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Knowledge Management System for Forest and Land Fire Mitigation in Indonesia: A Web-Based Application Development

Mitra Unik[1*], Yoze Rizki[1], Imas Sukaesih Sitanggang[2], Lailan Syaufina[3]

[1]Department of Informatic Engineering, Faculty of Computer Science, Muhammadiyah University of Riau, Jl. Tuanku Tambusai, Pekanbaru, Indonesia 28156
[2]Department of Computer Science, Faculty of Mathematics and Natural Sciences, IPB University Bogor, Academic Ring Road Campus IPB Dramaga, Bogor, Indonesia 16680
[3]Department of Silviculture, Faculty of Forestry and Environment, IPB University Bogor, Academic Ring Road Campus IPB Dramaga, Bogor, Indonesia 16680

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Abstract

Forest and land fires in Indonesia have serious impacts on many aspects, including the environment, health, economy, politics, and international relations. They cause haze pollution that extends to neighboring countries and peatland degradation. Despite extensive research and mitigation efforts, forest and land fires continue to occur and cost lives. Therefore, effective management and mitigation strategies are required. This research developed a web-based knowledge management system (*KMS*) *using the Laravel framework as an effective forest and land fire mitigation platform. The KMS aims to support decision-making, facilitate knowledge exchange, improve coordination between stakeholders, and expand access to relevant information, while maintaining the sustainability of forest and land resources in Indonesia. The KMS evaluation results cover two important aspects: blackbox evaluation and Performance Evaluation. The blackbox evaluation showed that KMS provides knowledge retrieval features based on expert knowledge. The Performance Evaluation revealed that the KMS provides easy and quick access to information on forest and land fire prevention and management. Thus, this research has great potential to help overcome the problem of forest and land fires in Indonesia and protect the environment and society from their adverse effects.*

Keywords: *forest fire, KMS, Knowledge sharing, mitigation, web application*

**Correspondence author, email*: *mitraunik@umri.ac.id*

Introduction

The contribution of forests to human life goes hand-in-hand with their sensitivity to climate change (Dieterle, 2009; Ulya et al., 2018). Together with precipitation trends in Indonesia, increasing temperatures and longer dry season periods lead to increased risk of forest and land fires, while forest and land fire feedbacks have driven climate change itself through modulation of the carbon cycle, greenhouse gas emissions, and aerosols (Berwyn, 2018; Holden et al., 2018). In 2020, the recalculation shows that about 64.1% of Indonesia's total land area is land forest area, while 35.9% is Other Use Areas, with the realization of forest area designation reaching ±88.4 million ha in December 2020 (KLHK, 2022). Forest and land fires periodically occur, as recorded in 1982, 1997, and 2015, resulting in environmental damage, loss of agricultural crops and forests, and release of CO_2 and air pollutants (Lennertz & Panzer, 1984; Goldammerl & Seibert, 1990; Huijnen et al., 2016; Taufik et al., 2017; Greenpeace International & Greenpeace, 2018).

Many studies and efforts have been conducted by academics, the private sector, organizations, local communities, and government agencies, especially under the Ministry of Environment and Forestry. These efforts encourage the government to formulate policies, coordinate and synchronize, and supervise the implementation of forest and land fire mitigation. The Indonesian government has issued various policies through laws and regulations, such as 1) Law Number 41/1999 on Forestry, article 50 paragraph 3 point (d); 2) Government Regulation Number 4/2001 on Control of Pollution and Environmental Damage Related to Forest and Land Fires; 3) Government Regulation Number 45/2004 on Forest Protection; 4) Law Number 24/2007 on Disaster Management; 5) Minister of Forestry Regulation Number P.12/Menhut/2009 on Forest Fire Control; 6) Law Number 18/2004 on Plantations; 7) Regulation Number 71/2014 on Peat Ecosystem Protection and Management.

However, despite various studies, regulations, and efforts, forest and land fires continue to occur and cause casualties. The 2019 fires recorded a total area of 1.6 million ha burned, exceeding the fires in the previous three years. According to statistics, in 2019, the area covered by forest and land fires reached 857,756 ha, with 630,451 ha occurring

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on mineral land and 227,304 ha on peatland. Thus, peatland fires account for only 26.5% of the total area of forest and land fires (Sadino et al., 2020). The economic impact of forest and land fires in 2019 reached USD5.2 billion, equivalent to 0.5% of gross domestic product (Staff, 2019).

