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Enhancing Forest Fire Mitigation through Communication Technology: Evidence from Riau Province, Indonesia

Firsa Rinaldy Parlita Tinambunan, Miftahul Rozaq*
Telkom University, Bandung, Indonesia
Email: [1]firsarinaldy@telkomuniversity.ac.id, miftahulrozaq@telkomuniversity.ac.id*

ABSTRACT

Forest and land fires (karhutla) in Riau Province, Indonesia, pose severe environmental, health, and economic challenges, mainly due to the flammable peatlands during dry seasons. Limited communication infrastructure exacerbates these issues, hindering firefighting coordination, hotspot reporting, and public information dissemination. This study examines the role of communication technology in mitigating karhutla, focusing on the Ministry of Environment and Forestry's efforts in Riau. Using a qualitative case study approach, data was collected through interviews and analysed thematically. Findings reveal inadequate communication technology support, with reliance on Handy Talky (HT) devices and radio transmissions, while cellular and internet networks remain insufficient. The study recommends enhancing communication infrastructure, developing integrated systems, and training personnel to address these challenges. Satellite-based internet is proposed as a potential solution for areas with limited connectivity, aiming to improve coordination and efficiency in karhutla mitigation efforts.

KEYWORDS *Communication Technology, KARHUTLA, Riau, Forest Fire Mitigation, Communication Infrastructure*

INTRODUCTION

Forest and land fires (KARHUTLA) are a serious problem that often occurs in Indonesia, with widespread impacts on the environment, public health, and economy. (Indonesia's large area and tropical climate conditions with a long dry season make several regions of Indonesia very vulnerable to forest fires. Riau Province is one of the most affected areas, experiencing a significant decline in forest areas due to deforestation and forest fires over the past three decades. Data from SiPongi shows that in 2019, Riau Province recorded forest and land fires covering an area of 90,550 hectares. Although there was a decrease in the following years, the number of fires remained significant in 2023, reaching 7,267 hectares. (Kementerian Lingkungan Hidup dan Kehutanan, 2024; Numata, 2022) Apart from Riau, other provinces, such as Jambi, South Sumatra, West Kalimantan, East Kalimantan, and South Kalimantan, also have the highest intensity of forest fires. (Brotestes Panjaitan & Saleh, 2019).

Areas prone to forest fires generally have complex geographical characteristics, such as vast peatlands that are quickly burned, limited accessibility and inadequate communication infrastructure, land clearing practices by burning, and a lack of public awareness of the dangers of forest and land fires. In remote areas, the main challenges include minimal communication networks, limited access to electricity, and limited monitoring tools, which hinder early detection and rapid and effective handling of fires. (Zaini, 2020). Difficult geographical conditions and massive changes in land use are the leading causes of recurring forest fires in this region, with additional impacts in the form of public health problems due to exposure to thick smoke and increased carbon monoxide. (Purnomo, 2021; Zaini, 2020).

Forest fire management requires an integrated and flexible approach due to its complex and dynamic nature. Technical constraints, such as limited communication tools and electricity-based servers, add to the challenge of ensuring an efficient response on the ground. (Anuar et al., 2024; Zaimes et al., 2018) Cross-agency coordination is key to mitigation efforts, as various stakeholders must share information quickly and accurately. Therefore, reliable and sustainable communication infrastructure support is needed to accelerate the response to forest fires.

Information and communication technology (ICT) provides an excellent opportunity to support forest fire mitigation. Satellite-based monitoring platforms like SiPongi enable real-time hotspot detection down to the village level. (Wicaksono et al., 2024). In addition, satellite-based communication networks, such as Starlink, can overcome the limitations of cellular networks in remote areas. (Gumilar et al., 2021). Handy Talky (HT) also remains the primary means of communication in the field due to its reliability in rugged terrain conditions. (Schweizer et al., 2024). Technologies like the Internet of Things, remote sensing, geographic information systems, and artificial intelligence can monitor fire hotspots, predict fire spread, map fire-prone areas, and support rapid and accurate decision-making. Therefore, integrating information technology in forest fire mitigation systems can strengthen early detection capabilities, improve coordination, and reduce the risk of losses due to forest fires.

