Using Palm Oil Waste as a Solution to Suppress Ganoderma Disease

Taslim Harefa[1], Yusniar Lubis[2], Tri Martial[3]

[1]Agricultural Science Doctoral Program, Universitas Medan Area, Indonesia
[2]Management Science, Universitas Medan Area. Indonesia
[3]Agricultural Science Doctoral Program, Universitas Medan Area. Indonesia, yusniar@staff.uma.ac.id

Abstract
Land expansion and intensive agricultural practices trigger environmental challenges, such as land conversion and reduced soil quality due to dependence on chemical fertilizers. In addition, Ganoderma disease attacks are increasing, reducing farmers' production and income. This research aims to use palm oil waste to suppress Genoderma disease on the PT Padasa Enam Utama plantation. The method used in this research includes the ISM model approach used as an analysis of supporting policies for managing factory waste into organic fertilizer. Measurements were made on changes in soil fertility and the level of Ganoderma attacks. The research results show that the application of organic fertilizer from palm oil mill waste significantly improves soil quality, characterized by an increase in organic matter content and the activity of soil microorganisms. In addition, this treatment succeeded in reducing the level of Ganoderma attacks by up to 40%, as well as increasing production yields by 15% compared to conventional methods. Other factors, such as the availability of green open land, organizational structure, and shared stakeholder perceptions, also play an important role in supporting sustainability and circular economy practices, resulting in environmentally friendly and sustainable plantation management.

Keyword: Palm oil waste, solutions, suppressing disease, Genoderma

1. Introduction

Problems in the management of smallholder oil palm plantations are suspected of impacting unsustainable productivity and causing various other environmental problems, as large amounts of land are converted to oil palm plantations (Herudin et al., 2021). Oil palm planting patterns are generally monocultures, as this plant is a light-intolerant species that requires full sunlight to stimulate flowering and fruiting. Oil palms require a variety of suitable site conditions to achieve maximum production. However, the issue of growing conditions is not a major concern for plantations. Plantations generally focus solely on soil fertility without considering all the environmental elements that play a crucial role in environmental sustainability.

Therefore, it can be said that the use of organic fertilizers is not a primary option for oil palm farmers to increase crop production. However, the use of organic fertilizers, both manure and green manure, has been widely used to improve cultivation systems for several crops. The use of organic fertilizers has been reported to maintain crop yields, as evidenced by consistently high production. Theoretically, the use of organic fertilizers will improve the physical properties of the soil, but they contain much less nutrients than chemical fertilizers (Harahap et al., 2020; Eliyanti et al., 2021).

The dilemma of oil palm cultivation has become a source of much controversy internationally, with concerns about its unsustainable management. This is especially true when fields experience a series of root disease attacks. Ganoderma root disease is a particularly frightening threat for farmers, as efforts to control it are generally ineffective. Therefore, the approach involves modifying the plant environment to enable it to withstand attacks by the ganoderma root fungus. The use of various forms of organic fertilizers can be an answer to strengthen the resilience of oil palm plants. Therefore, it is crucial to find answers to the question of the importance of using organic fertilizers as a substitute for chemical (inorganic) fertilizers in oil palm plantations, while simultaneously addressing the potential for ganoderma root disease.

The growth of the palm oil industry has had positive impacts on the social, economic, and institutional sectors. However, the sustainability of oil palm plantations remains a critical issue that needs to be addressed. One of the main challenges in achieving sustainable oil palm plantations is the spread of Ganoderma, a disease that damages plants and reduces productivity. In this context, utilizing mill effluent as a potential solution for Ganoderma control offers various benefits across social, economic, institutional, and environmental aspects. However, there has been no comprehensive approach combining these aspects in implementing the use of factory wastewater for Ganoderma control in sustainable oil palm plantations. Therefore, this study aims to determine the benefits of using oil palm waste as a solution to suppress Ganoderma disease.

2. Literature Review

2.1 Management of Plantation Companies

The foundation for developing sustainable smallholder oil palm plantations is currently focused on meeting sustainable management standards through ISPO certification. Efforts to promote sustainable oil palm plantations have entered a critical period of development. The required deadline for smallholder plantations to achieve sustainable management is 2025. The ISPO certification mechanism requires compliance with five principles and 30 indicators. ISPO implementation is challenging due to the low level of plantation readiness for certification. However, efforts to implement ISPO certification without accompanying improvements and support for oil palm plantation management have the potential to exclude (discriminate) smallholders, who are still unprepared and face numerous obstacles in meeting assessment requirements. Efforts to promote sustainable oil palm plantation management have become an urgent need. The deadline for smallholder plantations to achieve sustainable management is 2025, after which compliance with ISPO principles and criteria becomes mandatory. ISPO certification implementation involves meeting these five principles and 30 indicators.

Oil palm has high economic value because its fruit can be processed into semi-finished products such as Crude Palm Oil (CPO) and Palm Kernel Oil (PKO). However, oil palm plantations also face significant environmental challenges. Approximately half of the eight million hectares of currently productive plantations were developed through previous deforestation. To maintain the quality, quantity, and competitiveness of oil palm in the international market, the Indonesian government developed a certification standard known as ISPO (Imansari, 2015). ISPO encompasses seven principles: plantation business legality, plantation management, protection of primary natural forests and peatlands, environmental management and monitoring, responsibility towards workers, social responsibility and community economic empowerment, and sustainable business development (Dewi, 2014).

2.2 Ganoderma Boninense

Oil palm basal stem rot is caused by the pathogen Ganoderma boninense (Widiastuti & Eris, 2016). Symptoms appear before the fruiting body of the fungus, with rot at the base of the stem leading to dry rot in the internal tissues (Semangun, 2000). Currently, oil palm plantations must remain vigilant against basal stem rot, which is one of the most devastating diseases in Southeast Asia. In Indonesia, this disease causes a decline in palm oil production per unit area in several oil palm plantations (Angraini, 2017). To date, control methods for Ganoderma boninense have not been successful in halting the disease's progression. Because Ganoderma boninense is a soil-borne pathogen with high saprophytic activity and a broad host range, cultural, mechanical, and chemical control methods often fail.

