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Analysis of the Sustainability of Integrated Pest Management Technology of Rice Field in The Riau Province

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Abstract. This research was conducted from February to June 2024 in the rice field farming areas of Riau Province in four selected districts, namely Kampar, Siak, Bengkalis and Rokan Hilir Regencies. The location selection was carried out intentionally based on the placement of the national Integrated Pest Management (IPM) program for rice fields in Riau Province. Determination of respondents using the Slovin formula with a margin of error of 7 percent of the population of farmer households in each district. Data analysis using the Rapid Appraisal program with the Multi Dimensional Scaling (MDS) method. The purpose of the study was to determine the index and sustainability status and what attributes are most decisive for the sustainability of the integrated pest management technology dimension of rice fields in Riau Province. The results of the study showed that the index and sustainability status of the technology dimension of Kampar Regency (44.05%), Siak (48.01%), Bengkalis (45.17%) and Rokan Hilir (44.11%). In general, the index and sustainability status of IPM technology dimension in Riau Province (45.34%), meaning it is included in the less sustainable category (<50). The most determining attributes for sustainability are chemical, mechanical, biological control, combination of control, weed control and technical culture. The maximum stress value for all districts is 0.15 with a Correlation result of 0.94.

1. Introduction

Rice as one of the most widely consumed food crops in the world is a commodity whose sustainability needs to be considered. In Indonesia, the level of rice consumption is still high, namely 83.14 kg/capita/year, in Asia 77.2 kg/capita/year [1]. The current trend is an increase in food consumption along with the increasing population and economic growth.

Increasing national food production is done through intensification and extensification, especially in rice. Several programs and strategies have been implemented both nationally and regionally, including through the Special Efforts to Increase Rice, Maize, and Soybean Production, Integrated Plant Management Field School, and Integrated Pest Management Field School. The presence of pests and diseases is one of the obstacles in the program to achieve the expected production.

Pest and disease management has been widely carried out, but at the farm level farmers generally still use synthetic insecticides that candamage non-target organisms, pest resistance, pest recurrence, the emergence of secondary pests, and cause residual effects on plants and the environment [2] and [3]. According to [4], [5], plant disease pests are dynamic, their development is influenced by the biotic environment (plant growth phase, pressure changes that occur in the host, other organism populations) and abiotic (temperature, humidity, rainfall, season, agroecosystem). Climate change, plant stadia, cultivation quality, cropping patterns, the presence of natural enemies and control methods are the dynamics of pest and disease development [6]. One of the efforts to maintain food crop production in overcoming pest attacks is through IPM.

The concept of IPM is a concept that leads to sustainable agriculture. Sustainable agriculture is built with an approach that can maintain high agricultural production and profits without causing environmental damage [7], [8]. The goal of sustainable development is to improve the quality of human life in various aspects of life, so the concept of sustainable development is an effort to integrate 3 aspects of life, namely ecological, economic, and social aspects in a synergistic relationship [9], [10], [11]. Furthermore, [12], [13], [14], added a sustainable agricultural system with technological and institutional aspects.

The implementation of this subsystem requires the implementation of sustainability attributes. Sustainability attributes cover 5 dimensions, one of which is the technological dimension. Technologically, this activity is expected to be able to adopt agricultural technology faster through better infrastructure support. The sustainability index and status are assessed using the multi-dimensional scaling (MDS) method using Rapfish software modified into Rap-IPM. The Rap-IPM method can quickly and accurately describe the condition of technology utilization and management in a region, so that it can be used as an indicator of sustainable development performance. The implementation of this method is expected to be able to describe the dimensions of integrated pest management technology for lowland rice fields in Riau Province. The purpose of the study was to determine the sustainability index and status and what attributes are most decisive for the sustainability of integrated pest management technology for lowland rice fields in Riau Province.

2. Research Methods

This research was conducted in Riau Province in four selected districts, namely Kampar, Siak, Bengkalis and Rokan Hilir. The location selection was carried out intentionally (purposive) based on the placement of the national rice field IPM program in Riau Province from February to June 2024.

The materials and tools used were stationery, interview guide questionnaires, Rapfish software, data processing tools, and other supporting materials.

