among children, the elderly, and individuals with preexisting health conditions [33]. Increased risk of cardiovascular disease and lung cancer long-term exposure to air pollution [34].

The forest fires in Riau Province have also affected agriculture and the tourism sector, which are mainstays of the regional economy. The destruction of agricultural land from fire diminishes farmers' productivity and income and raises production expenses [35]. In the tourism sector, forest fires reduce the number of tourists due to air pollution and environmental degradation, which reduces the income received from tourism activities and disrupts the livelihood of

local communities whose economies depend on the tourism sector [36]. In general, the economies affected by forest fires, worse off in their well-being regionally, will represent an investment in recovery and rehabilitation after the fires are extinguished.

Table 1 shows the main findings based on an analysis of factors influencing the increase in forest fires in Riau Province.

Table 1. Summary of main findings

Category	Findings
A. Factors Causing Forest Fires	
1. Clearing land by burning	Illegal methods are often used because they are considered more economical and efficient. This practice increases the frequency and intensity of forest fires.
2. Extreme weather	The long dry season and high temperatures exacerbate the spread of fires and complicate extinguishing efforts.
3. Lack of supervision and law enforcement	The absence of adequate supervision and weak law enforcement means that illegal land burning continues unimpeded.
4. Land and ecosystem degradation	Reduced vegetation makes forests more vulnerable to fire, increases the amount of flammable material, and reduces the ecosystem's resistance to the spread of fire.
5. Lack of facilities and resources	Limited firepower, equipment, and infrastructure slow the response to fires, exacerbating their environmental and public health impact.
B. Impact of Forest Fires	
1. Ecosystem damage	Loss of biodiversity, land degradation, and loss of natural habitat for flora and fauna.
2. Decreased air quality and public health	Increased air pollution due to fire smoke causes respiratory problems (asthma, bronchitis, respiratory tract infections), as well as increasing the risk of cardiovascular disease and lung cancer.
3. Regional economic disruption	The agricultural sector is affected due to damage to agricultural land, while the tourism sector declines due to decreased air quality and environmental damage.

3.2 Adaptive and sustainable policies are needed

To overcome the impact of forest fires and ensure environmental and economic sustainability, it is necessary to implement adaptive policies.

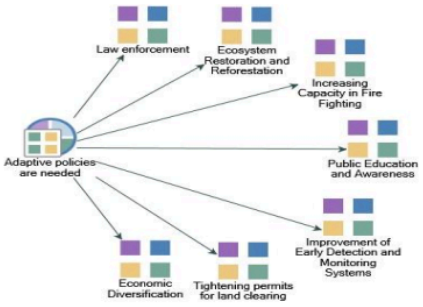

Figure 4. Adaptive and sustainable policies are needed

Figure 4 illustrates the components needed in adaptive and sustainable policies. Law enforcement efforts are a significant policy in countering forest fires due to the illegal burning of the land [37]. This more stringent law enforcement policy is characterized by appropriate and stern penalties that will deter transgressors. This practice is based on law enforcement theory, which posits that the prospect of swift and certain punishment can deter illegal activity [38]. For example, Brazil has successfully lowered deforestation rates in the Amazon with stricter law provisions and technology monitoring [39], even if some challenges remain in the long run.

Ecosystem restoration and reforestation are key strategies to restore ecosystem function and improve fire resistance. We must consistently maintain land pressure by rebuilding critical land and reforestation denatured forests. This involves protecting fire-prone peat forests and engaging communities and interested parties to make them sustainable." In South Kalimantan, for instance, the focus is on restoring damaged peat forests by encouraging the regrowth of native vegetation and improving management practices to mitigate fire risk [40]. The theory underlying this is the ecosystem principle, which requires comprehensive habitat restoration to achieve ecological balance and mitigate the impacts of climate change [41].

It starts with strengthening firefighting capability to accelerate fire response and mitigate the impact of fire. This includes strengthening firefighting resources via personnel training, providing adequate equipment, and better coordination with relevant agencies. The goal is to be prepared and do as much as possible to have the fires that do happen be managed efficiently. One initiative is the National Firefighter Training Program initiative in Australia, which provides ongoing training, cutting-edge firefighting equipment, and improvement in inter-agency coordination. It has been found to contribute to improved responses to bushfires [42]. The theory underlying this is risk management theory, which emphasizes the need to strengthen operational capacity and coordination to reduce risks and impacts effectively [43].