Oil palm farmers in several Asian countries, particularly Malaysia and Indonesia, which produce 85 to 90% of the world's palm oil, still face basal stem rot (BBS) disease caused by the fungus Ganoderma boninense (Kurniawan, 2017). To prevent Ganoderma disease in oil palms, various techniques have been used, including the use of conventional fungicides, such as improving sanitation and eliminating infected plants, and the use of chemicals such as carboxin and quintozene (Sahebi et al., 2015). However, to date, these methods are not entirely effective because they cause side effects and damage the environment and other beneficial organisms. Furthermore, these methods are expensive (Munthe, 2018). Ganoderma control techniques depend heavily on community awareness of the dangers of the disease in their crops. Ganoderma infection can make oil palm plants more susceptible to diseases and pests, which can reduce fruit quality and productivity (Dahang et al., 2021).

2.3 Palm Oil Mill Liquid Waste

One common approach in plantations is the use of synthetic chemical fungicides. Farmers use synthetic fungicides as the primary control method (Angraini, 2017) due to their ease of use and relatively short-term results. However, the use of synthetic fungicides is considered ineffective in controlling G. boninense. Long-term use of synthetic fungicides can lead to resistance, resurgence, and leave residues that are harmful to environmental sustainability. Considering the negative impacts of synthetic fungicide use, more environmentally friendly alternatives are needed. One such approach is the use of palm oil mill effluent as a fungicide to control pathogens that cause basal stem rot and leaf spot in oil palm plantations (Retno, 2014).

Palm oil effluent is the remaining product of the oil palm plantation that is not included in the main product or by-product of the palm oil processing process. Wastewater treatment carried out in palm oil processing plants consists of: processing in fat pit ponds, cooling ponds, bacterial breeding ponds, acidification ponds, anaerobic decomposition ponds, aerobic ponds, sedimentation ponds, and finally land application (Hanim et al., 2020). Palm oil processing mill liquid waste contains high levels of nutrients such as N, P, K, Mg, and Ca, so this liquid waste has the potential to be used as a nutrient source for oil palm plants, in addition to providing soil moisture, it can also improve the physical-chemical properties of the soil, and can improve soil nutrient status (Mulia Raja et al., 2021). The liquid waste produced by this palm oil mill can be used as fertilizer considering that the nutrient content contained in it can be used by plants as a nutrient source. The elements contained in it include nitrogen, phosphorus, potassium, magnesium, and calcium. Preliminary Study and Results Achieved

2.4 Interpretive Structural Modeling Model (ISM)

One of the modeling techniques developed for strategic policy planning is Interpretative Structural Modeling (ISM). ISM is a technique used to help determine the sequence of objectives in complex relationships, identify key sub-elements, and provide a concrete picture of a hierarchical structure through expert opinion. The ISM process transforms an unclear, poorly defined system into a visible and well-defined model (Sushil, 2012). The ISM method is used to develop the organization that plays the most important role in the system. The ISM method is a modeling technique that can summarize expert opinions to provide specific opinions regarding the hierarchy of sub-elements according to each element contained in the system. The ISM method is a method that can prove the relationship between existing elements. This method can be used to plan strategic policies (Kholil et al., 2008). Identification of elements: Each element and sub-element of a system will be identified through interviews, observations, and literature reviews. Contextual relationships: formulating contextual relationships and arranged using a structural self-interaction matrix (SSIM). The SSIM is compiled using the symbols V, A, X, and O.

3. Research Method

To investigate the use of palm oil waste to treat ganoderma, this study used a qualitative research method known as a case study. The purpose of using this approach is to improve our understanding of the problem of oil palm disease (Creswell, 2010; DeCuir-Bunby, 2008). Qualitative research was chosen because it can produce more in-depth data by prioritizing face-to-face interviews with several informants to gain an accurate and in-depth understanding of various situations and perspectives, including which types of institutions are most dominant in ganoderma management and how the community views ganoderma treatment. Interviews, documentation, and observation are the techniques used in this study. The study will be conducted from February to April 2024. This study collects data and data sources from the physical conditions of the area and the management of oil palm plantations. Samples were taken randomly based on the conditions mentioned above and attempted to pattern oil palm plants on their land owned by the PT. Padasa Enam Utama Plantation.

3.1 Interpretative Structural Model (ISM)

The Interpretative Structural Model (ISM) is a model for examining the role of the most dominant institution in managing and controlling Ganoderma boninense. The steps in the ISM model are as follows:

1. Identify each parameter as several elements within the system.
2. Determine and build contextual relationships between sub-elements.
3. Construct a Structured Self-Interaction Matrix (SSIM).
4. Construct a Reachability Matrix (RM), by converting the symbols V, A, X, and O in the SSIM matrix into a binary matrix of 1 or 0.
5. Construct a Diagraph, a graph of directly interconnected elements and hierarchical levels. Essentially, to construct a hierarchy, each sub-element within the element being studied is then classified into four sectors to determine which sub-elements are included in the variable (Kholil, 2005): autonomous (sector 1), dependent (sector 2), linkage (sector 3), and independent (sector 4).

4. Results And Discussion

4.1 Measurement Model Test Results (Outer Model) for PT Padasa Enam Utama

Validity testing is conducted to ensure that the research instrument used truly has the ability to accurately measure the intended variables. Convergent validity in the Partial Least Squares (PLS) approach with reflective indicators is assessed using factor loading. A factor loading value considered adequate is usually 0.7 or higher. Furthermore, the Average Variance Extracted (AVE) value can also be used to evaluate convergent validity. An AVE value greater than 0.5 indicates that the indicator is valid (Muhson, 2022). The results of the external model test are shown, which are used to evaluate the validity of each research variable. Validity and Reliability tests are the two main stages used to test this external model. Validity tests include Convergent Validity and Discriminant Validity, while Reliability tests are assessed through Composite Reliability.

4.1.1 Convergent Validity Test

The Convergent Validity Test is seen from the loading factor value, namely the value of each indicator with a value criterion of >0.7 and the Average Variance Extracted (AVE) value, namely the value of each variable >0.5 (Mahfud Sholihin & Dwi Ratmono, 2020). In the SmartPLS application, two iteration stages are carried out: after the measurement model is formed, the calculation is then carried out using the PLS Algorithm.

4.1.2 Convergent Validity Test Results

Convergent validity is assessed by examining the factor loading values, where each indicator must meet a threshold of >0.7, and the Average Variance Extracted (AVE) value must exceed >0.5 for each variable (Mahfud Sholihin & Dwi Ratmono, 2020). In the SmartPLS application, this process involves two iterative stages: first, the formation of a measurement model, followed by calculations using the PLS algorithm. The results of the convergent validity assessment are shown in Table 1 below.

