Bulgarian Journal of Agricultural Science, 27 (No 5) 2021, 829–837

The improvement of dryland farming sustainable management in food-insecure areas in East Nusa Tenggara, Indonesia

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Abstract

Riptanti, E. W., Masyhuri, M., Irham, I. & Suryantini, A. (2021). The improvement of dryland farming sustainable management in food-insecure areas in East Nusa Tenggara, Indonesia. *Bulg. J. Agric. Sci., 27 (5)*, 829–837

Sustainable management of dryland farming plays an important role in food-insecure areas. Various agricultural policies and programs cannot be achieved without considering the sustainability of farm management. This article aims to analyze the sustainability of the management of dryland farming in food-insecure areas and the strategies to increase its sustainability. The study took a sample of the area on three large islands in the Province of East Nusa Tenggara (ENT), Indonesia. The samples of 240 farmers were taken by snowball sampling. Data were analyzed using the Multi Dimensional Scale (MDS) method. In this method, an ordination technique called Rapid Appraisal for Dryland Farming Management (RAP-DAFARM) was applied. The results of the study show that multidimensional management of dryland farming is less sustainable. To improve the sustainability status of dryland farming management in the future, some strategies are implemented, including increasing the role of capital supporting institutions, grouped-farming management patterns, agricultural insurance programs, agricultural livestock waste utilization, and others.

Keywords: multi dimentional scale; livestock waste utilization; agricultural insurance; management patterns

Introduction

Dryland areas in developing countries currently occupy more than 40% of the earth's surface and are homes to around 2.5 billion people (Fraser et al., 2011). About one-third of the population depend on dryland agricultural production systems for their food security and livelihoods (Biradar et al., 2013)global positioning system and geographical information system. Policies, poverty alleviation programs and realization of development goals cannot be achieved without paying significant attention to dryland. The productivity of dry land farming is influenced by land conservation, vegetation, technology, institution, and community socioeconomic condition (Ramakrishna & Rao, 2008). According to Irawan & Pranadji (2002)more attention of the Indonesian government on dry land farming represents a key factor. The implementation of appropriate strategy in developing agribusiness in the dry land region is very important to overcome both the short term economic problem induced by the crisis, and the long term national development problem through its external benefit in reducing environment problem and natural resources degradation. In this relation, efforts required are : (1, problems faced in the dryland management in Indonesia are intrinsic barrier (land) and anthropogenic barrier.

Sustainable agriculture is a central issue in sustainable development which involves the development of complex human-environment systems (Wu et al., 2010). The main obstacles in the adoption of sustainable farming practices include financial limitations for farmers, limited farmers' knowledge about the principles and methods of sustainable agriculture, soil erosion, water shortage and lack knowledge of extension workers associated with low sustainable agriculture (Chizari & Ommani, 2009)pesticides, and maximal tillage, but rely more on crop rotation, crop residues, animal manure, green manure, legumes, and appropriate mechanical cultivation or minimal tillage to optimize soil and natural pest control activity. Farmers all over the world are working as managers of their farm; the farmers manage the production system to get returns from it. Effective management agricultural extension has special relevance in the Iranian context where agriculture plays a key role in meeting food requirements and providing raw materials. Effective management is crucial for obtaining high returns from a production system on a sustained basis. Therefore, it is essential that farmers and extension personnel are made aware of local resources for developing the managerial ability of farmers to cope with new demands, new problems and new challenges. The purpose of this article is to present the results of a study done about the analysis of dryland sustainability of wheat farmers in the Khuzestan province of Iran. The research method employed was correlative-descriptive. Wheat farmers in Khuzestan province were the target population for this study. A random sample of wheat farmers were selected (N = 5529, n = 359.

