International Journal of

INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

ISSN:2147-6799 www.ijisae.org Original Research Paper

Design of a Human-Centric Sensing Technology and Systems for Wildfire Prevention in Peatland of Riau Province

Diki Arisandi[1], Amir Syamsuadi*[2], Liza Trisnawati[3]

Submitted: 13/12/2023 **Revised**: 18/01/2024 **Accepted**: 31/01/2024

Abstract*:* Addressing the urgent concern of recurrent wildfires in the peatlands of Riau, particularly exacerbated during dry seasons and complicated by the geographical challenges faced by local rangers, this paper presents a novel solution—a human-centric sensing technology designed for effective wildfire prevention. Employing an agile methodology, our approach unfolds in three main sprints, beginning with the development of a comprehensive sensor network. The system's architecture extends to include a user-friendly dashboard, a proactive alert system for timely responses, and a dedicated mobile application specifically tailored to meet the needs of local rangers. In this research, the agile methodology serves as the backbone, providing a flexible and iterative framework conducive to addressing evolving requirements. The three main sprints cover the development of sensor nodes, the creation of the dashboard, and the crafting of the mobile application. The primary objective is to deliver a holistic monitoring solution that actively involves all stakeholders engaged in peatland preservation. By merging technological innovation with a human-centric design, the proposed system aims to overcome the challenges posed by the intricate geography of peatland terrain. This holistic approach not only enhances monitoring capabilities but also facilitates swift and informed decision-making in wildfire prevention efforts. The culmination of our research results in the delivery of a sophisticated human-centric monitoring system, positioned as a potent tool for safeguarding the invaluable peatland ecosystem for future generations. This project represents a pivotal stride toward harmonizing technological advancements with the imperative goal of preserving natural resources sustainably.

Keywords*: monitoring system, wildfire prevention, peatland, human-centric, Riau Province, Early detection.*

1. Introduction

Over the past few years, Riau's peatlands have faced a daunting challenge in the form of recurring wildfires, particularly intensifying since 2019 [1]. These wildfires have become an alarming and persistent threat, causing substantial damage to the delicate ecosystem [2] . The peatland, prone to ignition during the dry season, experiences frequent and extensive fires that pose a severe risk to the region's environmental stability [3]. The increasing frequency and intensity of these wildfires have raised urgent concerns among local communities and environmentalists alike, demanding immediate attention and innovative solutions to mitigate the far-reaching consequences. The repercussions of peatland wildfires extend beyond ecological concerns, directly impacting the well-being of local residents. The risks to human health, infrastructure, and livelihoods have escalated, as these wildfires release harmful pollutants into the air, exacerbating respiratory issues and creating hazardous living conditions [4]. In addition to the immediate threats posed to human safety, the economic ramifications are profound. The local economy, often dependent on agriculture and natural resources, faces disruptions due to damaged crops, loss of biodiversity, and the increased costs associated with firefighting and recovery efforts [5]. The specter of peatland wildfires in Riau has galvanized a diverse array of stakeholders into action, ranging from governmental bodies to impassioned environmental activists, diligent researchers, and even neighboring countries. Recognizing the gravity of the situation, these stakeholders have initiated multifaceted efforts to counter the relentless wildfires [6]. For instance, the government has launched comprehensive firefighting campaigns, deploying resources and manpower to contain and extinguish the flames [7]. Environmental activists, on the other hand, have been at the forefront of raising awareness and advocating for sustainable practices to prevent future outbreaks [8]. Researchers are contributing by developing innovative monitoring systems, like the one proposed in this paper, to enhance early detection and response capabilities [9]. Neighboring countries have engaged in collaborative initiatives, sharing resources and expertise to address the transboundary nature of this environmental crisis [10]. This collective endeavor reflects a unified front against the devastating impact of peatland wildfires, underscoring the importance of collaborative and cross-

---

1 Department of Informatics Engineering
Universitas Abdurrab, Pekanbaru, Indonesia
2 Department of Governmental Sciences
Universitas Abdurrab, Pekanbaru, Indonesia
3 Department of Informatics Engineering
Universitas Abdurrab, Pekanbaru, Indonesia
** Corresponding Author Email: authordiki@univrab.ac.id*

disciplinary approaches in tackling complex environmental challenges.

