

# The Analysis of the Social Sustainability of Integrated Pest Management in Rice Fields in Riau Province

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**Abstract.** The study on the social sustainability of integrated pest management in lowland rice fields in Riau Province was conducted from February to June 2024. The investigation encompassed four regencies: Kampar, Siak, Bengkalis, and Rokan Hilir. The research locations were purposefully chosen in accordance with the National Integrated Pest Management Program's allocation for lowland rice fields in Riau Province. A total of 729 respondents were selected for the study, with a 7% margin of error for the population of farmer households in each regency, using the Slovin formula. The Multi-Dimensional Scaling (MDS) method was employed to conduct data analysis using the Rapid Appraisal program. The objective of the investigation was to ascertain the sustainability index and status of the social dimension, as well as the attributes that contribute the most to the sustainability of the social dimension in integrated pest management in lowland rice fields in Riau Province. The results indicated that Siak Regency, Bengkalis, and Rokan Hilir were fairly sustainable (>50%), with a social sustainability index and status of 69.12%, 60.13%, and 57.86%, respectively. Kampar Regency achieved a score of 47.14%, which suggests that it was less sustainable (<50%). In general, Riau Province's IPM was classified as fairly sustainable (>50%), with a social sustainability index and status of 58.56%. Attending training, farming experience, farmer motivation in implementing IPM technology, local wisdom in pest control, periodic observations, and farmer education levels were the most influential attributes for sustainability. The correlation ( $R^2$ ) value was 0.94, and the maximal stress value for all regenceis were 0.15.

## 1. Introduction

Rice is the primary dietary item consumed by the majority of Indonesians. Efforts to satisfy Indonesia's rice requirements consistently prioritize availability, distribution, stability, and production capacity. The process of increasing national rice production involves extensification and intensification, which encompasses special initiatives to increase rice production, implement GAP, disseminate superior seeds, and implement integrated pest control. The program's ability to achieve the anticipated production is impeded by the presence of pests and diseases.

Pest and disease management has been implemented extensively. Nevertheless, chemical pesticides are still widely used at the farmer level, which can result in the emergence of secondary pests, pest resistance, pest resurgence, and residual effects on plants and the environment, as well as damage non-target organisms [1], [2], [3]. The availability of food in a country is significantly impacted by pest and disease problems. Integrated pest management (IPM) is one approach to sustaining food crop production and combating plant pest attacks. The government has provided political support for the IPM concept by enacting Government Regulation No. 5/1996, which mandates the use of IPM in plant protection, and Law No. 22/2019, which addresses sustainable

agricultural cultivation systems. The IPM concept is a concept that promotes sustainable agriculture.

Sustainable agriculture is characterized by a methodology that enables the maintenance of both high agricultural production and profits, while minimizing harm to the environment [4], [5]. The objective of sustainable development is to enhance the overall well-being of human beings by integrating and harmonizing ecological, economic, and social dimensions of life [6], [7], [8] [9]. In addition, [10], [11], [12] stated that a sustainable agricultural system consists of four tiers of subsystems: ecological, economy, technology, and social society. Socially sustainable development necessitates a development endeavor that fosters a fair allocation of development outcomes, upward social mobility, and the growth of both institutions and individuals.

The sustainability of integrated pest management in lowland rice may be efficiently studied and evaluated using a rapid appraisal software called Multi-Dimensional Scaling (MDS), which employs a non-parametric multi-variable method. The sustainability index of integrated pest management in sustainable rice farming is calculated using the MDS approach, specifically the Rapid Appraisal IPM (RAP-IPM).

This method's adoption is anticipated to effectively depict the social aspect of integrated pest management in lowland rice cultivation in Riau Province. The objective of the study was to assess the sustainability index and state of the social component of integrated pest control of lowland rice in Riau Province. Additionally, the study attempted to identify the most influential features for the sustainability of this practice.

## 2. Research Methods

The study was carried out between February and June 2024 in Riau Province, namely in four regencies: Kampar, Siak, Bengkalis, and Rokan Hilir. The location was deliberately selected based on the placement of the national rice field Integrated Pest Management (IPM) program in Riau Province. The resources and tools utilized included stationery, interview guide questionnaires, Rapfish software, data processing tools, and other supplementary items.