The province of the East Nusa Tenggara (ENT) is one of the provinces in Indonesia which has high level of food insecurity and poverty areas (BPS, 2018). Dryland area is 83.13% of paddy field area (Agricultural Data and Information Center, 2017). The food-insecure areas in ENT are 37 percent of the total areas of the district areas (Food Security Council, 2015). Most of the ENT population worked in the agricultural sector (61.65%) in 2016, and then the number dropped to 53.32% in 2017. However, the agricultural sector only contributed 29.65% to the Gross Regional Domestic Product (GRDP) in 2016 and fell to 28.89% in 2017 (Riptanti et al., 2018). This condition indicates that the contribution of the agricultural sector to the economy is smaller than the proportion of the population working in the agricultural sector. On the other hand, this sector has not been able to meet the food needs of the population. This is so because the productivity of food crops is much lower than the average national food crop productivity (Badan Pusat Statistik, 2018). Based on the results of the research by Mulyani et al. (2014) in Nusa Tenggara, changing farmers' work ethic and habits in optimizing the utilization of the natural resource potential. The process of adaptation and capacity building in the management of dryland farming is a matter of agricultural sustainability. Farmers manage dryland farming by responding to the physical, biological, and socioeconomic environments dealing with the goals, desires, and limited household resources (Righi et al., 2011). Sustainable agricultural management plays an important role in food-insecure areas. The purpose of this article is to analyze the sustainability of dryland farming management in food-insecure areas and the strategies to increase the sustainability. The novelty of this research is that there has not been any study scrutinizing dryland farming sustainability in food insecure area either in ENT Province or Indonesia. This province has a major problem related to food insecurity that requires immediate solution.

Based on the results of the research by Mulyani et al. (2014) in Nusa Tenggara, changing farmers' work ethic and habits in optimizing the utilization of the natural resource potential. The process of adaptation and capacity building in the management of dryland farming is a matter of agricultural sustainability. Farmers manage dryland farming by responding to the physical, biological, and socioeconomic environments dealing with the goals, desires, and limited household resources (Righi et al., 2011). Sustainable agricultural management plays an important role in food-insecure areas. The purpose of this article is to analyze the sustainability of dryland farming management in food-insecure areas and the strategies to increase the sustainability. The novelty of this research is that there has not been any study scrutinizing dryland farming sustainability in food insecure area either in ENT Province or Indonesia. This province has a major problem related to food insecurity that requires immediate solution.

Research Methods

Most of the ENT regions, which reach 70%, are mountainous and hilly areas, while the rest is lowland. ENT Province is an archipelago with 1192 islands and 44 inhabited islands. The climate is semi arid. The study was conducted in three large islands namely Flores, Sumba and Timor. One regency with largest food insecurity in each island was taken as sample, including East Manggarai, East Sumba and South Central Timor. Two food-insecure sub-districts in each regency and two villages in each sub-districts were selected as samples, see in Figure 1.

The data collecting techniques in this study were survey, interview, and observation. The data were gathered from April to May 2019. Respondents in this research were divided into two groups. The first group consisted of farmers and the second group included head of agricultural services in each sub-district, regency, and province, agricultural field extension officers, heads of farmer groups, and heads of villages. Farmer respondents were taken using snowball sampling. There were 20 respondents in each village and 240

