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Impact of technology and infrastructure support for sustainable rice in West Kalimantan, Indonesia

Ekawati[1,2*], Kusnandar[1], Novira Kusrini[3], Darsono[1]

[1]*Doctoral Program of Agricultural Science, University of Sebelas Maret, Kentingan, Surakarta 57126, Central Java, Indonesia*
[2]*Department of Agribusiness, Faculty of Agriculture, University of Panca Bhakti, Pontianak 78115, West Kalimantan, Indonesia*
[3]*Department of Agribusiness, Faculty of Agriculture, University of Tanjung Pura, Pontianak, West Kalimantan, Indonesia*
[*]*Corresponding author:* ekawatiupb@gmail.com

Abstract

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The sustainable rice availability absolutely requires the support of technology and infrastructure due to the limited land and water resources, more frequent climate changes, and high land conversion. Furthermore, the soil conditions are insufficient to promote plant growth due to the excessive use of chemicals. This research aimed to study the impacts of technological and infrastructure support on sustainable rice availability status and to determine the dominant influencing factors. Multidimensional scaling was used to know the impact of infrastructure and technology on sustainable rice availability; leverage analysis was used to determine the dominant influencing factors. The results show that technology and infrastructure are less supportive for sustainable rice availability in Kalimantan with a sustainability index of 42.52%; the dominant factors involve harvesting and post-harvest technology (3.37), cultivation of technology (3.01), support of road facilities and infrastructure (1.45), and availability of agriculture tools and machines (1.45).

Keywords: sustainable rice production; multidimensional scaling; Rap-Fish analysis; West Kalimantan; Indonesia

Introduction

West Kalimantan is one of border areas of Indonesia and Malaysia. The development of the agricultural sector, especially food crops, is an alternative solution to strengthen the food security of the people in West Kalimantan. Compared to Malaysia, the condition of Indonesia's border area is far behind. There are social, economic and welfare gaps between the resident of Indonesia's border and that of Malaysia (Bapenas, 2004). The residents of the Indonesian border region have difficulty to get communication access, technology and infrastructure as well as distribution access of basic needs. The life of human, vegetation, and the environment has been dramatically changed by globalization (Khayankan, 2016). This impacts on the potential for high food insecurity and weak human resources in the border areas (Munaf et al., 2008).

The local people's livelihoods still depend on the agricultural sector, especially the food sector. According to Rizieq (2008), the agricultural sector remains a supporting sector, and it correlates with other sectors in supporting the development of economic in West Kalimantan. Whereas, the food sector is a determinant of the welfare level of the majority of the rural population including poor farmers with small field, peasants, urban poor consumers whose income is mainly for consumption, especially for staple food (Musyafak et al., 2011).

Rice is one of the staple foods for almost all Indonesians. The fulfillment of food needs, especially rice, is a basic human right. The legal law of food fulfillment in Indonesia is guaranteed in Law no. 7 of 1996 on food refined in Law No. 18 of 2012 about food security stating that the condition of the fulfillment of food for the state embracing the individuals, is reflected from the sufficiency of adequate food, both quantity and quality, safe, diverse, nutritious, equally distributed, affordable, and not contrary to the religion, beliefs and culture of the community, to be able to live healthy, active and productive in a sustainable manner. The availability of rice in sufficient quantities and sustainable is influenced by the production of rice produced, which is a unity of productivity and area of wetland.

During the period 2010–2015, rice productivity in West Kalimantan tended to decrease from 3.14 tons/ha in 2010 to 2.94 tons/ha in 2015, still below the national productivity of 5.34 ton/ha. The declining trend of rice productivity is expected to continue. There are several factors affecting rice productivity, including land and water availability, soil physical properties, and climate change (Hosang et al., 2012), adoption of rice technology and the efficiency of the resources by farmers is still low (Hormozi et al., 2012). Land conversion is one of the triggers of environmental ecosystem instability (Suradisastra and Sutrisna, 2011). The fulfillment of the rice demand, which is increasing from time to time as the population increases, requires the use of big resources, especially water and land for food production. On the other hand, the population growth also requires more land for housing, industry, offices, and other facilities, leading to high frequency of land conversion. The conversion of national paddy fields reached 96.512 ha/year during the period of 2000–2015, and it is predicted that in 2045 the area of rice fields will decrease to 5.1 million ha from the existing 8.1 million ha of paddy fields (Mulyani et al., 2016). The conversion of agricultural land, especially productive rice fields, is caused by its high accessibility and position (Djaenudin, 2009). Therefore, land clearing to increase sustainable rice production is constrained by limited fund and low nutrient constraints (Prasetyo, 2006).