The urgency of implementing an early warning system for peatland wildfires lies in the critical window it provides for proactive intervention, offering the potential to avert catastrophic consequences. Unlike conventional fire response mechanisms, an early warning system allows for timely detection, enabling a swift and targeted response to emerging threats. In the context of peatlands, notorious for their susceptibility to rapid and extensive wildfires, early detection is paramount to preventing the uncontrolled spread of flames [11]. This is especially crucial during dry seasons when the risk is heightened [12], as it empowers stakeholders with the foresight needed to deploy firefighting resources and enact preventative measures, ultimately mitigating the environmental, economic, and human impact of wildfires [13].

For researchers, the imperative to develop an innovative and human-centric monitoring system stems from the need to bridge existing gaps in current approaches [14] . Conventional monitoring systems may fall short in addressing the nuanced challenges posed by peatland wildfires, necessitating a more adaptive and responsive framework. By infusing human-centric design principles into the system, researchers can ensure that it aligns with the practical needs of stakeholders, enhancing its effectiveness and usability [13]. This approach not only fosters a more seamless integration of technology into real-world scenarios but also promotes a collaborative relationship between technology and the human agents responsible for wildfire prevention and management.

Discrepancies between research results and on-the-ground realities highlight the existing gaps in current early warning systems for peatland wildfires. These gaps, encompassing differences in results, concepts, data, and theories, underscore the complexity of the challenge at hand. Addressing these disparities requires a more holistic and context-aware approach, considering the specificities of peatland ecosystems and the dynamic conditions influencing wildfire behavior. The proposed human-centric system seeks to bridge these gaps by leveraging advanced technologies like sensor networks and intuitive monitoring interface. This ensures a more nuanced and accurate early warning system that aligns with the intricacies of the peatland environment.

The proposed human-centric early warning system comprises several interconnected components. A sensor network forms the backbone, actively monitoring key indicators of fire risk [15]. Intuitive monitoring interface providing a broader perspective and aiding in the early detection of potential hotspots [15]. Data processing and analytics synthesize the information collected, generating actionable insights for decision-makers [16]. A user-friendly dashboard facilitates intuitive interaction, enabling stakeholders to interpret and act upon the data efficiently [14]. An alert system ensures timely communication of potential threats, while a mobile application tailored for local rangers enhances their on-the-ground responsiveness [17]. The adoption of an agile methodology is pivotal in the development process, allowing for iterative adjustments based on feedback and evolving requirements [18]. This iterative approach is crucial in addressing the dynamic and evolving nature of wildfire threats in peatlands, ensuring that the system remains adaptive and effective over time [19].

The main goal of this research is to create a smart and people-friendly solution to stop wildfires in Riau. With a focus on the real challenges faced during dry seasons, the research aims to build a monitoring system using sensors. The key is to make sure it's easy for everyone, especially local rangers and communities, to use. By bringing together technology and the practical knowledge of people in the area, the goal is to make a system that works well and helps prevent wildfires in Riau's peatlands.

2. Material and Objective of Sensing Technology

In crafting a human-centric monitoring system for wildfire prevention in the peatlands, the agile methodology serves as the guiding force, seamlessly intertwining adaptability and collaboration. The design approach prioritizes the needs and experiences of the local communities, ensuring a symbiotic relationship between technology and human intuition.

2.1 Agile methodology

Embarking on the design journey of a human-centric monitoring system for wildfire prevention using the agile methodology unfolds in three strategic sprints [20]. The first sprint focuses on the development of node sensors to meet the demands of the peatlands in Riau Province. Agile principles allow for quick feedback loops with stakeholders and environmental experts to fine-tune the sensor's capabilities. This iterative process ensures that the sensors are not only technologically sound but also finely attuned to the specific needs of the peatland ecosystem, enhancing their efficacy in detecting early signs of potential wildfires. The agile approach encourages constant communication between the development team and those on the front lines of wildfire prevention, fostering a symbiotic relationship between technology and human expertise [21].