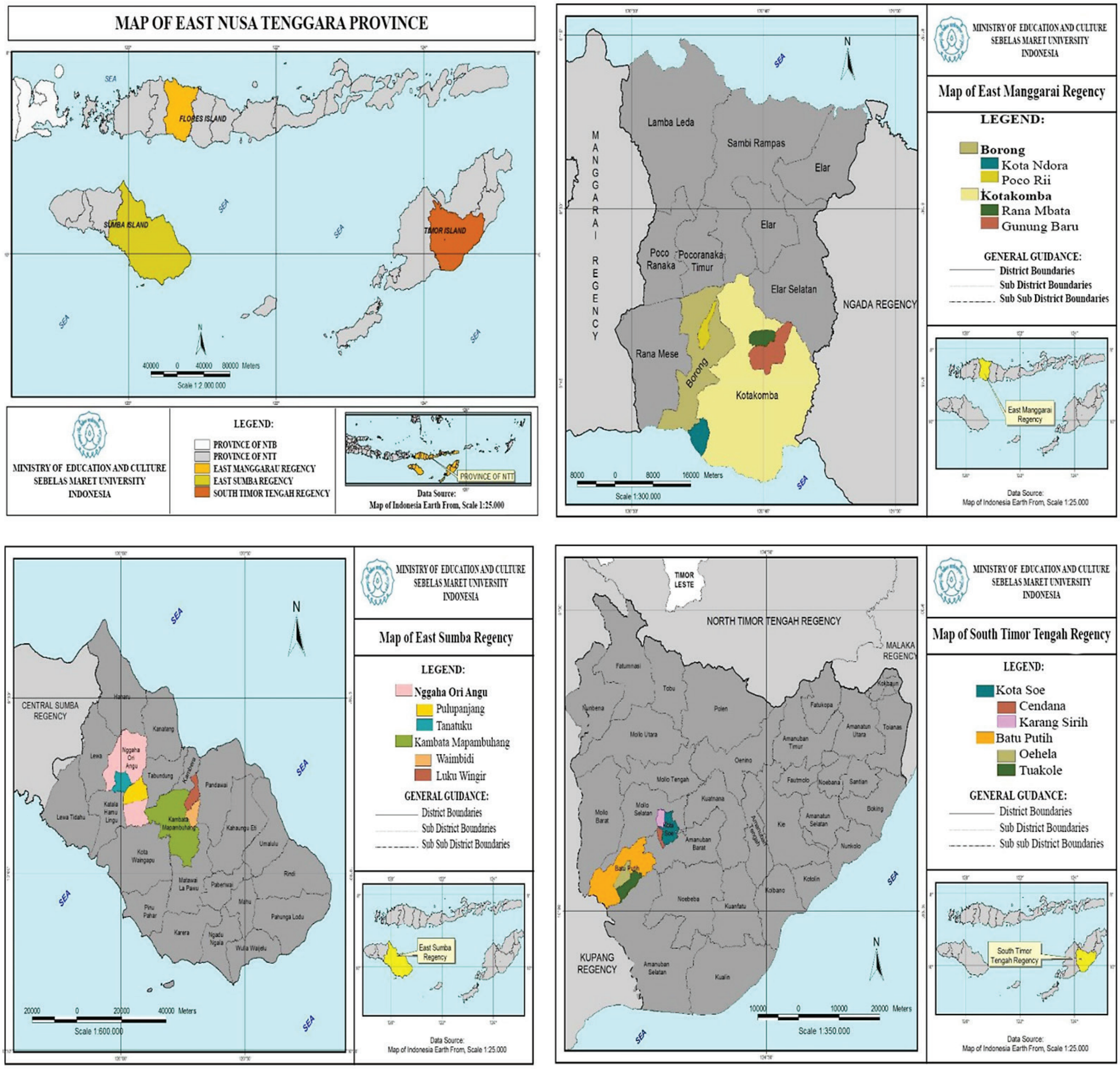

Fig. 1. Map of research location

respondents in all villages. The data from the first group were used to confirm the responses from the second group and provide recommendation for policy to improve sustainability.

The data were analyzed using a Multi Dimensional Scale (MDS) method. In this method, an ordination technique called Rapid Appraisal for Dryland Farming Management (RAP-DAFARM) was applied. RAF-DAFARM is a modification of the Rapid Appraisal for Fisheries (RAPFISH) method developed by Kavanagh (2001); Pitcher & Preikshot (2001). In this study, the method was used to determine the sustainability status of the environmental, economic and social dimensions. The attributes in these dimensions used the modification of the Dryland Sustainability Analysis Indicator by Sydorovych & Wossink (2008); Chizari & Ommani (2009); Haileslassie et al. (2016). Each attribute that was in good condition was given a score 3 (or 2), depending on the range defined by each attribute), while the worst was given a score 0 (Table 1). The score of each attribute was determined based on the reference research and inputs from experts.

The definitive score is the mode value. The score was analyzed to determine the point reflecting relative position of sustainability to the "good" and "bad" points using the multidimensional statistical ordination technique. Estimator score for each dimension was expressed using index values 0 (bad) and 100 (good) scale. The index values were grouped into four levels of sustainability status (Table 2).

Table 1. Attibutes and classifiers of "good" and "bad"

Attributes		Class	
		Good	Bad
Environmental dimension			
1.	The timely arrival of the rainy season every year	2	0
2.	Drough event	0	3
3.	Water conservation	3	0
4.	Land suitability	3	0
5.	Land management	3	0
6.	Land conservation	2	0
7.	Fertilizer use	3	0
8.	Agricultural waste utilization	3	0
9.	Pesticide use	2	0
10.	Planting frequency control	3	0
11.	Seed utilization	1	0
12.	Moving cultivation	0	2
Economic dimension			
1.	Land ownership status	3	0
2.	Profit-sharing mechanism for cultivated land (cultivator:owner)	3	0
3.	Feasibility of farming	2	0
4.	Marketing access	3	0
5.	Market coverage	2	0
6.	Role of capital supporting institution	2	0
7	Role of marketing institution	3	0
Social dimension			
1.	Agricultural extension	3	0
2.	Participation of family members in managing dryland	2	0
3.	Dryland management pattern	2	0
4.	The intensity of extension and training in sustainable agricultural technology	3	0
5.	Community development	3	0
6.	Mutual cooperation	1	0
7.	The role of agricultural extension center	2	0
8.	The role of agricultural insurance	2	0
9.	The role of farmer group	3	0
10.	Conflict occurrence	3	0
11.	Government support	2	0

