# Sustainability status for the remaining rice fields in the Air Manjuto irrigation area, Bengkulu, Indonesia


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*Keywords— Air Manjuto irrigation area, remaining rice fields, sustainability status.*


*Abstract—* ***Aim of this research was to determine sustainability indices based on ecological, economical, socio-cultural, technological and institutional dimensions, and their leverage analysis for the remaining rice fields in Air Manjuto irrigation area, Mukomuko District, Bengkulu Province. The research was conducted from October to December, 2021 at for Sub- districts involving Lubuk Pinang, Air Manjuto, XIV Koto, and V Koto Sub-districts. A purposive sampling method was used to find 60 key informants having quite relation with rice cultivation and sustainable management in this area. Collected data and information examined with a scalable and normative rapid appraisal multidimensional scaling (MDS) for the sustainability of rice cultivation involving broad attributes of ecological, economical, socio-cultural, technological and institutional dimensions based on the key informant perspectives. Accuracy of MDS analysis was analyzed with goodness of fit and Monte Carlo analysis, while sensitive attributes was fitted with root mean square leverage analysis. The dimension threated the sustainability status was various attributes of economic dimension with a value 49.45 and socio- cultural perceptions with a value 45.46. It is important to strengthen the sustainability of rice cultivation on the remaining rice fields in the Air Manjuto irrigation area through more subsidized agricultural inputs and agricultural community development. The agricultural inputs especially fertilizers significantly required for increasing the rice productivity of the marginal peat and peaty mineral rice fields. Furthermore, agricultural community development through adoptions of new technologies for rice cultivation were more attractive and responsive for smallholders through providing agricultural mechanizations to overcome household labor limited..***


## I. INTRODUCTION

Land Use and Land Cover Change (LUCC) is the emerging issue leading to the main topics of global change research related to the environmental concerns and the threaten food production sustainability. Also, issues of land use change from food crop areas into other functional uses in Indonesia has been fast raising in the last two decades [1]. The land use changes from rice fields to other land uses caused uncertain conditions for rice production and food security in Indonesia as well as in Bengkulu. Land conversion from rice fields to oil palm plantations by small-scale farmers would increase food deficits [2]. In fact, the land conversions from the paddy fields were highly alarm and without significant effort by the government to protect on the existing rice cultivation areas therefore the national food security and food self-sufficiency in Indonesia would face a high risk [3]. In Bengkulu Province, land use changes from paddy fields to other function uses such as expansions of industrial crops in particularly for rubber and oil palm plantations, fish pond extensification and intensification, and non-agricultural infrastructure threated not only staple food supply and food security but also multifunction of agricultural lands [4].

The land use changes from paddy cultivation areas to industrial crops cultivation such as oil palm and rubber plantation by small-scale farmers were actually revolutionary decision taken. The land conversions by the small-scale farmers were rational decisions to overcome their small revenue from rice cultivations. The reasons to change their paddy areas to industrial crops cultivations also related to weakness of government policies and incentives for food crops cultivations [5]. Furthermore, the small- scale farmers were attracted to land use change from rice field to oil palms because the farmers wanted to raise their household welfare from the increasing their family income and at the same time their labor used to decrease and the avoiding risk of harvested failure. The significant values influenced the small- scale farmers viewpoints to convert their agricultural food crops lands were not just the above reasons however various reasons significantly affected the farmers perspective to change their rice lands to other more economically



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agricultural activities. From some previous researches in Bengkulu, some driven factors accelerated the land use changes from rice fields to the industrial crop cultivations, fish pond intensification, social facilities and infrastructures were water supply limited because of poor irrigation channels and facilities, harvested failures, family labor limited, land rent, and lack of extension activities [6, 7, 8, 9, 10].

Sustainable rice production which part of the sustainable agriculture development should pay attention on current social behavior and economic needs without alleviating the future capacity of natural resources for next generations to fulfill their own needs [11]. Sustainable agriculture development includes activities that are economically, ecologically and socially sustainable [12]. Realizing a balance between economic, environmental and social benefits was almost impossible without institutional facilities to reach sustainable development [13]. The institutional roles set a significant view point to ensure the well suited and worth growth with other three dimensions [14]. Strong environmental and momentary economic outlooks had encouraged to societies towards more ecological balance to resource consumption therefore technology innovation and knowledge management put forward an extra ordinary view point in sustainable development [15]. It could be disowned that the assignment of technology was very important in contributing rice production in agricultural activities [16] therefore to accomplish mensuration sustainable development [17] should be updated with conceptual analysis used ecological, technological, economic, social, ethical and institutional dimension.

