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Institutionalization of integrated pest management in the food estate development area, Sungai Mandau Subdistrict, Siak Regency, Riau

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Abstract

The food estate program aims to enhance national food production, regional development, food security, and the welfare of farmers. Sungai Mandau, a peatland area in Siak Regency, was opened in 2010 as a food estate for rice cultivation to meet the rice demand in Riau Province. However, peatland development for agriculture faces challenges such as low soil fertility, acidic soil pH, and nutrient deficiencies. This research aims to study the agronomic factors, land suitability, pest management, and agricultural institutions in the context of food estate development in Sungai Mandau. This study starts from August 2022 to April 2023. The method was in-depth interviews with fifty farmers to capture the condition of the Sungai Mandau food estate. Additionally, field observations were conducted on land, soil conditions, pests and diseases. The land condition of the Sungai Mandau food estate falls into suitability class S3 (the lowest suitability) for rice cultivation. Farmers' pest management practices are far from the Integrated Pest Management (IPM) concept. The cultivation practices do not fully support IPM and are not in line with the land conditions. The lack of farmer knowledge is attributed to the ineffective roles of field agricultural extension officer (FAEO) and agriculture technopark (ATP), who should play a significant and close role with the farmers. Information dissemination at the cooperative and farmer group levels has not been effective for a long time. Non-Governmental Organizations (NGOs) play a role in institutionalizing IPM, and this institutionalization can occur when all institutions and stakeholders actively participate.

Keywords: Integrated Pest Management (IPM); Farmer knowledge and practices; Food estate development; Agricultural institutions.

1. Introduction

The government continues strengthening the agricultural sector to meet the increasing demand for food with the growing population. Sungai Mandau Subdistrict, Siak Regency, Riau Province, is one of the peatland areas opened by the government in 2010 as a food estate for rice cultivation. The land was opened to fulfill the rice demand in Riau Province. The fertility, maturity, and depth of Sungai Mandau's peat are considered suitable for agricultural development(1). However, the conversion of peatland into agricultural land faces several challenges such as low soil fertility, acidic soil pH, and nutrient deficiencies (2). Farmers' limited knowledge in managing peatlands and applying their existing knowledge has yet to become best practices in cultivating peatlands (3).

The challenges in meeting and achieving rice production targets, both currently and in the future, will become increasingly difficult due to the impacts of climate change such as drought, floods, salinity, and the rising population of pests and plant pathogen. The approach to control based on environmental management (agroecosystem) and plant health through the Integrated Pest Management (IPM) program has proven successful in Indonesia post the Green Revolution era. IPM involves the principles of cultivating healthy crops, utilizing natural enemies, monitoring, and

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farmers as IPM experts. Popularizing IPM also means enhancing farmers' capacity to understand ecological information, enabling them to condition a healthy agroecosystem for plants and utilize available natural components (4), with farmers playing a crucial role in the success of cultivation.

The development of food estates has long attracted attention due to numerous challenges that need to be addressed and failures that require re-evaluation. Agricultural development heavily relies on the good institutions of farmers (5). The capacity of farmers can increase in tandem with their participation in farmer institutions (6). Therefore, an assessment of land conditions, pest management practices, cultivation practices by farmers, and the institutionalization of IPM in the Sungai Mandau food estate is necessary. This information can contribute to the sustainability of land development programs and provide support for the growth of the agricultural sector.

2. Methods

2.1. Time and Research Location

This research was conducted from August 2022 to April 2023 in the food estate area covering three villages: Muara Bungkal, Muara Kelantan, and Lubuk Jering in Sungai Mandau Subdistrict, Siak Regency, Riau Province.

2.2. Type and Sources of Data

The collected data originated from both primary and secondary sources. Primary data were obtained through in-depth interviews, soil and water analysis, and field observations of pests and diseases. Secondary data were gathered from literature studies such as journals, books, internet data, and relevant information sources to support this research.