The types of data required in this study consist of primary data and secondary data. Primary data were collected using a survey method using interview techniques and direct observation in the field. Interviews with respondents using interview guides Secondary data were collected from various sources such as research reports, scientific research journals, proceedings, research institutions, universities and reports from related agencies/agencies.

The determination of respondents from the community was carried out by purposive sampling, with criteria that could represent, namely farmers who had attended IPM training or FS-IPM schools related to rice field farming. The number of research respondents was 729 people, the determination of respondents was carried out with a margin of error of around 7 percent of the total population of rice farmers in each selected district.

Determination of the number of research samples is calculated using the Slovin equation in [NO_PRINTED_FORM] [15] using the following equation:

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

Description:
n = number of samples
N = number of population

a = percentage error

The sustainability status of the social dimension is expressed in the form of a sustainability index based on the Rap-PHT approach by applying the MDS technique [16], [17]. The Rap-PHT approach is modified from the Rapfish (Rapid Assessment Techniques for Fisheries) program developed by the Fisheries Center, University of British Columbia [18]. According to [15], the MDS technique maps two points or the same objects in one point that are close to each other, conversely different objects or points are depicted by points that are far apart. Furthermore, the attributes that are estimated to most influence the sustainability of the technology dimension are arranged, the existing attributes are given a score based on the scientific judgment of the scorer. The score range ranges from 0-4 or depends on the condition of each attribute, which is interpreted from bad to good. The score results of each attribute are analyzed multidimensionally to determine one or more points that reflect the sustainability position, the development of sustainable management that is studied relative to two reference points, namely *the good point* and *the bad point*.

The definitive score is the mode value, which is analyzed to determine points that reflect the sustainability position of the system being studied relative to good and bad points with the MDS statistical ordination technique. The estimated score of each dimension is expressed on a scale from the worst 0% to the best 100%. The range of sustainability score values is: bad (0.00-25.00%), less (25.01-50.00%), sufficient (50.01-75.00%), and very good (75.01-100.00%). Another result obtained in the MDS analysis is the determination of leverage factors which are strategic factors of IPM in the future [17].

3. Results and Discussion

3.1 The index and status of technology sustainability

The attributes that are estimated to have an influence on the technology dimension are technical cultural control, use of resistant varieties, physical, mechanical, biological, chemical control, weed control and combination of control. The index and sustainability status of IPM for rice field against the technology dimension can be seen in (Figure 1).

The results of the MDS analysis (Figure 1) show that the technology dimension for the Regency (Kampar 44.05%, Siak 48.01%, Bengkalis 45.17% and Rokan Hilir 44.11%). This means that all regencies are included in the criteria for less sustainable because they have a value (<50%). Figure 1 explains that the technology dimension has not provided support for the sustainability of IPM for lowland rice in Riau Province. To optimize the sustainability of lowland rice farming, the development of the technology dimension needs to be improved, because at present technology is one of the requirements for achieving increased production. According to [19], technology is a whole method that rationally leads and has the characteristics of efficiency in every field of human activity.

Technology is the development and application of tools, machines, materials and processes that help humans solve their problems and is a process that increases the added value of a product, including fertilizer technology, varieties, irrigation, weed control and pest and disease control. The results of the study showed that a technology will be quickly accepted by farmers if the application of the technology provides economic benefits; in accordance with the local social environment; in accordance with the physical environment; has ease of application; saves labor and time and does not require large costs in its application. The application of various components of IPM technology requires good application so that the technology can be applied correctly, on target, effectively and profitably, so that the goal of increasing optimal production that is safe for consumption by realizing the sustainability of agricultural resources can be achieved in a sustainable agricultural system.