This study necessitates the inclusion of original data and secondary data. Data was obtained using primary sources, utilizing survey methodologies, interview techniques, and direct observation in the field. Interviews with participants utilized interview guides. The collection of secondary data encompassed a diverse range of sources, such as research papers, scientific journals, conferences, research institutions, universities, and reports from relevant agencies.

The selection of respondents from the community was conducted via purposive sampling, based on specific criteria: farmers who had received training in Integrated Pest Management (IPM) or had attended IPM field schools specifically focused on rice farming. The study included a total of 729 respondents, who were selected with a margin of error of approximately seven percent of the entire population of rice farmers in each chosen region. The research sample size was determined using the Slovin equation as described in [13], using the following formula:

$$n = \frac{N}{1 + N * \alpha^2}$$

Description:

- n = number of samples
- N = number of population
- a = percentage error

The sustainability of the social dimension is assessed by calculating a sustainability index utilizing the RAP-IPM approach and the MDS (Multi-Dimensional Scaling) technique [14], [15]. The RAP-IPM technique is derived on the Rapfish program, which was developed by the Fisheries Centre at the University of British Columbia [16]. The MDS technique is used to create a mapping of two points or identical objects that are in close proximity to each other. In contrast, distinct objects or points are represented by widely separated points [17]

The RAP-IPM ordination analysis is conducted through a series of steps. Firstly, attributes from the social dimension are identified. Secondly, each attribute is evaluated on a scale ranging from "poor" to "excellent" according to sustainability criteria. Thirdly, the rating value or score for each attribute is inputted into the RAP-IPM software, which then runs the ALSCAL Algorithm to determine the ordination and stress value. Lastly, the sustainability index and status are compiled. The current attributes are evaluated according to the scientific assessment of the scoremaker. The score range is either 0-4 or varies based on each attribute's status, with the interpretation ranging from poor to excellent. The scores of each characteristic are evaluated from several dimensions to establish one or more points that indicate the sustainability position of the investigated sustainable management development. This analysis is done in relation to two reference points: the poor and the excellent points.

The MDS statistical ordination technique uses the mode value as the decisive score. This score is then analyzed to identify the system's sustainability position in relation to the poor and excellent points. The estimated score for each dimension is shown on a scale ranging from 0% (worst) to 100% (best). The sustainability score values are categorized as poor (0.00–25.00%), less (25.01–50.00%), fair (50.01–75.00%), and excellent (75.01–100.00%). Another outcome derived from the MDS analysis is the identification of leverage variables, which are key strategic elements for the future implementation of IPM [18]

### **3. Results and Discussion**

#### *3.1 Index and status of the social dimension of sustainability*

The social dimension is estimated to be influenced by education level, farmer motivation in implementing IPM technology, participation in agricultural training, local wisdom in pest and disease control, farmer age, farming experience, and periodic observation. The social dimension sustainability index of integrated pest management of lowland rice is presented in Figure 1.

The MDS test findings indicated that the social dimension sustainability index values for Siak, Bengkalis, and Rokan Hilir were 69.12%, 60.13%, and 57.86% respectively, which suggests that these three regencies have achieved a fairly sustainable level (>50%) in terms of social sustainability. Kampar achieved an index value of 47.14%. The index is considered less sustainable if its value is below 50% according to the criteria. The unsustainability of the social dimension of Kampar is attributed to various issues, such as: 1) In Kampar, the management of rice farming has not supported the development of the social dimension, whereas in Siak, Bengkalis, and Rokan Hilir, the management of rice farming has been able to support the development of the social dimension. In order to maximise the sustainability of rice farming in Kampar, it is crucial to focus on and enhance the social dimension. 2) The Malay ethnic group, which makes up the majority of research respondents in Kampar, primarily works as fishermen and gardeners. Therefore, planting rice is only an additional income source.

The main source of revenue for farmers in Kampar is derived from their oil palm and rubber plantations. Due to the fact that rice cultivation served as a supplementary means of generating revenue, women were responsible for 85% of the agricultural labour. Males exclusively contribute to the management of pests and diseases, as well as the cultivation of land through the utilization of tractors. Farmers in Kampar are typically content with meeting their basic needs, which is why they lack the motivation to engage in intensive farming practices or explore innovative ways to generate additional income from their agricultural areas, unlike farming communities in the other three locations.