Communication infrastructure, such as cellular, radio, and satellite networks, is an important factor in supporting coordination and response in remote areas, including the use of satellite technology to overcome the limitations of cellular networks (Gumilar et al., 2021; Schweizer et al., 2024). Remote areas often face geographical constraints and low population density. Satellite-based communication technology has proven reliable in disaster management because it can create two-way connectivity even when ground infrastructure is unavailable or affected by disasters. However, cost challenges are a significant obstacle to large-scale implementation in remote communities. Integrating satellite technology with Internet of Things (IoT)-based infrastructure offers a cost-effective solution that can support the development of sustainable communications (Kagai et al., 2024).

Developing renewable energy-based communication technologies and infrastructure-sharing models provides excellent opportunities to improve access in remote areas sustainably. This approach helps overcome geographical limitations and encourages inclusive socio-economic development. Infrastructure-sharing models, such as those implemented by mobile network operators, have effectively reduced operational costs and improved service quality. (Dlamini & Vilakati, 2021). By combining green technology and communication innovation, remote areas can improve connectivity while supporting environmental sustainability and long-term development.

Internet of Things (IoT) technologies, satellite-based monitoring, and early warning systems have been critical in supporting real-time hotspot detection and accelerating decision-making. (Anuar et al., 2024; Wicaksono et al., 2024). IoT enables the continuous collection of environmental data through a network of connected sensors, which are then integrated and analysed through a cloud-based platform to provide real-time information. IoT-based early warning systems have been used effectively in disaster mitigation, such as floods, by monitoring rainfall, water levels, and other weather conditions, providing accurate predictions for faster response to emergencies. (Raman & Iqbal, 2024).

Satellite technology monitors large, hard-to-reach areas, enabling more comprehensive hotspot detection. Systems such as the Anomaly Hot Spots of Agricultural Production (ASAP) leverage remote sensing to detect anomalies in vegetation and weather patterns relevant to food insecurity and wildfires. By integrating satellite data with IoT-based processing models, this technology can provide more precise information about the location and time of events, allowing for preventive action before the situation worsens. (Rembold et al., 2019). The advantage of this approach lies in its scalability and ability to provide early warning to reduce risk.

The integration of IoT technology, satellites, and supporting communication infrastructure has the potential to be a comprehensive solution for hotspot detection and risk mitigation (Yasir et al., 2020). Similar technologies have been tested in geohazard risk management. IoT-based systems that monitor land displacement, rainfall, and ground cracks can leverage 5G communications for fast data transmission and advanced visualisation, resulting in more effective and timely decision-making. (Li et al., 2021) This data-driven approach underscores the potential of modern technologies to address the challenges of hotspot monitoring and disaster response while offering an efficient framework for environmental risk management.

Previous studies have highlighted various aspects of applying information and communication technology (ICT) in forestry management, including forest fire control, data management, and community-based monitoring—and responses to forest fires amidst the challenges of health protocols during the COVID-19 pandemic. Meanwhile, (2021) focuses on digitalising and integrating forestry data but has not addressed technical and operational limitations, such as access to electricity and communication networks in remote areas. The study by (Brofeldt et al., 2018) demonstrated the effectiveness of smartphone applications for reporting illegal forest activities. However, it did not examine the sustainability of using such technology in hard-to-reach forest areas (Rochyadi-Reetz & Wolling, 2023).

Based on this review, there is a significant research gap about the effectiveness of information technology implementation in remote areas with limited infrastructure. Earlier studies have not explored how infrastructure limitations, such as network access and electricity, affect the success of information technology implementation, especially in hard-to-reach forest areas. This research is important to ensure that technology solutions can be tailored to the local context, support effective responses, and are sustainable in the face of geographic and infrastructure challenges.

This study explores the potential use of Internet-based technologies, such as the Internet of Things (IoT), satellite monitoring, and early warning systems, to strengthen forest fire prevention and mitigation efforts in remote areas. This can be achieved by identifying factors that influence the implementation of these technologies, examining challenges arising from limited infrastructure, and evaluating the impact of technology in minimising losses due to forest fires. This research on the role of technology in improving communication and coordination between parties was conducted at the Environmental and Forestry Law Enforcement and Security Agency (BPPHLHK) for the Sumatra Region Section II.