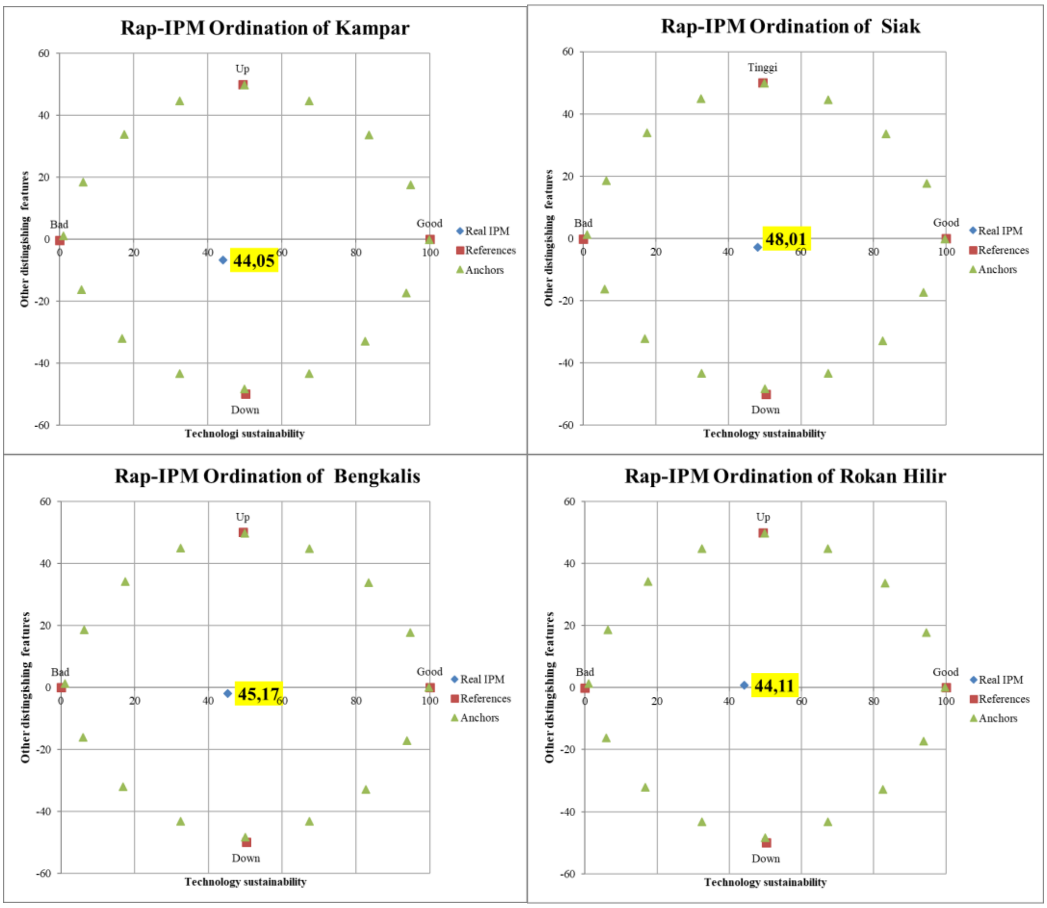

Figure 1. Index and status of sustainability of technology dimensions in four districts in Riau Province

3.2 Leverage Analysis

Rap-IPM analysis, in addition to obtaining the sustainability index, also produces output in the form of leverage of attributes. Leverage analysis aims to see sensitive attributes that influence the sustainability index value of all dimensions, as stated by [20] that the root mean score (RMS) value indicates the magnitude of the role of each attribute in the sensitivity of sustainability status. This means that the higher the RMS value, the greater the influence or role of the attribute in the sensitivity of sustainability. Leverage attributes are attributes that provide the highest percentage value in the sustainability of a management dimension (Figure 2).

The results of the leverage analysis (Figure 2) explain that the attributes that provide high sensitivity for the technology dimension are chemical control, mechanical control, biological control, weed control, technical cultural control and a combination of control. This means that apart from physical control and the use of resistant varieties, all attributes tested in the technology dimension are sensitive factors to the discontinuity of the technology dimension in Riau Province. This is because in controlling weeds and plant pests and diseases, farmers' main choice still relies on chemical pesticides. In fact, control that always uses chemical pesticides is a major problem in the agro-ecosystem.

Continuous use of chemical pesticides causes negative impacts on the biotic environment, health problems for users of inorganic agricultural products [2], pests become resistant to pesticides [21], kills pest predators [6], and health problems for farmer workers [22]. The use of chemical pesticides continues to increase from year to year because of their practical use and the results are quickly seen by farmers, but their use can incur high costs in agricultural businesses which have an impact on reducing the profits received by farmers.

