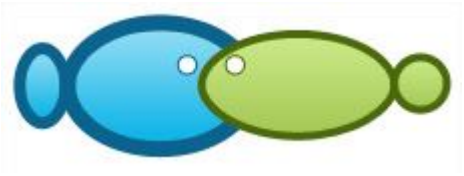

Sustainability assessment of swamp ecosystem management in Sawah village, Kampar Regency, Riau

[1]Nur El Fajri, [2]Sukendi, [2]Syafriadiman, [3]Windarti, [4]Muhammad Yusuf

[1] Department of Environmental Science, University of Riau, Riau, Indonesia; [2] Department of Aquaculture, Faculty of Fisheries and Marine, University of Riau, Riau, Indonesia; [3] Department of Aquatic Resources Management, Faculty of Fisheries and Marine, University of Riau, Riau, Indonesia; [4] Department of Agrobusiness, Faculty of Fisheries, Cokroaminoto University of Makassar, Makassar, Indonesia. Corresponding author: M. Yusuf, yusufhalim2014@gmail.com

Abstract. This present work aimed at discussing sustainability state and determine leverage factors for basis of composing management of swamp ecosystem sustainability in Sawah Village, Riau. Multidimensional Scaling (MDS) analysis was applied with aid of Rapid Appraisal for Fisheries (Rapfish) software, then properly modified as "Rapid Appraisal for Swamp" (Rap-Swamp), with identified attributes among 5 dimensions: ecology, economy, social, institution, and technology. As a result, the sustainability was evaluated according to the index, as follows: ecologic (44.89%, less sustainable), economic (49.89%, less sustainable), social (45.35%, quite sustainable), institutional (43.38%, less sustainable), and technological dimension (74.92, quite sustainable). The study also successfully identified 9 leverage factors, including; 1) carrying capacity, 2) dependence on swamps as a source of income, 3) economic benefits of the swamp, 4) local wisdom, 5) community's perception towards environment, 6) monitoring, 7) management rules, 8) management institution, and 9) swamp cultivation. The model constructed was analyzed for its validity, by comparing the sustainability index with Monte Carlo index, resulting in index difference of < 5%. This suggested that the model was valid. Furthermore, stress value was found between 13.85 and 17.02%, being a statistical indicator for acceptable model (< 20%). Goodness of fit test showed R-squared close to 1, meaning that the model could best estimate the sustainability.
Key Words: management, swamp, ecosystem, sustainability, Rap-Swamp.

Introduction. Natural resource management principally constitutes a planned, systematic, and integrated effort in utilizing the resource for achieving social welfare while also maintaining its sustainability (Yusuf et al 2016). As issued in Law No. 32 of 2009 (KLHK 2010), environmental protection and management is defined as a systematic and integrated act for sustaining the environmental benefits and preventing contamination and/or environmental degradation through means of planning policy, rational exploitation, development, maintenance, supervision, and law enforcement. Meanwhile, sustainable development refers to a designed and planned attempt through combination of many aspects such as environment, social, economic integrated with development strategies for ensuring environmental health, while also considering safety, capability, prosperity, and quality of future generation (Dahuri 2004). Hence, there is an essential need for investigation of current development sustainability status, regarding the importance of natural resource services for future sustainable development (Diesendorf 2001).

Sustainable development is designed to meet the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). Shortly, it can be defined as an attempt for comforming present needs without disturbing capability of future generations for satisfying their needs. Sustainability is actually a simple concept, but complex; thus, the exact definition can be constructed from multidimensional and multi-interpretating views. Fauzi (2004) described two dimensions

of sustainability concept i.e. (1) temporal dimension, linked to comprehension of the possible long-term impacts of our actions, and (2) interaction between triple points: economic, natural resources, and environment.

Regarding to management of swamp ecosystem especially in Sawah Village, further studies are needed mainly focusing on sustainability of the swamp ecosystem management connecting relevant dimensions as follows: ecology, economy, social, technology, and institution. The importance of sustainability for swamp ecosystem management is associated with its significant role as buffer zone, catchment area, raw material supplier, pollution absorber, and while also generating other services such as fisheries, agriculture, and tourism. The many functions of the swamp ecosystem make it vulnerable to natural resource degradation, impacts and conflicts. Besides that, sustainable management is expected to prevent environmental damage and eliminate conflicts over utilization. This is in accordance with Daris et al (2019, 2020) that natural resources must be managed in a sustainable manner so that conflicts do not occur in their use. This present work aims to assess the sustainability of swam ecosystem management in Sawah Village according to 5 dimensions: ecology, economic, social, institution and technology by using Multidimensional Scaling (MDS) analysis with aid of Rapid Appraisal for Fisheries (Rapfish) software, then modified as "Rapid Appraisal for Swamp" (Rap-Swamp).

Material and Method. The study was conducted in Sawah village, Sub-district of North Kampar, Regency of Kampar. The method of data collection in this study was carried out by field observation, measurement, sampling and survey using a questionnaire. Data collection methods are techniques or methods used to obtain data for further processing and obtaining new information (Nazir 2004; Yusuf & Daris 2018). The data collected consists of primary and secondary data. Primary data were collected from field observation, measurement, sampling, and questionnaire (Nasution 1996), while secondary data were obtained from relevant governmental agencies.