The use of inorganic fertilizers and pesticides among farmers has become a tradition in rice farming. The Farmers believe that the use of chemicals can increase their rice production, without realizing that chemicals can cause pollution in rice crops and in soil and water environments. Environmental degradation occurs due to farmers' dependence on the use of inorganic fertilizers (Hayat and Andayani, 2014); the residue of pesticide and herbicide also pollutes the soil, water and grasses, and it kills beneficial organisms (Aktar et al., 2009). The excessive and periodic use of pesticides weakens wetland ecosystems by triggering the emergence of toxin-resistant pest and plant viruses (Sitorus, 2006; Wiyono et al., 2015). This can decrease the soil's ability to support sustainable rice growth in both quantity and quality (Setyorini et al., 2010). Climate change affects production through soil water balance (Kang et al., 2009).

Based on the conditions, the increase of rice production and productivity in supporting the sustainability of rice availability can be improved through technological improvement and supported by the availability of adequate facilities and infrastructure of water system, roads, and bridges. The use of two-wheeled tractor in Indonesia is excellent and effective because there is generally small and narrow land (Mardinata and Zulkifli, 2014), cultivation technology through mechanization (Harmozi, 2012), harvesting and post-harvesting for securing rice production (Khan, 2010; Mejia, 2010; Setyono, 2010; Iswari, 2012; Kumar and Kalita, 2017).

According to Tarigan and Syumanjaya (2013) bridges are not only a connector between two regions but also means for the distribution of information, production facilities and production that ensure smooth transportation and communication.

Several researches have been undertaken in relation to the technology application and infrastructure development to increase rice production in supporting rice availability. However, the information on sustainability status of the existing technology and infrastructure in supporting the sustainability of rice availability is still limited. Therefore, this research was conducted to find out the index and sustainability status of technology and infrastructure to sustainable rice availability in West Kalimantan. The results of this study will provide information to relevant agencies and other related attributes.

Materials and Methods

This research was conducted from August 2015 to August 2016 in 4 districts of West Kalimantan province comprising Kubu Raya, Ketapang, Bengkayang and Landak. The consideration of West Kalimantan province as the research location was based on the vulnerability map of the Indonesian food security in 2009. There were 10 food-susceptible districts in West Kalimantan of 100 food-susceptible areas in Indonesia. In addition, West Kalimantan has a strategic position as a gateway to interact with Malaysia directly, showed in Fig. 1. Thus, the occurrence of rice scarcity as staple food has the potential to trigger social, political and security vulnerabilities and national security.

Fig. 1. Map of West Kalimantan

The data used in this study include primary and secondary data concerning aspects of technology and infrastructure supporting the sustainability of rice availability. The primary data were obtained from interviews with 144 farmers and experts and from direct field observations. The interviews were conducted in relation to the technology used by farmers. The secondary data were used to see the infrastructure support including road, communications, port, and market access and food storage on sustainable rice availability.

Rapid appraisal for multidimensional technique through MDS (Multidimensional scaling) was used to evaluate the sustainability of technology and infrastructure related to rice availability in West Kalimantan. This analytical method is a modification of Rap-Assessment Techniques for Fisheries, developed by the Fisheries Center of the University of British Columbia, Canada since 1998 (Kavanagh & Pitcher, 2004). In the Rap-Fish ordination technique, there is also Leverage analysis (Kholil and Dewi, 2014) used to determine lever attributes affecting the sustainable rice availability. Monte Carlo analysis was also used to estimate the effect of error in the analysis performed.

The Rap-Fish ordination analysis stages include:

1. Determination of technological and infrastructure dimension attributes on sustainable rice availability in West Kalimantan;

2. Assessment of each attribute on an ordinal scale (scoring) based on sustainability criteria of technology and infrastructure dimensions, ranging from 0-1, 0-2 or 0-3 according to the attributes described in Table 1;

3. Analysis of ordination to determine ordination and stress value using Rap-Fish software;

4. Assessment of index value and status of technology and infrastructure dimension, expressed with 0% (bad) to 100% (good) in four categories, show in Table 2;

5. Analysis of sensitivity (Leverage analysis) to see attributes or variables that are sensitively influenced expressed in terms of Root Mean Square (RMS) percentage with the highest percentage value (Kavanagh, 2001; Pitcher & Preikshot, 2001);

6. Monte Carlo analysis to evaluate the effect of random error, which is seen from the difference between MDS and Monte Carlo calculations. If the value is less than one, then the system is considered good enough or in accordance with real conditions (Kavanagh, 2001; Pitcher & Preikshot, 2001).