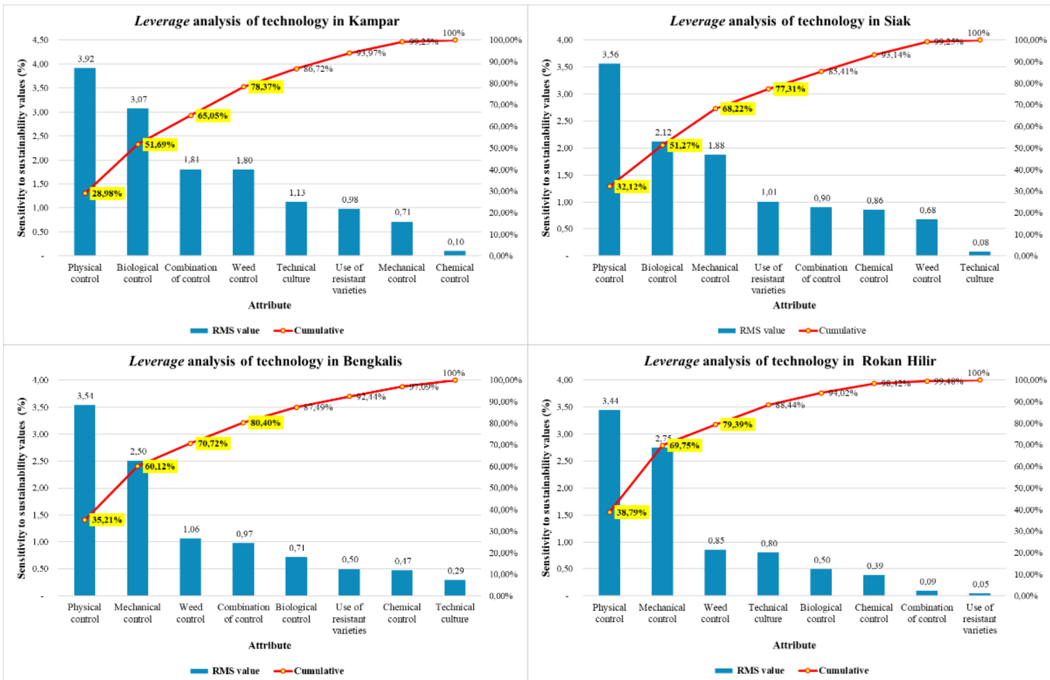

Figure 2. The role of each attribute of the technology dimension in four districts in Riau Province expressed in the form of RMS values.

According to [23] and [24] there are two practical ways to control pests and plant diseases without causing biotic environmental damage and without reducing human health in consuming agricultural products, namely by using biological agents and utilizing natural materials as botanical pesticides or better known as biological control. However, to implement the use of biological agents and botanical pesticides (in controlling pests and diseases in rice fields, respondent farmers are still somewhat reluctant, because the application of biological agents and botanical pesticides does not guarantee being free from pests. Farmers do not want to speculate on adopting pest and disease control with IPM which is technically more difficult, because there is no guarantee of being free from pests.

Plant pest and disease control using plant pesticides and biological agents, according to respondent farmers, requires patience and persistence in making it, while farmers are accustomed to farming instantly through conventional pest and disease control. The use of plant pesticides must be further developed because it has several advantages, including the materials used are easy to obtain and in their application do not poison plants. According to [25] and [26] the development of plant pesticides has advantages including being environmentally friendly, cheap and easy to obtain, does not poison plants, is compatible when combined with other controls and produces agricultural products that are free from pesticide residues. However, farmers do not want to bother to make and apply biological agents and plant pesticides, farmers prefer to use chemical pesticides that are ready to use, more practical, and provide a faster reaction, compared to biological or mechanical control.

Mechanical control aims to kill or move pests directly either by hand or with the help of other tools and materials. Mechanical control methods need to study pest phenology, feeding behavior and pest distribution. This needs to be done considering that each type of pest has a tolerance to physical environmental factors such as temperature, humidity, sound, light, and others. Without complete knowledge of the biology and ecology of a type of pest, we are likely to spend a lot of money, time and energy but only a few pests are killed or caught.