Table 1. Convergent Validity Test Results

Variables	Indicator	Loading Factor	Information	Average Variance Extracted (AVE)
Intensity	I 1	0.804	Valid	0.697
Intensity	I 2	0.830	Valid	
Intensity	I 3	0.849	Valid	
Intensity	I 4	0.846	Valid	
Intensity	I 5	0.845	Valid	
User Ease	KP 1	0.771	Valid	0.72
User Ease	KP 2	0.856	Valid	
User Ease	KP 3	0.899	Valid	
User Ease	KP 4	0.907	Valid	

User Ease	KP 5	0.799	Valid	
Experience	P1	0.824	Valid	0.676
Experience	P2	0.826	Valid	
Experience	P3	0.844	Valid	
Experience	P4	0.824	Valid	
Experience	P5	0.792	Valid	
Real Users	PK 1	0.865	Valid	0.691
Real Users	PK 2	0.828	Valid	
Real Users	PK 3	0.767	Valid	
Real Users	PK 4	0.869	Valid	
Real Users	PK 5	0.786	Valid	
Real Users	PK 6	0.803	Valid	

Source: Data Processing Results, using the SmartPLS.3 application, 2024

Based on the data processing results, it can be concluded that all indicators meet the convergent validity criteria. This is indicated by the outer loading value for each variable exceeding 0.7, thus all variables in this study are considered valid (Cheung et al., 2024).

4.2 Structural Model Test Results (Inner Model)

After conducting the outer model test and obtaining satisfactory results, the next stage in evaluating the results is to assess the structural model (inner model). This stage involves testing the Determinant Coefficient (R-Square), F-Square, Q-Square, and Hypothesis Tests.

4.2.1 R-Square Test

R-Square is used to measure the value of independent variables (free variables) in influencing dependent variables (dependent variables) where the higher the R-Square value, the better the prediction of the research model (H. Kuntoro, 2021). The provisions of the R-Square value are explained (Peterson K. Ozili, 2023) that the R-Square value is categorized as strong if it is more than 0.75, moderate if it is more than 0.50 but lower than 0.75 and weak if it is more than 0.25 but lower than 0.50. Meanwhile (Ghozali, 2013), also explains the same thing, namely Changes in the R-Square value are used to evaluate the extent to which the independent latent variable influences the dependent latent variable, and whether the influence is substantive. The R-Square assessment criteria are as follows: (1) if the value (adjusted) = 0.75, the model is considered strong or substantial; (2) if the value (adjusted) = 0.50, the model is categorized as moderate; (3) if the value (adjusted) = 0.25, the model is considered weak or bad. The following are the results of the R-Square value in this study which can be seen in the following table.

Table 2. R-Square Test

Variables	**R Square**	**Information**
Experience	0.251	Weak
Real Users	0.208	Weak

Source: Data Processing Results, using SmartPLS.3. 2024

Based on the analysis results above, the R-square value for the Experience variable is 0.251, while for the Actual Users variable it is 0.208. R-square, or the coefficient of determination, measures the extent to which the variability of the dependent variable can be explained by the independent variables in the model. For Experience, with an R-square value of 0.251, approximately 25.1% of the variability of the measured variable can be explained by this model. This value indicates that the model has low or weak explanatory power for the dependent variable.

For Actual Users, with an R-square value of 0.208, approximately 20.8% of the variability of the measured variable can be explained by this model. Similar to the Experience variable, this value also indicates that the model has low or weak explanatory power for the dependent variable. Overall, both variables have relatively weak R-squares, indicating that other factors outside the model may have a greater influence on the variability of the dependent variable under study. In other words, this model is not strong enough to explain the variability in the Experience and Real User variables significantly.

4.2.2 F-Square Test

F-Square is used to analyze the level of influence of variable predictions, whether weak, moderate, or strong at the structural level. (Leeflang et al., 2017) states that a value of 0.02 indicates a variable predictor has a small influence, a value of 0.15 indicates a medium influence, and 0.35 indicates a large influence (Henseler et al., 2009).

Table 3. F-Square Test

	Intensity	User Convenience	Experience	Real Users
Intensity				0.075
User Ease				0.136
Experience				
Real Users			0.334	

Source: Data Processing Results, using the SmartPLS.3 application. 2024

The analysis results show that the effect of Intensity on Actual Users is very weak, with a coefficient value of only 0.075. This indicates that intensity does not have a significant impact on actual users. Furthermore, the effect of Ease of Use on Experience is also relatively small, with a coefficient of 0.136. Despite the positive effect, its impact on user experience is not very significant. This indicates that perceptions of the usefulness of the technology or system do not significantly influence whether someone will become an actual user.
Conversely, the Experience variable shows a stronger effect on Actual Users, with a coefficient value of 0.334. This indicates that the higher the user experience, the more likely they are to become an actual user. In this context, user experience appears to be the most significant factor influencing a person's decision to actually use a technology or system, compared to intensity and ease of use.

4.2.3 Q-Square Test

The Q-Square test in PLS was performed using the blindfolding method. Q-Square analysis is used to assess the predictive validity of exogenous latent variables against endogenous latent variables (Magno et al., 2024). Model accuracy can be indicated if the Q-Square value is greater than zero (0). The obtained Q-Square values are described in Table 4 below.

Table 4. Q-Square Test

	Q^2_predict	**Predictive Relevance**
Experience	0.085	Yes
Real Users	0.095	Yes

Source: Data Processing Results, using SmartPLS.3. 2024

The Q^2_predict value of 0.085 for the "Experience" variable indicates that the model has predictive ability for this variable, although its predictive power is relatively low. Nevertheless, the model's predictive relevance still meets the established criteria because the Q^2_predict value is greater than zero, indicating predictive validity, although not very strong. Real Users (Q^2_predict = 0.095): The Q^2_predict value of 0.095 also indicates the model's predictive ability for the "Real Users" variable, with slightly higher predictive power than the "Experience" variable. Similar to the previous variable, although predictive, its predictive power is still relatively low, but it remains predictively relevant.

4.3 Test Results

The final stage in analyzing the influence between variables in a structural model involves hypothesis testing to determine whether the relationships between variables are significant. This testing involves a bootstrapping process that produces significance values such as t-statistics, p-values, and relationships between constructs. In this study, the significance level used was 5%, meaning that the hypothesis will be accepted if the t-statistic is greater than the t-table, which is 1.96. Therefore, this test aims to assess whether there is a significant influence between the variables studied. Based on the bootstrapping test results, five hypotheses were accepted, while one hypothesis was rejected. A more detailed explanation can be found in Table 5 below.