In the second sprint, the agile methodology pivots towards the creation of a comprehensive dashboard development. This phase prioritizes the end-users, crafting an interface that seamlessly integrates into the daily lives of local communities and authorities involved in wildfire prevention efforts. The iterative cycles allow for continuous feedback loops, ensuring that the design aligns with the diverse needs and capabilities of the users. Through this collaborative process, the monitoring system evolves into a tool that not only provides real-time data but also empowers users with actionable insights, enhancing their ability to respond swiftly and effectively to potential wildfire threats. The agile methodology, with its adaptability and emphasis on collaboration, becomes the driving force behind a technologically advanced yet human-centric solution. In the third sprint, the agile methodology conducted a mobile development for local ranger. The agile approach enhances the monitoring system's capabilities by providing a broader perspective, enabling a more holistic approach to wildfire prevention. The whole process of the agile method for the monitoring system can be seen in Figure 1 below.

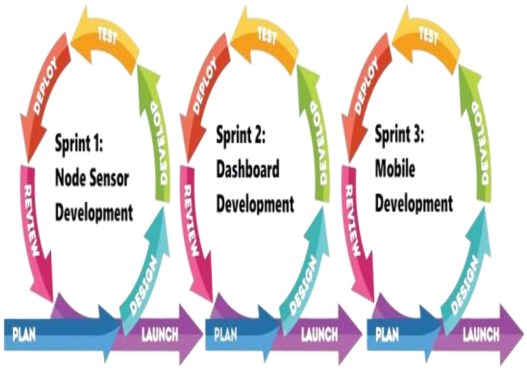

Fig 1. The Whole Agile Process

2.2 Node sensors development

In the first phase of designing a human-centric monitoring system for wildfire prevention, the focus narrows on crucial node sensor development. The goal is proactive wildfire prevention in the peatlands of Riau Province, necessitating a keen understanding of environmental dynamics. The node sensor module, a pivotal element in this strategy, comprises specialized sensors—soil moisture, air humidity, and groundwater debit—integrated with a microcontroller and a transmitter. This combination acts as a sentinel, constantly monitoring the environmental conditions that could precede a wildfire outbreak. To address the remote and off-grid nature of the area, each node sensor is fortified with a solar panel and an independent battery system, ensuring continuous, sustainable operation even in the absence of a conventional power supply.

The meticulous node sensor development adheres to agile principles, fostering iterative cycles of feedback and adjustments. Local stakeholders, environmental experts, and technology developers collaborate closely, refining the sensors' capabilities to be finely attuned to the unique challenges posed by the peatland ecosystem. The soil moisture sensor gauges the vulnerability of the peat to ignition, the air humidity sensor provides insights into atmospheric conditions conducive to wildfires, and the groundwater debit sensor offers a comprehensive understanding of water availability—critical factors in pre-emptive wildfire prevention. This agile approach not only ensures the technological robustness of the node sensor module but also underscores the human-centric aspect by incorporating local expertise. The result is a finely tuned system that acts as an anticipatory guardian, leveraging technology to prevent wildfires before they can wreak havoc in the delicate peatlands of Riau Province.

2.3 Dashboard and mobile development

Transitioning into the second sprint, the monitoring system involves the development of a web-based dashboard and a user-friendly mobile application. The dashboard serves as a centralized hub accessible to officers stationed remotely, providing a comprehensive overview of real-time data collected by the node sensors. This web-based app is designed for ease of use, offering a user interface that facilitates quick decision-making based on the critical information presented. The agile methodology guides the iterative development process, ensuring continuous feedback loops with officers to refine the dashboard's features and functionality. The goal is to empower officers to monitor and respond effectively to potential wildfire threats.

Simultaneously, the mobile application caters to the needs of local rangers patrolling the expansive peatlands. This user-centric mobile app leverages data from the node sensors to provide on-the-ground insights during patrols. Agile development principles drive the iterative cycles, allowing for constant refinement based on the feedback of local rangers. Through this agile approach, the human element is central to the technology, emphasizing the empowerment of local rangers with real-time data for proactive wildfire prevention. The dashboard and mobile application, both born out of the agile methodology, collectively form a comprehensive monitoring system that not only aids officers in remote stations but also equips on-the-ground local rangers with the tools they need to protect the peatlands of Riau Province.