Table 1. Attributes of technology and infrastructure dimension

No	Attribute	Criteria	
		Bad	Good
1	Response / Adoption of farmers to technology	0	3
2	Conformity of suggested technology with farmers capability	0	2
3	Soil tillage	0	2
4	Cultivation technology: based on the use of technology in the process of rice cultivation	0	1
5	Harvesting and post-harvest technology: based on the use of technology / equipment type at harvest time	0	1
6	Availability of irrigation network: based on irrigation network conditions in support of rice production system	0	2
7	Availability of agriculture tools and machines (tractor, transplanter, hand sprayer, rice thresher machine, rice milling machine, pump machine etc.)	0	2
8	Support of road facilities and infrastructure: based on the percentage of villages served / passed by public transport vehicles / four wheeled vehicle	0	2
9	Sea port access: based on the proximity of the harbor / pier with the highway	0	2
10	Means of communication: based on the percentage of villages that can't access communication (no cell phone network)	0	2
11	Availability of facilities, marketing infrastructure: based on the percentage of villages that have groups of shops and markets, street vendors, etc.	0	2
12	Availability of food barn and rice warehouse	0	2

Table 2. Index category and sustainability status

Index value	Category
00,00 – 25,00	Bad: not sustainable
25,01 – 50,00	Poor: less sustainable
50,01 – 75,00	Fair: fairly sustainable
75,01 – 100,00	Good: highly sustainable

Source: Nurmalina, 2008

Results and Discussion

The Rap-Fish multidimensional analysis of 12 technological and infrastructure dimension attributes in supporting the sustainability of rice availability in West Kalimantan resulted in an index value of 42.52% categorized as less sustainable; this indicates that the condition of technology and the current infrastructure is less supportive for the sustainable rice availability in West Kalimantan, as shown in Fig. 2.

The accuracy and validity of the attributes examined and the effect of variables outside the system on the sustainability of rice availability can be seen from the value of stress, determination coefficient (R^2) and Monte Carlo index value resulted from the MDS analysis using Rap-Fish software, as shown in Table 3.

Table 3 shows that the attributes studied are valid and accurate as shown by the value of stress is low at 0.13 and < 0.25, and the value of coefficient determination (R^2) at 0.95 indicates that the attributes used in the model are able to explain 95% of the sustainable rice availability system in Kalimantan. In addition, the small difference (< 5%) between the MDS index value and Monte Carlo analysis indicates that the MDS method used to determine the sustainability index of rice availability in West Kalimantan has a high level of confidence. This suggests that: a) the effect of making errors and scoring variations is very small; b) data query error is very small; c) procedural errors that may affect the stability of the MDS process are relatively small.

Based on leverage analysis, Root Mean Square (RMS) value of 12 attributes was obtained (Fig. 3). Attributes influencing the sustainability of rice availability are shown by the highest percentage of RMS, i.e. harvesting and post-harvest technology (3.37%), cultivation technology (3.01%), support of road facilities and infrastructure (1.45%), and availability of agriculture tools and machines (1.45%).

Harvesting and post-harvest handling is an important as-

Table 3. Value of sustainability index (MDS) and Monte Carlo, value of stress and determination coefficient

Sustainability Index		Difference	Value of stress	Determination coefficient (R^2)
MDS	Monte Carlo			
42.52	42.66	0.14	0.13	0.95

