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Sustainability status of paddy cultivation on marginal peat soils in Indonesia

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Abstract

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Erratic circumstances of agricultural food cultivation on marginal peat soils in Indonesia could be a barrier for sustainable rice production and food security because of various determinants. Purpose of this study was to evaluate rice cultivation sustainability on peatlands and to find the significant attributes that degraded the sustainable agricultural activities. This research was conducted from June to September 2020 at two areas of marginal peat soils in Air Hitam irrigated paddy fields in Central Bengkulu Regency and Air Manjuto irrigated paddy fields in Mukomuko Regency, Bengkulu Province. Purposive and snowball sampling method was used to obtain 50 key informants. A scalable and normative rapid appraisal multidimensional scaling (MDS) was used to examine sustainable status based on five dimensions of ecology, economy, socio-culture, technology and institution as well as 53 attributes. 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. Rice cultivation sustainability on marginal peat soils in Bengkulu under uncertain circumstance revealed less sustainable status with value 47.81. Determinants suppressed the sustainability status were various attributes of economic dimension and institutional and policies with values 40.95 and 32.48, respectively. Strengthening sustainability of rice cultivation on marginal peat soils in Bengkulu should initially be supported by government through increasing agricultural product price and more subsidized agricultural inputs. Facing uncertain circumstances causing harvesting failures, rice farmers proposed policy supports and facilities form agricultural insurances.

Keywords: Rice cultivation; sustainability determinants; marginal peat soils; sustainable paddy fields

Introduction

Rice is an economic and political strategic commodity in Indonesia (Mariyono, 2014) due to its status as the staple food for millions of Indonesian population (Aprillya et al., 2019a). Rice production in Indonesia was still not sufficient to meet population demands (Mustikarini & Santi, 2020). In 2019, rice production in Indonesia was about 54.6 million tons from harvested rice fields of 10.67 Mha in order to feed about 270 million people (BPS-Statistics Indonesia, 2020). Furthermore, from 2000, Indonesia again initiated importing rice and achieved the highest import in 2018 with a total at 2.14 million tons. In order to avoid rice import for Indonesia supplying food demand, paddy production today and in the future must continue to increase (Aprillya et al., 2019b).

Indonesian government had devised an achievement of food self-sufficiency and to become the world's food reserves by 2045 (Sulaiman et al., 2017). Regarding limited availability of highly suitable and fertile lands, agricultural expansion and increased productivity of peatland for increasing food production is a choice to make sure Indonesian food security (Surahman et al., 2018). Tropical peatland is a very valuable non-renewable natural resource that can be developed in agriculture cultivation and thus contributing towards a long-term economic growth (Lulie et al., 2002). Peatland in Indonesia covers about 16 to 27 Mha (Jaya et al., 2010; Page et al., 2007) or about 20.073 Mha (Rieley et al., 2008). However, the peatland utilization for agricultural development faces many limiting factors such as acidity, low base saturation, organic acid toxicity, and nutrient deficiency (Septiyana et al., 2017) both macro and micronutrients (Maftu'ah & Nursyamsi, 2019). Peat soil is marginal soil for agricultural activities because of its low nutrients content and soil fertility (Ompusunggu et al., 2020). Based on the peat soil properties, the peat soils were classified as oligotrophic (Wheeler & Proctor, 2000) ombrogenous peat (Sahfitra et al., 2020). Therefore, an appropriate management of marginal peat soil for rice cultivation is necessary to overcome these various constraints.

Hydrological system on peatlands has a distinctive characteristics which occurs it inundated along the year (Putra et al., 2019) and economically peatland plays an important role when the peat was constructed by drainage facilities, progressive degradation however at peatlands constructed with massive drainage channels caused peat decomposition released in CO_2 emission (Hooijer et al., 2010). The anthropogenic drainage facilitated to society needs (e.g. agriculture, plantations, etc.) had altered the hydrological system of peatlands and lead lowering the peat water table on peatlands during the dry season. During water table far below caused peat under dry conditions, peat is vulnerable to be fired because peat soils were mainly composed from carbon materials (Gaveau et al., 2014; Miettinen et al., 2012).

Indonesia concerns and is fully aware that the economic value of conserving resources of peatlands is very high and may not be lower than the value of its economic exploitation (Susanti & Mamat, 2017). Indonesian development was challenged by the demand to keep a high level of production with minimal negative impact to the environment (Agus, 2011). Thus, the agricultural development in peatlands should refer to the concept of sustainable agriculture systems (Wardie & Sintha, 2018). 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 (Yusuf et al., 2019). Sustainable agriculture development includes activities that are economically, ecologically and socially sustainable (Serageldin, 1996). In facts, social, economic, and environmental benefits to sustainable agriculture were less understandable by most conservative communities in food production system (Elias & Marsh, 2019).