It is important to have effective disaster management and mitigation strategies to reduce the impact of forest and land fires. According to Law Number 24/2007 on Disaster Management, mitigation is a series of efforts to reduce disaster risk through physical development, as well as increasing awareness and ability to deal with disaster threats. In recent years, innovation has focused on information availability and knowledge management to provide a more significant competitive advantage in the mitigation and data management of forest and land fires (Sitanggang et al., 2022). The adoption of technology, including the use of web-based knowledge management systems (KMS), can assist in the management and mitigation of forest and land fires by developing processes, products, habits, and best practices (Gil-Gomez et al., 2020; Syaufina et al., 2022).

Knowledge management (KM) is the systematic process by which knowledge is created, shared, and utilized to achieve competitive advantage and improved performance (Mildon et al., 2022). KM involves various knowledge processes, such as knowledge acquisition, creation, packaging, application, and reuse (North & Gita, 2018). The goal of KM is to facilitate collaborative knowledge sharing to enhance learning, access information and knowledge, and improve decision-making processes (Blake et al., 2019).

Knowledge sharing becomes an important basis in facilitating effective performance in an organization. There are various ways to share knowledge, one of which is through cataloguing and repurposing proprietary, hard-to-imitate, valuable, and rare knowledge held by a particular individual or subject within the organization (Israilidis et al., 2015). Several knowledge models were discussed in empirical studies in the 1990s and the 2000s (Nonaka & Takeuchi, 1995; Singh Sandhawalia & Dalcher, 2011; Wu & Lin, 2013). These models cover processes related to the creation, flow, storage, and reuse of knowledge. The focus of each model varies in its elements and approaches, such as sequencing, synergies, and networks, and the impact of the external environment on knowledge creation, strategic thinking, decision-making, or even problem-solving processes. These factors significantly influence an organization's culture and strategy; therefore, it is important to emphasize the suitability of a knowledge management system to a particular organization.

The level of technology is considered an important factor in some situations, but is often only discussed in the context of information storage. However, at its core, what is important is that interested individuals should have access to the stored information and that the organization is responsible for its maintenance. Framework Wiig (1993) discussed the use of tools for knowledge sharing, including the creation of "who knows what" repositories containing references and libraries for easy access to knowledge by all. Bukowitz and Williams (1999) distinguish between information management and knowledge management, with the key factor of difference being that in order to access tacit knowledge, not only is a relationship with the content through high or low technology required, but also a relationship with the individual or group that possesses the knowledge. Gamble (2020) explains that experiences recorded in the form of documents (explicit knowledge) and tacit knowledge are only a small part (around 30%) of the whole, while the rest remain embedded in the minds of the staff/experts (tacit knowledge).

KMS has important potential in fire mitigation for stakeholders, such as government agencies, communities, NGOs, researchers, and other parties involved in fire prevention and control (Oktari et al., 2020). The KMS plays a role in improving the efficiency and effectiveness of knowledge exchange, coordination between stakeholders, speed and accuracy of decision-making, and producing more effective strategies for preventing and controlling forest and land fires to minimize damage (Robins et al., 2022).

This research discusses the development of a web-based forest and land fire mitigation KMS, its key features, and its benefits. The challenges faced during the development and implementation of the KMS will be noted, as well as the potential for future development of the technology. The KMS model to be developed in this research is the knowledge-sharing system. The main objective of this research was to demonstrate the importance of using technology in disaster management and mitigation efforts. This research also aims to expand and improve the quality of knowledge of the community and authorized officers quickly, accurately, and consistently related to the prevention, suppression, and control of forest and land fires. In addition, this research is expected to improve skills and knowledge related to forest and land fires sourced from experts and become an important element in sustainable decision-making and protection in efforts to reduce and mitigate forest and land fires in Indonesia.

Research stages This research was adapted from Abdul Aziz et al. (2020), starting from evaluating existing infrastructure, organizing a knowledge management team, acquiring knowledge, designing KMS, verifying and validating KMS, making corrections, implementing KMS, managing changes, and evaluating the system. Each stage produces outputs such as those from KM teams, KMS category mapping of forest and land fire mitigation, KMS architecture, and web/mobile applications. The knowledge management system life cycle is shown in Figure 1.