Source: Data analysis, 2017

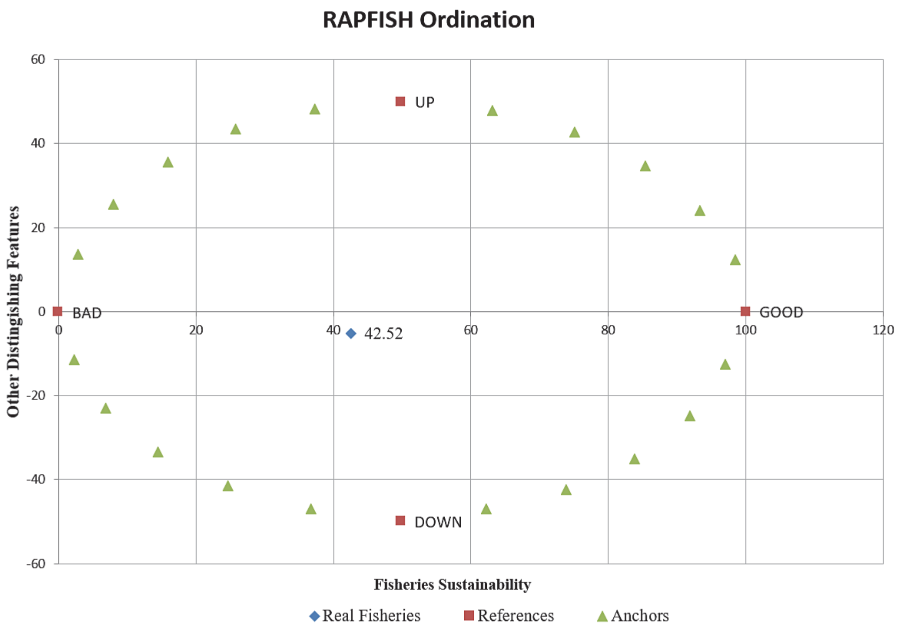

Fig. 2. Index value of sustainability of technology and infrastructure on availability rice in West Kalimantan

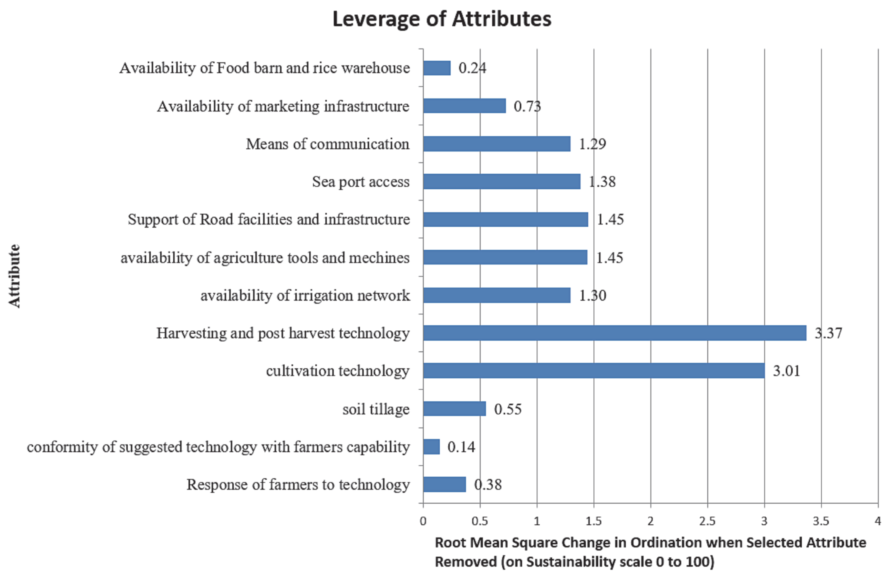

Fig. 3. Root mean square (RMS) value of technology and infrastructure attribute

pect in the development of rice system. This is related to the high yield loss, the low rice grain quality, and unstable price of rice grain. This problem tends not to intensify the increase of farmer's income.

An efficient post-harvest refers to a system that includes harvesting, processing, and consuming that aim to minimize loss and to maintain the quality of crops (Mejia, 2002). How to handle and to use harvesting and post-harvest technology determines the amount of wasted yield (Iswari, 2012). Post-harvest technology can secure crops and produce more qualified products (Sulardjo, 2014).

The application of pre-harvest and post-harvest technology by farmers is still simple. The process of harvesting, threshing, drying and transporting is mostly still done manually. Crop harvesting using hand cutting tools traditional such as ani-ani and sickle, threshing by slamming and drying on the floor in the sun with the help of sunlight take a lot of energy, time, depending on the weather and cause a high loss during harvest. According to the study conducted in Indonesia, 21.09% of the yield loss was due to the use of traditional sickles, threshing by way of slamming, sun drying, conventional milling and others (Iswari, 2012). Moreover, the high loss during post-harvest was caused by social and cultural factors such as farmers' reluctance to accept innovation, limited knowledge, inadequate technology, and poor storage infrastructure (Kumar and Kalita, 2017). In India, the delayed harvest was caused by inadequate harvest machine and thresher machine; this resulted in 1.74% to 1.92% of yield (Kannan et al., 2013). Other risks involved the attacks of insects, mice, and birds (Mejia, 2002).