In this case, MDS analysis using Rapfish software was carried out. The use of MDS approach enabled to elucidate similarities and dissimilarities between individual pairs and variables (Young 1987). Van Sickle (1997) argued that MDS was able to present ordination method effectively. The stages of our study were elaborated as follows:

- determining attributes for sustainability management of swamp ecosystem covering 3 dimensions, i.e. ecology, economic, and social. 1) Assessing the attribute using ordinal scale for each dimension, 2) Constructing index and status of sustainability, 3) Each attribute was scored at range of 0-5 (represented as bad to good) according to scientific judgment;
- the score was then analyzed using MDS approach to identify point(s) capable of representing the current state of sustainability. The definite score is modus value, enabling to determine points that reflect the present state of the sustainability studied over "bad" or "good" points by using MDS ordination method. The estimated score of each dimension was expressed between worst scale ("bad", 0%) to the best (good, 100%). Table 1 represents the score for sustainability index of each dimension.

Table 1

Category for sustainability of swamp ecosystem management in Sawah Village

Index value	*Category*
0.00-25.00	Bad (poor sustainable)
25.01-50.00	Low (less sustainable)
50.01-75.00	Sufficient (quite sustainable)
75.01-100.00	Good (very sustainable)

The application of MDS allows to visualize the points in horizontal and vertical axis. When rotated, position of the points can be visualized in horizontal axis, enabling to display sustainability score as depicted in Figure 1.

Furthermore, the sustainability index of each dimension can be visualized in one graph using a kite diagram, as illustrated in Figure 2.

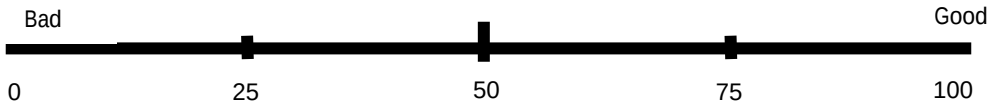

Figure 1. Horizontal axis illustrating the sustainability index in ordination scale.

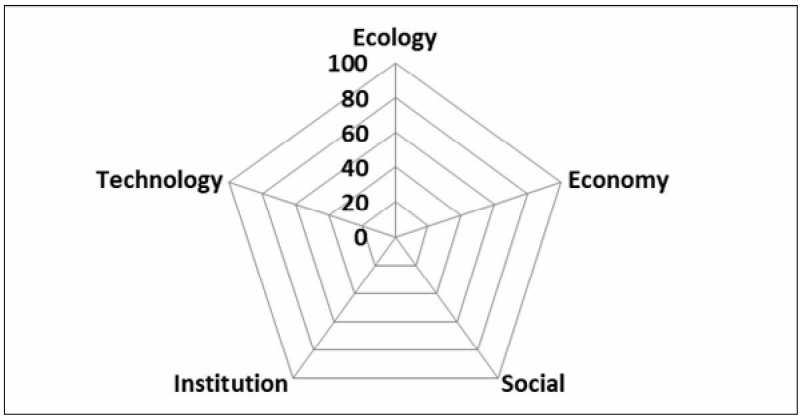

Figure 2. Kite diagram illustrating sustainability index for each dimension.

Sensitivity analysis was carried out to determine the attribute that most affects sustainability index, based on the changes in Root Mean Square (RMS) of ordination on X axis. The value of RMS positively relates to sensitivity of the attribute.

Monte Carlo simulation can be used to estimate errors. As described by Kavanagh & Pitcher (2004), Monte Carlo error analysis also enables to investigate:

1. the impacts of scoring error due to imperfect knowledge of conditions of the study site or misunderstanding of the attributes and scoring procedures;
2. the impacts of scoring variation caused by dissimilarities of opinion or judgement;
3. the stability of MDS analysis for successive operation (iteration);
4. data entry errors or missing data;
5. high stress value of Rap-swamp analysis result (acceptable stress value is < 25%).

In this current work, Rap-swamp was applied according to modified version from Alder et al (2000) and Fauzi & Anna (2005). The flowchart of analysis was depicted in Figure 3.