Mechanical control can be done by taking them directly by hand, by fumigating, by smoking, and by setting traps, traps are given chemicals that can attract or attach or kill pests. Another method is to apply expulsion techniques, namely by expelling pests that are in the plantation or that are heading to the plantation. This method is carried out by respondent farmers by making a scarecrow in the middle of the rice field, or installing colorful or shiny ropes, all of which are to scare and repel birds that usually attack ripe rice grains..

Technical culture control is one of the inhibiting factors for the sustainability of the technological dimension in Bengkalis Regency. Technical culture control is preventive in nature, it is the control of Plant Pest Organisms by managing the plant environment in such a way that it is less suitable for the life and reproduction of Plant Pest Organisms. Control activities through technical culture include sanitation by cleaning the planting area from various plant residues, and wild grass or weeds. Carrying out perfect soil cultivation, good and regular water management, implementing simultaneous planting, arranging planting distances with the jajar legowo system, planting trap crops and planting resistant varieties.

The combination of control is a factor inhibiting the sustainability of the technology dimension for the four districts. The combination of control is a strategy that combines efforts to reduce the population of pests and diseases with several control techniques. This strategy is considered beneficial because if one technique fails, other techniques can help control the pests. In addition, the level of effectiveness of a control technique can be increased if used together with other control techniques. This statement is in line with the results of research by [27] who stated that new technology in rice cultivation is substitutive or supplementary to existing native technology, therefore it is almost never the case that new technology replaces all native technology that is adaptive to specific agroecology, therefore new technology must be compatible with existing native technology components.

3.3 Stress values, coefficient of determination, Monte Carlo and error effects

The ability of each attribute to explain and contribute to the sustainability of the system being studied is by looking at the coefficient value (R^2) of each dimension being analyzed. The stress value and coefficient of determination of the technology dimension are presented in Table 1. The accuracy of the configuration of a point that reflects the original data can be measured by looking at the stress value from the results of the Rap-IPM ordination analysis of the dimensions being analyzed.

Table 1. *Stress* values, coefficient of determination, *Monte Carlo* and error effects

Regency	Technology				
	MDS	S-stress	R^2	Monte Carlo	MDS-MC
Kampar	44.05	0.15	0.94	43.81	0.24
Siak	48.01	0.15	0.94	47.82	0.19
Bengkalis	45.17	0.15	0.94	44.93	0.24
Rokan Hilir	44.11	0.15	0.94	43.96	0.15
Sustainability index of Riau	45.34	0.15	0.94	45.13	0.21

Table 1 shows the S-stress value of 0.15. This means that the S-stress value obtained is <20%, meaning that the output produced can describe the actual situation. [28] stated that the tolerable S-stress value is <20%, the lower the stress value, the better/more suitable the model is. Thus, the model can be accepted well because the stress value obtained is a maximum of 15%. The Correlation (R2) results in this study averaged 0.94. The R-square value is getting closer to 1, meaning that the existing data is mapped more perfectly. This value illustrates that 94% of the attributes assessed for each dimension are able to explain and contribute 94% to the sustainability of the system being studied, the remaining 6% is explained by other factors. Pitcher et al. (2013) stated that a good Squared Correlation (R2) value is greater than 80% or close to 100%.

The parameters of the statistical test results indicate that the Rap-IPM method is good enough to be used as one of the tools for evaluating the sustainability of rice field IPM implementation quantitatively and quickly (rapid appraisal). According to [20], Monte Carlo analysis can be used as a simulation method to evaluate the impact of random errors in statistical analysis. The results of the Rap-IPM analysis are acceptable considering that the results of the validation test obtained a difference in the sustainability index value with the Monte Carlo value of 0.15 to 0.24 which shows a very small difference (less than 5. This means that the Rap-IPM model for the implementation of integrated pest management in rice fields is declared adequate as an estimator of the sustainability index value.

4. Conclusions

The index and sustainability status of IPM for the technology dimension in Riau Province (45.34%) are included in the less sustainable category (<50%). The index and sustainability status of the technology dimension for the Regency (Kampar 44.05%, Siak 48.01%, Bengkalis 45.17% and Rokan Hilir 44.11%), meaning that all regencies are included in the less sustainable category (<50%). The most determining attributes for the unsustainability of the technology dimension are chemical control, mechanical control, biological control, weed control, technical cultural control and a combination of control.

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