Realizing a balance between economic, environmental and social benefits was almost impossible without institutional facilities to reach sustainable development (Cottrell et al., 2005). The institutional roles set a significant view point to ensure the well suited and worth growth with other three dimensions (Shen et al., 2009). Some outlooks that generally be used to evaluate development sustainability were environmental perspectives, institutional and policies, economic values, and also social performances (Pokharel et al., 2015). 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 (Kumar & Kumar, 2017). It could be disowned that the assignment of technology was very important in contributing rice production in agricultural activities (Faisal et al., 2019) therefore to accomplish mensuration sustainable development (Pitcher et al., 2013) should be updated with conceptual analysis used ecological, technological, economic, social, ethical and institutional dimensions.

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.

Method

A case study was to evaluate rice cultivation sustainability on marginal peat soils at 2 (two) irrigated peat rice fields in Bengkulu; Air Manjuto irrigated area in Mukomuko Regency and Air Hitam irrigated area in Central Bengkulu Regency, Bengkulu Province (Figure 1) conducted from June to September 2020. Good climatic conditions and landscapes covering the irrigated rice fields favor for intensively rice farming systems however peat soil ecosystems could be constraint for sustainable rice cultivation. Rainfall average 295.8 mm month^{-1} with number rain day of 19 day month^{-}. Maximum temperatures range between 32°-34°C and minimum temperatures range between 22°-23°C with relative humidity in in range between 80-88%. These cultivated rice fields are some parts covered by marginal peat soils.

A combination of purposive and snowballing samples was used to find 50 farmers as key informants who had planted rice on their paddy's fields and 5 experts relevant to each dimension. Collected data and information about the sustainable rice cultivation on marginal peat soils involved a broad attributes of ecological, economical, socio-cultural, technological, and institutional and policies dimensions based on farmers perspectives. 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 evaluate the sustainability of irrigated rice fields in Bengkulu Province. This analytical method was a modified Rap-Assessment Techniques for Fisheries, developed by the Fisheries Center of the University of British Columbia, Canada (Pitcher & Preikshot, 2001), and transformed each dimension and multi-dimension for rice cultivation (Rao & Rogers, 2006). Monte Carlo analysis was also used to estimate the effect of error in the analysis performed and leverage analysis was used to determine more sensitive attributes affecting the sustainable rice field cultivation.

The Rap-Fish ordination analysis stages include: First, determination of attributes of each dimension on sustainable rice cultivation; second, assessment of each attribute on an ordinal scale (scoring) ranging from 0-3 (Appendix 1); third, analysis of ordination to determine stress value and ordination (Fauzi & Anna, 2005). Ordination technique in MDS based on Euclidian distance using the following formula:

$$sd_{i,j} = \sqrt{(Xi - Xj)^2 + (Yi - Yj)^2 + (Zi - Zj)^2 + \dots}, \quad (1)$$

where $d_{i,j}$ = Euclidian distance; X, Y, Z = Attributes; i, j = observation.

Euclidian distance between two points (di,j) in calculated with regression formula in the following equation

$$d_{i,j} = \alpha + \beta_{i,j} + \sigma, \quad (2)$$

where $d_{i,j}$ = Euclidian distance; α = intercept; $\beta_{i,j}$ = regression coefficient; σ = standard error.

Regression analysis for these formula used ASCAL algorithm available in SPSS software. ASCAL algorithm optimized square distance d_{ijk} for quadratic data from initial point