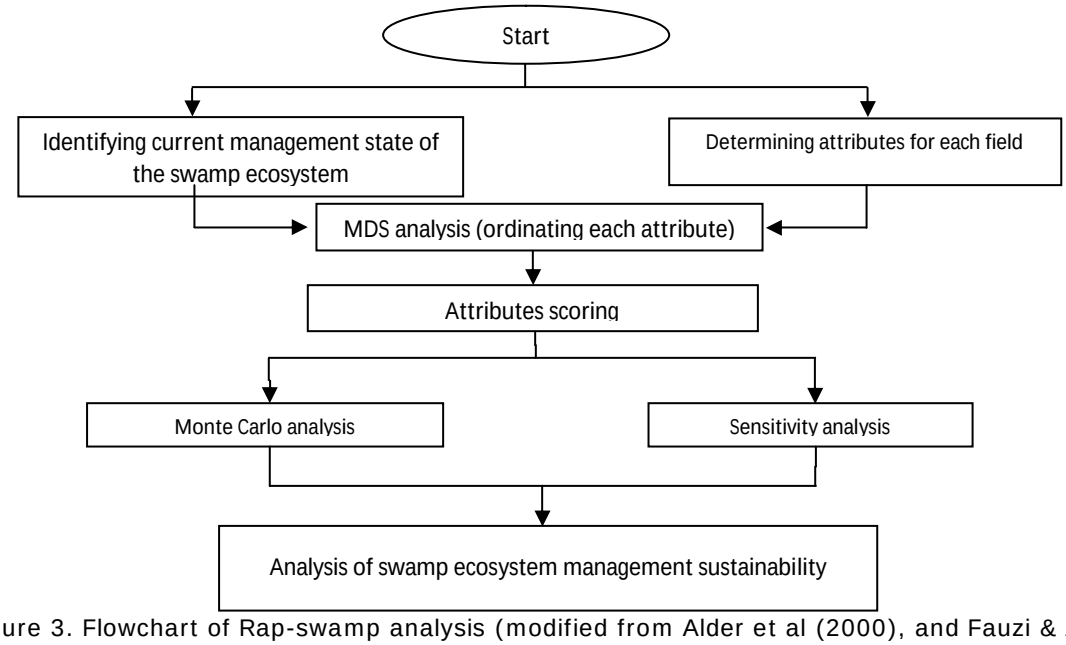

Figure 3. Flowchart of Rap-swamp analysis (modified from Alder et al (2000), and Fauzi & Anna (2005)).

Result and Discussion

Ecological dimension. The results showed that sustainability value for ecologic dimension was 44.89% (Figure 4). Management for swamp ecosystem sustainability in Sawah Village is less sustainable, indicating that the present attempts are less effectively carried out. Location observation indicates that there is depletion in ecosystem health, mainly caused by the rising of human settlements in swamp area.

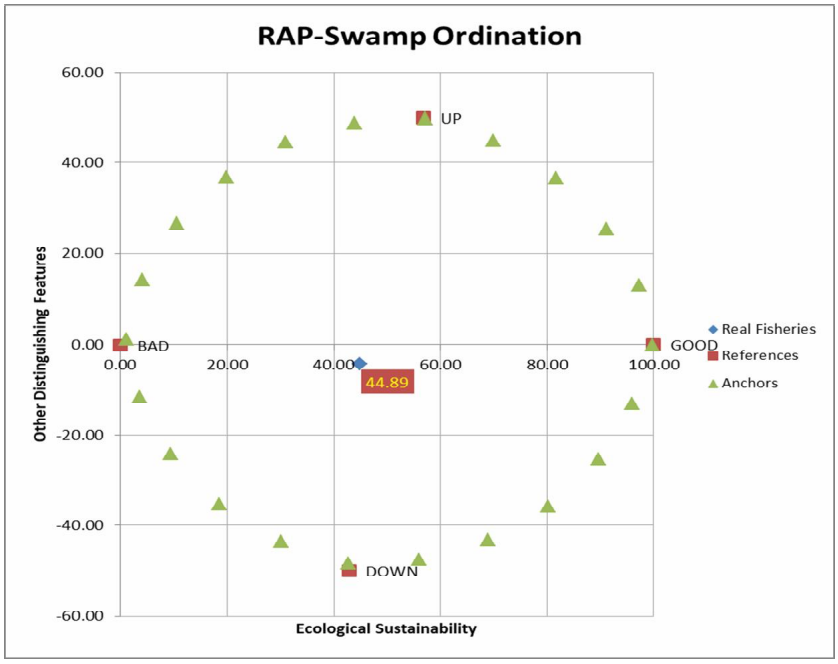

Figure 4. Sustainability index of ecological dimension.

The index value obtained for ecologic dimension was less sustainable. Furthermore, leverage analysis was conducted to examine which attributes most influence the ordination, and found that the most sensitive attribute was the carrying capacity (Figure 5). This condition demonstrates a situation in which swamp ecosystem in Sawah Village is highly susceptible to human activities in land.