2.3. In-Depth Interview

In-depth interviews were conducted through direct and thorough interview processes. Interviews were carried out with fifty farmers in the Sungai Mandau food estate area. The interview results were analyzed using a descriptive approach, processing both qualitative and quantitative data by tabulating the data. The analysis results provided an overview of the characteristics of the respondent farmers. Additionally, open interviews were conducted with the field agriculture extension coordinator, the head of the farmers' group association, the manager of agricultural machinery service businesses, and non-governmental organizations (NGOs).

2.4. Soil and Water Analysis

Samples of soil and water were taken in the Sungai Mandau food estate location. Soil samples were taken at three depths: 0-30, 30-60, and 60-100 cm at a location considered representative of the overall land conditions. Water and soil sample analysis was conducted in a testing laboratory. The results of soil and water analysis were then interpreted according to irrigation water quality standards and the suitability class for rice field.

2.5. Pest and Disease Observation

Observations of pests and diseases were conducted on 25 rice fields out of the 50 respondent farmers. Pest and disease observations were carried out in two phases of rice plants: vegetative and generative, by taking four plots from the rice field area. Each plot involved sampling three plants, resulting in 300 plant samples. Observations included the intensity of pest and disease attacks.

3. Result and discussion

3.1. Research Area Description

Sungai Mandau has a vast area of 1,407.14 km^2 (7). This subdistrict is divided into several zones, including conservation zones, agricultural zones, plantation zones, and forest zones, following the spatial planning of Siak Regency regulated by the Siak Regency Government (8). The transformation into an agricultural zone occurred in 2010 when the government opened secondary forests with the status of other land use (APL) into a food estate area. Sungai Mandau Subdistrict consists of nine villages, with food estate areas only located in Muara Kelantan Village (220 ha), Muara Bungkal Village (225 ha), and Lubuk Jering Village (85 ha), with a total area of 530 ha. Each farmer has 1 ha of paddy fields provided by the village government with land-use rights status. The majority of farmers are of Javanese descent, while the majority of the local population is of Malay descent (indigenous people). This is because the indigenous

population once attempted cultivation but failed due to their background in managing plantation crops rather than food crops.

The majority of respondent farmers are male (62%), aged over 50 years (60%), and 76% have elementary school education. Almost all farmers consider farming as their main occupation and 70% of all respondent farmers have side jobs such as casual laborers, traders, and palm/rubber farmers. All farmers have at least 1-10 years of farming experience. This is because respondent farmers were previously agricultural laborers in other areas and tried to move to the Sungai Mandau food estate area to manage their own land. Sources of farming information and knowledge are mostly obtained from parents, indicating a lack of knowledge and innovation, and most respondent farmers come from farming families. Some other farmers obtain information by self-learning from experience and through information on social media. Field vegetation observations show that many pineapple and banana plants can grow and produce well in acidic land conditions. In addition to cultivating rice, many people also cultivate horticultural crops. Horticultural crop cultivation will be successful only if using rainwater or deep wells (artesian). Harvest yields will decrease if plant irrigation uses canal water.

3.2. Land Conditions

The soil analysis results in Table 1 indicate that the suitability class of the Sungai Mandau food estate for rice cultivation is in suitability class S3 (the lowest suitability level) because it has inhibiting factors, namely soil acidity (pH) and rainfall. Besides temperature, the depth and thickness of peat are also limiting factors in land suitability for rice cultivation. The land falls into the category of alluvial plains with the dominant order of inceptisols and the type of soil endoaquepts. This is indicated by the presence of a mineral soil layer between peat layers due to the formation of land from organic material deposited by rivers.