Research equipment The software and hardware used in this research are: 1) Hardware: Processor Intel(R) Core(TM) i5-4300U CPU @ 1.90GHz (4 CPUs), ~2.5GHz, and memory: 4096MB RAM., 2) Software: Operating system: Windows 10 Pro for Workstations 64-bit, Framework Laravel 7, XAMPP and Sublime Text as a text editor.

Results and Discussion

Infrastructure evaluation The vast scale, unfavorable environmental conditions, limited access, ecosystem complexity, irresponsible illegal logging practices, and lack of coordination and collaboration are the reasons for the difficulty of overcoming or extinguishing forest and land fires. Referring to KM processes and systems according to (Becerra Fernandez & Sabherwal, 2014) which is seen from

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five dimensions, namely organizational culture, organizational structure, technology and information infrastructure, general knowledge, and physical infrastructure. This stage aims to identify that the infrastructure used in the knowledge management system functions properly, meets user needs, and supports organizational goals.

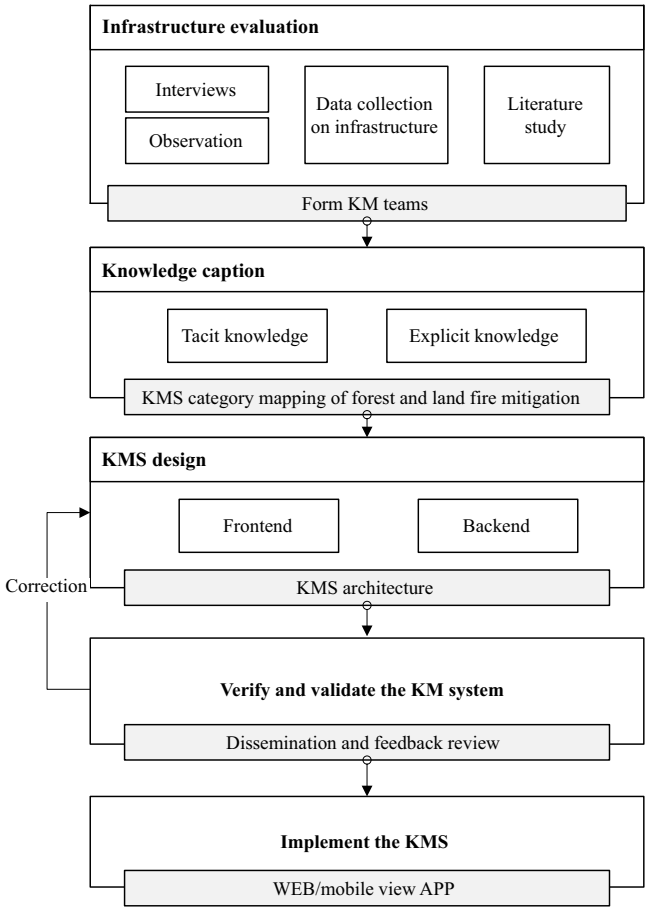

Figure 1 Research flow chart.

This stage produces knowledge of the types of mitigation that can be done to reduce the risk of impacts from forest and land fires (*karhutla*), such as prevention, preparedness, response, recovery, and collaboration and co-operation (Syaufina, 2018). Remote sensing monitoring technology has been developed (Unik et al., 2023). However, some sensing results have not been understood by field officers and the community due to limited counselling from forest and land fire experts. The formation of a knowledge management team and identification of stakeholders involved in the KM team were conducted based on the results of the infrastructure evaluation as a guide. Stakeholders who are members of the KM team include officers, experts, the government, and the IT team. Table 1 displays the roles and tasks of the forest and land fire mitigation KMS development teams.

Knowledge capture Knowledge mining is the process of identifying, extracting, and utilizing knowledge that is hidden or unstructured in data or other information resources. The goal of knowledge mining is to uncover new knowledge, patterns, trends, or insights that can be used for decision-making, innovation, or problem solving. Sources of tacit knowledge and explicit knowledge are obtained through various methods, such as text mining (literature repository), interviews, and focus group discussions. The category of forest and land fire mitigation involves various approaches and actions, as shown in Figure 2.

The KM system architecture for disaster mitigation of forest and land fires in Indonesia is divided into two parts: front-end and back-end. The KMS system architecture design is divided into two parts: front-end and back-end development. The design of the KMS system architecture is shown in Figure 3.