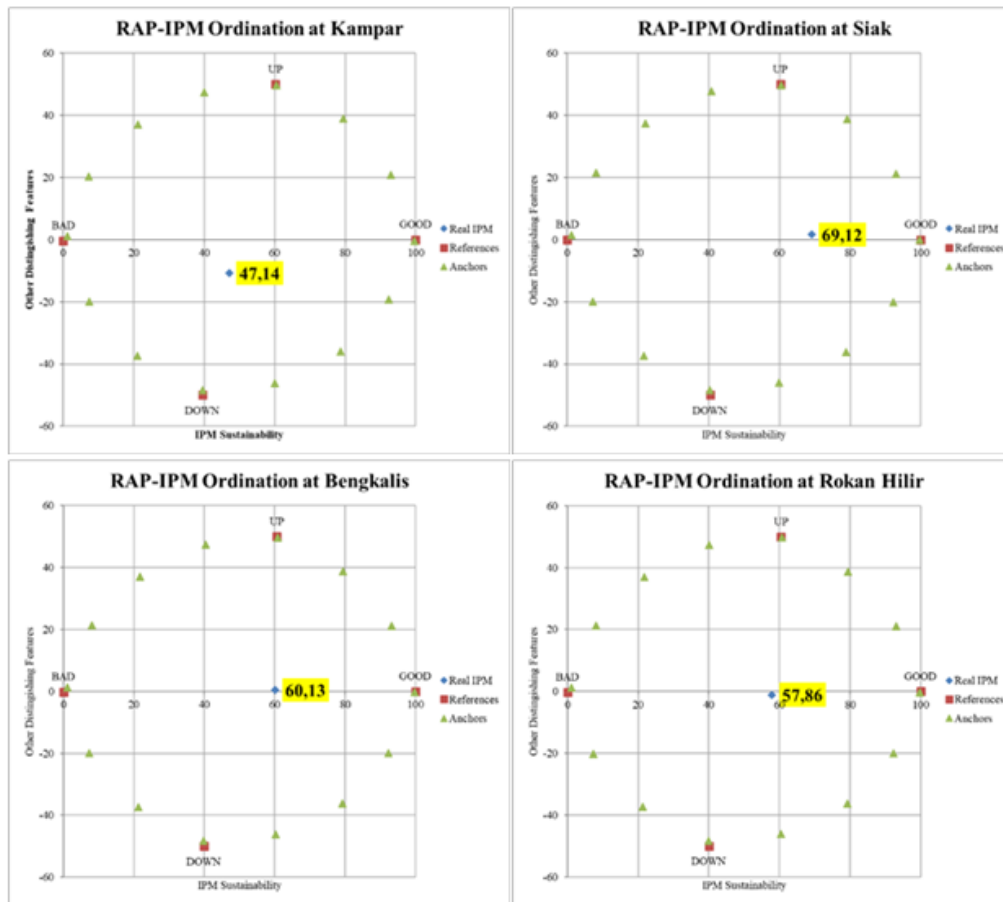


Figure 1. Figure 1. Index and sustainability status of social dimensions in four regencies in Riau Province.

### 3.2 The Leverage Analysis (determination of sensitive attributes/leverage attributes)

Efforts to optimise the sustainability of integrated rice pest management in Kampar include knowing what sensitive attributes influence the decline in the social dimension sustainability index value and what interventions must be done to improve the sustainability status. Attributes that provide high sensitivity to sustainability can be identified from the leverage analysis (Figure 2).

The attributes that provide high sensitivity for the social dimension are attending training, having experience in farming, motivating farmers to implement IPM technology, having local wisdom in controlling pests and diseases, making periodic observations, and having an education level. Attending training provides quite a high level of sensitivity for all regencies. The training attribute is critical to consider in maintaining the sustainability of IPM in lowland rice fields in Riau Province. Through training, farmers become aware, understand and comprehend how to cultivate the land properly, select quality seeds/seedlings, use suitable fertilizers and pesticides, utilize natural enemies, make botanical pesticides, conduct periodic observations, and what factors must be considered so that the sustainability of IPM can be maintained.