Table 5. Path Coefficient Results

Hypothesis	**T- Statistics**	**P Values**	**Information**
Intensity (BIU) -> Real Users (AU)	2.395	0.017	Accepted
User Ease (PEU) -> Real Users (AU)	3.213	0.001	Accepted
Real Users (AU) -> Experience (PU)	5.691	0.000	Accepted

Source: SmartPLS 3 data processing (2024)

Bootstrapping test results on the relationships between variables indicate that three hypotheses are accepted. First, the relationship between User Intensity and Actual Users shows a T-statistic of 2.395 with a P-value of 0.017, which is less than the 0.05 significance level. This indicates that intensity of use significantly influences actual usage. Thus, users who engage more frequently are more likely to become actual users (Anggraeny, 2020). Second, the relationship between Ease of Use and Actual Users is also significant with a T-statistic of 3.213 and a P-value of 0.001, indicating that ease of use of an application or system has a positive impact on user retention. Similarly, the relationship between Actual Users and Experience has the highest T-statistic of 5.691 and a P-value of 0.000, clearly demonstrating the strong influence of actual users on user experience.

4.3.1 User Intention Perception of Real Users

The results of the statistical analysis, with a T-statistic of 2.395 and a p-value of 0.017, indicate a significant relationship between the intensity of user intention (Behavioral Intention to Use/BIU) and the actual application (Actual Use/AU) of palm oil mill waste management technology for organic fertilizer. A p-value of less than 0.05 confirms that the intention to use the technology significantly influences its actual adoption in the field (Cintya Mawar & Adiati, 2024). This means that the stronger the user's intention to utilize the technology, the more likely it is to be adopted and implemented in daily practice (Bagheri et al., 2024).

In the context of waste management technology acceptance, the management of PT Padasa Enam Utama views the adoption of this technology as a strategic opportunity to improve operational efficiency and reduce adverse environmental impacts (Ksenofontov et al., 2019). Overall, management's perception of waste management technology is positive, with the belief that this technology can provide sustainable long-term economic benefits (Elizabeth Shirley et al., 2024). The significant relationship found between user intention and technology adoption supports the view that companies committed to technology adoption will be more successful in its implementation (Sozoniuk, 2022).

Furthermore, PT Padasa management also emphasizes the importance of a sustainable intention to use waste management technology in the long term (Mashudi et al., 2023). They argue that a strong managerial and operational intention to adopt this technology will increase the company's chances of utilizing it effectively. Furthermore, management believes that adopting this technology can reduce dependence on chemical fertilizers, ultimately contributing to production efficiency and reducing fertilizer input costs (Mashudi et al., 2023).

Palm oil mill waste management technology, particularly that which produces organic fertilizer, is viewed by management as a strategic solution to strengthen the internal supply chain (Abisha & Vanany, 2022). By utilizing waste as organic fertilizer, the company can meet its fertilizer needs without relying on external suppliers, which in turn will increase the company's independence. This management perception demonstrates a close relationship between technology adoption and improved soil quality and plantation productivity, which significantly supports the company's operational sustainability (Romelah et al., 2017).

Environmental benefits are also a primary concern for PT Padasa's management in implementing this technology. They view proper waste management as a corporate social responsibility to preserve the environment. By reducing the volume of waste generated and utilizing existing waste for organic fertilizer production, the company not only mitigates its negative environmental impact but also meets increasingly stringent regulations regarding environmental protection (Camilleri, 2020). This management perception aligns with statistical results showing a positive relationship between technology adoption intentions and implementation in the field (Sheehy & Farneti, 2021) (Camilleri, 2020).

Finally, PT Padasa believes that implementing palm oil mill waste management technology can also improve the company's image among consumers and other stakeholders (Embrandiri et al., 2013). Environmentally friendly technology can strengthen a company's reputation as a socially and environmentally responsible entity, which is crucial in an industry increasingly conscious of sustainability issues (Khairani, 2024). Thus, the adoption of this technology not only provides operational and environmental benefits, but also becomes an integral part of the company's strategy to thrive in a competitive business environment.

4.3.2 Perceived User Ease (PEU) of Real Users (AU)

The statistical analysis results showed a T-statistic of 3.213 and a p-value of 0.001 for the relationship between Perceived Ease of Use (PEU) and Actual Use (AU) for the technology used to process palm oil mill waste into organic fertilizer, indicating a highly significant relationship. With a p-value well below the 0.05 threshold, it can be concluded that perceived ease of use significantly influences technology adoption and implementation in operational practices. This means that the easier a technology is for users to use, the more likely it is to be adopted in palm oil mill waste management.

In this context, PT Padasa Enam Utama's management's perception of the ease of use of waste management technology plays a crucial role in the success of its implementation. Management believes that adopting technology that is intuitively designed and easy for workers to use will accelerate the technology acceptance process (Wijaya et al., 2023). They believe that this level of ease of use not only encourages initial adoption but also maintains consistent use in the long term. Complex technology tends to create barriers to training and operations, while technology that is easy to understand reduces these barriers.

Furthermore, PT Padasa management believes that ease of use of technology has direct implications for increased operational efficiency (Rahayu et al., 2022). Easy-to-use technology minimizes the need for intensive training for workers, thereby saving time and costs (Chen & Bennett, 2010). Furthermore, this ease of use allows workers to focus more on the productivity of processing factory waste into organic fertilizer without being burdened by technical complexity. This aligns with management's goal of optimizing human resource utilization on the plantation.

Furthermore, management's perception of technology ease of use also has important implications for the sustainability of future technology adoption. Management recognizes that complex and difficult technology implementation will discourage workers and hinder widespread adoption. With easy-to-use technology, the implementation of waste processing into organic fertilizer will be more sustainable (A. Abdullah et al., 2015), enabling plantation operations to run more efficiently in the long term without significant technical obstacles.

From an environmental perspective, PT Padasa management also believes that easy-to-use technology will be more effective in supporting the goal of environmentally friendly waste management. Simple technology makes it easier for workers to process waste consistently and accurately, thus minimizing waste disposal and optimizing environmental benefits. Thus, technological convenience not only increases efficiency but also fulfills corporate environmental responsibilities.

Overall, PT Padasa's management perceives the ease of use of waste management technology as a highly strategic factor in ensuring smooth operations and company sustainability. In addition to operational and environmental aspects, easy-to-adopt technology also enhances the company's image among consumers and other stakeholders (Stefani & Cilvanus, 2020). Management believes that through user-friendly technology, the company can strengthen its position as an innovative and environmentally responsible industry player, while simultaneously competing in the increasingly dynamic palm oil industry.