2.4 Testing Scenario

The testing scenario focuses on assessing the understanding of the monitoring system by users, specifically station officers and local rangers. The testing adopts a usability testing approach, which is an evaluation method employed to gauge the user-friendliness and effectiveness of a product's interface. The primary goal is to observe real users interacting with the system, identifying any challenges, confusions, or areas for improvement related to navigation, clarity of information, and overall user satisfaction. This method is designed to ensure that the system's design aligns with user expectations, delivering a seamless and intuitive experience.

3. Results and Discussion

Due to preventing wildfires in peatland, strategically distributing sensor nodes is essential. The sensor nodes, equipped with fire detection capabilities, should be carefully positioned across the peatland landscape. An optimal distribution takes into account the vulnerability of different areas to wildfire outbreaks, considering factors such as vegetation density, topography, and historical fire occurrences. By deploying these sensor nodes strategically, the network can effectively monitor the peatland in real-time, promptly detecting any signs of fire. This early detection is crucial for enabling swift response and intervention to mitigate the spread of wildfires, ultimately safeguarding the fragile ecosystem of peatlands and reducing the risk of extensive environmental damage. Following the strategic distribution of sensor nodes across peatland to detect wildfires, the collected data is transmitted to the cloud for processing. In the cloud environment, the processed information is then delivered to a user-friendly dashboard and a mobile application. This real-time accessibility empowers stakeholders. The dashboard and mobile application provide comprehensive visualizations, alerts, and updates, allowing users to make informed decisions and respond promptly to emerging threats.

3.1 Node sensor unit

To meet stakeholder requirements for wildfire monitoring in peatland, the deployed sensors must possess the capability to detect anomalies in the surrounding environment before a fire occurs. Additionally, these sensors should regularly transmit data about the situational conditions to enable field officers and station personnel to monitor the land periodically. It is crucial to emphasize that the selected sensors are intended to detect environmental changes preceding a fire rather than identify areas already affected by fire.

Detecting air temperature and humidity using the DHT22 sensor is crucial for environmental monitoring in peatland, particularly in the context of wildfire prevention. The DHT22 sensor provides accurate readings of both temperature and humidity, offering valuable insights into the prevailing atmospheric conditions [22]. Monitoring these parameters is essential in wildfire prevention, as dry and hot conditions significantly contribute to the risk of fire outbreaks. High temperatures and low humidity levels can increase the flammability of vegetation, making it crucial to detect and mitigate such conditions promptly. The DHT22 sensor operates by utilizing a calibrated digital signal output, providing precise and reliable data. Its working principle involves a capacitive humidity sensor and a thermistor for temperature measurement. This information is pivotal for developing warning systems, enabling timely intervention and proactive measures to prevent wildfires in vulnerable areas.

Soil moisture detection using the FC-28 sensor plays a critical role in environmental monitoring, particularly in identifying drought conditions or monitoring soil moisture levels in peatland areas. The FC-28 sensor is instrumental in gauging the moisture content of the soil, offering valuable insights into the health and resilience of vegetation [23]. In the context of peatland, maintaining optimal soil moisture is crucial to preventing the occurrence of wildfires. Peatlands are highly susceptible to fire outbreaks when the soil becomes excessively dry. The FC-28 sensor operates based on the principle of electrical conductivity, where changes in soil moisture alter the conductivity of the sensor. As the soil moisture decreases, the electrical conductivity increases, providing a quantitative measure of soil moisture levels. This real-time data aids in proactive measures, allowing local ranger or firefighter to implement interventions to mitigate the risk of fire in peatland areas.

Groundwater level observation using the SL067 sensor is crucial for environmental monitoring, particularly in preventing drought conditions and managing soil moisture in peatland areas. The SL067 sensor provides accurate readings of groundwater levels, offering essential information to comprehend the hydrological dynamics of an area [24]. Maintaining an appropriate groundwater level is vital to preventing the risk of wildfires. Groundwater acts as a natural buffer against soil desiccation, and its depletion can lead to increased flammability of peat, making it more susceptible to ignition. The SL067 sensor operates using pressure transducer technology, where changes in groundwater levels are measured by variations in pressure. Real-time data from this sensor assists stakeholders in preventing the occurrence of wildfires in peatland areas and ensuring the ecological health of the environment.

All the sensors mentioned were installed on each sensor node to provide warnings tailored to the characteristics of peatland and stakeholder preferences. To achieve desired outcomes, calibration was performed on all three sensors to ensure results aligned with expectations, as reflected in Table 1 below.