Enhancing farmers' knowledge and its application in farming is anticipated to boost production and productivity, hence enabling farmers to enhance their quality of life and welfare. Providing training sessions to farming communities to change their thoughts, behaviors, and activities according to established rules greatly enhances the sustainability of rice-integrated pest management (IPM). [19], [20] have found that providing training to farmers can enhance their knowledge and lead to a substantial boost in productivity and income, up to 40%. Additionally, training has the potential to lower production costs.

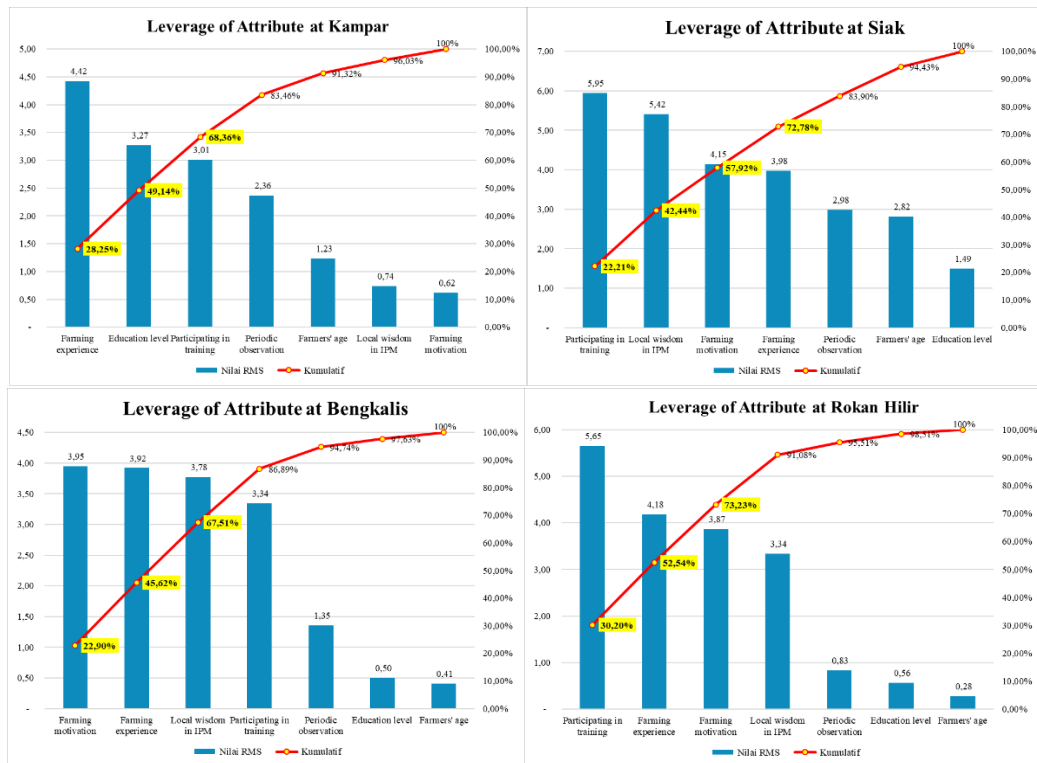


Figure 2. The role of each social dimension attribute in four regencies in Riau Province is expressed in the form of RMS (Root Means Square) values.

The study findings demonstrated that training has a favourable effect on long-term farming since it enhances experience and skills, and effectively addresses all issues related to integrated rice pest management. Training is a strategic investment made by farmers to enhance the skills and knowledge of their workforce, hence fostering more motivation and passion for agricultural activities. Training is a type of informal education that can enhance the skills of farmers in the field of rice growing. Research has demonstrated that farmers who regularly participate in training sessions have a more receptive mindset, which facilitates the resolution of challenges encountered during the implementation of integrated rice pest management in their agricultural practices.