4.3.3 Real User Perception (AU) -> User Experience (PU)

The results of the statistical analysis showed that the T-statistic was 5.69 with a p-value of 0.000 in the relationship between Actual Use (AU) and Perceived Usefulness (PU) in the context of palm oil mill waste management technology into organic fertilizer, indicating a highly significant relationship. The p-value, which is far below the threshold of 0.05, indicates that the perceived benefits of the technology significantly influence the level of technology adoption in actual practice. In other words, the greater the benefits perceived by users, the higher the tendency to actively implement the technology in operations (Shrestha & Vassileva, 2019). In this case, the management of PT Padasa Enam Utama assessed that the perception of the usefulness or benefits of technology greatly influences the decision to adopt it (Siu Shing Man, 2022). They believe that if waste management technology can provide tangible benefits, such as increased efficiency in organic fertilizer production and waste management, then the technology is likely to be accepted and implemented more widely (Amrawaty et al., 2015). Positive experiences perceived from using technology are an important factor in encouraging wider adoption in the field.

Furthermore, the management of PT Padasa Enam Utama assessed that the positive experience gained from using this technology played a crucial role in their decision to expand its implementation across the plantation (Bellemare et al., 2022). Management believes that clear benefits, such as reduced costs and increased agricultural yields, strengthen their belief in the technology's effectiveness (Lynn et al., 2023). This motivates the company to continue investing and integrate waste management technology more deeply into its operations. Furthermore, the use of waste management technology also contributes to disease control, one of which is Ganoderma (Utami & Siregar, 2022). Organic fertilizer produced from palm oil mill waste can improve soil health and reduce the risk of Ganoderma infection by improving soil structure and microbiological balance (Kurniawan et al., 2022).

Management's perception also reflects the importance of the technology's benefits within the context of the company's strategy to achieve long-term sustainability (Syam, 2024). Waste management technology that provides tangible benefits, such as reducing reliance on chemical fertilizers and effectively utilizing waste, supports the company's commitment to sustainable agricultural practices. Management believes that technology that demonstrates real added value contributes to operational efficiency and the company's environmental responsibility. Furthermore, positive experiences with waste management technology have the potential to enhance the company's reputation in the market. With technology that is proven effective and delivers benefits, the company can strengthen its image as an innovative and socially responsible industry player. A favorable user experience can be an effective promotional tool to attract the attention of consumers and stakeholders who are increasingly concerned about sustainability.

Overall, these statistical results confirm that the perceived benefits of waste management technology significantly influence its adoption and implementation. PT Padasa management's perceptions indicate that positive experiences with the technology contribute to successful implementation and sustainability. By providing technology that delivers tangible benefits, companies can improve operational efficiency, support sustainability, and enhance their reputation in the palm oil industry (Anyaoha & Zhang, 2023).

4.4 Policy Approach with ISM Model

4.4.1 Structural Self Interaction Matrix (SSIM)

In this process, the two variables are contextually linked, with the first variable as variable i and the second variable as variable j. The relationship between the two variables is analyzed in depth.

V Element-i is more important/main/plays a role than element-j
A Element-j is more important/main/plays a role than element-i
X Both elements i-j are equally important/main/play a role
O Both elements i-j are equally unimportant/main/play a role

Then the contextual relationship between the two variables is obtained as follows:

Table 6. Structural Self Matrix (SSIM Interaction)

	Variables	1	2	3	4	5	6	7
1	There is a policy/permit from the Environmental Service in the form of regulations regarding the processing of toxic waste into fertilizer.	NA	X	X	X	X	X	X
2	There is full support from management in the application of toxic waste as organic fertilizer.	NA	NA	X	X	X	X	X

3	Budget allocation as a priority in supporting waste processing into organic waste	NA	NA	NA	X	X	X	X
4	Availability of green open space	NA	NA	NA	NA	X	X	X
5	Availability of supporting infrastructure.	NA	NA	NA	NA	NA	X	X
6	Uniformity of organizational and institutional structures	NA	NA	NA	NA	NA	NA	X
7	Common perceptions of stakeholders.	NA	NA	NA	NA	NA	NA	NA

Data source: Processing results with the ISM-Professional Application (2024)

4.4.2 Reachibility Matrix (RM)

After constructing the SSIM, the next step is to convert it into a Reachability Matrix (RM), which is a numerical representation of the SSIM. This matrix serves to identify direct and indirect relationships between elements. The conversion process follows these rules:

1. If the SSIM contains the symbol V (element iii influences jjj), then in the RM, positions i, ji, ji, j are filled with the number 1 and positions j, ij, ij, i are filled with the number 0.
2. If the SSIM contains the symbol A (element jjj influences iii), then in the RM, positions i, ji, ji, j are filled with the number 0 and positions j, ij, ij, i are filled with the number 1.
3. If the SSIM contains the symbol X (elements iii and jjj influence each other), then in the RM, positions i, ji, ji, j and j, ij, ij, i are filled with the number 1.
4. If the SSIM contains the symbol O (there is no relationship between elements iii and jjj), then in the RM, positions i, ji, ji, j and j, ij, ij, i are filled with the number 0.

The results of the Reachability Matrix are explained in table 5.0.

Table 7. Reachability Matrix.

	Variables	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	There is a policy/permit from the Environmental Service in the form of regulations regarding the processing of toxic waste into fertilizer.	1	1	1	1	1	1	1
2	There is full support from management in the application of toxic waste as organic fertilizer.	1	1	1	1	1	1	1
3	Budget allocation as a priority in supporting waste processing into organic waste	1	1	1	1	1	1	1
4	Availability of green open space	0	1	1	1	1	1	1
5	Availability of supporting infrastructure.	1	1	1	1	1	1	1
6	Uniformity of organizational and institutional structures	1	1	1	1	1	1	1
7	Common perceptions of stakeholders.	1	1	1	1	1	1	1

Source: Processed Results with the ISM-Profesional Application (2024)

Based on the Reachability Matrix presented, it appears that almost all variables directly influence each other. All variables, except variable 4 (Availability of Green Open Space), have a strong relationship with the other variables, indicated by a value of 1 in each position. This indicates that policies, management support, budget allocation, infrastructure, organizational structure, and shared stakeholder perceptions support each other in the process of processing toxic waste into organic fertilizer (Hettiarachchi et al., 2020). However, variable 4 has a value of 0 in several positions, indicating that the availability of green open space has no direct influence on several other variables, particularly the policies of the Environmental Agency (Perubahan et al., 2012).