Public education and awareness are also crucial in preventing forest fires. Education regarding the negative impacts of forest fires and the importance of responsible land management must be improved to facilitate community understanding and participation. Environmental awareness campaigns involving local communities can play an active role in preventing forest fires by educating them about safe practices and the negative impacts of fires [44]. For example, ecological education in Greece involves students in fire prevention training and activities and education about the environmental impacts of fires [45]. The theory underlying this is behavior change theory, which emphasizes the need for education and community involvement to change behavior and increase awareness of environmental risks [46].

Improving early detection and monitoring systems is an effort to deal with forest fires effectively [47]. Developing and expanding technology-based early detection systems like drones, satellites, and heat sensors enable early fire detection. This technology can provide real-time information that facilitates faster and more effective extinguishing actions before fires spread widely [48]. For example, the use of technology implemented in Brazil has helped in the early detection and monitoring of fires more efficiently [49]. The theory underlying this is technology-based risk management theory, which emphasizes the importance of advanced detection tools to reduce the impact of disasters [50].

Arranging plantation and forest permits is also necessary to

ensure that land clearing is carried out in accordance with applicable environmental standards. Reviewing and tightening land clearing permits for plantation and forestry companies and closely monitoring their activities can prevent illegal land burning. For example, strict regulations in Brazil regarding forest permits for companies have shown significant reductions in illegal deforestation [51]. The theory underlying this is environmental regulation theory, which emphasizes strict monitoring to protect natural resources and avoid negative impacts [52].

On the other hand, economic diversification for local communities is an important strategy to reduce dependence on land clearing using burning methods. Developing economic diversification programs, such as agroforestry or environmentally friendly plantations, provide a more sustainable economic alternative for society [53]. For example, agroforestry programs in Nepal have provided local farmers with an alternative income and reduced their need to clear new land [54]. The theory underlying this is sustainable development theory, which emphasizes the importance of economic alternatives to improve people's welfare while protecting the environment [55].

Forest fire impacts can be resolved through a multi-partite response, contributing to environmental and economic sustainability-government, communities, and the private sector. Synergies of adaptive and sustainable policies need to be in place, such as expanding law enforcement, restoring ecosystems, increasing firefighting ability, public education, early detection systems, licensing arrangements, and economic diversification. The government coordinates the design and implementation of these policies and generally ensures collaboration and comanagement between the institutions and stakeholders involved. Enable these initiatives to attain the desired results in the prevention of forest fires and environmental sustainability through support and participation from all.

4. CONCLUSIONS

Five dominant factors aggravate the occurrence of fire in the Riau Province. First, the illegal practice of land clearing through burning, which is still used extensively as it is widely viewed as the most cost-effective option, is an important factor in aggravating the frequency and intensity of ignitions. Second, extreme weather-including prolonged dry seasons and higher temperatures-fuels fires' spread and hampers efforts to put them out. Third, illegal burning practices are challenging to prevent as there is little supervision and law enforcement. Fourth, land and ecosystem degradation weakness the natural resilience of forests to fire and leads to increased fire spread. Fifth, insufficient facilities and resources severely limit ability to respond quickly and effectively to fire incidents, increasing environmental impact and public health issues. These factors can only lead to ecosystem degradation, worse public health, and adverse effects on local economies.

Overcoming the aftermath of forest fires based on adaptive and sustainable policies that ensure environmental and economic sustainability. Steps that need to be taken to overcome the fire problem are to increase law enforcement by giving strict sanctions to perpetrators of illegal burning, restoration, and reforestation of critical land and peat forest, increase firefighting capability through adequate training and equipment, education and public awareness about the impacts of fires and responsible land management, development of technology-based early detection and monitoring systems, regulation of plantation and forest permits to prevent illegal practices, and economic diversification for local communities as a sustainable alternative. Due to the nature of the policy, the government, society, and the private sector must work together to minimize the potential emergence of forest fires and promote sustainability. These findings highlight the importance of implementing adaptive and sustainable policies to address forest fires.

Limitations of this study include dependence on secondary data, which may fail to embody real-time dynamics and localized variations in forest fire occurrences. Moreover, limitations that can be methodological due to the difficulties in verifying the effectiveness of policy implementation can introduce potential biases in how to interpret the results. The lack of thorough primary data gathering restricts the extent of empirical examination, while political and economic outside influences can distort policy evaluations. These limitations can be addressed in future research through long-term field studies, analyses of real-time data, and the emergence of more rigorous evaluation frameworks that will improve accuracy and reliability.