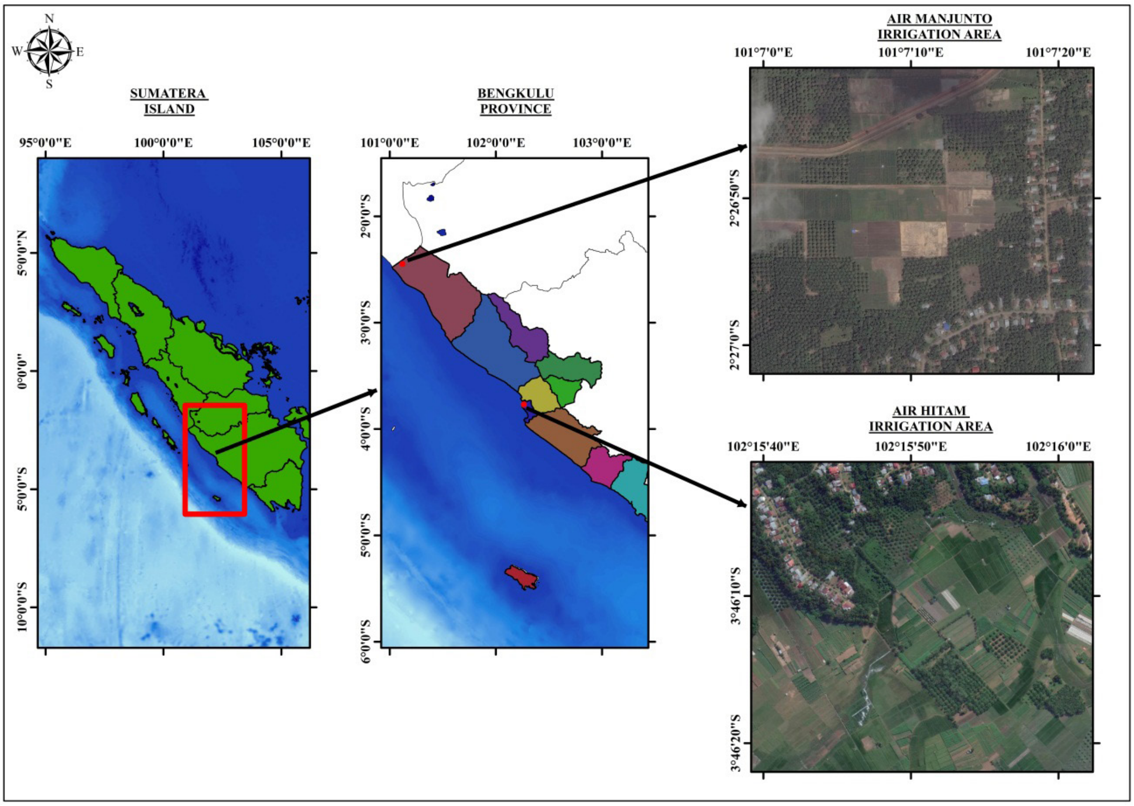

Fig. 1. Research location in Air Hitam and Air Manjuto irrigation areas, Bengkulu

0_{ijk} in form of three dimensions (*i, j, k*) as S-stress written following formula:

$$\text{S-stress} = \sqrt{\frac{1}{m}\sum_{k-1}^{m}\left(\frac{\sum_i \sum_j \left(d_{ijk}^2 - O^2\right)_{ijk}^2}{\sum_i \sum_j O_{ijk}^2}\right)}, \tag{3}$$

where m = number of attributes, d_{ijk} = Euclidian distance within *i, j, k* dimensions, O_{ijk} = initial point within *i, j, k* dimensions.

S-stress value S < 0.25 and determinant coefficient R^2 > 80% expressed the accuracy of statistical analysis (Kavanagh & Pitcher, 2004). Forth, assessment of index value and status of sustainability each dimension and multi-dimension of the rice cultivation, expressed with 0% (bad) to 100% (good) in four categories (Table 1) and in general, sustainability index value >50 indicated that the analyzed system has been sustainable while sustainability index value < 50 indicated that the analyzed system yet or not sustainable.

Tabel 1. Index value and sustainability status

No	Index value	Category
1	00.00 – 25.00	Bad (not sustainable)
2	25.01 – 50.00	Poor (less sustainable)
3	50.01 – 75.00	Fair (fairly sustainable)
4	75.01 – 100.00	Good (highly sustainable)

Source: Nurmalina (2008)

Fifth, leverage analysis of sensitivity to see attributes are sensitively influenced expressed in terms of Root Mean Square (RMS) percentage with higher value; Sixth, Monte Carlo analysis to evaluate the effect of random error 95% of MDS . If the different value between MDS and Monte Carlo was less than one, then the system was considered good enough or in accordance with real conditions.

Results And Discussion

Future uncertainty of rice cultivation sustainability

Paddy cultivation on marginal peat soils in Bengkulu was categorized less sustainable with an index value 47.81 (Figure 2).

This value indicated that future rice cultivation sustainability on marginal peat soils in Bengkulu faced with uncertainty conditions. Sustainability indices and status based on each dimension were revealed in Figure 3.

The sustainability of the rice cultivation was contributed by ecological, socio-cultural, and technological conditions with values respectively 54.69; 50.08; and 60.86 while economical and institutional and policy conditions with values