Table 2. The sustainability status of dryland farming management

Index value	Sustainability status
0 – ≤ 25	Not sustainable
>25 – 50	Less sustainable
>50 – 75	Quite sustainable
>75 – 100	Sustainable

Source: Firmansyah et al. (2016)

Goodness of fit in MDS is reflected in the magnitude of S-Stress and R^2 values. S-Stress is the lack of fit or the error. A low S-stress value indicates good fit, while a high S-stress value indicates the opposite. In the RAPFISH approach, a good model is shown by S-Stress <0.25 (Fauzi & Oxtavianus, 2014). R^2 value that shows good fit is R^2 that is close to 1.

Sensitivity analysis is used to determine the leverage of attributes that sensitively affect the status of sustainable management of dryland farming. The change in the value of Root Mean Square (RMS) is the value obtained from the final analysis. When the value of RMS leverage is greater, the role of these attributes in improving the sustainability status of farm management is more sensitive. Pitcher & Preikshot (2001) found that the attribute chosen as the main lever factor is the attribute that has the highest RMS value up to the half of the value of each dimension of sustainability. Monte Carlo analysis in the RAP-DAFARM method was carried out to estimate the random error rate in the model resulted from MDS analysis for all dimensions at a 95% confidence level. When the difference in value between the results of MDS analysis and the analysis is smaller, the Monte Carlo model produced by the RAP-DAFARM method is better.

Results and Discussion

Multidimensional sustainability was analyzed using the RAP-DAFARM approach. The sustainability index of the economic dimension is 51.08 and considered quite sustainable. Meanwhile, the indexes of the social and environmental dimensions are 49.86 and 38.51 and are considered less sustainable. The result of multidimensional RAP-DAFARM analysis shows that the sustainability index is 46.48 and this falls into less sustainable. Indices for all dimensions of sustainability based on MDS analysis are presented in Figures 2, 3 and 4.