This study advances previous research on forest fire mitigation through its comprehensive focus on the integration of modern communication technologies, such as IoT, satellite systems, and early warning platforms, within areas facing severe infrastructure challenges. Unlike earlier works, which often highlighted general ICT applications in forestry or focused on community monitoring (e.g., Brofeldt et al., 2018), this study delves into the operational limitations—such as restricted electricity and communication network access—that impede technology deployment in remote regions. By addressing these gaps, it proposes innovative solutions like satellite-based communication networks and IoT-enabled systems tailored for real-time hotspot detection and risk mitigation. This approach not only complements existing knowledge but also provides actionable insights for adapting technology to local conditions, ensuring practical implementation and sustainability in geographically challenging environments.

RESEARCH METHOD

This research is case study research. Case study research allows for in-depth exploration of complex issues by considering the various dimensions and factors involved in the phenomenon's context. (Baxter & Jack, 2015) This approach is considered relevant because it allows researchers to identify contextual factors that influence the effectiveness of technology use in handling KARHUTLA. In addition, case studies make it easier for researchers to gain in-depth insights from informants' direct experiences, which play an important role in providing a specific and applicable empirical understanding of a case. (Shannon, 1998).

This study uses thematic analysis to analyse factors related to using information technology to prevent and handle forest and land fires in Riau Province. Thematic Analysis (TA) is a qualitative analysis method that aims to identify, analyse, and interpret patterns of meaning or themes in qualitative data. This method was chosen. It is known to be flexible because it is not tied to a particular theoretical framework, making it a technique that can be used in various research paradigms. TA was first popularised by Braun and Clarke (2006), who developed a systematic approach based on six steps: data introduction, initial coding, theme search, theme review, theme naming, and compilation of analysis results. (Braun & Clarke, 2006).

The thematic analysis technique was chosen in this study because of its flexibility that allows the identification, analysis and interpretation of meaningful patterns or themes in qualitative data. This method is not tied to a specific theoretical framework, making it suitable for exploring complex phenomena such as the use of communication technology in forest fire mitigation, which involves multiple technical, social and geographical dimensions. Compared to other methods such as grounded theory which focuses more on new theories or content analysis which tends to be limited to counting categories, thematic analysis offers a richer depth of interpretation. In addition, the systematic steps in thematic analysis, such as coding data, searching for themes, and drafting reports, ensure organized and relevant results, especially in a case-based study like this one. This technique also allows researchers to integrate insights from interviews, official documents and field data, providing a holistic context to the challenges and opportunities faced in the implementation of communication technologies in remote areas.

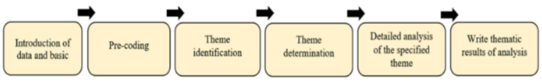

Figure 1 Stages of Thematic Analysis (Source: Clarke & Braun, (2018))

This study uses structured interviews as the primary technique for data collection. Structured interviews for data collection allow researchers to ask all informants the same questions. (Creswell & Creswell, 2018). Structured interviews help produce more systematic and reliable data, especially when the topic being discussed requires uniformity in the answers collected from various informants. This makes structured interviews an effective tool for obtaining data based on the objectives and methods of the research. Interviews were conducted face-to-face between researchers and informants to explore the perspectives and experiences of informants regarding the support of communication technology in mitigating forest fires in the forest areas of Riau Province. This interview covers various aspects, ranging from the role of communication technology in supporting tasks in the field to technical obstacles faced in forest areas. Interview questions were designed so that informants could share detailed experiences regarding the use of technology in handling forest fire cases. The interview consisted of 27 questions divided into six parts, namely: three general questions, five questions related to information sources (source), five questions about transmitters (transmitters), five questions related to communication channels (channels), five questions about receivers (receivers), and four questions about destinations (destinations).

The research informants were selected using purposive sampling techniques. Purposive sampling is a non-probability technique to select research informants based on specific criteria relevant to the research objectives. This technique provides flexibility in selecting individuals with in-depth knowledge or experience of the studied subject, thus allowing for more affluent and specific data extraction. (Tongco, 2007) This method is often used in qualitative research, such as this study, when the data is more focused on a specific context. Purposive sampling has the advantage of increasing the credibility of research results by selecting sources appropriate to the study's needs. (Campbell et al., 2020) This study's interview sources include M. Hariyanto (Person in Charge of the Pekanbaru Intelligence Center Daily), Tommy Manumpak Nainggolan (Head of Section II Pekanbaru, BPPHLHK Sumatra Region), and members of the Operational Room team of the Riau Province Ministry of Environment and Forestry/Section II Region, namely Andri Hidayat and Alkhalid Mawar Dani. These sources were selected for their involvement in monitoring and disaster management in forest areas.