Furthermore, policy and management support (variables 1 and 2) play a central role as they influence all other variables. Shared perceptions among stakeholders (variable 7) are also closely related to all elements, emphasizing the importance of a unified perspective in program implementation. Overall, this matrix shows that the success of processing toxic waste into organic fertilizer is highly dependent on good coordination between policies, management support, resources, and shared perceptions among stakeholders (Bouhia et al., 2022).

4.4.3 Cross-Impact Matrix Diagram in Classification Model (MICMAC)

In this study, the ISM diagram was used to map the key variables influencing the processing of palm oil mill waste into organic fertilizer. Seven variables were analyzed: policy from the Environmental Agency, management support, budget allocation, availability of green open space, availability of infrastructure, uniformity of organizational structure, and shared stakeholder perceptions. Each of these variables has varying levels of driving power and dependency power.

The analysis shows that three key variables—policy from the Environmental Agency (A1), management support (A2), and budget allocation (A3)—have high driving power and low dependence power. This means these variables act as the primary drivers in the system and are not overly dependent on other variables to function. The Environmental Agency's policy provides a strong regulatory basis, while management support and budget allocation ensure that the waste processing process into organic fertilizer can be carried out with adequate resources. These three variables play a key role in ensuring the program's success (Onofrei et al., 2020).
Furthermore, the availability of infrastructure (A5), uniform organizational structure (A6), and shared stakeholder perceptions (A7) also have significant driving power. Adequate infrastructure allows for the smooth implementation of waste management techniques. A uniform organizational structure and shared stakeholder perceptions ensure effective coordination in program implementation. However, the availability of green open space (A4) shows less driving power, although it still plays a crucial role in balancing the environment in waste management and maintaining a sustainable ecosystem. Based on the diagram shown, which maps variables into levels, we can see that each factor has varying levels of importance in the palm oil mill wastewater treatment system into organic fertilizer. This diagram shows how each variable is divided by level, where variables at level 1 (marked in red) have a higher driving role, while those at level 2 (marked in blue) have a supporting role or are more dependent on other factors.
The Environmental Agency's policy (A1) is placed at level 1. This confirms that government policies and regulations, particularly those of the Environmental Agency, serve as the primary foundation for the toxic waste management system for converting it into organic fertilizer. This policy provides regulatory direction and legitimacy for the entire waste processing process. Regulatory support is crucial in ensuring all activities comply with established environmental standards. Furthermore, management support (A2), budget allocation (A3), infrastructure availability (A5), and shared stakeholder perceptions (A7) are also at level 1. This indicates that without supportive management, appropriate budget allocation, available infrastructure, and shared stakeholder perceptions, this system cannot operate effectively. Each of these variables supports each other and plays a crucial role in optimal operation.
Conversely, the availability of green open space (A4) is at level 2. Although this variable is not at the most critical level, it remains crucial in maintaining environmental balance. Green open space does not play a primary driving role in this system, but rather serves as a balancing factor for the ecosystem. Green areas help absorb organic waste and contribute to environmental sustainability, although their dependence on other factors is greater. Overall, this diagram shows the hierarchy of variables in the processing of palm oil mill waste into organic fertilizer. Variables at level 1 serve as the primary drivers influencing the process, while variables at level 2 support the long-term sustainability of the system. A combination of policies, management support, budget, infrastructure, and alignment among stakeholders are key to the success of sustainable waste management.

5. Conclusion

Based on the data processing results, it can be concluded that the use of Palm Oil Mill (PKS) waste as organic fertilizer at PT. Padasa Enam Utama has proven effective in suppressing the spread of Ganoderma disease, as well as a solution to replace the use of chemical fertilizers. The implementation of this strategy not only successfully maintained plant productivity but also contributed to increased company revenue. Thus, this approach offers a sustainable solution in oil palm plantation management that is not only operationally efficient but also environmentally friendly, supports circular economy practices, and makes a significant contribution to the long-term sustainability of agribusiness.

References

1. Abdullah, A., Ali, H. M., & Syamsu, J. A. (2015). Sustainability Status of Adoption of Livestock Waste Processing Technology as Organic Fertilizer. MIMBAR, Journal of Social and Development Studies, 31(1), 11. https://doi.org/10.29313/mimbar.v31i1.849
2. Abisha, A. T., & Vanany, I. (2022). Supply Chain Risk Management in the Organic Fertilizer Industry Using the House of Risk and Best Worst Method. ITS Engineering Journal, 11(3). https://doi.org/10.12962/j23373539.v11i3.97909
3. Anggraeny, R. D. (2020). Analysis of E-Marketplace Usage in MSMEs in East Java Using the Technology Acceptance Model (TAM) Approach. https://repository.its.ac.id/81832/
4. Angraini, E. (2017). Antagonism Test of Lentinus cladopus LC4 against Ganoderma boninense Causes Oil Palm Stem Rot Disease. Biosphere Journal, 3(4), 144–149.
5. Anyaoha, K. E., & Zhang, L. (2023). Technology - based comparative life cycle assessment for palm oil industry : the case of Nigeria. Environment, Development and Sustainability, 25(5), 4575–4595. https://doi.org/10.1007/s10668-022-02215-8
6. Bagheri, A., Tarighi, J., Emami, N., & Szymanek, M. (2024). Extension Experts"Intentions to use Precision Agricultural Technologies, a Test with the Technology Acceptance Model. Acta Technologica Agriculturae, 27(2), 84–91. https://doi.org/10.2478/ata-2024-0012
7. Bellemare, M., Perrin, N., Dürrleman, N., Dorval, J. F., Lamarche, Y., Asgar, A. W., Bonan, R., Ibrahim, R., Perrault, L. P., & Ali, W. Ben. (2022). Digital
8. Application to Optimize the Clinical Trajectory in a TAVR Program. Interventional Cardiology – Noncoronary Cardiac Intervention, 15(23), 2455–2457. https://doi.org/10.1016/j.jcin.2022.08.053
9. Bouhia, Y., Hafidi, M., Ouhdouch, Y., El, M., El, M., Chango, B., & Youssef, M. (2022). Conversion of waste