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REFERENCES

[1] Fitriany, A.A., Flatau, P.J., Khoirunurrofik, K., Riama, N.F. (2021). Assessment on the use of meteorological and social media information for forest fire detection and prediction in Riau, Indonesia. Sustainability, 13(20): 11188. https://doi.org/10.3390/su132011188

[2] Siregar, R.A. (2024). 2.632 Ha lahan terbakar di riau sepanjang 2023. detik.com. Pekanbaru. https://www.detik.com/sumut/berita/d-7120071/2-632-ha-lahan-terbakar-di-riau-sepanjang-2023.

[3] Fadhillah, A., Pandin, M.G.R., Koesbardiati, T. (2023). Analyzing forest and land fire disaster prevention programs in Riau, Indonesia. Qubahan Academic Journal, 3(4): 198-205. https://doi.org/10.58429/qaj.v3n4a173

[4] Karya, D., Hasan, H., Kadir, E.A. (2017). Impact of forest fire to economic and environment in Riau Province Indonesia. International Business Management, 11(2): 474-477. http://repository.uir.ac.id/id/eprint/2635

[5] Adni, D.F. (2023). Controlling forest and land fires in Riau Province using collaborative governance: Support for smart environment. E3S Web of Conferences, 440: 1-13. https://doi.org/10.1051/e3sconf/202344002006

[6] Lucas, F.M.F., Araujo, E.C.G., Fiedler, N.C., da Silva Santana, J.A., Tetto, A.F. (2023). Perspective: Scientific gaps on forest fires in Brazilian protected areas. Forest Ecology and Management, 529: 120739.