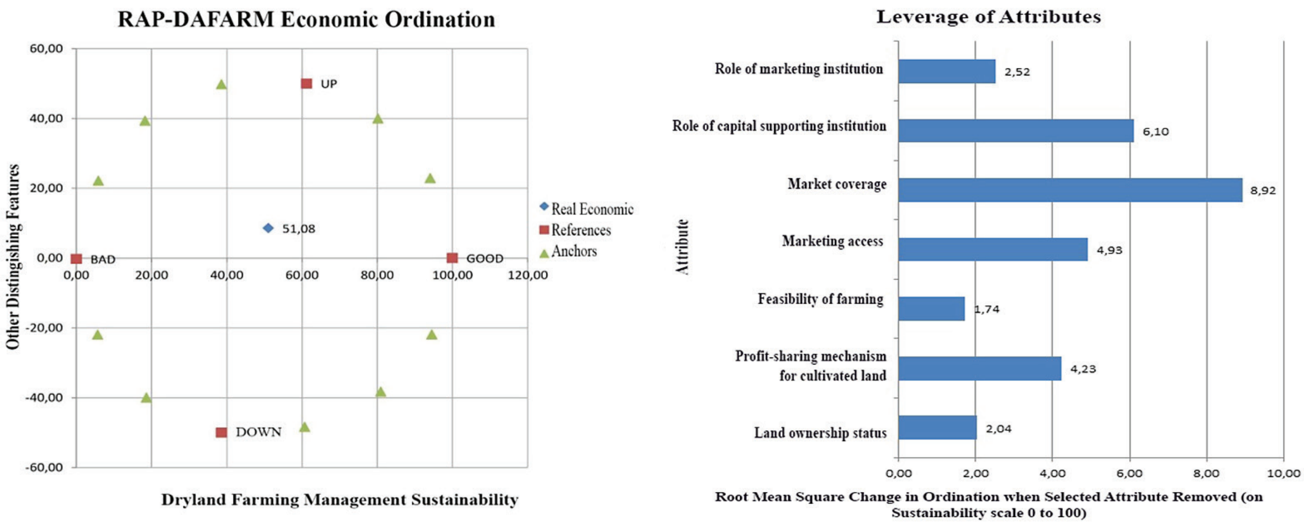

Fig. 2. Economic dimension

Sources: Outputs of RAP-DAFARM analysis, 2020

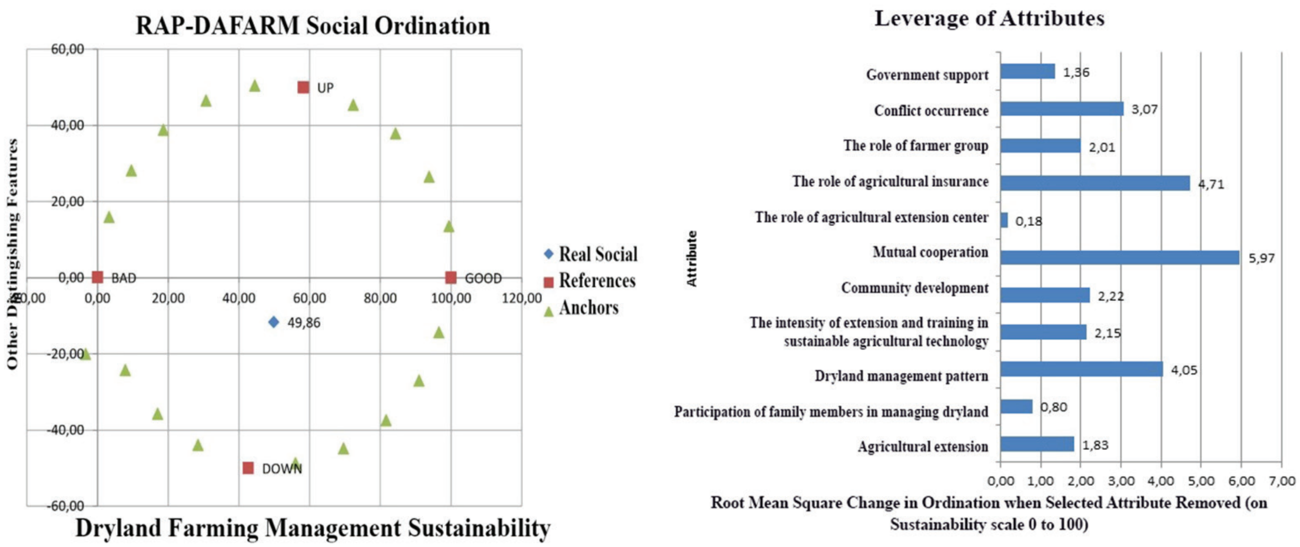

Fig. 3. Social dimension

Sources: Outputs of RAP-DAFARM analysis, 2020

Figure 2 indicates that the economic dimension is quite sustainable. This implies that the economic dimension in dryland farming management in food-insecure areas provides a sufficient economic value compared to other dryland farming management. The sustainability of this economic dimension is supported by the development of commodities needed by the community throughout the year and the relatively high selling price of agricultural commodities in the local market (Mutoko et al., 2014)development programs to enhance agricultural productivity have achieved mixed results. This study investigates farm household responses to a changing agro-environment in one of the most densely populated rural districts in SSA and examines practical implications for the promotion of sustainable land management (SLM. Based on the analysis of leverage on economic attributes, the market reach attribute (RMS = 8.92) and the role of capital supporting institution (RMS = 6.10) are the most sensitive to the improvement of sustainability status in the economic dimension.

Figure 3 demonstrates that the social dimension is less sustainable, which means that the community life is less