Verify and validate the KM system The verification and validation stage of the KM design is carried out to ensure the correctness of the KM design that has been carried out in the previous stage. One method of participation of experts is through verification and validation. At this stage, the results

Table 1 Forest and land fire mitigation KMS development team

Role	Tasks
Knowledge developer	Develop the KMS system design and define the scope of the development project, lead the implementation of the KMS project, and liaise with experts
Project leader	Ensure that the KMS is fit for purpose and oversee its implementation, as well as organise and coordinate team members involved in managing the KMS
System designer	Design, develop and implement the KMS by liaising with programmers to ensure that the system meets the needs and desired objectives
Expert	Provide information related to forest and land fires, both in the form of explicit knowledge and as a party to validate the information.
Back-end developer	Conduct back-end development for mobile and web applications and conduct knowledge exploration.
Front-end web developer	Developing the interface of the KMS web application with the aim of improving its appearance and functionality, as well as conducting the knowledge exploration process.

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of the KM design are presented and explained to academic experts in fire disaster management, either directly by visiting the location or via a video conference. Subsequently, experts were asked to provide feedback on the KM design results. The feedback provided will be analyzed to obtain a design that suits the needs of KMS development.

Implement the KM system The user interface was built using the Laravel framework. On the "home" page of the web-based KMS system, there is a knowledge search feature that makes it easy for users to find the information they need.

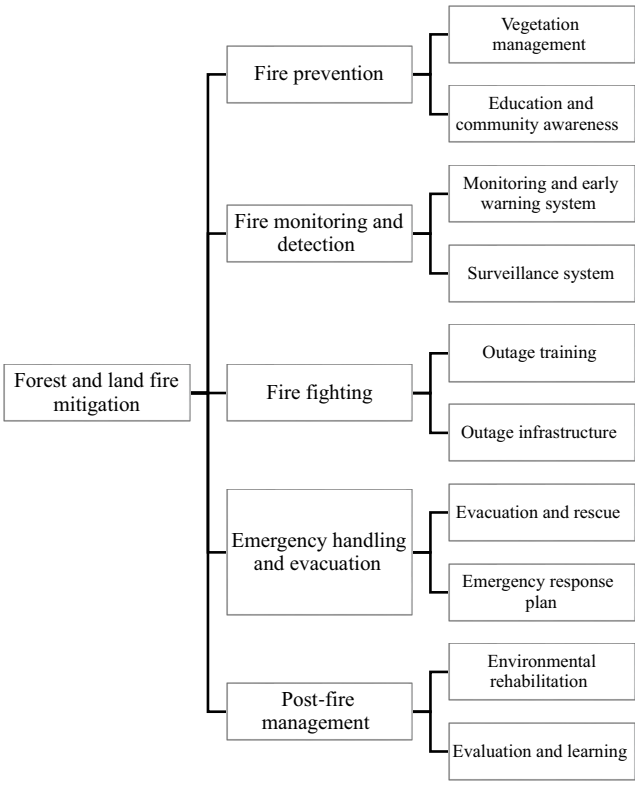

Figure 2 KMS category mapping of forest and land fire mitigation.

This feature allows users to enter keywords or phrases related to the topic of interest, and the system performs a search in the available knowledge database. In addition to the search box, there is a navigation menu that allows users to explore knowledge categories and view a list of recent or popular knowledge. This knowledge search feature is very important for improving the accessibility and efficiency of users in obtaining the required knowledge. Figure 4 provides a visual depiction of the appearance of the "home" page with the knowledge search feature in the web-based KMS system.

The repository features on the "home" page are grouped into three categories: articles, e-books, and video reports. This feature provides services for users to search and access various types of knowledge resources contained in the KMS system repository. The categories of articles, e-books, and video reports allow users to choose the type of knowledge resources that suit their preferences. This feature provides flexibility to users in obtaining quality and varied information and accommodates different learning styles. With this repository feature, users can easily search for and access a variety of relevant and up-to-date knowledge sources. Figure 5 provides a visual display of the repository feature with three categories found on the "home" page of the web-based KMS system.

On the "home" page, there is a detailed knowledge topic-based category feature that offers six choices of topics relevant to forest and land fire prevention and suppression. These topics included *tupoksi petugas*, types of mitigation, resource management, action management, case reports, and collection of regulations. This feature makes it easy for users to access information that suits their requirements. Figure 6 shows a visual display of this feature, providing an overview of topic options in the web-based KMS system.