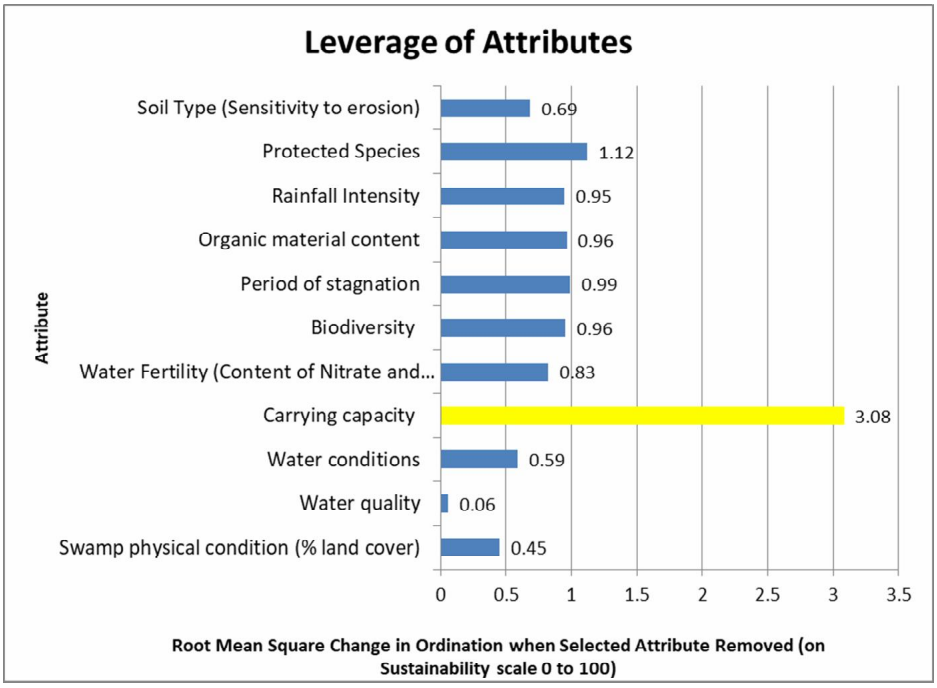

Figure 5. Attribute leverage of ecological dimension.

Figure 5 indicates that carrying capacity is a very sensitive attribute. The state of carrying capacity can be examined through availability of raw materials and energy, waste generation (and its managing activities), as well as interactions between living creatures on the ecosystem. In short, carrying capacity undoubtedly needs to cover physical, biological, and psycological aspects.

Economic dimension. Sustainability index for economic dimension was 49.89% (Figure 6), grouped as less sustainable. This means that the management for swamp ecosystem sustainability is less satisfied and less effective in terms of economic view. The drawback is driven by imperfect attempts on occupying natural resources, without considering economic aspect. Such condition can be viewed from the high dependence of local people on swamp ecosystem services.

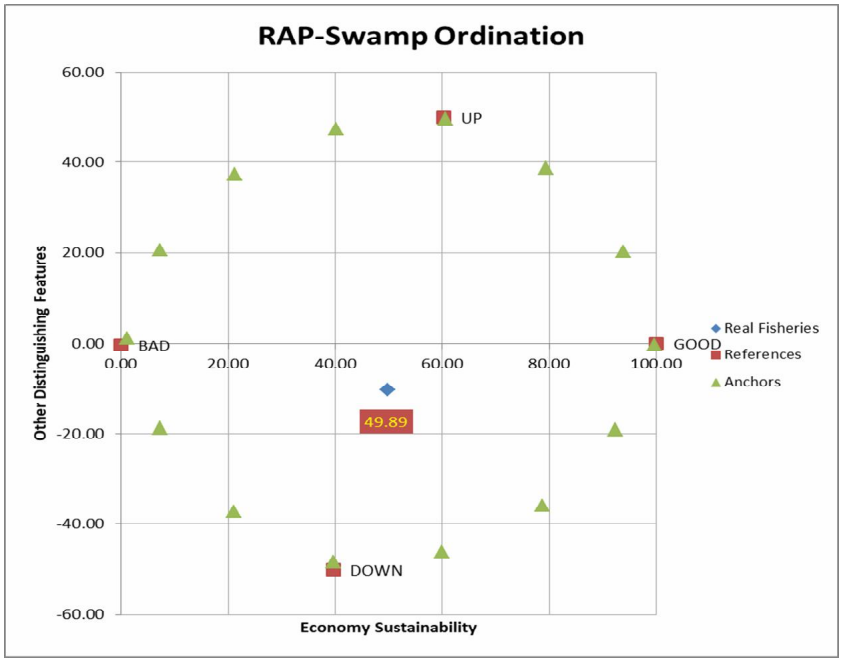

Figure 6. Sustainability index of economic dimension.

Figure 7 depicts the attributes that most contribute to sustainability index in terms of economic dimension.

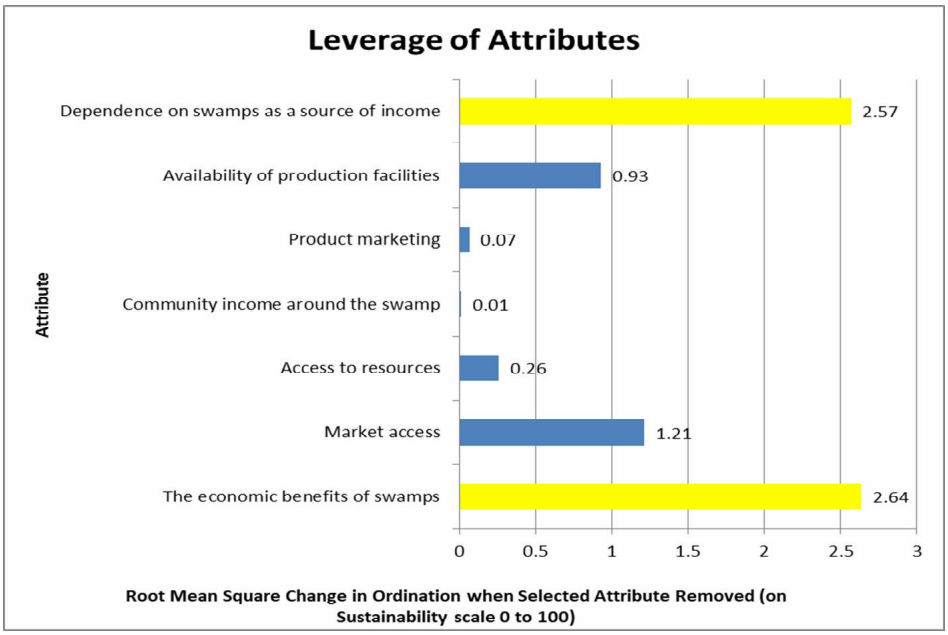

Figure 7. Attribute leverage of economic dimension.