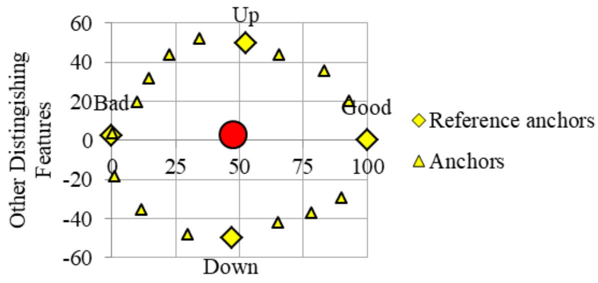

Fig. 2. Sustainability index of rice cultivation on peat soil in Bengkulu

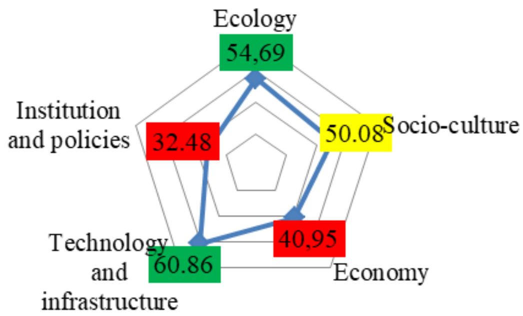

Fig. 3. Sustainability index based on each dimension

40.95 and 32.48, respectively suppressed to put on less sustainable status for paddy cultivation on marginal peat soils in Bengkulu Province.

The accuracy and validity of the attributes examined and the effect of variables outside the system on the sustainability of rice cultivation on marginal peats in Bengkulu were determined with the value of S tress, determination coefficient (R^2) and Monte Carlo index value resulted from the MDS analysis using Rap-Fish software, as shown in Table 2.

The small difference with value 0.04% (< 1%) between the MDS index and Monte Carlo value indicated that the MDS method used to determine the sustainability index of rice cultivation at the marginal peat soils in Bengkulu Province had a high level of confidence. The fact that a) effect of error occurrences and scoring variations was very small; b) errors of collected data in questionnaire was very small; c) errors of procedural technique that might affect the stability of the MDS process were relatively small. Furthermore, the attributes were valid and accurate as revealed by the S-stress value was low at 0.20 or < 0.25, and the value of coefficient determination (R^2) at 0.84 or >0.80 indicates that the attributes used in the model were able to explain the validity of

Table 2. Value of MDS and Monte Carlo, stress and determination coefficient

Dimensions	Indices		Differences	Stress	R^2
	MDS	Monte Carlo			
Ecology	54.69	54.33	0.36	0.18	0.88
Socio-culture	50.08	50.23	0.15	0.19	0.87
Economy	40.95	41.30	0.35	0.19	0.86
Technology and infrastructure	60.86	60.05	0.81	0.25	0.72
Institution and policies	32.48	33.33	0.85	0.19	0.88
Multi-dimension	47.81	47.85	0.04	0.20	0.84

the sustainable paddy's cultivation system in marginal peat soils in Bengkulu.

Comparing to other research in Kubu Raya Regency West Kalimantan Province, rice cultivation on peat soils also revealed less sustainable with sustainability index 47.05 and almost all dimensions suppressed sustainability status which each value of ecological, socio-cultural, economy, technological and institutional dimensions was 48.77, 50.02, 49.33, 46.70, and 43.24, respectively (Santoso et al., 2018). Furthermore, flood occurrence and erratic rainfall pattern as ecological obstacles for sustainable rice cultivation in peatlands while farming revenue, product price and agricultural inputs as economic challenges for rice production sustainability in West Kalimantan. Land use change from rice fields to oil palm plantation was another important factor influenced rice production uncertainty in Kubu Raya Regency.

Ecological constraints to sustainability

Almost all ecological attributes could be constraint factors to sustainability rice production in marginal peat soils in Bengkulu except soil and land suitability for rice, cereal and lowland vegetables cultivations however with index 54.69 revealed that ecological dimension generally supported rice cultivation sustainability on marginal peat soils (Figure 4). In some season in within 4 years rice farmers would face with extreme conditions rice harvested getting in low yields.

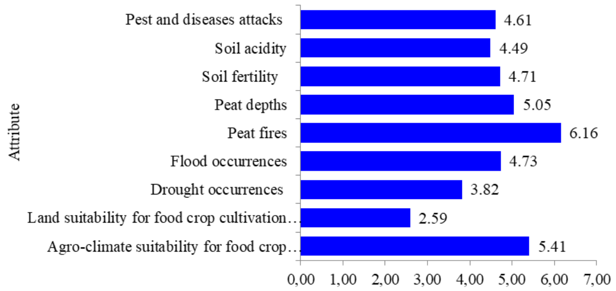

Fig. 4. RMS value of leverage analysis for ecology attributes

Due to its high organic matter content, peat soils are prone to fires (Warren et al., 2017). Peat fires when drought season occurrences could be the highest ecological constraint for sustainability of rice cultivation on marginal peat soils. Any long-term solution looked for alleviate both the tropical peat degradation and the occurrences of peat burnt must struggle to restore peat ecosystem resilience; in the important one, the peat has to be maintained wet conditions therefore this will require hydrological interventions on drained peatlands in order to decrease peat decomposition and avoided the risk of fire (Page & Hooijer, 2016). Furthermore, this would face with ineluctable economic consequences for agricultural production for rice farmers. Maintaining hydrological system and its management including temporary blocking of canals should be implemented in order to alleviate peat subsidence and CO_2 emissions and to obtain sustainable productive cultivation of peatlands through maintaining water table above ground of the peatlands (Tata, 2019).