Table 1 Results of soil analysis for Sungai Mandau Food Estate 2022

No	Parameter	Soil Depth								
		0-30			30-60			60-100		
		value	category	LSC	value	category	LSC	value	category	LSC
1	Soil Acidity	4	VA	S3	3,3	VA	S3	3,4	VA	S3
2	Organic Carbon (C)	19,35	VH	S1	21,26	VH	S1	22,31	VH	S1
3	Total Nitrogen (N)	0,54	H	S1	0,29	M	S1	0,31	M	S1
4	C/N Ratio	36	VH		73	VH		72	VH	
5	Available P2O5	54,5	H	S1	59,3	H	S1	50	H	S1
6	Available P2O5	44	H	S1	13	L	S1	16	L	S1
7	Potential K2O	32	M	S1	32	M	S1	54	H	S1
8	Cation Exchange Capacity (CEC)	58,41	VH	S1	55,43	VH	S1	54,68	VH	S1
9	Base Saturation (BS) (%)	6	L	-	7	L	-	14	L	-
10	Temperature	25-27					S1			
11	Annual Rainfall	2257,5					S3			
12	Peat Depth	60-140					S2			
13	Peat Thickness	sapric, hemic					S2			

Explanation: VA (very acid), VL (very low), L (low), M (medium), H (High), VH (very high), LSC (land suitability class for rainfed rice cultivation), S1 (very suitable), S2 (quite appropriate) S3 (marginally appropriate).

Based on interviews with extension coordinators, the local government through the Public Works and Housing Service (*Dinas PUPR*) in 2015 reduced the water level by deepening canals (canalization) to 3 meters. This canalization process did not take into account that the soil layer at a depth of more than 60 cm contains acidic sulfate and pyrite (Fe^2S), which causes pyrite to oxidize. In an oxidized condition, pyrite can cause the soil to become acidic and very acidic (pH 2-3) (9). The use of dolomite at 2 tons/ha can increase soil pH by one point (10). In practice, farmers in this region generally apply dolomite before planting, with a minimum application of 100 kg/ha and a maximum of 700 kg/ha, so the

application of dolomite is considered to be very insufficient to neutralize the acidity of the soil (11). The impact of this oxidation also results in the canal water as an irrigation channel having a low pH and potentially harming plant growth. The canal water used by most farmers has a very low pH (3.43), which is very unsuitable for the criteria for irrigation water quality and can increase acidity in agricultural land. The total Manganese (Mn) content of 1,021 mg/L and total Aluminum (Al) of 0.106 mg/L in canal water with low soil pH can also be toxic to plants.

3.3. Integrated Pest Management (IPM)

Observations of pests and diseases of rice commodities showed that in the vegetative phase, the pests that attacked the most were, in order, the yellow stem borer (*Scirpophaga incertulas*), the black bug (*Scotinophara coarctata*), and the small spot disease on rice (*Cercospora oryzae*). In the generative phase, in order, they were *C. oryzae, S. coarctata, and S. incertulas*. The narrow brown spot disease (*C. oryzae*) on rice leaves dominated the attacks from the vegetative to the generative phase. This pathogen can spread through spores carried by the wind to healthy rice leaves. Two of the three major types of seeds used by farmers are seeds that are susceptible to *C. oryzae* attacks. The *S. incertulas* bug is a pest that attacks a lot in both phases, namely *sundep* (vegetative phase) and *beluk* (generative phase). *S. coarctata* (groundhopper) attacks were found on almost every farmer's crop. A large decrease in production can occur because the attacks can cause a reduction in tillers and the panicle does not develop perfectly.