After the primary data through interviews were collected, the Thematic Analysis process was carried out following the steps developed by Braun and Clarke (2006), as illustrated in Figure 1. The first step is to reread the interview transcripts in depth to understand the overall context of the data. The researcher notes down initial ideas that emerge during the reading process. Each interview, recorded and written as a transcript, will be reviewed repeatedly to ensure no important details are missed. The researcher identifies data segments relevant to the study and then assigns codes. For example, codes such as "device reliability" or "device range" can be identified from interviews with sources related to transmitters. Once all data were coded, similar codes were grouped into initial themes. A thematic review was conducted on the identified themes to ensure their relevance to the overall data. The researcher ensured that each theme had sufficient supporting data and that none were too broad or unclear. After the themes were revised, they were named and clearly defined. The final step was to compile a report explaining the themes found, supported by direct quotes from the interviews, to strengthen the analysis. The researcher ensured that this report included thematic explanations understandable to lay readers.

To increase validity, triangulation of data sources was conducted by comparing the interview results with official documents related to forest fire management policies, procedures for the use of communication technology, and field observation data. This approach ensured that the identified themes reflected individual views and were supported by other evidence.

Table 1 Forest Area of Riau Province

No	Forest Type	Area (Ha)
1	Protected forest	229.776
2	Nature Reserves and Conservation	630.622
3	Limited Production Forest	1.013.165
4	Permanent Production Forest	2.329.904
5	Production Forests Can Be Converted	1.149.035

(Source: Badan Pusat Statistik,(2023)

The scope of this study covers the forest area in Riau Province, with the object of research being the communication technology support used in the forest area. Riau Province is one of the provinces in Indonesia with an area of ± 5,406,992 Ha, as shown in Table 1. Riau Province was chosen as a research area because it is Indonesia's sixth most significant area, with a forest area deforestation rate reaching 9,254.8 Ha from 2020 to 2021 (Badan Pusat Statistik, 2023).

RESULT AND DISCUSSION

In part to facilitate the analysis process, the researcher provides abbreviations to identify each source: M. Hariyanto (N01), Tommy Manumpak Nainggolan (N02), and team members Andri Hidayat (N03) and Alkhalid Mawar Dani (N04).

Based on the results of the analysis, 17 codes were successfully identified. Similarities in each code lead to factors that influence technology implementation in strengthening forest fire prevention and mitigation efforts in remote areas. Codes that have similar meanings are grouped into themes. There are six themes as a result, namely:

- Source
- Transmitter
- Channel
- Noise source
- Receiver
- Destination

Theme 1: Information Sources

Climate Change Control (PPI) is the primary source of information in the communication system implemented in forest areas, especially in forest and land fire monitoring efforts (karhutla). This analysis shows that information provided by PPI must be accurate and timely to support effective karhutla prevention measures. This is by the statements of several sources:

"PPI is responsible as a source of information on fire incidents that send reports to us." (N02 and N03)

"The role and responsibility of information sources in the context of monitoring and supervision of forest areas is to find out activities that are suspected of causing criminal acts of unlawful acts." (N04)

Field information must be accurate so that the actions taken are right on target and security is carried out effectively. This is important because handling karhutla depends on speed, accuracy, and coordination with other agencies, such as the Directorate General of Gakkum (if handling is related to unlawful acts). Several sources stated this:

“By opening the site, we can find out hotspots or fire points down to the village level, and the Director General of Gakkum carries out security such as PPLH lines and signs.” (N02)

“Of course, information must have high accuracy.” (N03)

“The role and responsibility for monitoring forest and land fires must be carried out objectively and carefully to produce accurate data.” (N04)

To provide accurate information, information and communication technology are needed to facilitate real-time monitoring. The SIPONGI site facilitates real-time monitoring down to the village level, ensuring tighter supervision and rapid response. This underscores the importance of collaboration between units and digital technology to increase the effectiveness of forest and land fire monitoring. Several sources supported this statement:

“We used to have satellite cellphones, but now we do not use them anymore. Communication now uses HT.” (N02)

“PPI is responsible as a source of information; they monitor forest and land fires through the SIPONGI Website.” (N03)

“The most effective technology for communication is the smartphone.” (N03)