Also, the last few decade rice farmers in these areas faced with changes in rainfall pattern in line with global climatic changes therefore the farmers faced with difficulty determining the planting calendar. Drought and flood occurrences were two extreme conditions because of changes in rainfall pattern could be the ecological determinants causing rice farmers in these areas would face with harvested failure. Rice farming was classified as high risk facing with harvested failure on the other hand low return because agricultural activities were dependent on often erratic weather conditions. When rainfall patterns changes and droughts or floods occurred, rice farmers would lose all, rice grain and money (Ngammuangtueng et al., 2019). Avoiding harvest failure because of uncertainty water supply in dry season for rice cultivation, farmers applied right setting of planting season (Naylor et al., 2007). However, some traditional farmers cannot be fully used as a reference in determining the planting season (Runtunuwu et al., 2011). Rice farmers often take into consideration either a narrowed planted area down or schedule irrigation events so that plants do not run into stress in periods of sensitive growth stages (DeJonge et al., 2012). Some farmers changed in agricultural land into coconut and rubber plantation (Dolly et al., 2018), oil palm (Fahri, 2016).Peat thickness is the inherent peat properties resulted low crop productivities could barrier for agricultural activities in marginal peat soils. Agricultural cultivation on thick peats ineluctable problems ongoing land surface subsidence caused an alleviation of productivity (Kirk et al., 2015). Furthermore, peat decomposition and soil subsidence was taking place when peats soils had been converted to agricultural lands however with rice cultivation systems reduced the rate of carbon emission from peat soils relative to other drained agricultural practices.

Soil fertility and soil acidity are chemical soil characteristics significant affect sustainable rice cultivation in marginal peat soil in Bengkulu. Main limiting factors of agricultural development in peat soils were low soil pH, low base saturation and low available nutrients and content (Hadi et al., 2018), low activities of exchangeable bases and total phosphor and potassium (Hikmatullah & Sukarman, 2014), and low contents of micronutrients Fe, Cu, Zn, Mn and Mo (Nelvia, 2018). Neutralizing soil acidity and improving nutrient content in cultivated peat soil, it should implemented ameliorants and fertilizers applied. Amelioration treatments could improve soil pH, raise available nutrients, and increase in soil adsorption for nutrient exchanges (Ratmini, 2012). From previous study, soil acidity in these field was range between pH 4.8 and pH 5.2 (Riwandi et al., 2009). Application of dolomite up to 2 000 kg ha^{-1} on peat soil revealed rice growth and yield increase in linearly trend (Idwar et al., 2004). When soil acidity in peat soil ranged between pH 5.0 and pH 5.6, application of lime for amelioration soil acidic constraint for rice growth required dolomite from 2 600 kg ha^{-1} to 5 490 kg ha^{-1} (Gultom & Mardaleni, 2014). Total nitrogen content in peat soils is in huge amounts, but a low amount in form of mineral nutrients because nitrogen contents in peat present mainly in the form of nitrogen organic complexes, which was not directly available minerals for plants uptake and metabolism (Moilanen et al., 2010). Deficiency in phosphorus can severely limit rice yields (Islam et al., 2008). P deficiency affected a significant reduction in the net photosynthesis rate in rice plants (Balemi & Negisho, 2012). Phosphorus deficiency on rice can significantly reduce yields often noticed on low pH soils (Fageria, 2014).

The last attribute could be a barrier for intensive rice cultivation on peat was pests and diseases attacks causing rice harvested failure. Rice cultivation usually face with harvest failure due to massive attacks of the brown plant hopper (*Nilaparvata lugens*), rice leaffolder (*Cnaphalocrocis medinalis* Güenée), small brown planthopper (*Laodelphax striatellus* Fallen), rice hispa (*Dicladispa armigera* Oliver), yellow stem borer (*Scirpophaga incertulas* L.) and white-backed planthopper (*Sogatella furcifera* Horvath) (Ali et al., 2019). Pests endangered food production and food security in the regions where rice was the staple food (Heong et al., 2013).

Socio-cultural constraints to sustainability

Almost all attributes of socio-culture were significantly susceptible to place uncertain condition for sustainability rice cultivation in these areas which value of socio-cultural dimension 50.08 and it only closed to less sustainability for paddy cultivation on these marginal peat soils. Leverage analysis of socio-cultural attributes affected rice cultivation sustainability on marginal peat soils in Bengkulu revealed in Figure 5.