The findings are consistent with the studies conducted by [21], [22], which concluded that training enhances knowledge and abilities, as well as positively influences individuals' attitudes and behaviours, leading to increased productivity. Training in integrated pest management offers advantages by providing knowledge on advancements in the realm of sustainable plant cultivation, identification and utilisation of natural predators, production and application of plant-based pesticides, and the use of biological agents as eco-friendly controllers of pests. Enhancing the frequency of training sessions using diverse approaches (such as field meetings, field schools, and technical guidance) and utilising extension media (such as leaflets, posters, magazines, and books) can augment farmers' knowledge and comprehension of integrated rice pest control.

The enhancement of production and productivity is not solely driven by the training that farmers receive, but is also significantly determined by the practical knowledge and expertise acquired by farmers. Farmer experience refers to the knowledge that farmers acquire from their regular farming activities and the situations they have encountered. The experience gained by farmers is crucial to the management of their farming companies. They assume the role of educators in every decision-making process, as well as exploring numerous viable alternatives for conducting their agricultural operations. An individual's proficiency and skill in overseeing their agricultural land is contingent upon their level of farming experience. The longer a person's

farming experience, the more he/she will understand how to farm well and obtain optimal results by utilising the available land.

The sustainability of the social dimension in four regencies is heavily influenced by farming experience, which in turn impacts the reactivity, response, and adoption of farmers towards the information offered. Extended duration of engagement in farming might enhance farmers' receptiveness to recommended technologies and significantly impact their ability to effectively manage their agricultural enterprises. This remark is consistent with the findings of [23], [24], which indicate that the duration of farming has a positive impact on farmers' adoption of technology. Experienced farmers demonstrate greater agility in evaluating and selecting farming techniques.

The respondents' average experience in rice farming exceeds 20 years, as shown in Table 1. Therefore, the respondent farmers had adequate knowledge and skills to effectively engage in rice farming. This experience can serve as valuable knowledge and lessons for effectively managing pests and plant diseases in the future. It can act as a reliable guideline to mitigate the risk of failure caused by plant pests and disease infestations.

**Table 1.** Length of farming experience of respondent farmers.

Regency	Length of farming (%)		
	< 10 years (low)	10 – 20 years (moderate)	> 20 years (higt)
Kampar	5.02	14.53	80.45
Siak	3.74	35.83	60.43
Bengkalis	20.65	24.46	54.89
Rokan Hilir	5.85	31.58	62.57
Average	8.82	26.60	64.58

The respondents' farming experience in Kampar Regency has an opposite correlation to the farmers' ability to adopt IPM technology. Consequently, the more years a person has been engaged in farming, the less the degree of implementation. The respondents' farming experience, which has been inherited from their parents as a tradition, makes it challenging to alter farmers' behaviour in order to effectively manage plant pests using an integrated approach.

This finding is consistent with the research conducted by [25], [26], which indicates that experienced farmers acquire knowledge from their past experiences to comprehend the characteristics of their agricultural land. Throughout this period, they have faced diverse challenges and developed tactics to surmount these obstacles associated with plant production. These insights can be used as a guide and plan for making optimal decisions and taking steps to manage plant pests on their property, therefore promoting the adoption of new developments.

The use of integrated pest management technology by farmers contributes to the sustainability of the social dimension in three regencies, excluding Kampar Regency. The reason for this is that rice cultivation in these three regencies serves as the primary means of generating income to support the agricultural households' livelihoods. Table 2 presents the motivations of respondent farmers to implement IPM principles.

Stated by [21], [27] that training has a significant impact on an individual's incentive to work and exert greater effort, both in terms of creativity and productivity, whether directed towards oneself or the surrounding environment. The evaluation of farmer motivation in adopting IPM technology is based on four categories suggested by [24], [28]. These categories include the very low category (IPM principles implemented less than 25% of the time), low category (IPM principles implemented 25-50% of the time), moderate category (IPM principles implemented more than 50-75% of the time), and high category (IPM principles implemented more than 75% of the time). The level of motivation among farmers in Kampar Regency to follow IPM principles is classified as low, with an implementation rate of 25-50%. In contrast, the other three regencies have a moderate level of motivation, with an implementation rate of over 50-75%. These findings indicate that farmers in Siak, Bengkalis, and Rokan Hilir Regencies are highly

motivated to adopt IPM technology on their farmland in order to expand their enterprises and fulfil their family's requirements.