Table 1. Sensor Calibration

Components	Calibration
Air temperature sensor	≤ 30^{0}c = Safe 30^{0}c – 40^{0}c = Normal 41^{0}c – 60^{0}c = Alert > 61^{0}c = Danger
Soil Moisture sensor	≤ 50 = Dry ≥ 51 = Moist
Groundwater level Sensor	480 – 615 = low 660 – 690 = normal 700 – 710 = high

Sensors in Table 1 are positioned on each sensor node unit, with each unit also equipped with a solar panel and independent battery for power supply, a microcontroller for data processing, and a GSM transmitter module for sending data to the cloud server. The entire set of components is illustrated in the block diagram in Figure 2.

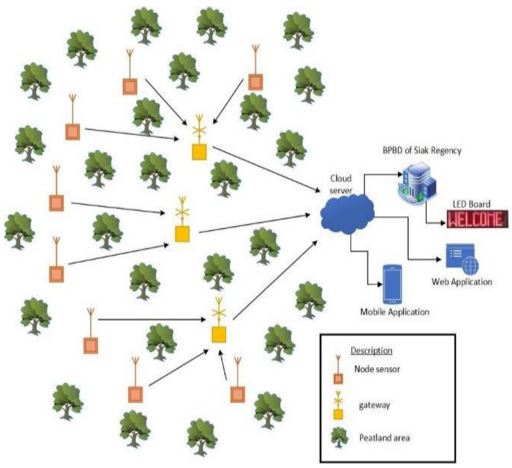

Fig 2. Node Sensor Unit Diagram

The distribution of sensors in peatland must also take into consideration several factors, including sensor coverage (R), overlap of coverage (O), energy distribution (E), and sensor density (D). Proper placement of sensors is essential to ensure comprehensive coverage of the peatland area and effective monitoring. The sensor coverage (R) denotes the maximum distance a sensor can detect, while the overlap of coverage (O) ensures that there are no gaps in monitoring. Energy distribution (E) is crucial for maintaining a balanced power supply among sensors to sustain their functionality. Additionally, achieving an optimal sensor density (D) involves determining the appropriate number of sensors per unit area.

$$Ideal\ distance = R\ x\ (1 - O)\ x\ \sqrt{\frac{E}{D}} \qquad (1)$$

The strategic consideration of these factors enhances the efficiency of the sensor network in capturing accurate and reliable data for environmental monitoring in peatland areas. Figure 3 provides a visual representation of the node sensor distribution.

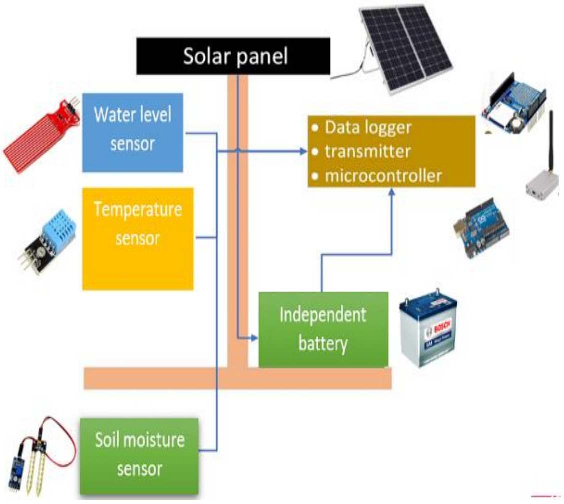

Fig 3. Node Sensor Distribution

3.2 Dashboard and mobile application

After the sensor nodes have been successfully developed, the environmental conditions in the peatland will be recorded and periodically sent to the cloud server. The data stored on the cloud server will serve as information for the web-based dashboard and mobile application, providing stakeholders with real-time insights and facilitating effective monitoring of peatland conditions, as seen in figure 4. The information displayed on the dashboard includes data based on the sensor's location and the surrounding conditions for each sensor, encompassing air, soil, and groundwater level monitoring. The dashboard presents information in easily comprehensible graphs tailored to user preferences, ensuring that each piece of information can be quickly understood. This user-friendly approach enhances the accessibility and usability of the dashboard, enabling stakeholders to make informed decisions promptly based on the visualized data.