The "watch share videos" feature on the home page gives users access to a collection of videos relevant to forest and land fire mitigation. Users can watch and share these videos to broaden their understanding of forest and land fire prevention and mitigation. Figure 7 shows a visual display of the features, allowing users to select and watch videos according to their interests and needs. With this feature, the web-based KMS system provides an interactive and interesting alternative medium for presenting information related to forest and land fire mitigation to users.

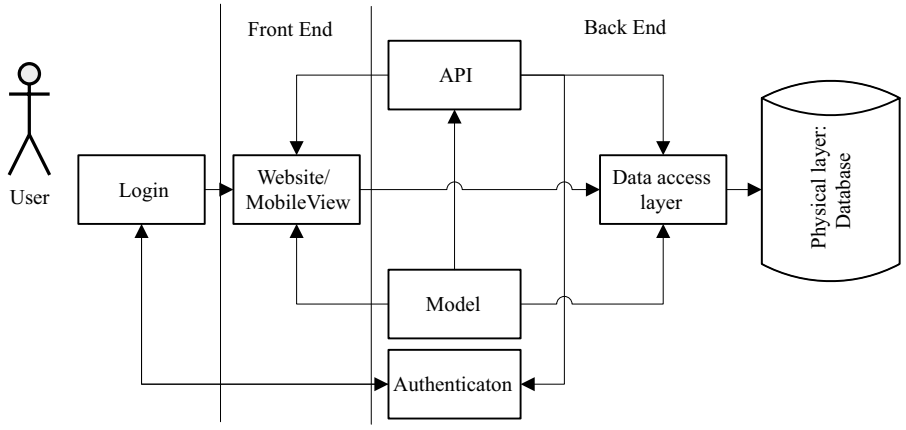

Figure 3 KMS architecture.

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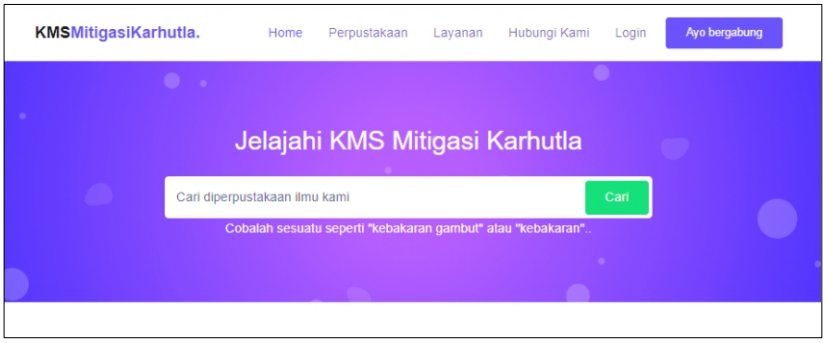

Figure 4 Main page - Forest fire mitigation knowledge search feature.

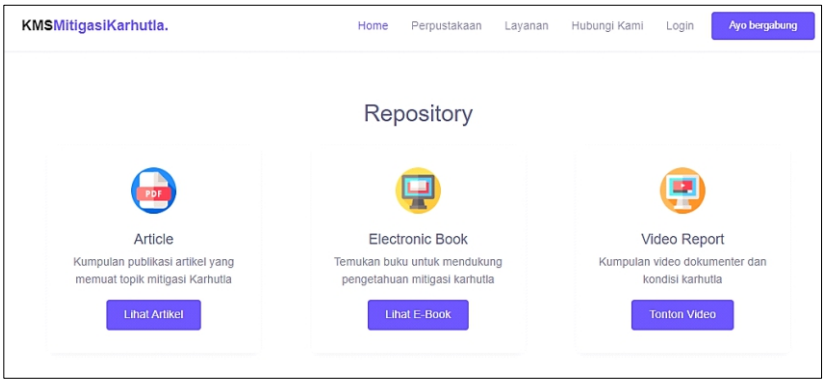

Figure 5 Main page - Features repository of articles, eBooks and videos.