**Table 2.** The motivation of respondent farmers in implementing IPM principles.

Regency	IPM Components	Level of implementation (%)			
		Very Low	Low	Moderate	High
Kampar	Healthy plant cultivation	19.34	33.70	29.28	17.68
	Utilisation of natural enemies	24.86	40.34	24.86	9.94
	Periodic observation	24.86	35.37	29.83	9.94
Average		23.02	36.47	27.99	12.52
Siak	Healthy plant cultivation	6.95	24.06	39.04	29.95
	Utilisation of natural enemies	19.79	25.67	39.57	14.97
	Periodic observation	11.23	28.88	43.32	16.57
Average		12.66	26.20	40.64	20.50
Bengkalis	Healthy plant cultivation	4.95	25.82	39.56	29.67
	Utilisation of natural enemies	20.33	28.02	40.11	11.54
	Periodic observation	12.64	29.67	41.76	15.93
Average		12.64	27.84	40.48	19.04
Rokan Hilir	Healthy plant cultivation	13.41	25.14	45.25	16.20
	Utilisation of natural enemies	20.11	34.64	35.75	9.50
	Periodic observation	17.88	34.64	32.40	15.08
Average		17.13	31.47	37.80	13.60
Riau Province	Healthy plant cultivation	11.17	27.18	38.28	23.37
	Utilisation of natural enemies	21.28	32.16	35.07	11.49
	Periodic observation	16.65	32.14	36.83	14.38
Average of Riau Province		16.36	30.49	36.73	16.42

Except for Kampar Regency, local wisdom traits also contribute significantly to the sustainability of the social component in the three regencies. Local wisdom is commonly understood as the indigenous knowledge that encompasses information and diverse approaches to address environmental challenges, fulfil food requirements, and develop community resilience in response to shifts in the natural and social surroundings. Local wisdom refers to fundamental understanding on the harmonious coexistence of humans and the environment.

The development of local wisdom is closely tied to the inherent capabilities of natural resources and the surrounding environment [29]. In addition, according to [30], the implementation of ecosystem management policies and strategies include the advancement of the socio-economic and cultural aspects of the community in order to achieve community well-being based on local knowledge. Local wisdom is a practical and educational approach that focusses on taking action to solve problems that are specific to a particular community or region. There is a belief held by certain individuals that adhering to traditional knowledge and practices would result in a bountiful harvest.

The significance of local knowledge as a law or rule is vital, considering its historical context and intergenerational transmission. Local wisdom refers to a set of fundamental principles and beliefs that are inherited and transmitted from one generation to another. These principles are expressed through religious practices, cultural traditions, and societal norms. The local knowledge and traditions of farmers when it comes to rice cultivation are intricately intertwined with their belief system. This consciousness can be implemented through diverse activities to avert different malfunctions. The farmers interviewed described the several types of indigenous knowledge and traditions they follow, such as relying on the Javanese calendar to decide when to plant crops and occasionally observing celestial bodies. Once the planting period has been established, the community usually carries out a customary ceremony, referred to as the prelude to entering the rice fields. During this event, all attendees fervently invoke Allah SWT, beseeching for a bountiful harvest.

Prior to descending to the rice fields, farmers engage in a religious ritual, beseeching the divine for improved outcomes and protection against adversities such as pests and diseases, thus augmenting rice yield. Prayers are usually led by religious experts from the local community, and are followed by a communal feast or an expression of thanks in the rice field area. This ritual symbolises the beginning of the rice planting season. After the rite is finished, farmers can continue their labour in the fields. During rice cultivation, farmers employ a traditional practice known as scarecrow utilisation. Scarecrows are strategically positioned around rice plants to deter avian pests from perching on them. Scarecrows are deployed during the grain filling phase of rice plants to effectively deter avian pests and minimise the potential loss of crops for farmers.