Several studies have been implemented partial dimension related to rice cultivation on marginal peatlands however widely perspective on diverse determinants and sustainability index of rice cultivation on peats is still not enough. Purposes of this study find out some determinants prone to the sustainability of rice cultivation on marginal peatlands in Bengkulu. The results of this research could offer important information for Indonesian government and other related stakeholders.

## II. MATERIALS AND METHOD

This study was conducted in the Air Manjuto irrigation area involving four sub-districts; Lubuk Pinang, XIV Koto, V Koto, and Air Manjuto sub-districts from October to December, 2021. The study area lays on $101.03^0 – 101.33^0$ long., and $2{,}37^0 – 2.52^0$ alt with mean annual rainfall 3,495 mm $year^{-1}$, maximum temperatures 31.38°C and minimum temperatures 24.71°C with relative humidity in about 68.5% [18]. These cultivated rice fields are some parts covered by marginal peat soils. Based on land suitability and water supply from Air Manjuto Dam built in years of 1983 – 1986 and its channels, on this area could be developed rice fields about 9,493 ha [19]. From previous research, the rice field covered 9,063 ha or closed to potential paddy field in the Air Manjuto area. Land uses covered the Air Manjuto irrigation area in 2000 was shown in Figure 1. In 2019 however the rice fields remained about 2,368 ha. In other words, the rice fields at this area were extraordinary loss of 6,819 ha or about 74 % in the two decades (Figure 2).

The study used data both primary and secondary data concerning ecological, economical, socio- cultural, technological, and policy perspectives supporting sustainability cultivation on the remaining paddy's fields. Purposive sampling method was used [20] to obtain 60 key informants namely 45 rice farmers involved in local farmers institutions (*GAPOKTAN)*, water uses farmer association (P3A) from 16 villages, 10 informants from field agricultural extension (*PPL*), and 5 informants from Mukomuko government offices. The secondary data were collected in all aspects related to this research such as action planning from government offices, government rules and policies, the infrastructure support including road, and market access, etc.

Scalable rapid appraisal for multidimensional technique through multidimensional scaling (MDS) was used to determine sustainability indices of the remaining irrigated rice cultivations. The analytical method was a modification of Rap-Assesment Techniques for Fisheries, released by the Fisheries Center of the University of British Columbia, Canada [21] and ever replicated each dimension and multidimension for agricultural paddy's cultivation [22]. Monte Carlo analysis was applied to estimate the error for this method, and leverage analysis[23] used to determine leverage of the attributes affecting the sustainable rice field cultivation.