They include (1) high economic dependence on swamp ecosystem, (2) economic benefits of swamp. This result clearly indicates that swamp ecosystem of the Sawah Village did not tremendously contribute to economic growth for local community. Currently, the benefits of the ecosystem for income source are very low. This closely relates to the reduction of carrying capacity of the swamp ecosystem. In this case, a dual concern needs to highlight, i.e. the rising dependence of local people on swamp ecosystem and the capability of the swamp ecosystem to completely fulfill their expectation.

Social dimension. Sustainability index for social dimension was recorded at 48.00% (Figure 8), indicating that the management for swamp ecosystem sustainability in terms of social field is less sustainable.

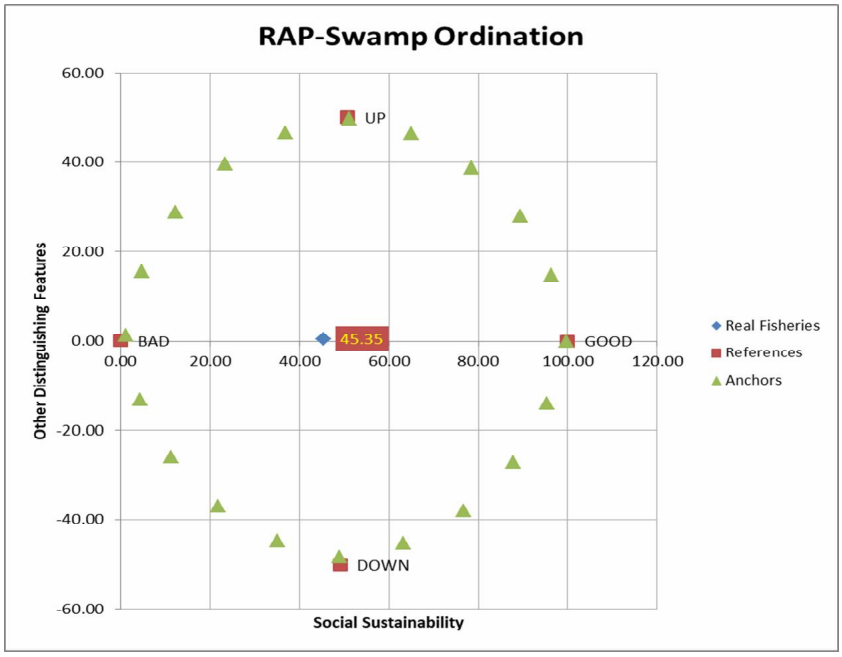

Figure 8. Sustainability index of social dimension.

As depicted in Figure 9, leverage analysis revealed that the most sensitive attributes included (1) local wisdom, (2) community's perception to environment, and (3) potential conflict. These attributes showed a great contribution to sustainability state of the swamp ecology management. Sustainable environment management can be achieved in presence of proper balance between the needs for natural resource and integrated system that manages environmental resources by local settlers or authorities. Local wisdom existing in the community can offer a brief view in how people protect their environment as essential assets not only for present use, but also for future. The local wisdom plays as a basis for sustainable utilization of environmental resource. For this reason, government needs to involve local wisdom as a referene in policy making process, resulting in a perfect combination between government and local community in achieveing the welfare.

Related to community's perception towards environment, it serves a crucial role in management of swamp ecosystem sustainability. Community with better knowledge on environmental stability also showed high awareness. Such social awareness is crucial for protecting the environment. Therefore, attempts for rising the awareness are required, including continuous extension services. The existence of swamp ecosystem should generate sources of livelihood for local settlers, as long as all forms of economic activities in the area are strictly regulated, enabling to eliminating potential conflicts or serious problems in future. The management is important for reaching sustainability of the swamp ecosystem.