According to [31], [32], the utilisation of scarecrows can effectively reduce expenses for farmers in managing pests. In addition, [33] stated that the use of scarecrows to deter avian pests is not only cost-effective but also environmentally friendly. Respondent farmers also engage in a local tradition when they gather to pray and recite the Prophet's prayers before commencing the first harvest, which is then followed by a shared feast. Harvesting on Fridays is prohibited due to the community's belief that Friday is a highly auspicious day. Harvesting is prohibited at the death of a neighbour. Engaging in physical altercations is also prohibited. Uttering vulgar language is forbidden, as is offering charitable donations to the ground as a gesture of thanks to Allah SWT and nature.

Additional elements that contribute to the lack of sustainability of the social aspect in Kampar Regency include the educational level and consistent monitoring. The amount of education often impacts an individual's understanding. A higher level of education, encompassing both formal and non-formal education, directly influences one's attitude and their capacity to readily embrace new technologies. According to [27], [34], [35], the level of education has a significant impact on the speed of decision-making when it comes to embracing technology, particularly formal education. To address this issue, it is crucial to enhance human resource development in the agricultural sector by implementing more effective formal education policies, hence raising the educational attainment of farmers.

Enhancing non-formal education can effectively contribute to human resource development by enhancing farmers' understanding and expertise in environmental matters. State by [36], [37] that there is a direct correlation between the level of education and the adoption of environmentally sustainable behaviors. Cognitive training aims to equip individuals with the necessary skills to confront the ever-evolving obstacles encountered in life. Education plays a crucial role in upholding stability and continuity while also fostering a more promising future. The study's findings indicated that the education level of potential adopters and their family members was a significant factor in determining the rate at which adoption occurred. The average level of education of the farmers who participated in the survey is presented in Table 3.

**Table 3.** Average level of education of respondent farmers.

Regency	Education Level (number of people (%))			
	Elementary School	Junior High School	Senior High School	College/ University
Kampar	51.38	33.15	13.81	1.66
Siak	25.67	31.02	39.57	3.74
Bengkalis	28.57	24.73	40.11	6.59
Rokan Hilir	29.05	26.82	32.40	11.73
Average	33.67	28.93	31.47	5.93

Table 3 explains that (51.38%) of respondent farmers in Kampar Regency have graduated from elementary school, graduated from junior high school (33.15%), and graduated from high school (13.81%); only (1.66%) have completed a diploma/college. This description of farmer education levels reveals that the majority of respondent farmers in Kampar Regency still possess a low level of formal education and lack sufficient experience in formal learning. State by [21],

[38] that an individual's level of education can affect the individual's knowledge and ability to carry out a business activity. Increasing the knowledge and abilities of farmers can be done through non-formal education, such as courses, training, seminars, and seeking new sources of knowledge from various print and electronic media.

Non-formal education is a way to increase knowledge and develop thinking skills in understanding an innovation. Attending more training or seminar activities will increase knowledge and broaden its scope. The activeness and participation of farmers in seminars, training, farmer courses, and technical guidance related to integrated pest management innovations can be used to measure non-formal education. Participation in training and seminars can provide farmers with insights into innovations, enabling them to understand the benefits and applications of these innovations for the development of their farming business.

Periodic observation provides quite high sensitivity to the discontinuity of IPM in Kampar Regency. Periodic observation involves routinely identifying the condition of plants and land on their farmland every week, as part of plant protection activities. This includes collecting information on the population or level of OPT attacks, as well as the land conditions and factors that influence the development of these OPTs. Observations are carried out by the landowner farmers themselves, under the guidance of OPT observer officers. In this study, periodic observations were conducted by the respondents in the field, where they observed the soil, rice plants, natural enemies, and OPT. They then discussed the results of these observations and took appropriate actions. The concept of IPM that respondents need to observe is plant pest organisms, namely the types of pests and plant diseases that exist in rice plants, the condition of natural enemies, and plant development.

According to Table 2, the level of implementation of periodic observations in Kampar Regency is, on average, in the low category (35.37%), with implementation rates between 25% and 50%. It then moves to the medium category (29.83%), with implementation rates between 50 and 75%. Finally, it moves to the very low category (24.86%), with implementation rates below 25%, and finally, it moves to the high category (9.94%), with implementation rates above 75%. The results of this study indicate that farmer respondents in Kampar Regency do not yet have a strong motivation to implement periodic observations on their rice fields. This is because farmers feel it is difficult to carry out pest observations according to the guidelines [39].