Fig 4. Dashboard Interace

The desktop-based dashboard application is tailored for users stationed at the base or office, providing a comprehensive interface for in-depth data analysis and monitoring. In contrast, local rangers responsible for on-site inspections of peatland conditions benefit from a more streamlined mobile application. This mobile application (Figure 5) prioritizes simplicity, ensuring quick and efficient reporting and decision-making capabilities while in the field.The mobile application's concise design aims to enhance usability, allowing field users to seamlessly navigate and report their findings with minimal effort. By optimizing for mobile use, the application becomes an invaluable tool for local rangers, providing them with the necessary features to make informed decisions and contribute to the overall effectiveness of peatland management.

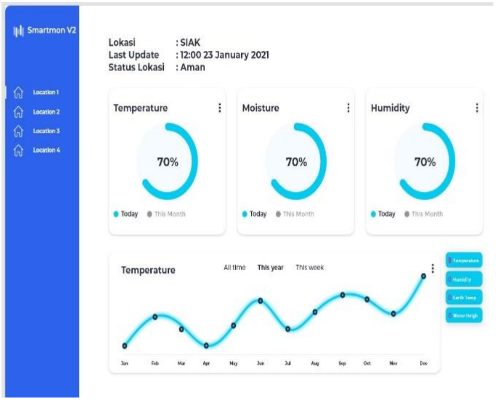
Lokasi : SIAK
Last Update : 12:00 23 January 2021
Status Lokasi : Aman

Fig 5. Mobile Application

3.3 Usability testing

Usability testing involves 10 station officers and 25 local rangers. It is anticipated to serve as a benchmark in achieving the effectiveness of the built system that meets the users' needs. The testing scenarios are divided into 5 aspects related to how users utilize the monitoring system under realistic simulation. Within these 5 aspects, station officers and local rangers are given different yet interconnected scenarios. The goal of this usability testing, aside from assessing success metrics, is to observe the extent to which station officers and local rangers collaborate in handling peatland wildfire incidents based on the information available on their interfaces. The results of the usability testing can be seen in the following Table 2.

Table 2. Usability Testing Result

Item	***Subject***	***Scenario***	***Test Score Result (%)***
Incident recognition	Station officer	Use the web-based dashboard to locate and understand the details of the reported incident, such as its exact location and nature based on node sensor	90
	Local ranger	Assess the ability to comprehend the incident information presented on the mobile application	100
Navigation and Information Retrieval	Station officer	Test the ease of navigation on the web-based dashboard to retrieve additional information about the environmental conditions	100
	Local ranger	Evaluate the capability to quickly find relevant information on the mobile application	90
Coordination and Communication	Station officer	Utilize the web-based dashboard to coordinate with other field rangers, sharing updates on the situation	90
	Local ranger	Test the effectiveness of communication features on the mobile application for coordinating with other rangers in real-time	95
Decision-Making	Station officer	Assess the clarity of information displayed on the web-based dashboard, focusing on its contribution to informed decision-making in managing the incident.	100
	Local ranger	Evaluate the mobile application's support for on-the-spot decision-making based on available data	100
Reporting	Station officer	Assess the simplicity and completeness of reporting features on the web-based dashboard	100
	Local ranger	Use the mobile application to generate actions taken during the event	100

The usability testing results for the Monitoring System for Wildfire Prevention are highly encouraging, indicating a well-designed and user-friendly interface for both the web-based dashboard and the mobile application. Station officers and local rangers demonstrated a commendable understanding of the system's functionalities, showcasing their ability to efficiently perform critical tasks. Based on the result above, the system's overall usability is commendable, with users expressing satisfaction in their ability to navigate, coordinate, make informed decisions, and generate reports seamlessly. The minor areas for improvement identified will be addressed in future updates to enhance the user experience further. The Monitoring System for Wildfire Prevention has proven to be an effective tool for both station officers and local rangers in managing and preventing wildfire incidents in peatland areas.