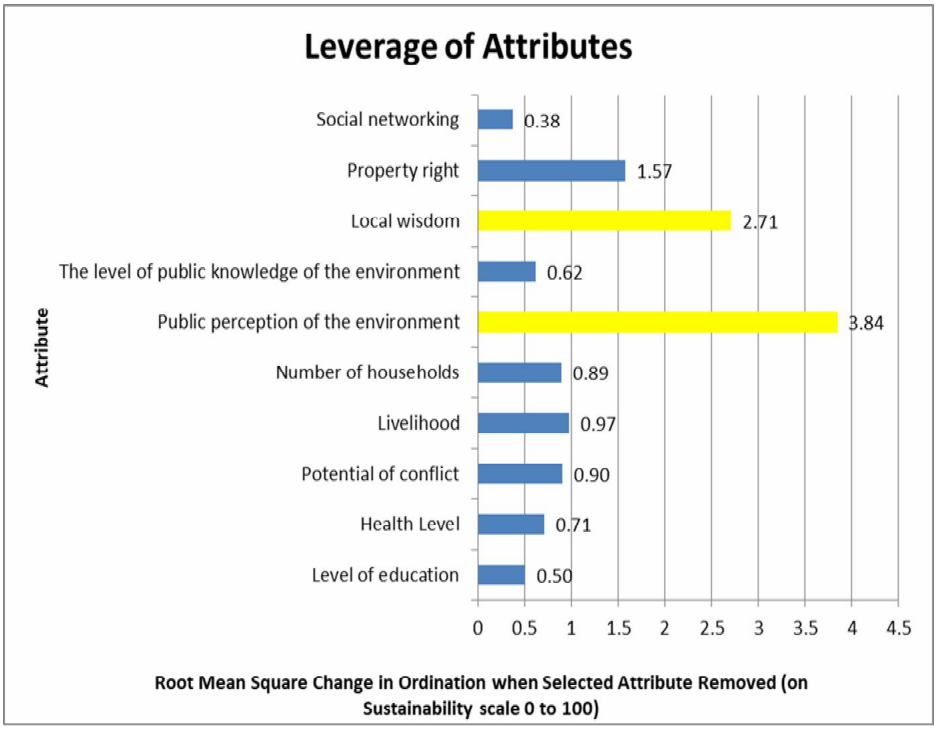

Figure 9. Attribute leverage of social dimension.

Institution dimension. Sustainability value for institution dimension reached 43.38% (Figure 10), which was classified as less sustainable. This suggests that insitution field for reaching sustainability of swamp ecosystem is not involved at best.

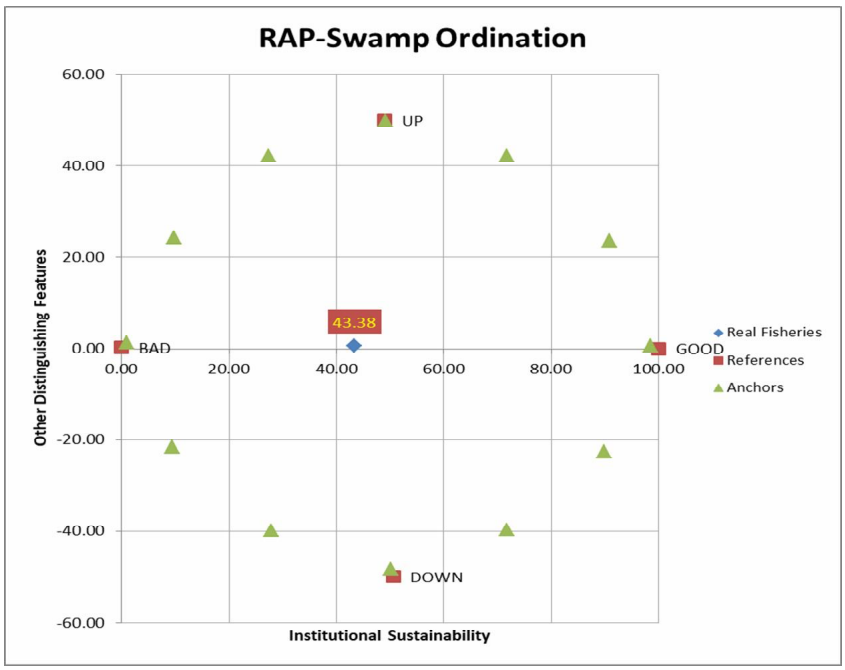

Figure 10. Sustainability index of institutional dimension.

Leverage analysis was performed to examine the most sensitive attribute. As the results, three attributes were recorded to show high sensitivity including monitoring activities, regulation for resource use, and institution for resource management (Figure 11).

Figure 11 depicts the result of leverage analysis, showing three most sensitive attributes, i.e. monitoring activities, regulation for resource use, and institution for resource management. Furthermore, our field observation and interview revealed that all three sensitive attributes are not found in the studied area. Therefore, authorities need to

seriously consider those attributes, allowing to enhance sustainability of swamp ecosystem.

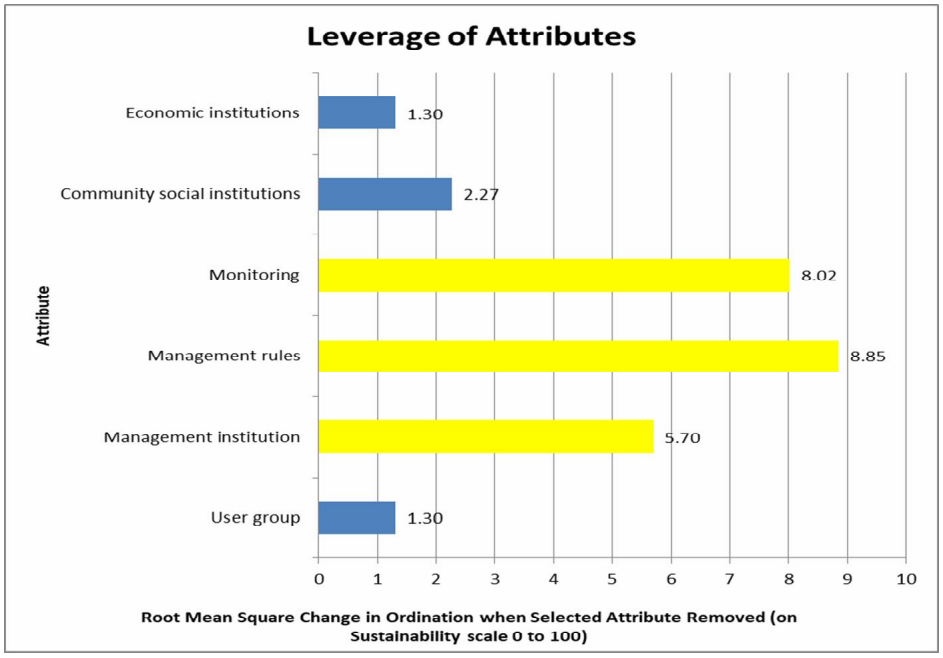

Figure 11. Attribute leverage of institutional dimension.