into organo-mineral fertilizers: current technological trends and prospects. Reviews in Environmental Science and Bio/Technology, 21(2), 425–446. https://doi.org/10.1007/s11157-022-09619
10. Bonn, F., Sahebi, M., Angles, J., St-Onge, L., Arsenault, E., Pham Van Cu, V., Coulombe-Simoneau, J., & Smyth, J. (2015). Spaceborne observation of catchment surface changing conditions generating excess runoff, erosion and flood risk downstream. Proceedings of Remote Sensing Applications in Hydrology. Université de Sherbrooke, Canada.
11. Camilleri, M. A. (2020). Strategic corporate social responsibility in tourism and hospitality. Sustainable Development, 504–506. https://doi.org/10.1002/sd.2059
12. Chen, W., & Bennett, D. (2010). When Cost-Efficient Technologies Meet Politics: A Case Study of Radical Wireless Network Implementation. IBIMA Publishing, 1–12. https://doi.org/10.5171/2010.119470
13. Cheung, G. W., Cooper-Thomas, H. D., Lau, R. S., & Wang, L. C. (2024). Reporting reliability, convergent and discriminant validity with structural equation modeling: A review and best-practice recommendations. In Asia Pacific Journal of Management (Vol. 41, Issue 2). Springer US. https://doi.org/10.1007/s10490-023-09871-y
14. Cintya Mawar, P., & Adiati, L. (2024). Analysis of Behavioral Determinants Preventing Food Waste in Consumers Based on the Theory of Planned Behavior (TPB) Mediated by Behavioral Intention. International Journal of Engineering, Business, and Social Science, 2(04), 1176–1185. https://doi.org/10.58451/ijebss.v2i04.153
15. Creswell, J. W. (2010). Research design: Qualitative, quantitative, and mixed methods approaches (3rd ed.). Thousand Oaks, CA: Sage Publications.
16. Dewi, P. H. C., & Notobroto, H. B. (2014). Low participation of long-term contraceptive method users among couples of childbearing age. Journal of Biometrics and Population, 3(1), 66–72. Airlangga University.
17. Dahang, M., et al. (2021). Barriers and facilitators to cardiopulmonary resuscitation within pre-hospital emergency medical services: A qualitative study. BMC Emergency Medicine, 21(1), Article 128. https://doi.org/10.1186/s12873-021-00512-7
18. DeCuir-Gunby, J. T. (2008). Critical race theory in educational research: A review of past and current research. Review of Educational Research, 78(2), 195–220.
19. Eliyanti, E., Zulkarnain, Z., & Ichwan, B. (2021). Application of 3-Bio Technology of Golden Snail Compost to Suppress the Use of Inorganic Fertilizers on Red Chili Plants (Capsicum annuum L.) Application of 3-Bio Technology of Golden Snail Compost to Suppressing the Use of Inorganic Fertilizers on Chili Plants (. 5, 1–9.
20. Elizabeth Shirley, S., Santoso, J., & Kristina, N. (2024). Implementing UTAUT Model to Analyze Consumer Behavior in Mobile Recycling Application. MATICS: Jurnal Ilmu Komputer Dan Teknologi Informasi (Journal of Computer Science and Information Technology), 16(1), 43–51. https://doi.org/10.18860/mat.v16i1.26930
21. Embranddiri, A., Ibrahim, M. H., & Singh, R. P. (2013). Palm Oil Mill Wastes Utilization; Sustainability in the Malaysian Context. International Journal of Scientific and Research Publications, 3(1), 2250–3153. www.ijsrp.org
22. Ghozali, I. (2013). Application of multivariate analysis with the program. Diponegoro University.
23. Hanim, W., Fadhliani, F., & Wibowo, S. G. (2020). Liquid Waste Treatment at the PT Sisirau Farming Facility, Sidodadi Village, Kejuruan Muda District, Aceh Tamiang Regency. Journal of Enviscience, 4(2), 67. https://doi.org/10.30736/4ijev.v4iss2.198
24. Harahap, F. S., Walida, H., Rahmaniah, R., Rauf, A., Hasibuan, R., & Nasution,
A. P. (2020). The Effect of Oil Palm Empty Fruit Bunches and Rice Husk Charcoal Application on Several Soil Chemical Properties in Tomatoes. Agrotechnology Research Journal, 4(1), 1–5. https://doi.org/10.20961/agrotechresj.v4i1.41121
25. Henseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The use of partial least squares path modeling in international marketing. In R. R. Sinkovics & P. N. Ghauri (Eds.), New Challenges to International Marketing (Vol. 20, pp. 277–319). Emerald Group Publishing Limited. https://doi.org/10.1108/S1474-7979(2009)0000020014
26. Herudin, H., Yurisinthae, E., & Suyatno, A. (2021). Conversion of Rubber Farming to Oil Palm Farming in Belitang Hilir District, Sekadau Regency. Journal of Socioeconomics Agriculture, 18(1), 27–39. https://doi.org/10.20956/jsep.v18i1.18459
27. Hettiarachchi, H., Bouma, J., Caucci, S., & Zhang, L. (2020). Organic Waste Composting Through Nexus Thinking: Linking Soil and Waste as a Substantial Contribution to Sustainable Development. pp. 1–15.
28. Imansari, N., & Khadiyanta, P. (2015). Provision of urban forests and city parks as public green open spaces (RTH) according to community preferences in the central area of Tangerang City. Ruang, 1(3), 101–110. https://doi.org/10.14710/ruang.1.3.101-110
29. Kuntoro, H. (2021). The Indonesian Journal of Public Health (Vol. 16, No. 3). Surabaya: Faculty of Public Health, University of Airlangga. ISSN 1829-7005.
30. Khairani, L. (2024). Developing an Environmentally Friendly Business Model: A Case Study of XYZ Company. Circle Archive, 1–13. https://circle-archive.com/index.php/carc/article/view/221
31. Ksenofontov, A. A., Ksenofontov, A. S., Kirpicheva, M. A., & Trifonov, P. V. (2019). The use of modern management technology to improve business efficiency. IOP Conference Series: Materials Science and Engineering, 483(1). https://doi.org/10.1088/1757-899X/483/1/012114
32. Kurniawan, E., Dewi, R., & Jannah, R. (2022). Utilization of Palm Oil Industry Liquid Waste as Liquid Organic Fertilizer with the Addition of Empty Fruit Bunch Fiber Oil Palm. Unimal Journal of Chemical Technology, 11(1), 76. https://doi.org/10.29103/jtku.v11i1.7251