Conclusion

In the face of recurring wildfire disasters in the peatland areas of Riau Province, the imperative for a human-centric monitoring system that caters to user needs becomes evident. The development of this monitoring system follows the agile methodology, delineated into three sprints: node sensor development, dashboard development, and mobile development. This iterative and collaborative approach ensures adaptability and responsiveness to user requirements throughout the developmental stages. Following the comprehensive development of the monitoring system, the evaluation phase involves user testing, specifically engaging station officers and local rangers. This testing encompasses a meticulous assessment of five key aspects, aiming to validate the system's functionality and user-friendliness. The user-centric design philosophy is aimed at empowering users to comprehend and effectively navigate the intricacies of the monitoring system. The testing results unveil a promising outcome, demonstrating that users not only grasp each facet of the system's functionality but also exhibit a heightened ability to coordinate seamlessly during peatland wildfire incidents. This user-centric monitoring system, finely tuned to the needs of station officers and local rangers, stands as a testament to the successful fusion of agile development principles with a human-centered design approach.

Acknowledgment

1. The authors express their gratitude to the Abdurrab University Research and Community Service Board for the invaluable support and guidance extended throughout this research endeavor. Special appreciation is extended to BPBD Siak Regency and its dedicated staff for the collaborative efforts. Furthermore, we extend our thanks to the Ministry of Research, Technology, Education, and Culture for the generous grant funding that facilitated this research.
2. This paper was presented at the 5th International Conference on Vocational Innovation and Applied Sciences (ICVIAS), held in Surabaya, Indonesia, on October 10, 2023. The conference was organized by the Faculty of Vocational Studies, Universitas Airlangga

References

[1] R. Uning *et al.*, “A review of Southeast Asian Oil Palm and its CO2 fluxes,” *Sustainability*, vol. 12, no. 12, p. 5077, Jun. 2020, doi: 10.3390/su12125077.

[2] B. Widyatmoko, “Interests arrangement in the implementation of Indonesian sustainable palm oil certification: Case study of Sari Makmur Palm oil smallholders in Riau Province,” in *Global environmental studies*, 2023, pp. 197–222. doi: 10.1007/978-981-99-0906-3_11.

[3] T. Nikonovas, A. Spessa, S. H. Doerr, G. Clay, and S. Mezbahuddin, “Near-complete loss of fire-resistant primary tropical forest cover in Sumatra and Kalimantan,” *Communications Earth & Environment*, vol. 1, no. 1, Dec. 2020, doi: 10.1038/s43247-020-00069-4.

[4] P. O. Ukaogo, U. Ewuzie, and C. V. Onwuka, “Environmental pollution: causes, effects, and the remedies,” in *Elsevier eBooks*, 2020, pp. 419–429. doi: 10.1016/b978-0-12-819001-2.00021-8.

[5] Z. D. Tan, S. Sutikno, L. R. Carrasco, and D. K. Taylor, “Local community representations of tropical peatlands and implications for restoration in Riau, Indonesia,” *Restoration Ecology*, vol. 31, no. 5, Apr. 2023, doi: 10.1111/rec.13900.

[6] R. K. Bhomia and D. Murdiyarso, *Effective monitoring and management of peatland restoration*. 2021. doi: 10.17528/cifor/008142.

[7] F. Farhan and P. R. J. Hoebink, “Can campaigns save forests? Critical reflections from the Tripa campaign, Aceh, Indonesia,” *Forest Policy and Economics*, vol. 105, pp. 17–27, Aug. 2019, doi: 10.1016/j.forpol.2019.04.012.

[8] N. I. Fawzi, I. Z. Qurani, and R. Darajat, “Alleviating peatland fire risk using water management trinity and community involvement,” *IOP Conference Series*, vol. 914, no. 1, p. 012037, Nov. 2021, doi: 10.1088/1755-1315/914/1/012037.

[9] D. Arisandi, A. Syamsuadi, L. Trisnawati, and S. Hartati, “A Development of Multi-Platform Based Forestry Wildfire Prevention System Using Incremental Model: Case study: a peatland area in Siak Regency,” *D. Arisandi*, Sep. 2022, doi: 10.1109/ieit56384.2022.9967894.

[10] H. Varkkey, “Emergent geographies of chronic air pollution governance in Southeast Asia: Transboundary publics in Singapore,” *Environmental Policy and Governance*, vol. 32, no. 4, pp. 348–361, Apr. 2022, doi: 10.1002/eet.1994.