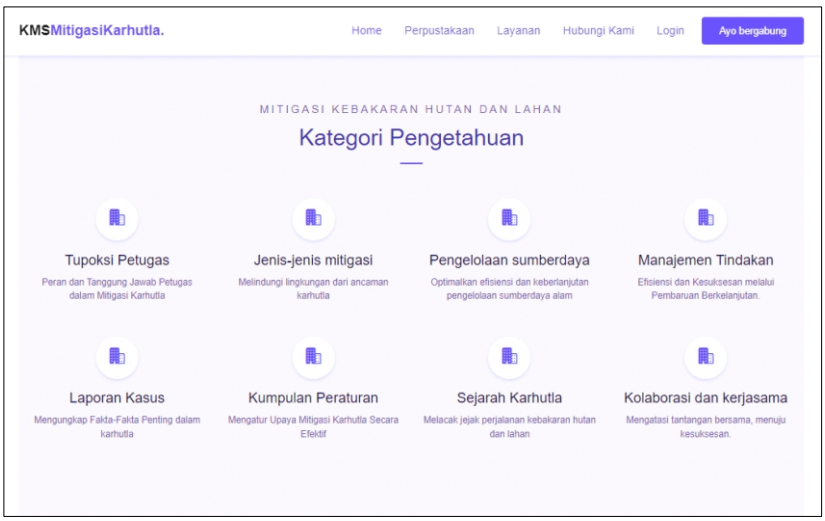

Figure 6 Main page - Knowledge categories.

The search result webpage is the view that appears when a user enters a search keyword, such as the keyword "fire" as shown in Figure 8. This page displays information relevant to the keywords, including articles, e-books, video reports, and other knowledge resources related to the topic of fire. Users can view a summary or short description of each search result and choose to explore it further if they are interested. This page helps users easily find the information they need related to fire, thus facilitating quick and effective access to relevant knowledge sources.

The user selects the information with the title "Guide to Forest and Ground Fire Prevention" from the previous search results. On that page (Figure 9), users can access comprehensive and detailed content on forest and ground fire prevention provided by the KMS web. Users are presented with content derived from the knowledge and experience of

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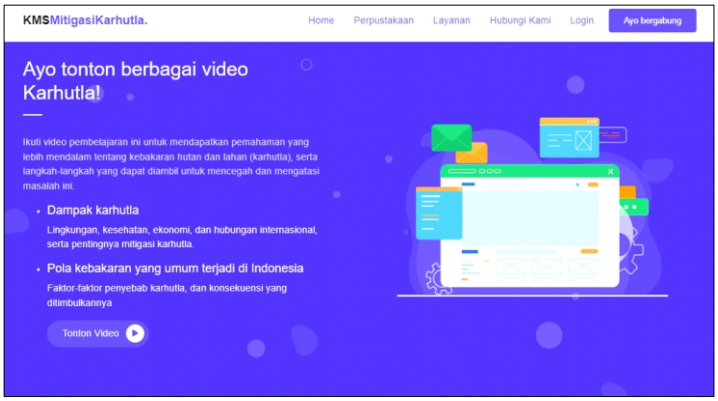

Figure 7 Main page - Learning video feature.

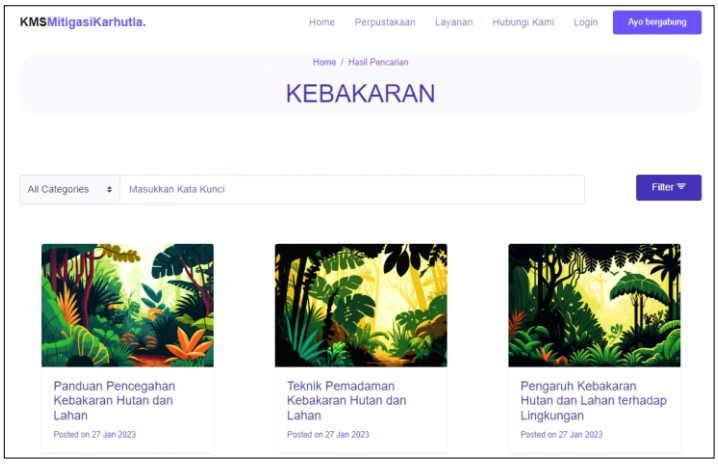

Figure 8 Search results page with keywords "*kebakaran*".