https://doi.org/10.1016/j.foreco.2022.120739
[7] Zaini, J., Susanto, A.D., Samoedro, E., Bionika, V.C., Antariksa, B. (2020). Health consequences of thick forest fire smoke to healthy residents in Riau, Indonesia: A cross-sectional study. Medical Journal of Indonesia, 29(1): 58-63. https://doi.org/10.13181/mji.oa.204321
[8] Suhardono, S., Fitria, L., Suryawan, I.W.K., Septiariva, I.Y., Mulyana, R., Sari, M.M., Ulhasanah, N., Prayogo, W. (2024). Human activities and forest fires in Indonesia: An analysis of the Bromo incident and implications for conservation tourism. Trees, Forests and People, 15: 100509. https://doi.org/10.1016/j.tfp.2024.100509
[9] Mantero, G., Anselmetto, N., Morresi, D., Meloni, F., Bolzon, P., Lingua, E., Garbarino, M., Marzano, R. (2024). Modeling post-fire regeneration patterns under different restoration scenarios to improve forest recovery in degraded ecosystems. Forest Ecology and Management, 551: 121520. https://doi.org/10.1016/j.foreco.2023.121520
[10] Wunder, S., Calkin, D.E., Charlton, V., Feder, S., Martínez de Arano, I., Moore, P., y Silva, F.R., Tacconi, L., Vega-García, C. (2021). Resilient landscapes to prevent catastrophic forest fires: Socioeconomic insights towards a new paradigm. Forest Policy and Economics, 128: 102458. https://doi.org/10.1016/j.forpol.2021.102458
[11] Walker, W.E., Rahman, S.A., Cave, J. (2001). Adaptive policies, policy analysis, and policy-making. European Journal of Operational Research, 128(2): 282-289. https://doi.org/10.1016/S0377-2217(00)00071-0
[12] Sismawati, S., Anggraeny, K.D. (2023). Law enforcement of forest and land fires in Rokan Hilir Regency of Riau Province. AIP Conference Proceedings, 2706(1): 120357. https://doi.org/10.1063/5.0120357
[13] Çamalan, G., Akıl, S., Ali Pekin, M. (2023). Using meteorological early warning system (MEUS) and meteorological indices for assessment of Manavgat forest fires occurred in Turkiye July-August 2021. European Journal of Forest Engineering, 9(1): 10-25. https://doi.org/10.33904/ejfe.1288070
[14] Espinoza-Valenzuela, C., Hurtado, M. (2021). Risk management for forest fires at a world heritage site: Vulnerability and response capacity by Rapa Nui indigenous community. Understanding Disaster Risk: A Multidimensional Approach, pp. 257-277. https://doi.org/10.1016/B978-0-12-819047-0.00014-7
[15] De la Fuente, R., Aguayo, M.M., Contreras-Bolton, C. (2024). An optimization-based approach for an integrated forest fire monitoring system with multiple technologies and surveillance drones. European Journal of Operational Research, 313(2): 435-451. https://doi.org/10.1016/j.ejor.2023.08.008
[16] Musri, I., Ainuddin, A.N., Hyrul, M.H.I., Hazandy, A.H., Azani, A.M., Mitra, U. (2020). Post forest fire management at tropical peat swamp forest: A review of Malaysian experience on rehabilitation and risk mitigation. IOP Conference Series: Earth and Environmental Science, 504(1): 012017. https://doi.org/10.1088/1755-1315/504/1/012017
[17] Morgan, G.W., Tolhurst, K.G., Poynter, M.W., Cooper, N., McGuffog, T., Ryan, R., Wouters, M.A., Stephens, N., Black, P., Sheehan, D., Leeson, P., Whight, S., Davey, S.M. (2020). Prescribed burning in south-eastern Australia: History and future directions. Australian Forestry, 83(1): 4-28. https://doi.org/10.1080/00049158.2020.1739883
[18] Steenberg, J.W.N., Duinker, P.N., Nitoslawski, S.A. (2019). Ecosystem-based management revisited: Updating the concepts for urban forests. Landscape and Urban Planning, 186: 24-35. https://doi.org/10.1016/j.landurbplan.2019.02.006
[19] Leite, R.V., Amaral, C., Neigh, C.S.R., Cosenza, D.N., Klauberg, C., Hudak, A.T., Aragão, L., Morton, D.C., Coffield, S., McCabe, T., Silva, C.A. (2024). Leveraging the next generation of spaceborne earth observations for fuel monitoring and wildland fire management. Remote Sensing in Ecology and Conservation, 11(2): 133-155. https://doi.org/10.1002/rse2.416
[20] Elvan, O.D., Birben, Ü., Özkan, U.Y., Yıldırım, H.T., Türker, Y.Ö. (2021). Forest fire and law: An analysis of Turkish forest fire legislation based on Food and Agriculture Organization criteria. Fire Ecology, 17: 12. https://doi.org/10.1186/s42408-021-00102-7
[21] Wijayanto, A., Wiraraja, H.A., Idris, S.A. (2022). Forest fire and environmental damage: The Indonesian legal policy and law enforcement. Unnes Law Journal, 8(1): 105-132. https://doi.org/10.15294/ulj.v7i1.52812
[22] Suri, D.M., Nurmandi, A. (2021). Deep learning methods as a detection tools for forest fire decision making process fire prevention in Indonesia. In International Conference on Human-Computer Interaction, pp. 177-182. https://doi.org/10.1007/978-3-030-90176-9_24
[23] Purnomo, H., Puspitaloka, D., Okarda, B., Andrianto, A., et al. (2024). Community-based fire prevention and peatland restoration in Indonesia: A participatory action research approach. Environmental Development, 50: 100971. https://doi.org/10.1016/j.envdev.2024.100971
[24] Central Bureau of Statistics. (2023). Jumlah Kejadian Bencana Alam Menurut Kabupaten/Kota Di Provinsi Riau, 2023. https://riau.bps.go.id/id/statistics-table/3/TUZaMGVteFVjSEJ4T1RCMlIyRjRTazVvVDJocVFUMDkjMw==/jumlah-kejadian-bencana-alam-menurut-kabupaten-kota-di-provinsi-riau--2023.html?year=2023, accessed on Sep. 14, 2024.
[25] Helmi, H., Djafri, D., Mutiani, C., Halim, N.A., Badri, M., Yefni, Y. (2021). Indigenous people in the dynamics of land use changes, forest fires, and haze in Riau Province, Indonesia. In Natural Resource Governance in Asia: From Collective Action to Resilience Thinking, pp. 291-308. https://doi.org/10.1016/B978-0-323-85729-1.00023-2
[26] Yiari. (2024). Ini dia Penyebab Kebakaran Hutan dan Lahan Serta Cara Pencegahannya! Internationalanimalrescue.or.id. https://internationalanimalrescue.or.id/penyebab-karhutla/, accessed on Sep. 14, 2024.
[27] Syarbaini, Makhsun, Wahyudi, Syahrial, Jasmiyati. (2019). Release of radioactive particulates into the air during forest fire in Riau Province, Indonesia. Atom Indonesia, 45(2): 81-87. https://doi.org/10.17146/aij.2019.829
[28] Thoha, A.S., Istima, N., Daulay, I.A., Hulu, D.L.N., Budi, S., Ulfa, M., Mardiyadi, Z. (2023). Spatial distribution of 2019 forest and land fires in Indonesia. Journal of Physics: Conference Series, 2421(1): 012035. https://doi.org/10.1088/1742-6596/2421/1/012035
[29] Adrianto, H.A., Spracklen, D.V., Arnold, S.R. (2019).