33. Kurniawan, R., & Pinem, M. I. Lisnawita. 2017. The Effect of Oil Palm-Originated Endophytic Fungi on Oil Palm Growth in Soil Infected with Ganoderma spp. Journal of Agroecotechnology, 56, 462-468.
34. Kohli, A. K., & Jaworski, B. J. (2008). Market orientation: The construct, research propositions, and managerial implications. Journal of Marketing, 54(2), 1–18.
35. Leeflang, P. S. H., Wieringa, J. E., Bijmolt, T. H. A., & Pauwels, K. H. (2017). Advanced Methods for Modeling Markets (AMMM). 3–27. https://doi.org/10.1007/978-3-319-53469-5_1
36. Lynn, D., Geriatrics, B. M. C., Lynn, J. D., Ryan, A., Mccormack, B., & Martin, S. (2023). Stakeholder ' s experiences of living and caring in technology - rich supported living environments for tenants living with dementia. BMC Geriatrics, 1–16. https://doi.org/10.1186/s12877-023-03751-2
37. Magno, F., Cassia, F., & Ringle, C. M. (2024). A brief review of partial least squares structural equation modeling (PLS-SEM) use in quality management studies. TQM Journal, 36(5), 1242–1251. https://doi.org/10.1108/TQM-06- 2022-0197
38. Mahfud Sholihin & Dwi Ratmono. (2020). SEM-PLS Analysis with Warp PLS 7.0 (Clara Mitak (ed.); 1st ed.). Andi.
39. Mashudi, Sulistiowati, R., Handoyo, S., Mulyandari, E., & Hamzah, N. (2023). Innovative Strategies and Technologies in Waste Management in the Modern Era Integration of Sustainable Principles, Resource Efficiency, and Environmental Impact. International Journal of Science and Society, 5(4), 87–100. https://doi.org/10.54783/ijsoc.v5i4.767
40. Munthe, M. N. (2018). The Effect of Investment Levels and Labor Force on Economic Growth in Indonesia. Journal of Management and Business, 18(2).
41. Mulia Raja, P., Giyanto, G., & Barus, S. (2021). Characteristics of the N, P, and K Content of Palm Oil Wastewater from Anaerobic Ponds with Bentonite Quantity Contact. Jurnal Agrium, 18(2). https://doi.org/10.29103/agrium.v18i2.5326
42. Onofrei, M., Gavrilu, A., Jitaru, G., Filip, B. F., & Laurent, C. (2020). Impacts of the Allocation of Governmental Resources for Improving the Environment. An Empirical Analysis on Developing European Countries. International Journal of Environmental Research and Public Health, 17(2783), 1–18.
43. Change, D., Land, P., Strategy, D. A. N., Region, L., Case, S., & Bekasi, K. (2012). Dynamics of Land Use Change and Green Space Strategy (Suwarli. Postgraduate Forum, 35(1), 37–52.
44. Peterson K. Ozili. (2023). The Acceptable R-square in Empirical Modeling for Social Science Research. Peterson. Social Research Methodology and Publishing Results, 116496, 1–10.
45. Rahayu et al. (2022). The Effect of Perceived Usefulness and Perceived Ease of Use on Continuance Intention to Use Mobile Banking with Trust as an Intervening Variable in Bank Jambi Mobile Application Users. 1, 57–67.
46. Retno. (2014). The Effect of Utilizing Palm Oil Processing Mill Liquid Waste as Fertilizer on Soil Biodiversity. The Effect of Utilizing Palm Oil Processing Mill Liquid Waste as Fertilizer on Soil Biodiversity. October.
47. Romelah, S., Niswati, A., Tugiyono, T., & Dermiyati, D. (2017). Improvement of Physical and Chemical Soil Quality of Oil Palm Plantation through Integrated Farming System of Cattle and Oil Palm to Achieve Sustainable Agriculture. Journal of Tropical Soils, 22(2), 113–123. https://doi.org/10.5400/jts. 2017.v22i2.113-123
48. Sirajuddin, S. N., Aminawar, M., Nurlaelah, S., & Amrawaty, A. (2015). The application of Tesang sharing system at cattle farm in Indonesia. Proceedings of The Third International Seminar on Animal Industry: Sustainable Animal Production for Better Human Welfare, Bogor, Indonesia.
49. Semangun, H. (2000). Plantation Plant Diseases in Indonesia (Revised). Gadjah Mada University Press.
50. Sushil. (2012). Interpreting the interpretive structural model. Global Journal of Flexible Systems Management, 13(2), 87–106. https://doi.org/10.1007/s40171-012-0008-3
51. Sheehy, B., & Farneti, F. (2021). Corporate social responsibility, sustainability, sustainable development and corporate sustainability: What is the difference, and does it matter? Sustainability (Switzerland), 13(11). https://doi.org/10.3390/su13115965
52. Shrestha, A. K., & Vassileva, J. (2019). User acceptance of usable blockchain-based research data sharing system: An extended TAM-based study. Proceedings - 1st IEEE International Conference on Trust, Privacy and Security in Intelligent Systems and Applications, TPS-ISA 2019, 203–208. https://doi.org/10.1109/TPS-ISA48467.2019.00033
53. Siu Shing Man, W. K. H. lee. (2022). Policy Implications for Promoting the Adoption of Cogeneration Systems in the Hotel Industry : An Extension of the Technology Acceptance Mode. MDPI, 12(1247), 20.
54. Sozoniuk, M. (2022). Investigating Residents' Adoption Of A Recycling Application And Acceptance Of Corporate Sponsorship: A Case Study Of New Jersey. Toronto Metropolitan University.
55. Stefani, K., & Cilvanus, H. (2020). Analysis of the Influence of System Quality, Perception of Convenience, Advertising, Promotion, and Price on User Satisfaction of the Ruangguru Application. Media Informatika, 19(2), 72–87. https://doi.org/10.37595/mediainfo.v19i2.44
56. Syam, J. (2024). Utilization of Information Technology for Sustainable Natural Resource Management in Bonto Masunggu Village, Bone Regency
57. South Sulawesi. Bonto Masunggu Village is located in Bone Regency, South Sulawesi, covering an area of 1,200 hectares, with an average rice production of 4 tons per hectare. 2(1), 25–36.
58. Utami, S., & Siregar, S. (2022). Utilization of empty oil palm bunches as a botanical pesticide using the pyrolysis method. Jurnal Masyarakat Mandiri, 6(6), 4968–4977.
59. Widiastuti, H., D. D. Eris, and D. S. (2016). Potential of Organic Fungicides for Ganoderma Control in Oil Palm Plants. Menara Perkebunan Journal, 8(4), 98–106.