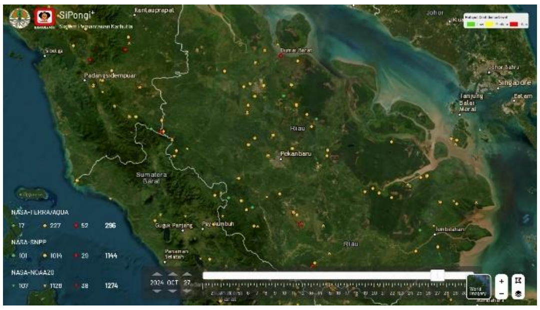

Figure 2 SIPONGI Site

To improve the accuracy of data sources, each member involved in handling forest and land fires must be capable of doing so. Therefore, training is needed for members who are the primary data sources. This was stated by one of the sources:

"Every year, the ministry in charge of controlling the use of this technology holds several trainings." (N04)

"OSIN is more about profiling. If the term is in law enforcement. I patrol, well there everyone is trained." (N04)

Triangulation is carried out by comparing records from the SIPONGI system with information obtained from key informants, including officials from the Ministry of Environment and Forestry (KLHK) and field officers. The data is then verified through a review of relevant literature, including studies on forest fire mitigation using satellite technology. The results of the verification show that remote sensing technology can provide accurate information to support forest fire mitigation efforts (Anuar et al., 2024; Wicaksono et al., 2024). This technology utilises weather data from BMKG and data obtained through four main satellites, namely Terra Aqua, NOBM, SNPP, and Landsat 8. One significant application of information technology in improving inter-agency collaboration in Indonesia is the SIPONGI system. This system, as explained by Wicaksono et al. (2024), allows for real-time detection of hotspots and accelerates the decision-making process in forest fire mitigation. Thus, SIPONGI is a monitoring tool and a major supporter of more coordinated and efficient disaster management.

Theme 2: Transmitter

Handy Talkie (HT) is the primary tool used by field officers. This was conveyed in several statements from the sources:

"Currently, in addition to smartphones, there are HTs that are used as communication tools." (N03)

"Just Handy Talkie." (N04)

This is related to the reliability of HT when used in the field. HT does not require a cellular signal. Its radio signal technology allows HT to be used in various fields with supportive weather conditions. This was stated by the source Alkhalid Mawar Dani:

"It is known that until now, the transmitter has been functioning well and has been a mainstay when my colleagues and I are in the field. Very reliable as long as it is within the range, there have been no obstacles; the most will be when the weather is rainy, or the battery runs out." (N04)

Based on the source's experience, HT's reliability depends on signal quality. The signal range is considered good enough to meet operational needs, especially when weather conditions are supportive with no bad weather or difficult field conditions. The source conveyed this as a field person:

"If there are no obstacles from bad weather or difficult terrain, the signal quality can reach from 800 m-1.2 km." (N03)

"The signal produced is quite good as long as it is within the radius." (N04)

However, the use of HT also has disadvantages. HT is a device that has low compatibility and can only communicate with its partner. The source stated this:

"Not compatible because this HT cannot be used on other devices or connected to other devices." (N03)

"Not compatible with other devices." (N04)

To analyse the dependence on HT as the primary field communication tool, the researcher compared the results of interviews with field officers about their experiences using HT with literature discussing the use of HT in areas with poor cellular signals. (Schweizer et al., 2024) The analysis's results show that the evolution of satellite-based networks, such as Starlink, allows remote areas to utilise satellite technology as an alternative means of communication.

Theme 3: Communication Channels

Mobile phones and radio are the most popular means of communication in rural and forest areas. Radio is most preferred because of its broad reach in remote areas, followed by mobile phones, satellite networks, and general internet networks. This is to the statements of the informants:

"Radio is the easiest to use and affordable means." (N02)

"Currently the most effective types of channels to use are radio, mobile, satellite, internet." (N03)

Strategic efforts to improve communication in the field have been made by utilising satellite technology, which allows easy communication access even in remote areas. Tommy Manumpak Nainggolan stated this:

"Currently building the Starlink satellite network." (N02)

Theme 4: Noise Source

Communication channels using radio signals are not without obstacles. Several obstacles, such as weather interference, radio signal range, and terrain, make it too difficult to block the signal. The source stated this:

"It is not uncommon for bad weather conditions such as heavy rain accompanied by lightning to make it difficult for the network to be captured by the channels we have, but after the storm is over, the conditions will return to normal where the channel will return to capturing the network, and we can communicate again." (N03)