Agricultural rice cultivation required a lot of time from seed preparation to post harvest activities in 3 month planting period. Farmers should allocate time for seed preparation, twice soil tillage and thaw the planting media, planting young plant, weeds, pests and diseases control, water flow control, harvested, and post-harvest activities. Comparing to allocation time other agricultural activities, rice cultivation consumed much more time than oil palm and rubber plantation had therefore in rice farmers perspective rice production wasted a lot of time. Learn from oil palm farmers, cultivating oil palm seemingly was no wasting time for cultivation, easier in cultivation management, no ecological barrier, and higher benefit gained (Hamdan, 2012). Based on Figure 5, time allocation for agricultural food cultivation significantly affected for sustainability rice cultivation on marginal peat soils. Low education achievement, decrease in women participation in agricultural food cultivation, abstain in local indigenous technologies such as implementation organic fertilizers, long-life experience but lose of motivation for

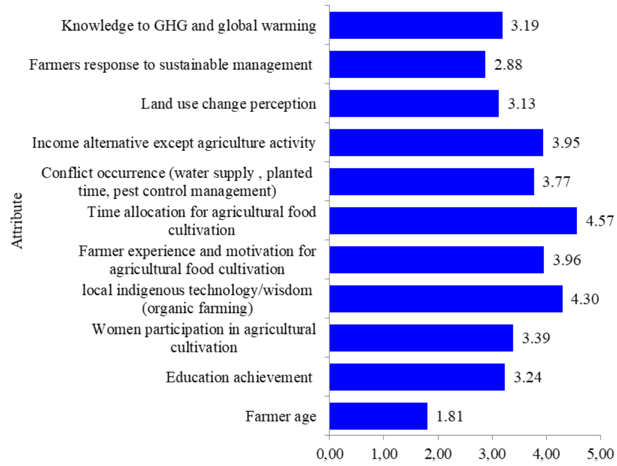

Fig. 5. RMS value of leverage analysis for socio-culture attributes

agricultural food cultivation were significant constraints for sustainable rice cultivation on low productive peat soils.

One of the constraints met in the agricultural cultivation on peatlands was the low participation of the farmer societies in the development of peatland management (Syahza et al., 2019). Abstains of indigenous wisdom or traditional technologies could degrade ecosystem services for agricultural activities on peatlands such as organic fertilizers applied and paludi-culture. A concept of paludi-culture, the implementation of water level above ground or re-watering peatlands for agriculture, has been promoted in European countries to avoid further peat subsidence and release greenhouse gas to atmosphere (Yokochi et al., 2020). Paludi-culture comprised wet cultivation tillage in peatland and could conserve peat soil properties and providing ecosystem services in sustain (Budiman et al., 2020a). While in this case, the farmers maintained water supply with intermittent irrigation for weeds, pests and diseases controls, and intermittent watering could accelerate peat oxidation to emit carbon emission.

Conflict among farmers occurred because of limited water supply, not simultaneous planting calendar avoiding pests and diseases attacks, and pest control managements could be barrier for sustainability crop cultivation in these areas. Water conflict was judged as one of the main challenges in water management for agricultural cultivation which farmers in downstream were often did not get in water supply (Bijani & Hayati, 2015). Furthermore, the major determinants for water conflicts in agricultural activities were water scarcity, drought, and the kind of water management. Education levels, imbalance water supply in water management, and attitude toward water scarcity because of rainfall pattern changes had a significant relationship with water conflict.

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Economic constraints to sustainability

Sustainability rice cultivation on marginal peat soils was vulnerable due to economical perspective from rice farmers in Bengkulu. Sustainability index from economic dimension was only 40.95, the less sustainability value for agricultural food activities.

Significant determinants could play future uncertainty for rice cultivation and production sustainability on marginal peat soil in Bengkulu showed in Figure 6.

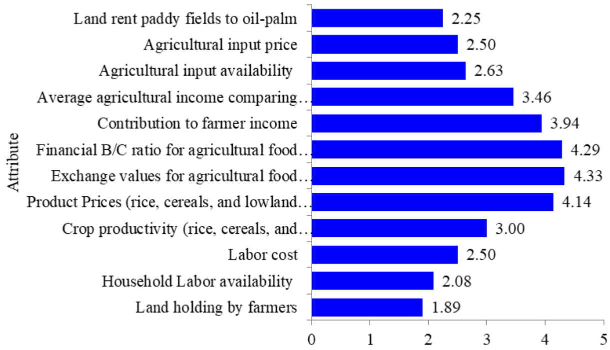

Fig. 6. RMS value of leverage analysis for economic attributes

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. Rice cultivation activities was not enough efficient because of the high price of production inputs, particularly fertilizer, pesticides and labor (Pudaka et al., 2018), and farmers' income furthermore was lower than the regional minimum wage. Rice farmers faced many obstacles in carrying out their farming which all factors of production in rice farming is still not technical, price and economical efficient while farming efficiency plays an important role in increasing farmers' income (Setiawan & Bowo, 2015). Furthermore, the losses obtained by the farmers who sell grain in wet conditions to the middlemen are also quite a lot. Other word, huge profit margin will not be enjoyed by the farmers but by the middlemen and wholesalers.