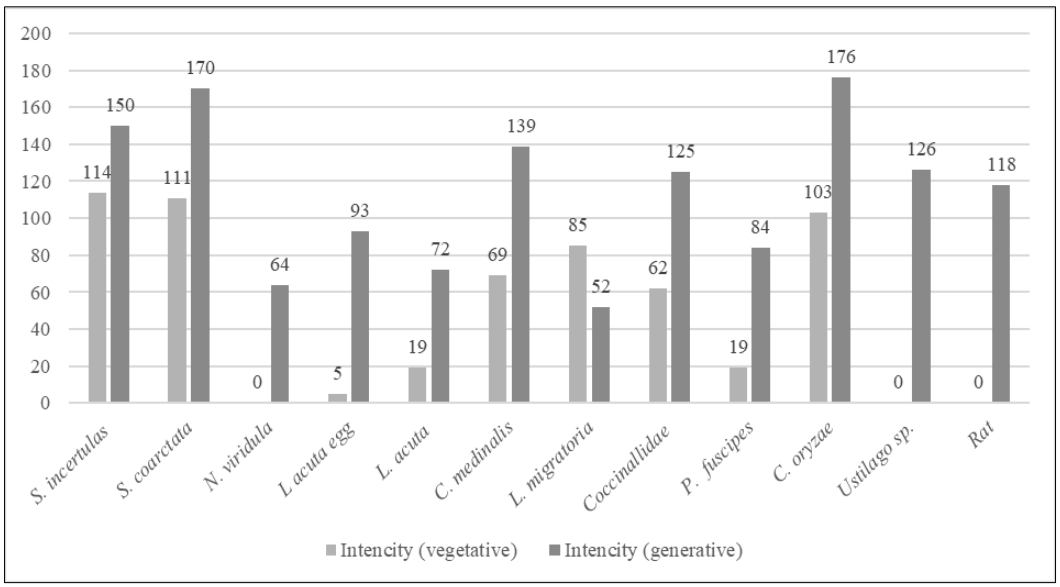


Figure 1 Intensity of pest attacks in the vegetative and generative phases on the farmers' land

Based on the results of the questionnaire, some pests that are considered important by farmers are birds, rats, and weeds. Due to the vastness of the existing food estate land, in the generative phase, many birds are active in eating on farmers' land. In addition, rats are also an important pest because rats attack and come from the forest. Weeds are important because of the high resistance of weeds to herbicides and most farmers already use broad-spectrum herbicides to control them.

Table 2 Knowledge and actions of Sungai Mandau farmers in managing pests

No	Indicator variable	Percentage farmers (%)	
	Knowledge	K	DK
1	Farmers are aware of the types and uses of pesticides	62	38
2	Farmers can distinguish between natural enemies and pests	22	78
3	The decrease in the number of natural enemy insects is related to the use of pesticides in rice cultivation	56	44
4	Monitoring pests is important	42	58

5	Intercropping, planting flowering plants, and planting pest-repelling plants can reduce pest and disease attacks	48	52
	Actions	D	DD
1	The older the age of the rice plant, the higher the dosage of spraying	26	74
2	If farmers find something like an egg, they take it and kill it	64	36
3	Pesticide spraying is carried out as early as possible when signs of pest and disease attacks are seen	22	78
4	Only by spraying regularly, farmers can save the harvest	42	58
5	Preserving the natural enemies that exist because it can reduce pest and disease attacks	30	70

Explanation: K (know), DK (do not know), D (do), DD (do not do)

The results of the questionnaire on farmers' knowledge and actions on pest management showed that the majority of farmers did not know and did not practice integrated pest management (IPM). The majority of farmers also carried out regular pesticide spraying. As many as 64% of farmers collect and kill egg clusters if they find egg-like shapes, but 78% of farmers do not know the difference between natural enemies and pests. All indicator variables also show that farmers do not know that there is a role for natural enemies provided by the ecosystem to control pest attacks in the field. This is also supported by the actions taken by farmers by not providing a good ecosystem for natural enemies to live in. Overall, the percentage of farmers who do not know and do not take IPM actions is higher than the percentage of farmers who know and take IPM actions.

3.4. Crop Cultivation

The soil in the Sungai Mandau area has low acidity, which requires a specific cultivation pattern. The acidic pH can inhibit the performance of nutrients and potential microorganisms that can be beneficial for plants.

Table 3 Cultivation according to soil conditions and cultivation by Sungai Mandau farmers