Technology dimension. Sustainability value for technological dimension in management of swamp ecosystem of Sawah Village was 72.48% (Figure 12). The index suggested that the sustainability management was technologically at "quite sustainable" level. This implies the efficacy of technological field, although improvement is still necessary to gain better impacts. The results of field observation revealed the depletion of enviromental quality in some aspects such as land conversion and highly intensive human activities in the swamp area. Additionally, aqueous plants covered more than 40% of total swamp area.

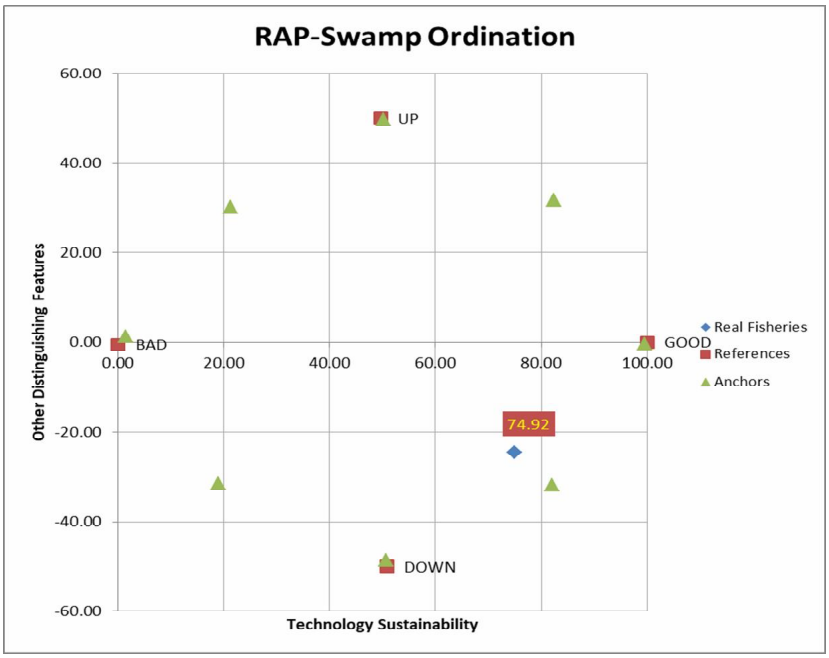

Figure 12. Sustainability index of technology dimension.

Furthermore, leverage analysis was performed to evaluate the most sensitive attribute contributing to the sustainability index value for technological dimension. The result suggests that swamp area management constitutes the most influential attribute (Figure 13). The swamp area was at good condition, but it constinuously declines as more intense activities on the land, thereby adversely affecting the carrying capacity and water quality in the swamp area.

Figure 13 demonstrates the high sensitivity of swamp area management attribute. However, it is noteworthy that the consideration of the carrying capacity on managing this swamp ecosystem has remained unclear. No available data discussed about the issue.

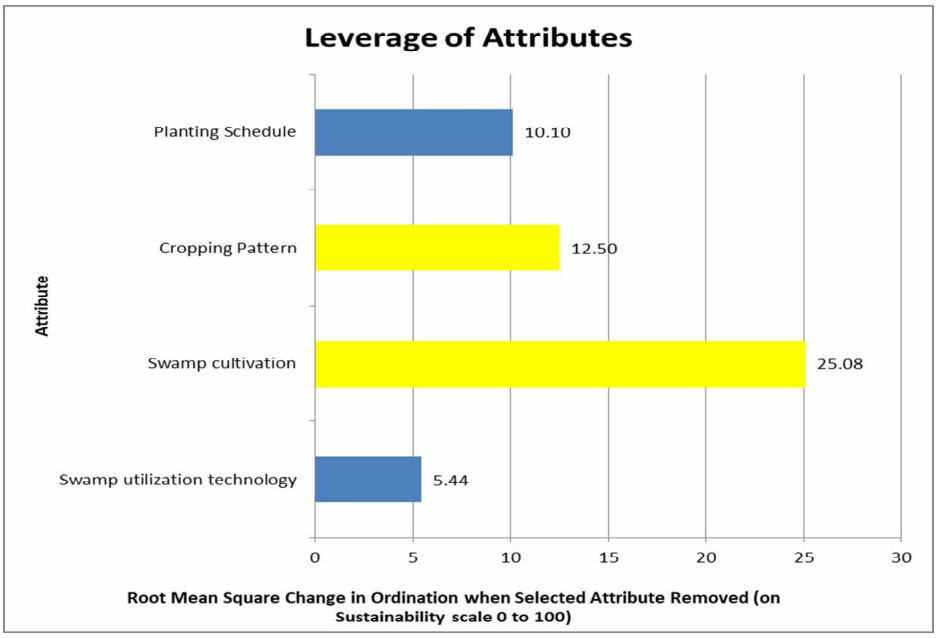

Figure 13. Attribute leverage of technology dimension.