[11] J. Phelps, A. Zabala, W. Daeli, and R. Carmenta, “Experts and resource users split over solutions to peatland fires,” *World Development*, vol. 146, p. 105594, Oct. 2021, doi: 10.1016/j.worlddev.2021.105594.

[12] I. S. Hikouei, K. N. Eshleman, B. H. Saharjo, L. L. B. Graham, G. Applegate, and M. A. Cochrane, “Using machine learning algorithms to predict groundwater levels in Indonesian tropical peatlands,” *Science of the Total Environment*, vol. 857, p. 159701, Jan. 2023, doi: 10.1016/j.scitotenv.2022.159701.

[13] M. Taufik, M. T. Widyastuti, A. Sulaiman, D. Murdiyarso, I. P. Santikayasa, and B. Minasny, “An improved drought-fire assessment for managing fire risks in tropical peatlands,”

Agricultural and Forest Meteorology, vol. 312, p. 108738, Jan. 2022, doi: 10.1016/j.agrformet.2021.108738.

[14] Z. Ali, A. E. Saddik, B. Er-Raha, A. Labbaci, and M. Ouessar, “ClimInonda a Web Application for Management the Climate Da-Ta: Case Study of the Flooding Risk in Bayech Transboundary Basin,” *Z. Ali*, vol. 15, p. 16, Jun. 2023, doi: 10.20944/preprints202306.0713.v1.

[15] W. F. Cheung, T. H. Lin, and Y. C. Lin, “A Real-Time construction safety monitoring system for hazardous gas integrating wireless sensor network and building information modeling technologies,” *Sensors*, vol. 18, no. 2, p. 436, Feb. 2018, doi: 10.3390/s18020436.

[16] I. H. Sarker, “Data Science and Analytics: An Overview from Data-Driven Smart Computing, Decision-Making and Applications Perspective,” *SN Computer Science*, vol. 2, no. 5, Jul. 2021, doi: 10.1007/s42979-021-00765-8.

[17] D. T. Cronin *et al.*, “Application of SMART software for conservation area management,” in *Oxford University Press eBooks*, 2021, pp. 201–224. doi: 10.1093/oso/9780198850243.003.0010.

[18] T. Thesing, C. Feldmann, and M. Burchardt, “Agile versus Waterfall Project Management: Decision Model for Selecting the Appropriate Approach to a Project,” *Procedia Computer Science*, vol. 181, pp. 746–756, Jan. 2021, doi: 10.1016/j.procs.2021.01.227.

[19] K. R. Sarangee, J. B. Schmidt, P. B. Srinath, and A. Wallace, “Agile transformation in dynamic, high-technology markets: Drivers, inhibitors, and execution,” *Industrial Marketing Management*, vol. 102, pp. 24–34, Apr. 2022, doi: 10.1016/j.indmarman.2021.12.001.

[20] D. Braines, A. Preece, C. Roberts, and E. Blasch, “Supporting Agile User Fusion Analytics through Human-Agent Knowledge Fusion,” *2021 IEEE 24th International Conference on Information Fusion (FUSION)*, Nov. 2021, doi: 10.23919/fusion49465.2021.9627072.

[21] R. A. Khan *et al.*, “Practices of Motivators in Adopting Agile Software Development at Large Scale Development Team from Management Perspective,” *Electronics*, vol. 10, no. 19, p. 2341, Sep. 2021, doi: 10.3390/electronics10192341.

[22] O. Moussaoui, M. Azizi, and M. Moussaoui, “USING IOT AND ML FOR FOREST FIRE DETECTION , MONITORING , AND PREDICTION : A LITERATURE REVIEW,” *J. Theor. Appl. Inf. Technol.*, vol. 100, no. 19, pp. 5445–5461, 2022.

[23] P. Bhadani and V. Vashisht, “Soil Moisture, Temperature and Humidity Measurement Using Arduino,” *P. Bhadani*, pp. 567–571, Jan. 2019, doi: 10.1109/confluence.2019.8776973.

[24] J. J. Flores-Sedano, H. Estrada-Esquivel, A. M. Rebollar, and J. J. J. F. Prieto, “A New Approach to Automate the Connectivity of Electronic Devices with an IoT Platform,” in *Communications in computer and information science*, 2023, pp. 123–139. doi: 10.1007/978-3-031-28454-0_9.