Stage	**Cultivation according to soil conditions**	**Cultivation by farmers**	**Farmers' reasons**
Seed	Superior varieties that are adaptive and tolerant to Al	Sadani, Anak Daro, Inpari 42 varieties	Consumer preferences, and only Sadani is tolerant of Al
	Certified seeds	Offspring seeds, except subsidized seeds	Already adapted to the environment
	Seed soaking with water/PGPR	Soaking with canal water pH 3.43	Some farmers do not have artesian wells
Seedling	Application of manure	Some farmers do not do it	Makes the weeds more abundant
	Application of dolomite 2 tons/ha	Average application of dolomite 100-700 kg/ha	The amount of subsidy provided is not enough
Land preparation	Superficially (maximum 30 cm)	Washing the soil by turning the deep soil upwards	An effort to eliminate acidity
Transplanting	1-2 seedlings per hole	4-5 seedlings per hole	Produces more
Weeding	Mechanical control using hand rotary	Using broad-spectrum herbicides	More effective at controlling weeds and more practical
Fertilization	Fertilization 3 times as land needed	Dominated by N fertilizer	Cheaper and green plants

Farmers in Sungai Mandau are cognizant of the acidic nature of the soil they manage, which is unfavorable for plant growth. However, their cultivation practices have not entirely adjusted to the soil conditions. The majority of farmers do not employ seeds that are adaptive and tolerant to aluminum (Al), mainly due to the limited availability of suitable seeds accessible to them. Subsequent to the realization that acidity escalated following canalization, some farmers resorted to drastic soil cultivation methods, involving extensive soil turning. This practice, perceived by farmers as a means to bury topsoil acidity using the lower soil layer, is, however, ineffective and may lead to the incorporation of pyrite into various soil layers. This suggests an incomplete understanding and knowledge among farmers regarding cultivation practices in acidic soil conditions.

Table 4 Farmers' knowledge and actions in crop cultivation

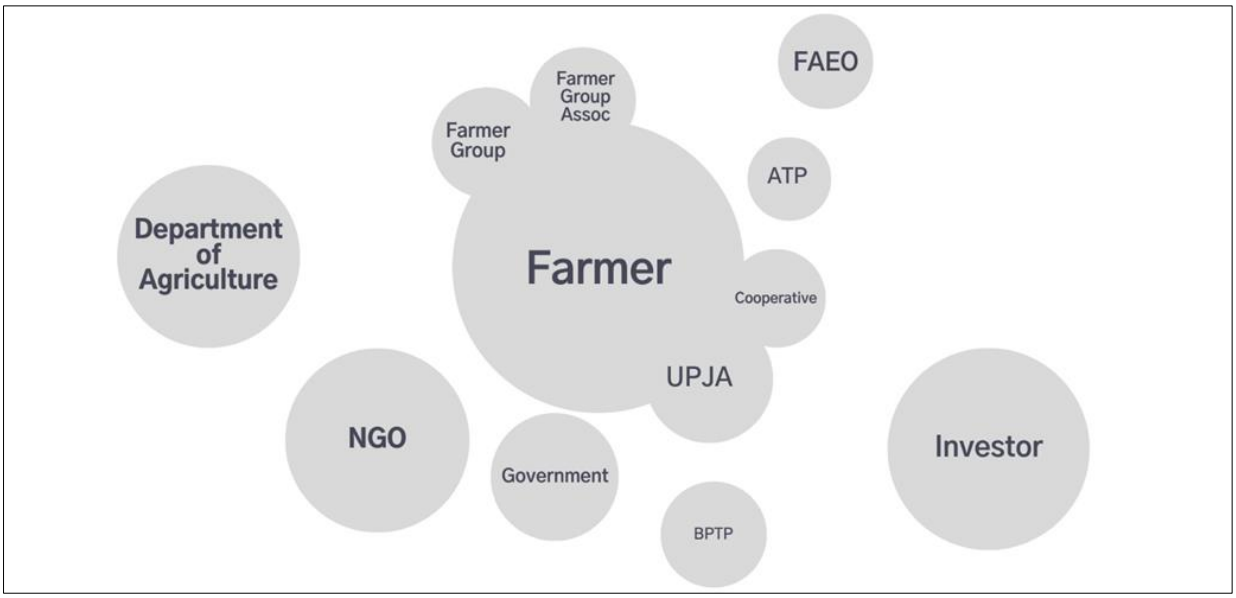
No	Indicator variable	Percentage of farmers	
	Knowledge	**K**	**DK**
1	Manure can fertilize the soil	80	20
2	The more nitrogen fertilizer is given, the better for rice plants	22	78
3	The harvest will be better if the planting distance is closer	78	22
4	Rice is a water plant and must be flooded continuously	80	20
	Actions	**D**	**DD**
1	Farmers apply manure	24	76
2	Farmers combine fertilizers according to the age of the plants	54	46
3	Farmers apply the appropriate planting distance	50	50
4	Farmers drain the water according to the plant phase	64	36