Sustainability state. MSD and Rap-swamp analysis showed a variation on the category of sustainability for each dimension field (Table 2). The results were then expressed as kite diagram to visualize 5 dimensions in one graph (Figure 14).

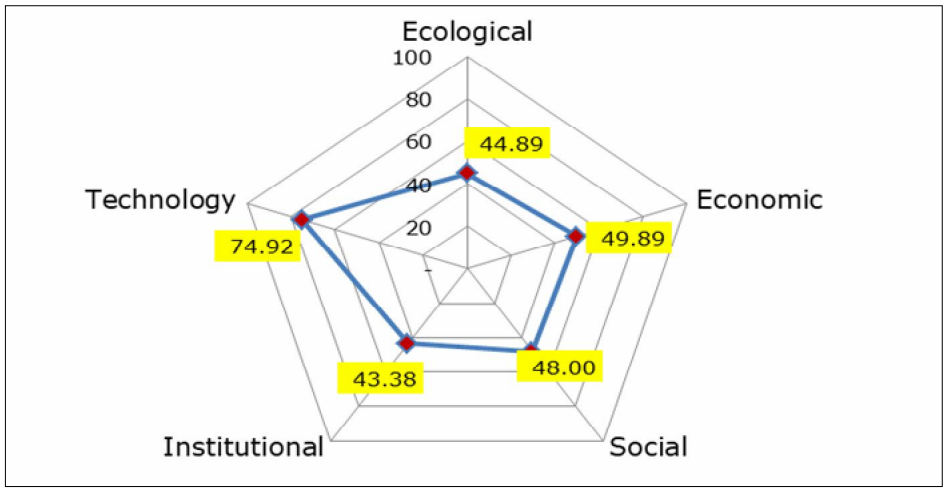

Figure 14. Kite diagram representing Sawah Village's swamp ecosystem sustainability scores in 5 dimensions.

Furthermore, the analysis released 9 determining factors for management of swamp ecosystem sustainability (Table 3). These factors are then used as the leverage for constructing the scenario of possible policies.

Table 2

Index value and sustainability status of swamp ecosystem in Sawah village

No.	*Dimension*	*Sustainability index*	*Category/Status*
1	Ecological	44.89	Less sustainable
2	Economic	49.89	Less sustainable
3	Social	48.00	Less sustainable
4	Institutional	43.38	Less sustainable
5	Technology	74.92	Quite sustainable

Table 3

Determining factors obtained from MDS & Rap-swamp analysis

No.	*Attributes*	*Dimension*
1	Carrying capacity	Ecology
2	High economic dependence on swamp ecosystem	Economy
3	Economic benefits of the swamp	Economy
4	Local wisdom	Social
5	Community's perception towards environment	Social
6	Swamp area management	Technology
7	Monitoring	Institutional
8	Regulation for resource use	Institutional
9	Institution for resource management	Institutional

Conclusions. This study concludes that the level of sustainability of swamps ecosystem management in Sawah village is classified as less sustainable with an average sustainability index value of less than 50%, consisting of; ecology (44.89%), economy (49.89%), social (45.35%), institutional (43.38%) and technological (74.92%). Thus, the level of sustainability of swamp ecosystem management in Sawah village must be increased by leverage of sustainability, including; 1) carrying capacity, 2) dependence on swamps as a source of income, 3) economic benefits of the swamp, 4) local wisdom, 5) community's perception towards environment, 6) monitoring, 7) management rules, 8) management institution, and 9) swamp cultivation.

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Authors:
Nur El Fajri, Department of Environmental Science, University of Riau, Indonesia, St. Pattimura No. 9, Gobah, Cinta Raja, Sail District, Pekanbaru City, Riau, Indonesia, 28127, e-mail: nur.elfajri@lecturer.unri.ac.id
Sukendi, Department of Aquaculture, Faculty of Fisheries and Marine, University of Riau, St. HR Subrantas, KM 12.5 Panam Pekanbaru, Riau, Indonesia, e-mail: sukendi@lecturer.unri.ac.id
Syafriadiman, Department of Aquaculture, Faculty of Fisheries and Marine, University of Riau, St. HR Subrantas, KM 12.5 Panam Pekanbaru, Riau, Indonesia, e-mail: syafriadiman@lecturer.unri.ac.id
Windarti, Department of Aquatic Resources Management, Faculty of Fisheries and Marine, University of Riau, St. HR Subrantas, KM 12.5 Panam Pekanbaru, Riau, Indonesia, e-mail: windarti@lecturer.unri.ac.id
Muhammad Yusuf, Department of Agrobusiness, Faculty of Fisheries, Cokroaminoto University of Makassar, St. Tamalanrea, KM 11, Tamalanrea, Makassar, Indonesia, e-mail: yusufhalim2014@gmail.com
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