Relationship between fire and forest cover loss in Riau Province, Indonesia between 2001 and 2012. Forests, 10(10): 889. https://doi.org/10.3390/f10100889

[30] Saharjo, B.H., Yungan, A. (2018). Forest and land fires in Riau Province: A case study in fire prevention policy implementation with local concession holders. In Land-Atmospheric Research Applications in South and Southeast Asia, Springer, Cham, pp. 143-169. https://doi.org/10.1007/978-3-319-67474-2_8

[31] Syaufina, L. (2018). Forest and land fires in Indonesia: Assessment and mitigation. In Integrating Disaster Science and Management: Global Case Studies in Mitigation and Recovery, pp. 109-121. https://doi.org/10.1016/B978-0-12-812056-9.00008-7

[32] Purnomo, E.P., Rahmasari, F.V., Trisnawati, D.W., Erviana, R. (2021). Observed data of forest fire hotspots effects on Respiratory Disorder by Arc-GIS in Riau Province, Indonesia. IOP Conference Series: Earth and Environmental Science, 717(1): 012036. https://doi.org/10.1088/1755-1315/717/1/012036

[33] Machado-Silva, F., Libonati, R., de Lima, T.F.M., Peixoto, R.B., de Almeida Franca, J.R., Magalhães, M.D.A.F.M., Santos, F.L.M., Rodrigues, J.A., DaCamara, C.C. (2020). Drought and fires influence the respiratory diseases hospitalizations in the Amazon. Ecological Indicators, 109: 105817. https://doi.org/10.1016/j.ecolind.2019.105817

[34] Navarro, K.M., Kleinman, M.T., Mackay, C.E., Reinhardt, T.E., Balmes, J.R., Broyles, G.A., Ottmar, R.D., Naher, L.P., Domitrovich, J.W. (2019). Wildland firefighter smoke exposure and risk of lung cancer and cardiovascular disease mortality. Environmental Research, 173: 462-468. https://doi.org/10.1016/j.envres.2019.03.060

[35] Adrianto, H.A., Spracklen, D.V., Arnold, S.R., Sitanggang, I.S., Syaufina, L. (2020). Forest and land fires are mainly associated with deforestation in Riau Province, Indonesia. Remote Sensing, 12(1): 3. https://doi.org/10.3390/RS12010003

[36] Rauf, R., Zainal, Prayuda, R., Rahman, K., Fitra Yuza, A. (2020). Civil society's participatory models: A policy of preventing land and forest fire in Indonesia. International Journal of Innovation, Creativity and Change, 14(3): 1030-1046.

[37] Webb, E.L., Jamaludin, J. (2024). Fire is associated with forest degradation and economic land concessions, but not land conversion in the rapidly transforming Cambodian landscape. Environmental Research Letters, 19(9): 094005. https://doi.org/10.1088/1748-9326/ad6678

[38] Barragan, M. (2022). Policing and punishing illegal gun behavior: An examination of jail detainee experiences with gun law enforcement in Los Angeles. Social Problems, 69(4): 1170-1187. https://doi.org/10.1093/socpro/spab025

[39] Mataveli, G., de Oliveira, G., Chaves, M.E., Dalagnol, R., Wagner, F.H., Ipia, A.H., Silva-Junior, C.H.L., Aragão, L.E. (2022). Science-based planning can support law enforcement actions to curb deforestation in the Brazilian Amazon. Conservation Letters, 15(6): e12908. https://doi.org/10.1111/conl.12908