Explanation: K (know), DK (do not know), D (do), DD (do not do)

Farmers' knowledge and actions do not support the concept of IPM overall. Farmers' knowledge in cultivation has a high percentage except for the variable of nitrogen fertilizer application by farmers. However, in actions, there are decreases and increases. Manure is included in one of the government assistance provided to farmers. However, the number of farmers who apply manure is only 24% due to the perception that manure increases the number of weeds in the rice field. Many farmers (78%) are not yet aware that the addition of large assistance amounts of nitrogen fertilizer does not always produce better rice plants. The addition of N levels that are already high (Table 1) on the land can increase soil pH (12). The knowledge and application of good planting distance (25 x 25 cm) have been done by some farmers and farmers have also applied water regulation according to the plant phase. The arrangement of the rice field so that it is not flooded continuously is beneficial for the control of pests and diseases of plants (4). Before the canalization was carried out, the highest harvest yield could reach 5-6 tons per hectare. This figure is very far from the results of interviews in the field, which show that farmers can only produce the highest harvest of 1-2 tons per hectare.

3.5. Farmers and the Institutionalization of IPM

The process of farmers' cultivation and pest management does not show that farmers are cultivating healthy plants. Farmers' knowledge of natural enemies is also low and they do not monitor pests. The canalization carried out by the Public Works Agency to lower the water level of the peat swamp land, did not take into account other aspects, namely the existence of pyrite. The Department of Agriculture, the District Government and the Village Government as the responsible parties for the development of the food estate did not provide subsidies that were appropriate and sufficient for the needs of farmers and their land. Knowledge of cultivation on peat land in this case is not only necessary for farmers, but also for stakeholders around farmers.



Note: NGO (Non-Governmental Organization); FAEO (Field Agricultural Extension Officer) or PPL in Indonesia; ATP (Agriculture Technology Park); *UPJA* (Unit for the Provision of Agricultural Machinery and Equipment); *BPTP* (Agricultural Technology Assessment Center).

Figure 2 Venn diagram of the roles and existence of institutions in the Sungai Mandau food estate

Farmer groups and farmer group associations, serving as forums for farmers, play a limited role due to the lack of information dissemination within them, despite their proximity to farmers. Farmer Agriculture Extension Officers (FAEOs), responsible for providing information, also have a limited role and are not closely connected to farmers. The Department of Agriculture, being the source of subsidies for farmers, plays a significant role, but its proximity to farmers is lacking. According to Indonesian Law No. 22 of 2019, Chapter IX, Article 48, plant protection is carried out through an integrated pest management system, addressing the impacts of climate change, and the implementation is the joint responsibility of the Central Government and the Regional Government.

In line with this legislation, the government, particularly the Department of Agriculture, possesses the capacity and knowledge of Integrated Pest Management (IPM) and should disseminate it to farmers through FAEOs. If FAEOs play a prominent and close role in popularizing IPM, the role of farmer groups and farmer group associations will also be more significant for farmers. This is crucial as the implementation of IPM in the food estate area cannot be carried out on an individual basis. Additionally, one effective method to integrate IPM into the farming community is through IPM field schools (*SLPHT*) facilitated by farmer groups.