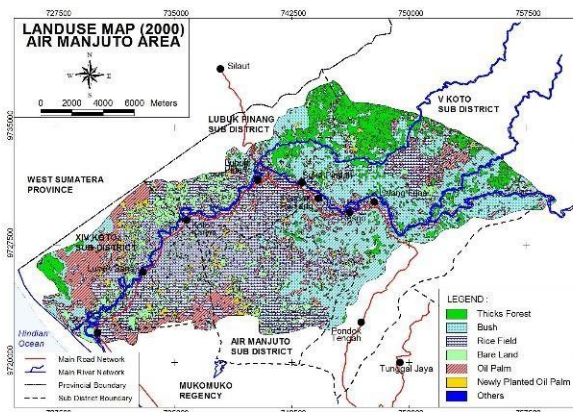


**Figure 1**. Land uses in 2000

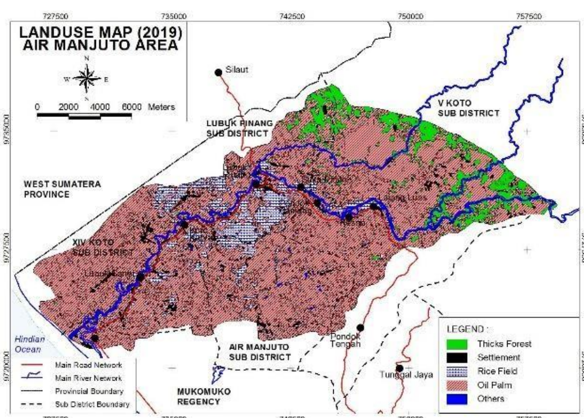


**Figure 2**. Land uses in 2019

The ordination analysis for the Rap-Fish method involve: 1) determining attribute used for each dimension on the sustainability of the remaining rice cultivation; 2) deciding each attribute on an ordinal scale with score ranging from 0-4; 3) comparing among S-stress value (S <0,25), the dimension analysis and the Monte Carlo analysis provided Rap-Fish software. When the value is less than one, then the analysis was decided good enough or following with real conditions; 4) assessment of index value and status of sustainability each dimension and multidimension of the remaining rice cultivation, figured with 0% (bad) to 100% (good) in 4 (four) classes (**Table 1**); 5) leverage analysis of sensitivity revealedin terms of Root Mean Square (RMS).

**Tabel 1**. Indices values and sustainability status [24]

| Sustainability indices | Status |
|---|---|
| 00.00 – 25.00 | Bad |
| 25.01 – 50.00 | Poorly |
| 50.01 – 75.00 | Fairly |
| 75.01 – 100.00 | Good |

## III. RESULTS

Sustainability status of the remaining rice fields in the Air Manjuto irrigation area, Mukomuko District, Bengkulu Province fairly sustainable with the average value of 55.77. This fairly sustainable value was donated by ecological-(55.88), economical-(49.45) dan technological and infrastructure-(62.31), socio- cultural-(57.19) and institutional and policy-(54.01) dimensions to put on fairly sustainable status for the remaining rice field cultivation (**Table 2** and **Figure 3)**.

**Table 2.** Indices and sustainability status of the remaining rice field cultivation in the Air Manjutoirrigation area

| Dimensions | Indices | Status |
|---|---|---|
| Ecology | 55.88 | Fairly sustainable |
| Economics | 49.45 | Poorly sustainable |
| Socio-culture | 45.46 | Fairly sustainable |
| Technology and infrastructure | 62.31 | Fairly sustainable |
| Institution and policies | 54.01 | Fairly sustainable |
| Multi-dimension | 53.42 | Fairly sustainable |

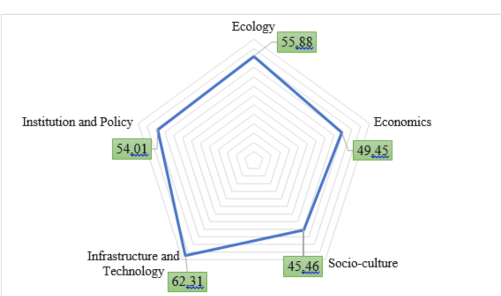


**Figure 3.** Sustainability indices of the remaining rice fields in the Air Manjuto irrigation area

The accuracy and validity of the attributes examined and the effect of variables outside the system on the sustainability of the remaining paddy field cultivation was determined with the value of S tress, determination coefficient ($R^2$) and the Monte Carlo indices values came from the MDS analysis using Rap-Fish software, as revealed at **Table 3**.

**Table 3**. Sustainability indices, Monte Carlo, stress and determination coefficient

| Dimensions | Indices | | Differences | Stress | $R^2$ (%) |
|---|---|---|---|---|---|
| | MDS | Monte Carlo | | | |
| Ecology | 55.88 | 55.69 | 0.19 | 0.21 | 94.07 |
| Socio-culture | 45.46 | 45.47 | 0.01 | 0.23 | 93.04 |
| Economy | 49.45 | 48.87 | 0.58 | 0.22 | 92.46 |
| Technology and infrastructure | 62.31 | 62.17 | 0.14 | 0.22 | 93.14 |
| Institution and policies | 54.01 | 52.32 | 1.69 | 0.24 | 91.18 |
| Multidimension | 53.42 | 52.90 | 0.52 | 0.22 | 92.77 |

Comparison between MDS and Monte Carlo analysis revealed with 95 % confidential test resulted no significantly different with values between 0.01 and 1.69 with an average value 0.52 (smaller than 1). Furthermore, the MDS values validated with S-stress showed the values between 0.21 and 0.24 with the average value 0.22 while MDS were validated with $R^2$, the values were ranged from 91.18 to 94.07 % and the average of 92.77 %.