The improvement in commerce or market chain is one strategy to address the problem of agricultural product marketing. The efficiency of the commerce chain is a quite important to the stability of the price of agricultural products. Strengthening the farmers' institution is also one of the strategies to strengthen the bargaining position of farmers in marketing the product. With collective system, sale of their products through farmer groups are expected to increase the grain price received by farmers. Through a group of farmers, alliance of farmers' groups, and coop, farmers can be assisted to conduct business, seek of means of production, and marketing the farming product, as well as addressing the issue together (Herman, 2011).

Land rent paddy comparing to oil palm could be a significant determinant for land use change from paddy fields to oil palm plantation resulting rice production under uncertain choice. Farmers were very responsive to the economic opportunity and they did not doubt to move their livelihood if it could increase their revenue (Feintrenie et al., 2010). Oil palm plantation gave value of land rent was higher than paddy production activities did therefore this higher revenue together with some constraints faced by the small-scale rice farmers made the land use system sustainability was difficult to maintain (Daulay et al., 2016). Farmers were attracted to land use change from rice field to oil palms because farmers wanted to increase their living standard, expecting their income to increase and their labor used to decrease and the avoiding risk of harvested failure (Zahri et al., 2019). Furthermore, farmers considered the conversion to oil palm plantation to be the most profitable choice, as compared to other agricultural crops. Based on farmer perfectives in Bengkulu Province, rice field conversion to rubber and oil palm plantation was highly influenced by economical land values (Siswanto, 2007; Sugandi et al., 2012; Yanti et al., 2013).

Technology and infrastructure constraints to sustainability

Air Hitam irrigated rice fields and Air Manjuto rice fields lay on widespread of marginal peat soils had been built irrigation channels and appropriated irrigation facilities, and also some farmer institution facilitated with water pump in order to avoid limited water supply when drought season. Each farmer institution had been facilitated with soil tillage tractors for land preparation by both local and national government (Figure 7).

Technologies and infrastructures facilities supported sustainability rice cultivation for staple food production in these areas with value 60.86, the highest index for sustainability

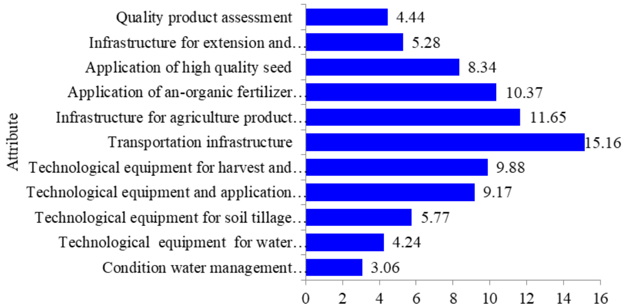

Fig. 7. RMS value of leverage analysis of technology and infrastructure attributes

rice cultivation. In each sub-district was facilitated with extension building and technological dissemination and in each district was equipped with quality product assessment therefore some infrastructures could not be determinant for rice production in these areas.

Transportation infrastructure could be the highest limiting factor for sustainability rice cultivation in these areas. Government investments in agriculture and rural infrastructure were important (Rada et al., 2011). Low bulk density of peat soil caused low buffering capacity of peat soils to support stable accessibility for transportation infrastructure over rice fields. Low volume density and high porosity resulted in peat subsidence therefore farm road unstable and needed regular maintain except the road hoarded with mineral materials. Rice cultivation on peat soils required technological equipment for integrated pest and diseases management. Controlling pests and diseases attacks and application of fertilizers to rice plant on peat soils in vast areas was very difficult because moving for manual spraying pesticide solution and fertilizers spreading inhibited by unstable peat where the feet stand and walk. Peat soils have geo-technical problems such as high compressibility and low shear strength (Kazemian et al., 2011). Peat has characterized with significant negative geotechnical behaviors such as high water content, low shear strength, high organic content, and low bearing capacity and as a result a significant severing high compressibility characteristic that consider the peat soils as ones of the most difficult soils for building constructed structures over the natural condition (Abdel-Salam, 2018).