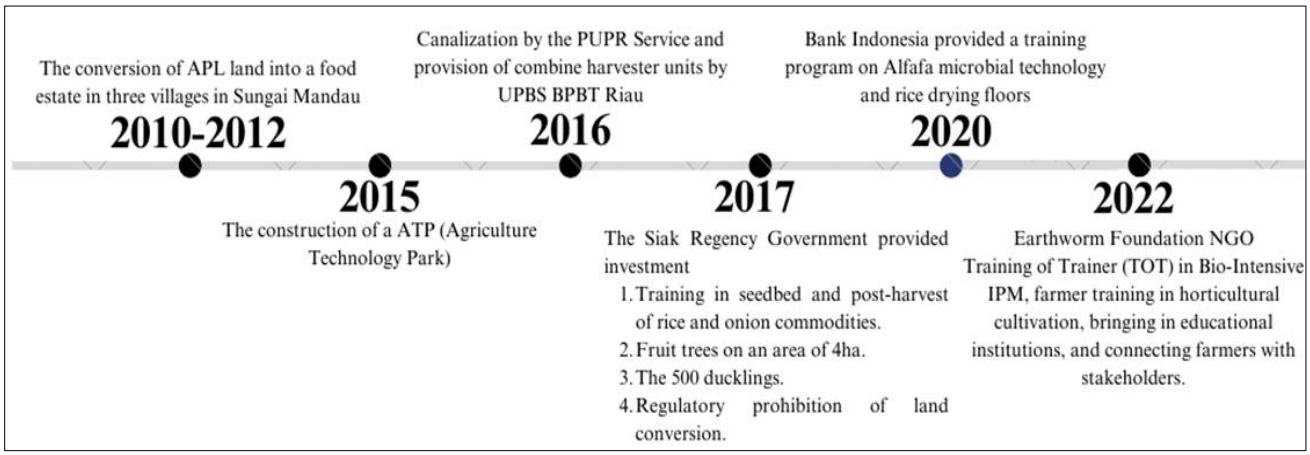


Figure 3 Timeline of stakeholder roles in the Sungai Mandau Food Estate farmer institution

Investments have been made by stakeholders around farmers since the opening of the food estate area. However, until now, the development of food estate land is still far from being successful. The construction of the ATP (Agriculture Technology Park) aims to develop a business based on agricultural commodities through the downstream of research results in innovation, training, internships, and business incubation for agricultural actors (13). The role of the ATP should be to produce appropriate varieties and farmers who can cultivate and have knowledge of IPM. In addition, there is also investment from the Siak Regency Government and Bank Indonesia in the development of the Sungai Mandau food estate. No matter how broad the investment that is given for the development of food estate by stakeholders, if it is not accompanied by the improvement of farmers' capacity, farmers will not be independent and the investment will not be sustainable. There needs to be a collective movement among all stakeholders involved so that the role of each stakeholder can be felt systematically by farmers.

Based on Figure 3, significant institutional contributions to farmers come from Non-Governmental Organizations (NGOs) and investors, despite their physical distance from farmers and lack of obligation to develop the food estate continuously, as they cannot always be present with farmers. Investors previously played a role by fulfilling farmers' agricultural needs and purchasing their harvests, but this was short-lived in the Sungai Mandau food estate. Integrated Pest Management (IPM) was only introduced to farmers in 2022 through NGOs, particularly in collaboration with educational institutions such as IPB University through the Tani and Nelayan Center, as depicted in Figure 3. NGOs initiated the introduction of IPM to farmers through Training of Trainer Bio-Intensive IPM programs and horticultural cultivation training, aiming to enhance economic prospects for farmers who faced challenges and found rice cultivation on peat land in the Sungai Mandau food estate to be unprofitable. The collaboration between NGOs and educational institutions enables NGOs to directly consult with the agricultural expert council to address farmers' challenges in the field. Additionally, NGOs serve as liaisons for farmers to collaborate with other stakeholders in the Sungai Mandau food estate environment.