Ecologically, the remaining rice fields in the Air Manjuto irrigation area would be fairly sustainable because only two attributes were not suppression the sustainability of the rice cultivation namely continuously water supply from irrigation channels because of the upstream covering by virgin forest of Kerinci Seblat national park. In the future however some ecological attributes could treat the sustainability of the paddy's cultivation such as 1) marginal suitable land for rice cultivation because of 2) marginal soil fertility, 3) peat depth, 4) high soil acidity, therefore the farmers applied 5) continuous an-organic fertilizers caused water pollution, 6) while lack of organic fertilizer applied, 7) pest and diseases attacks, and 8) unfriendly sounds of pesticides treatments. (**Figure4**).

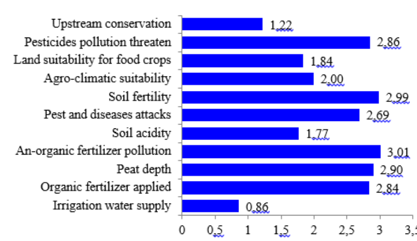


**Figure 4.** RMS values of leverage analysis of ecological attributes

The sustainability of the remaining rice cultivation on the Air Manjuto area suppressed by economical perspectives from the rice farmers because of 1) high cost for agricultural inputs such as fertilizers, pesticides and agricultural tools and machines, 2) family labor limited therefore using outside labor, while 3) rice production low, and 4) facing with long market chain therefore the farmers having 5) lowrice cultivation revenue. (**Figure 5).**


*Figure 5. RMS values of leverage analysis of economical attributes*

Historically, the rice farmers in this area are traditional farmers with hold small-scale cultivation lands therefore they do not concern about 1) greenhouse gases and the global warming, 2) leaving local knowledge such as today some of the farmers using rice straw for increasing soil fertility by burning residual waster. In this case, the farmers need 3) empowerment to improve their capacity in agricultural production as well as the environmental concern required. The leverage analysis of the socio-cultural attributes is revealed in **Figure 6**.

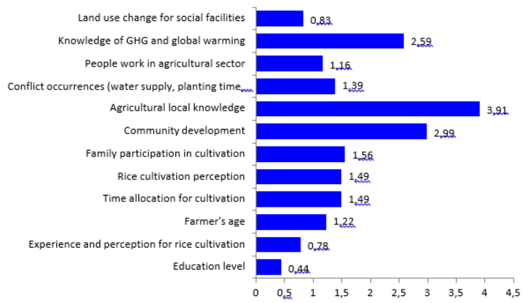


**Figure 6.** RMS values of leverage analysis of socio-cultural attributes

Irrigation channels of the Air Manjuto area had been built for a long period therefore no limited of water supply for agricultural activities especially rice cultivation. Today, the main problems of technological and infrastructures constraints to the sustainability of the remaining rice fields for paddy cultivation related to the limited family labor and high cost of the labor outside the family are introduced the agricultural machines. Innovation to implement the agricultural machines would overcome the limited family labor however the small holder farmers have not financial cost 1) to hold and 2) to rent the expensive agricultural machines for land preparation, 3) to implement rice harvesting using high technological method, 4) to access agricultural information, 5) to implement integrated pest management, and 6) to provide superior rice seed. Accessibility to farmland also determine for the intensive rice cultivation because of 7) mainly farm road under muddy condition. (**Figure 7).**