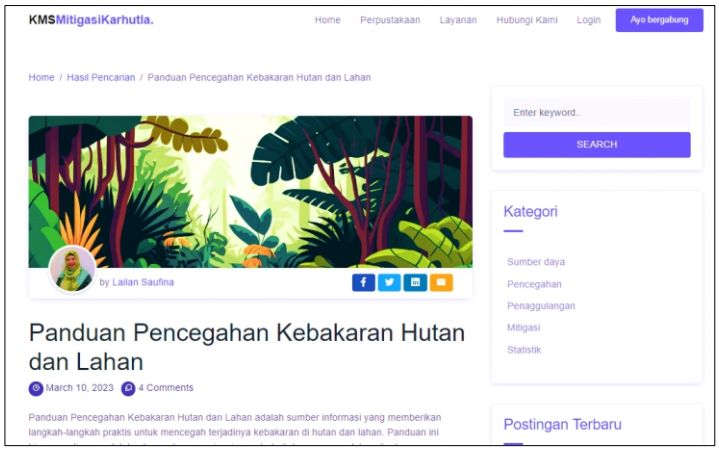

Figure 9 Details page "*Panduan pencegahan kebakaran hutan dan lahan*".

experts in the field, providing a reliable and valuable source for users who wish to learn more. In addition, this page also has other features that make it easier for users to continue searching for other knowledge.

Evaluation system To ensure that the website functions properly, fulfils the needs of users, and achieves the set goals, the black box method and system responsibility are carried out. The results of testing the black box method on the KMS system for forest and land fire mitigation in Indonesia are shown in Table 2**.**

Based on the results of the Blackbox testing conducted, the KMS website for forest and land fire mitigation in Indonesia can be considered successful in terms of performance, usability, compatibility, security, and functionality. No significant problems were found during the

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Table 2 Blackbox testing results

Assessment	Testing results
Performance	The website loaded quickly on the various devices and browsers tested. No significant performance glitches or issues were found.
Usability	The navigation on the website is intuitive, and users can easily find the information they are looking for. All the main features such as search, library, services and login, work as expected. Forms on the website validate input well and provide clear error messages.
Compatibility	The website is well accessible on various browsers including Chrome, Firefox, and Safari. Responsive and well displayed on both mobile and desktop devices.
Security	No significant security issues were found during testing. The information data in the database was well protected and there were no significant security gaps.
Functionality	All features tested such as, login, search and checking access status, run well. There are no critical errors that hinder the functionality of the website.

Table 3 Performance evaluation

Assessment	Testing results
Load time	Measurement of the loading time of the main pages on the website. Results show that most pages load quickly, with average loading times below [value in seconds].
Responsiveness	Responsiveness testing was conducted on various devices, including mobile phones, tablets, and desktops. The website displays good responsiveness, with displays suitable for various screen sizes.
Capacity and scalability	Capacity testing is done to measure how the website handles concurrent user traffic. The website is able to handle large amounts of user traffic without experiencing significant performance degradation.
Stability	A stability evaluation was performed during the continuous testing period. No significant system failures were detected during the test period.
Load testing	Load testing was conducted by gradually increasing the user load to identify performance limitations. The website showed good tolerance to increased user load.

testing, and the website could be used comfortably by end-users. The next test was a performance evaluation of the application. The test results are listed in Table 3.

Based on the results of the performance testing, the KMS website for forest and land fire mitigation in Indonesia can be considered to meet the established performance standards. Fast loading times, good responsiveness on various devices, and the ability to handle large user loads are positive indications of the quality of website performance.

Conclusion

This research concludes that the implementation of a web-based KMS for forest and land fire mitigation in Indonesia is a strategic step in reducing the impact of forest and land fires. KMS has the potential to improve information accessibility, enrich the knowledge base of communities and authorities, and improve efficiency in decision-making related to forest and land fires. The results of the performance evaluation revealed that the KMS website met the established performance standards, with fast loading times, optimal responsiveness, and the ability to handle large user loads. However, it is important to conduct periodic performance monitoring and regression testing when changes to a website occur.

Recommendation

There are several recommendations for future research. One of them is the need to analyze the effectiveness of the Karhutla Mitigation KMS to evaluate the extent to which this KMS has been effective in preventing and reducing forest and land fires. Especially in terms of website features and functionality, it is recommended to identify and develop additional features and functionality on the Karhutla Mitigation KMS to improve its effectiveness, such as in big data processing and the development of more sophisticated search algorithms.

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