4. Conclusion

The land condition in the Sungai Mandau food estate falls within the S3 land suitability class, indicating the lowest suitability for rice fields. Pest management practices by farmers exhibit a considerable gap from the Integrated Pest Management (IPM) concept in terms of both knowledge and actions. Furthermore, farmers' cultivation practices do not align with the overarching principles of IPM and are not tailored to the specific conditions of the land. The introduction and implementation of IPM reached a limited number of farmers through Non-Governmental Organizations (NGOs) in 2022, specifically through the Training of Trainer (TOT) Bio-Intensive IPM program. This initiative was organized in collaboration between NGOs and the Tani and Nelayan Center. The deficiency in farmers' knowledge can be attributed to the ineffective roles of Field Agriculture Extension Officers (FAEOs) and Agricultural Technology Park (ATP) personnel, who are expected to have a significant and close connection with farmers. Information dissemination at the levels of farmer groups and farmer group associations has also been inactive for an extended period. The institutionalization of IPM can be achieved through the active involvement of all institutions and stakeholders, ensuring each plays a suitable and effective role in the process.

Recommendations

Consistent application of soil acidity management and minimal soil tillage is imperative for cultivating rice plants. This practice ensures that essential nutrients and the inherent natural potential in the soil, including beneficial microorganisms, remain readily available to the plants. The implementation of Integrated Pest Management (IPM) field schools (SLPHT) has the potential to transform both the mindset and actions of farmers, fostering a controlled approach to field challenges and enhancing farmers' capacities.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Soewandita H, Sudiana N. Potential and characteristic analysis peat as a consideration material for planning directions area development in Siak district. Jurnal Sains dan Teknologi Indonesia. 2011 August 5;13(2): 130-136.

[2] Ministry of Public Work and Housing. Initial draft (R0) of guidelines for developing peat swamp land for agriculture in Indonesia for the 2016 fiscal. Bandung (ID): Center for Water Resources and Development. 2016.

[3] Hardiansyah G, Junaidi, Yusro F, Mariani Y, Roslinda E, Kusrini N, et al. A study of sustainable peat cultivation implemented by the community of Tumbang Nusa Village, Central Kalimantan. In: IOP Conference Series: Earth and Environmental Science. Institute of Physics; 2022.

[4] Widodo, Wiyono, Triwidodo H. Pengelolaan Hama Terpadu Bio Intensif: Menjaga Produksi Padi Berkelanjutan. 1st ed. Bogor : IPB Press; 2023. 130–136 p.

[5] Baga LM, Utami AD, Wahyudi AF. Exploring the Relation between Farmer Group Membership and Agricultural Productivity: Evidence from Indonesian Rice Farming. Agraris. 2023 Jan 1;9(1):65–78.

[6] Anantanyu S. Farmers institutions: role and strategy capacity development. SEPA. 2011 January 6;7(2):102–109.

[7] Central Statistical Agency of Siak District. Sungai Mandau sub-district in 2020 figures. Siak (ID): BPS Kabupaten Siak. 2020 September.

[8] Siak Sendagho, Siak district government. Siak Road Map Green District: guidelines for encouraging sustainability principles in the use of natural resources and improving the community's economy. Siak (ID): Siak District Government. 2019. 1-87.

[9] Primayuda A, Suriadikusumah A, Solihin MA. Identifying pyrite layer depth and its association to oil palm (Elaeis guineensis Jacq.) health and productivity (A case study at PT Sawit Sumbermas Sarana Tbk's oil palm plantation. J. Il. Tan. Lingk. 2022 Mar 14;24(1):6–13.

[10] Santri JA, Maas A, Utami SNH, Annisa W. Leaching and fertilization of Acid sulphate soil for improvement of chemical properties and rice growth. Jurnal Tanah dan Iklim. 2021 Jun 11;45(2):95.

[11] Shi J, Long T, Zheng L, Gao S, Wang L. Neutralization of Industrial Alkali-Contaminated Soil by Different Agents: Effects and Environmental Impact. Sustainability (Switzerland). 2022 May 1;14(10).

[12] Kaya E, The effect of organic fertilizer and NPK fertilizer on pH and K available in soil as well as K support, growth and yield of field rice (Oryza sativa L). Buana Sains. 2014. Vol. 14(2). 113-122.

[13] Jaya R. Construction of agricultural technology park: conceptual and case study of Jantho City Agro Techno Park development. BPTP Aceh. 2016. 723-738.