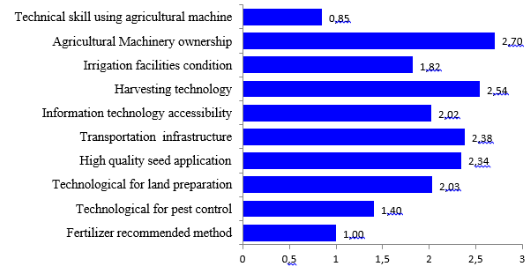


***Figure 7.*** *RMS values of leverage analysis of technological and infrastructure attributes*

*The traditional farmers with small hold lands for their agricultural activities have financial weakness therefore the farmers should be supported by 1) micro financial institutions for loan facilities. The small- scale farmers have limited capacities to organize themselves through 2) water user farmer association (*P3A/GP3A*) (**Figure 8).***

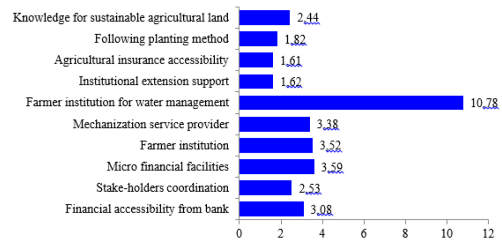


**Figure 8.** RMS values of leverage analysis of institution and policies

## IV. DISCUSSION

Sustainability status of the remaining rice fields in the Air Manjuto irrigation area, Mukomuko District, Bengkulu Province fairly sustainable however in the future, based on the farmers viewpoints, the economical perspectives could treat the sustainability rice cultivation and food security in this area because of land use changes. Driving forces of land-use change mainly accelerated by political economy and political structure [25]. Economic factors had the greatest impact on agricultural land use changes followed by social, management and policy making related, personal and technical factors [26].

Production costs of agricultural inputs such as fertilizers, pesticides, seeds significantly affected rice field conversion. Fertilizers are the main production input for agriculture sector. Farmers often face with fertilizers distribution not on time availability especially subsidized fertilizers. The increasing production costs for rice cultivation because of the high prices of agricultural inputs were determinant factors caused rice field land use change to oil palm plantation and rubber [27]. Economic determinants significantly put on future uncertainty for rice cultivation sustainability on marginal peats soils such as labor cost, crop productivity, product price, farmer exchange income, benefit cost ratio, contribution agricultural food income, farmer income comparing regional minimum wage, and agricultural input price [28]. Rice cultivation activities was not enough efficient because of the high price of production input [29].

Rice farmers faced many obstacles in carrying out their farming which all factors of production in rice farming were still not technical, price and economical efficient while farming efficiency plays an important role in increasing farmers' income [30]. Despite the interventions of the government in the rice sector, low rice profitability has continued to be a major problem that discouraged the farmer from venturing into rice farming [31]. The key inputs of rice production are seeds, fertilizers, pesticides, insecticides, farmland, and hired labor, and some may include irrigation infrastructure and machinery rentals [32]. Furthermore, the use of fertilizers is remarkably high in short-term farming like rice cultivation compared to medium- and long-term agriculture such as industrial crops cultivation. Rice farming was characterized as high risk but low return due to high production cost including labor, energy, seed, fertilizers and pesticides costs promoted land use change from rice fields to other agricultural non rice attractiveness and more profitable land uses. Therefore, the role of the agricultural rice cultivation should be supported by the agricultural input subsidy policy.

One of the constraints met in the sustainable rice cultivation on the Air Manjuto irrigation area was the low concerning of the farmer societies in the environmental issue such as rice cultivation could be sources greenhouse gases. Also, abstains of indigenous wisdom or traditional technologies could degrade ecosystem services from the rice field cultivation such as organic fertilizers applied and paludi-culture. Therefore, friendly environmental sounds in rice cultivation through alleviating inorganic fertilizers replaced by organic fertilizers using manure at the same time without burning agricultural residual waste should introduce to the farmers. In this case, capacity building for the rice farmers today in order to concern on the environmental issues was prerequisite in the sustainable agricultural production.

In short, if the agricultural inputs cost would be as a significant driven factor causing rice filed land use change to other functions in the remaining rice fields in the Air Manjuto irrigation area, the future rice production for population staple food demand could face with the uncertainty supply and would disrupt food security stabilities. So, viable policies from Indonesian government to favor of economic benefits for agricultural rice cultivation and the farmer empowerment or capacity building concerning improving rice production as well as the environmental issues were expected solution as fruitful conclusions for the small-scale rice farmers.

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