Rice varieties planted on marginal peat soils in Bengkulu used rice varieties for lowland mineral soils. High quality seed for high rice yield production cultivated on marginal peat soils until now has not been found. Low productive rice seed could be determinant for sustainable rice cultivation on marginal peat lands. The complicated development and genetic breeding process, limited seed production and fertile land available, have resulted in high prices for genetic hybrid rice seeds prevented the sustained adoption of genetic engineering varieties by Indonesian farmers (Krishnamurti & Biru, 2019). When farmers harvested rice simultaneously over vast areas, the farmers required fast rice drying technologies and warehouse for grain storage in order to grain quality was maintained for a long time. Also, farmers required market sell infrastructure to ensure stable and profitable price for agricultural products.

Institution and policy determinants to sustainability

The poorest determinant for sustainability of paddy cultivation on marginal peat soils which caused future uncertainty for food supply and food security in Bengkulu was institution and policies dimension. The value of institution and policies dimension for sustainable rice cultivation on marginal peat soils was only 32.48, the lowest index causing rice cultivation sustainability in doubt. Although government provided subsidized paddy seed, empowerment of farmer association, farmer institution for irrigated water management and scheduled coordination among stakeholders, from farmer perspectives, government policies and institutional supports and facilities were still weak for maintain sustainability rice cultivation on marginal peat soil in Bengkulu. Leverage analysis for attributes of institution and government policies based on RMS revealed in Figure 8.

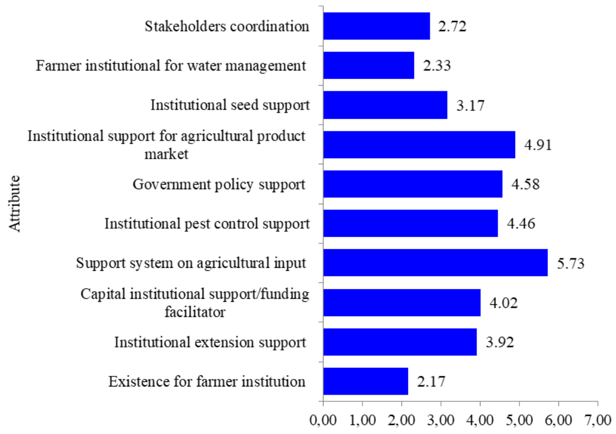

Fig. 8. RMS value of leverage analysis for institution and policy attributes

The highest degraded opportunity for rice cultivation sustainability was government support systems on agricultural input facilities. The agricultural inputs such as fertilizers, pesticides, and high quality selected seed should be available on time with planting calendar. Fertilizers and pesticides prices in last few years continue to increase therefore the farmers needed more subsidized prices for the agricultural inputs. Implementation of the agricultural input by subsidy policy stimulated domestic agricultural production (Azumah & Zakaria, 2019).

The role of the agricultural sector should be supported by the fertilizer subsidy policy (Wildayana & Armanto, 2019). Furthermore, the principle of provision of subsidized fertilizers has to meet six criteria, namely the accuracy of time, type, quantity, price, location and quality. Government facilitated some subsidies in agricultural cultivation focused on improving agricultural food production with the adoption of new technologies were more attractive to and responsive for smallholders (Poernomo, 2017).

Rice farmers required support funding capital for buying in sufficient quantity of the inputs. Low rice yields were related to insufficient agricultural inputs especially fertilizers applied limited. Small-scale rice farmers were not enough financials to pay cash for all agricultural inputs required. Also, when farmers harvested rice at the same time over vast paddy areas, rice yields piled up in large grain volume, the farmers met price reduction of rice products by middlemen. Therefore, rice farmers needed price protection and guarantee from government for their agricultural products.

Today, rice farmers faced with uncertain circumstances of climatic changes, drought and flood occurrences, changing rainfall patterns, pests and diseases attacks which caused the rice farmers threatened harvested failure so that they proposed insurance guarantee as government policy support and facilities. The government could promote the innovation by facilitating fiscal and non-fiscal incentives such as financial support for sustainable agricultural development (Budiman et al., 2020b). Furthermore, non-fiscal incentives should involve legal certainty regarding the agricultural insurance, and easy access to loans for local farmers. This scheme should be followed by monitoring and evaluation mechanisms amongst the stakeholders.

Conclusion

Future agricultural rice cultivation on marginal peatlands in Indonesia, in this case in Bengkulu Province was predicted less sustainable because of economic transformation pressures and institutional policies disadvantage for rice cultivation sustainability. Less impartial policies had the greatest impact on unsustainable rice cultivation on marginal peat soil followed by lower economic revenue promoting farmers to look for an economic opportunity for better livelihood. 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. Viable policies from Indonesian government to favor of economic benefits for agricultural rice cultivation were expected solution concerning sustainable paddy production to small-scale rice farmer as fruitful conclusions.

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