Similarly, in the process of rice milling, although some of the farmers have used modern tools, the use is still not optimal due to farmers' limited knowledge, provision of facilities and capital; the impact on the quality of rice produced is still low. The condition caused the price difficult to compete with the price of rice from outside the island. According Shimizu et al. (2004), the main causes of loss through rice production from harvest to consumption involve characteristics of the variety, equipment and facilities, unsuitable milling equipment, inadequate facility management, and socioeconomic factors.

In terms of cultivation technology, farmers have long been familiar with cultivation technology through extension activities and training conducted by field extension officers, from Indonesian Center for Agricultural Technology Assessment and Development of West Kalimantan and through research application activities from various educational institutions. However, the cultivation technology applied in the research area is still simple. Some farmers still apply traditional methods for their farming. Consequently, the results obtained are also not optimal. The farmers still face obstacles such as inadequate financing capability, low agricultural yield and low regional accessibility (Hutahaean et al., 2015). Expensive farm machinery has contributed to the slow adoption of rice mechanization (Yaoming, 2004).

The use of high quality seed is difficult to implement due to the high price of certified superior seeds (Waridin, 2013). To anticipate the high price of the seeds, the farmers use seeds of their own yield or buy them from the seed breeders which does not pass the process of certification. Whereas, the use of fertilizer is still below the suggested amount; the high price and the scarcity of fertilizer at a time required makes the farmers not to be able to apply balanced fertilizer specific to location. Based on interview with farmers, sometimes to obtain input of production facilities such as fertilizers, seeds, pesticides and the other inputs, farmers should seek out their village or sub-district and even out other district that are very far away. The dependence of farmers on government's fertilizer aid is remarkably high.

Infrastructure is the primary public infrastructure for effective and efficient economic activities. West Kalimantan is one of the vast areas surrounded by many rivers. Some villages can only be passed by land transportation, some can be passed by water transportation, and some of them can be passed by both. There are 1.237 villages that can be traversed by land transportation, 107 villages are by only water transportation, 765 villages are by both; there are 1.191 villages or 56.47% which cannot be accessed with public transportation. Hence, the better the facilities and infrastructure of land transportation and water transportation, the better the distribution and mobility of the population and other resources.

The condition of the road network determines the distribution of rice and production facilities to the regions. There is positive correlation between the quality of road infrastructure and marketing system. The better the road infrastructure quality, the more farmers directly market their agricultural products to the market (Tarigan & Syumanjaya, 2013). Based on the primary data processing results, almost 60 percent of sample farmers stated that road conditions in their areas have not been good, referring to medium and bad road network conditions. The poor road condition causes high production costs such as fertilizers and pesticides. As illustration, the farmers living in Ketapang District must travel a distance of approximately 100 km to obtain fertilizer and pesticides. Under normal conditions, the distance can be reached in approximately 2-3 hours, but during the rainy season with muddy and perforated road conditions it takes approximately 7-10 hours; it is very difficult for loaded four-wheeled vehicles to pass the road. Inadequate road infrastructure leads to the delay of good distribution resulting in increased distribution cost and unaffordable goods price for producers and consumers (Saikudin et al., 2014).

The availability of agricultural tools and machinery in adequate quantities and conditions is helpful in increasing rice production. Agricultural tools and machinery that are often used by farmers are soil tillage and post-harvest equipment including tractor, irrigation pump, pest sprayer, power thresher, and rice milling. These tools and machines can save time and energy, improve yield quality, reduce yield loss, improve yield productivity, water supply. The use of the machine at the planting and maintenance stage can save the workforce from 60% to 2% (Hormozi et al., 2012), power thresher can reduce yield loss at the grading stage of 4.79% by the method of slamming to 1.90% (Iswari, 2012).

However, in practice, the user and machine ownership at the farm level is still limited and generally farmers still use manual and simple ways. Limitations of knowledge and high prices of agriculture tools and machineries make farming ownership to remain very low. The availability of tools and machinery is still far from the need. The potential land area in West Kalimantan is 530,478 ha, with the assumption that the capacity of 1 tractor can cultivate 25 ha/planting season then the tractor need is 21.219 units of tractor. The number of available tractors is 4.668 units, there is a shortage of 16.551 units of tractors.

Conclusions

The technological and infrastructure dimension support for sustainable rice availability is in a category of less sustainable as indicated by the MDS index of 42.52%. Attributes triggering that condition are post-harvest technology (RMS = 3.37%), cultivation technology (RMS = 3.01), road infrastructure (RMS = 1.45%), and availability of agriculture tools and machines (RMS = 1.45%) These triggering attributes could be the input of relevant agencies to develop policies to improve the availability of sustainable rice in the future.

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