The reasons why farmer respondents have not implemented periodic observations according to the recommended procedures are that farmers feel they do not have time, are not used to it, do not feel the need, and only add to activities and costs. Periodic observations are crucial for farmers, as they significantly impact the outcomes of the rice crops they cultivate. Periodic observations enable farmers to understand the condition of the rice field agro-ecosystem, particularly the presence of pest attacks and natural enemies. This knowledge enables farmers to promptly take preemptive and preventive actions if their analysis warrants them. Consequently, they require support from various related parties, including local government policies, extension workers, and pest observers in the field, to ensure the sustainable implementation of integrated pest management. This is in line with the research results of [35], [40], which state that the sustainability of a business is not only the responsibility of farmers but is also greatly determined by government policy.

### *3.3. Stress Value, Determination Coefficient, Monte Carlo Simulations, and the Impact of Errors.*

The accuracy of the configuration of a point that accurately represents the original data may be assessed by examining the stress value derived from the results of the RAP-PHT ordination analysis for each dimension studied. The sustainability of the system being researched can be assessed by examining the coefficient value ( $R^2$ ) of each dimension analysed, which indicates the extent to which each characteristic contributes to explaining the system's sustainability. The stress value and determination coefficient of the social dimension are displayed in Table 4.

**Table 4.** Stress value, determination coefficient, Monte Carlo and the influence of error.

Regency	Dimension				
	Index of sustainability (MDS)	S-stress	R <sup>2</sup>	Monte Carlo Analysis (MC)	Differences (MDS-MC)
Kampar	47.14	0.15	0.94	46.91	0.23
Siak	69.12	0.14	0.94	67.66	1.46
Bengkalis	60.13	0.15	0.94	59.30	0.83
Rokan Hilir	57.86	0.15	0.94	57.08	0.78
Index of Sustainability at Province level	58.56	0.15	0.94	57.74	0.82

Table 4 displays the S-stress value, which varies between 0.14 and 0.15. This indicates that the S-stress value obtained is less than 20%, suggesting that the output generated accurately represents the real condition. [15] indicated that the acceptable threshold for S-stress is below 20%. A lower stress value indicates a higher level of suitability for the model. Therefore, the model can be deemed satisfactory as the stress value obtained does not exceed 15%. The mean correlation coefficient (R<sup>2</sup>) value in this study was 0.94. The R-square value is approaching 1, indicating a higher degree of flawless mapping of the existing data. This result demonstrates that 94% of the attributes evaluated for each dimension have the ability to elucidate and contribute 94% to the sustainability of the system under investigation; the remaining 6% is accounted for by other factors. [15] asserted that a strong squared correlation (R<sup>2</sup>) value is one that exceeds 80% or approaches 100%.

The statistical test findings demonstrate that the RAP-IPM approach is sufficiently effective to be utilised as a tool for quantitatively and expeditiously assessing the sustainability of IPM implementation in lowland rice (rapid appraisal). [41] suggest that Monte Carlo analysis is a simulation technique that can be employed to assess the influence of random mistakes in statistical analysis. The RAP-IPM study results are considered satisfactory, as the validation test results showed a little discrepancy in the sustainability index value between the Monte Carlo values of 0.23 and 1.46, suggesting a difference of less than 5 points. This figure indicates that the influence of errors in scoring is generally insignificant. The RAP-IPM model has been deemed suitable for estimating the value of the sustainability index in lowland rice while using integrated pest management.

#### 4. Conclusions

The social dimension index and sustainability status of Integrated Pest Management (IPM) in Riau Province, which is 58.56%, show that it falls within the category of fairly sustainable, as it exceeds the threshold of 50%. Kampar Regency has a sustainability status index of 47.14%, which places it in the less sustainable group. On the other hand, the Regencies of Siak, Bengkalis, and Rokan Hilir have a sustainability status index greater than 50% and are therefore considered to be in the fairly sustainable category. The key factors that significantly contribute to sustainability are participation in training programs, practical experience in agriculture, farmers' strong motivation to follow Integrated Pest Management (IPM) principles, utilization of local knowledge to manage pests and diseases.

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