"When we are outside the path that the channel can capture, communication is disrupted." (N03)

Although HT can overcome signal-related obstacles, this device is far from ideal and has severe limitations in transmitting images or maps. HT still has problems transferring visual data, which is important for hotspot studies. This limitation dramatically affects success, as stated by M. Hariyanto:

"But if it is via HT, the visual image does not come in. But that is what interferes with success, reduces our success." (N01)

HT is a device that uses radio signals. This signal requires a large amount of electrical energy to expand its reach. This causes dependence on electricity. This dependence can be an obstacle when the device is operated in areas with limited electricity availability, as stated by Alkhalid Mawar Dani:

"If the condition of the post is in the middle of the forest, we depend on electricity and usually use diesel. When the fuel arrives late, or there are obstacles in receiving it, it becomes a problem." (N04)

Theme 5: Receiver

The receiver in the communication system functions to receive data in the form of files. This data is received and stored in a web-based server. This server is important to the field's data collection and processing system. The resource person stated this:

"The communication system in the field uses a web-based server that functions as the main receiver" (N02)

"Currently, what we use is a server to receive data in the form of files." (N03)

"For that, we have been using a web-based server all this time." (N04)

Figure 3 Receiver Device

To verify that the data on the receiver component was accurate, researchers compared data from the web-based server in the field with interviews conducted by technicians and officers at the command centre to identify operational limitations, such as power failures. Power failures are rare but can disrupt operations at times. The interviewee stated this:

“The quality of the receiver is excellent; unless the AC is off, the server has to be turned off first.” (N02)

“Very good unless there are obstacles such as power outages.” (N03)

Theme 6: Destination

After receiving information, the primary purpose of this communication system is to ensure that the data collected in the field is sent to the proper party. Intelligence information collected by the field team is often passed on to the Section Head, Brigade Commander, or Unit Head. This was stated by Andri Hidayat and Alkhalid Mawar Dani:

“It depends on the division that is involved in the case.” (N03)

“The first supervisor, in our office it, is the Section Head. Then it is forwarded to the Brigade Commander, and the Brigade Commander is forwarded to the Unit Head.” (N04)

Forest fire prevention and extinguishing efforts benefit greatly from cooperation between units and fast communication, as shown in this study. This is related to the feedback given by the recipient of the information. This feedback is done via email or WhatsApp groups managed by the head office, thus affecting the speed of information delivery. The informant stated this:

“Through office email and WhatsApp groups managed by the centre.” (N03)

“Sometimes by calling.” (N04)

The Role of Communication Technology

Communication technology plays a central role in forest fire mitigation in remote areas. Using the SIPONGI site as a real-time monitoring platform has been shown to support monitoring down to the village level and enable rapid response to forest fires. This is in line with research by Anuar et al. (2024) and Wicaksono et al. (2024), which shows that satellite technology, including Terra Aqua, NOBM, SNPP, and Landsat 8, can provide accurate information to support decision-making. In addition, Handy Talkie (HT) remains the primary tool in the field because of its reliability in conditions without cellular signals. The interviews and field analysis results show that HT allows coordination between teams in rugged terrain and areas without other communication access.

Obstacles and Challenges

Communication network disruption is one of the main challenges in controlling forest and land fires (KARHUTLA) in forest areas. One source of disruption that often occurs is the limited reach of cellular networks in rural areas. Handy Talky (HT) devices are used as an alternative. Tommy Manumpak Nainggolan explained that although HT helps overcome the limitations of cellular networks, this device still has shortcomings in transferring visual data, such as maps or images, that are very important for hotspot analysis.

Bad weather, such as storms and lightning, is also a factor that often disrupts communication transmissions, as explained by Alkhalid Mawar Dani. This kind of communication disruption usually slows down coordination in the field. Torbjørnsdatter (2024) Explained that communication networks for disaster mitigation must be resilient to bad weather because heavy rain and lightning often disrupt communication stability, slowing down coordination in the field.

According to Andri Hidayat, another technical challenge is understanding the digital data sent, which often requires additional communication to clarify the message. Devices and media that are not synchronised in transferring complex data, such as maps or visualisations of hotspots, are often the cause of disruptions (Dennis et al., 2008).