[40] Otsamo, A., Ådjers, G., Hadi, T.S., Kuusipalo, J., Vuokko, R. (1997). Evaluation of reforestation potential of 83 tree species planted on Imperata cylindrica dominated grassland: A case study from South Kalimantan, Indonesia. New Forests, 14(2): 127-143. https://doi.org/10.1023/A:1006566321033

[41] Jia, Q., Jiao, L., Lian, X., Wang, W. (2023). Linking supply-demand balance of ecosystem services to identify ecological security patterns in urban agglomerations. Sustainable Cities and Society, 92: 104497. https://doi.org/10.1016/j.scs.2023.104497

[42] McLennan, J., Birch, A. (2005). A potential crisis in wildfire emergency response capability? Australia's volunteer firefighters. Environmental Hazards, 6(2): 101-107. https://doi.org/10.1016/j.hazards.2005.10.003

[43] Bacciu, V., Sirca, C., Spano, D. (2022). Towards a systemic approach to fire risk management. Environmental Science and Policy, 129: 37-44. https://doi.org/10.1016/j.envsci.2021.12.015

[44] Souza-Alonso, P., Omil, B., Sotelino, A., García-Romero, D., Otero-Urtaza, E., Lorenzo Moledo, M., Reyes, O., Rodríguez, J.C., Madrigal, J., Moya, D., Molina, J.R., y Silva, F.R., Merino, A. (2024). Service-learning to improve training, knowledge transfer, and awareness in forest fire management. Fire Ecology, 20(1): 19. https://doi.org/10.1186/s42408-023-00226-y

[45] Papaspiliou, K., Skanavis, C., Giannoulis, C. (2014). Civic ecology education and resilient societies: A survey of forest fires in Greece. Journal of Education and Training Studies, 2(2): 48-57. https://doi.org/10.11114/jets.v2i2.271

[46] Ardoin, N.M., Bowers, A.W., Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. Biological Conservation, 241: 108224. https://doi.org/10.1016/j.biocon.2019.108224

[47] Barmpoutis, P., Papaioannou, P., Dimitropoulos, K., Grammalidis, N. (2020). A review on early forest fire detection systems using optical remote sensing. Sensors, 20(22): 6442. https://doi.org/10.3390/s20226442

[48] Roldán-Gómez, J.J., González-Gironda, E., Barrientos, A. (2021). A survey on robotic technologies for forest firefighting: Applying drone swarms to improve firefighters' efficiency and safety. Applied Sciences, 11(1): 363. https://doi.org/10.3390/app11010363

[49] Luz, A.E.O., Negri, R.G., Massi, K.G., Colnago, M., Silva, E.A., Casaca, W. (2022). Mapping fire susceptibility in the Brazilian Amazon forests using multitemporal remote sensing and time-varying unsupervised anomaly detection. Remote Sensing, 14(10): 2429. https://doi.org/10.3390/rs14102429

[50] Orimoloye, I.R., Ekundayo, T.C., Ololade, O.O., Belle, J.A. (2021). Systematic mapping of disaster risk management research and the role of innovative technology. Environmental Science and Pollution Research, 28(4): 4289-4306. https://doi.org/10.1007/s11356-020-10791-3

[51] Tacconi, L., Rodrigues, R.J., Maryudi, A. (2019). Law enforcement and deforestation: Lessons for Indonesia from Brazil. Forest Policy and Economics, 108: 101943. https://doi.org/10.1016/j.forpol.2019.05.029

[52] Dechezleprêtre, A., Sato, M. (2017). The impacts of environmental regulations on competitiveness. Review of Environmental Economics and Policy, 11(2): 183-206. https://doi.org/10.1093/reep/rex013

[53] Kassie, G.W. (2018). Agroforestry and farm income diversification: Synergy or trade-off? The case of Ethiopia. Environmental Systems Research, 6(1): 1-14.

https://doi.org/10.1186/s40068-017-0085-6
[54] Ghimire, M., Khanal, A., Bhatt, D., Dahal, D., Giri, S. (2024). Agroforestry systems in Nepal: Enhancing food security and rural livelihoods-A comprehensive review. Food and Energy Security, 13(1): e524. https://doi.org/10.1002/fes3.524
[55] Kaya, A., Tok, E., Koc, M., Mezher, T., Tsai, I.T. (2019). Economic diversification potential in the rentier states towards a sustainable development: A theoretical model. Sustainability, 11(3): 911. https://doi.org/10.3390/su11030911

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