The lack of reliable communication networks, especially in remote locations in Riau, is a significant obstacle in extinguishing forest and land fires (BBKSDA Riau, 2019). Based on data from Badan Pusat Statistik (2023), As many as 437 settlements, including those in Kampar, Pelalawan, and the Meranti Islands, have poor cellular signal quality. Diskominfo Riau (2022) Noted that there are around 30 villages that still need the construction of Base Transceiver Stations (BTS) to improve communication networks. Bengkalis Regency also faces limited access to ICT services, with 160 empty points, as Badan Pusat Statistik (2023) reported.

Infrastructure Improvement Recommendations

Developing modern technology-based communication infrastructure is a priority step to overcome these obstacles. Torbjørnsdatter (2024) highlighted the importance of a resilient communication network in disaster mitigation. This ensures that communication devices can still be used in bad weather conditions, such as heavy rain and lightning. Using satellite networks such as Starlink is proposed to overcome the limitations of cellular signals in remote areas. (Maurya et al., 2024). This technology enables real-time visual data transfer and increases the effectiveness of the response to forest fires. In addition, technical training for field officers is needed to ensure they can use sophisticated communication devices and better understand digital data (Torbjørnsdatter, 2024). Integrating cloud-based servers with IoT is also a relevant strategy to improve real-time data processing. (De Sanctis et al., 2016). Combining these steps is expected to increase the effectiveness of forest fire mitigation in areas with limited communication infrastructure.

One step the Riau Provincial Government has taken is developing the Signal Monitoring (SIGMON) application to track and display signal strength in real-time in areas with weak or no signal. (Diskominfo Riau, 2022). However, creating new infrastructure, such as BTS or satellite-based solutions, still requires significant financial and logistical support. (Kementerian Lingkungan Hidup dan Kehutanan, 2023). As an alternative, Zubaidah et al. (2019) state that the visible Infrared Imaging Radiometer Suite (VIIRS) and satellite imagery are still effective in detecting forest fire smoke in Indonesia, especially in areas with weak signals.

CONCLUSION

Based on the research results, it can be concluded that using Internet-based technologies such as the Internet of Things (IoT), satellite monitoring, and early warning systems has significant potential to support forest fire prevention and mitigation in remote areas. This technology enables real-time monitoring and faster decision-making, primarily through platforms such as SIPONGI, which effectively detect hotspots down to the village level. However, implementing this technology faces challenges, including limited communication infrastructure in remote areas, such as lack of cellular signals, restricted range of Handy Talkie (HT) devices, and reliance on incompatible hardware.

Destructive weather disturbances, such as heavy rain and lightning, are significant barriers to information transmission, slowing down coordination in the field. In addition, technical challenges in understanding and processing digital data require additional training for field officers to ensure the effectiveness of technology in supporting forest fire mitigation. Solutions such as developing the Starlink satellite network and using remote sensing technology such as the Visible Infrared Imaging Radiometer Suite (VIIRS) are recommended to overcome signal constraints in remote areas. This step must be supported by improving communication infrastructure, such as constructing Base Transceiver Stations (BTS) and integrating cloud-based servers to process data more efficiently.

Forest fire prevention and handling efforts can be significantly improved through inter-agency collaboration, increased technical training, and the adoption of modern technology. Thus, the application of internet-based technology not only accelerates the response but also minimises ecological and social losses due to forest fires.

This study only uses the Thematic Analysis methodology with a scope of only one institution. Data were collected from only one interview for each informant, and there were only four informants. Thematic Analysis has several weaknesses, including the risk of overly subjective interpretation if the researcher does not reflect his/her influence in the analysis process. Other methodologies can be used besides Thematic Analysis, such as the Analytical Hierarchy Process (AHP) methodology or other qualitative methodologies. To enrich the research results, increasing the number of informants and adding informants from various parties within the organisation can increase the possibility of other factors emerging or strengthening factors that have been identified. Increasing the number of researchers who interpret interview results can reduce the potential for subjective interpretation by researchers.

To improve the effectiveness of forest fire mitigation in remote areas such as Riau, it is recommended to implement satellite-based communication networks, such as Starlink, and IoT systems to monitor real-time environmental data, as well as integrate these technologies with satellite monitoring platforms such as SiPongi. Periodic training for field officers is required to operate technological devices and understand digital data. In addition, the use of renewable energy such as solar panels can support the operation of devices in areas with minimal electricity. The development of an inter-agency digital collaboration platform is also important to strengthen coordination, while policies that encourage technology adoption and device interoperability will ensure the sustainability and effectiveness of the forest fire mitigation system.

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