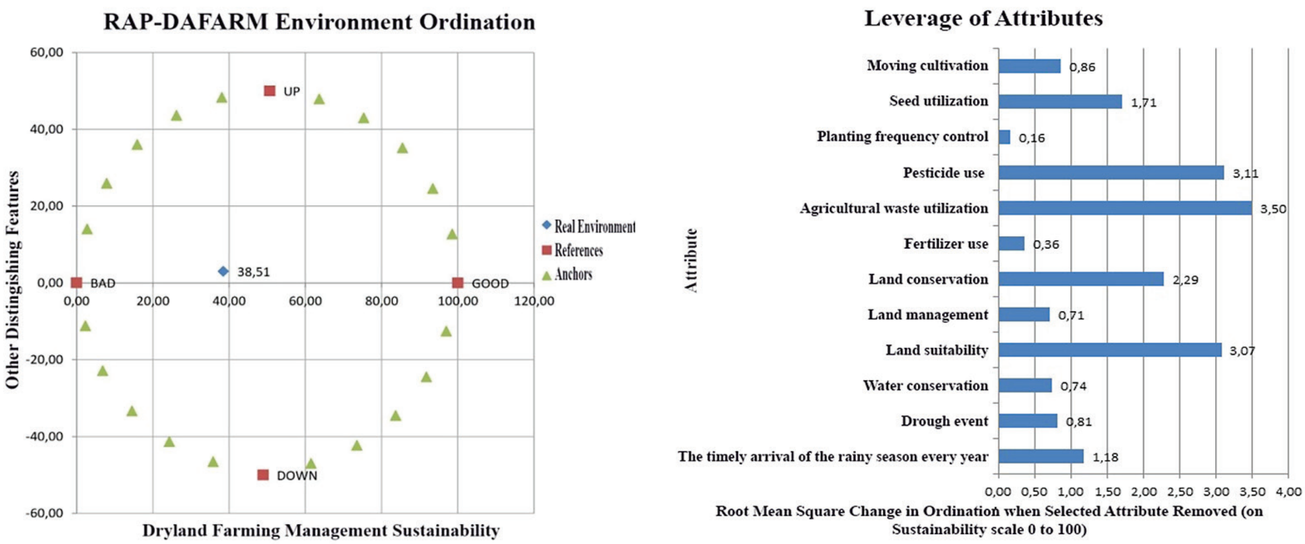

Fig. 4. Environmental dimension

Sources: Outputs of RAP-DAFARM analysis, 2020

supportive to dryland farming management in food-insecure areas. The agricultural lands that are very far from farmers' houses and separated from the other houses cause them to rarely communicate in managing their farming. It's contributing to individualized dryland management. Likewise, the roles of Counseling Centers, agricultural field extension officers (AFEO), and farmer groups are relatively low because the number of AFEOs is not balanced with the number and the distance of villages. Based on the analysis of leverage on social attributes, mutual cooperation habit (RMS = 5.97), the role of agricultural insurance (RMS = 4.71) and the pattern of dryland management (RMS = 4.05) are most sensitive to the increase of sustainability status in the social dimension.

The sustainability index in the environmental dimension as displayed in Figure 4 is considered less sustainable, meaning that attributes in the environmental dimension less supportive to dryland farming management in food-insecure areas. The availability of inputs and capital resources is a limiting factor in dryland management (Mutoko et al., 2014)development programs to enhance agricultural productivity have achieved mixed results. This study investigates farm household responses to a changing agro-environment in one of the most densely populated rural districts in SSA and examines practical implications for the promotion of sustainable land management (SLM. Farmers have not utilized sustainable agricultural cultivation technologies such as the processing agricultural waste as agricultural inputs, the use of organic/biological pesticides for pest and disease control, and land conservation (Srivastava et al., 2016)the complex network of dynamic interactions in the agro-ecosystem soil at spatiotemporal dimensions holds crucial importance. It reflects the inherent tendency of dynamic ecosystems to achieve a more efficient state successively through improved interactions. The short-sighted and inefficient agro-management during Green Revolution decades has been detrimental to these interactions in agricultural soils, which is widely evident by its boomerang effects (i.e. declining efficiency, productivity and multi-functionality. Organic or biological pesticides such as plant allelopathy, neem extracts or microbial bio-control agents (e.g. *Trichoderma, Pseudomonas* and *Bacillus sps*.) can be applied in the study areas. On the other hand, most farmers practice farming with minimum tillage/zero tillage, which is one of the principles of agricultural conservation that can increase sustainable agricultural production and reduce production costs (Kassam et al., 2012). In fact, minimum tillage/no tillage is not supported by good management practices. The attributes on environmental dimension that are sensitive to an increase in the sustainability index are agricultural waste utilization (RMS = 3.50), pesticide use (RMS = 3.11), land suitability (RMS = 3.07) and land conservation (RMS = 2.29).

The results of the RAP-DAFARM analysis, the goodness of fit, show that S-Stress <0.25 and R^2 >0.94, are close to 1, which means that the three dimensions in the RAP-DAFARM model belong to good fit. Monte Carlo analysis in RAP-DAFARM was carried out to estimate the random error rate in the model resulted from MDS analysis for all dimensions at a 95% confidence level. The results of the Monte Carlo analysis at the 95% confidence level indicate no significant difference between the results of the RAP-DAFARM analysis and the results of Monte Carlo test (Table 3).

Table 3. Differences in the value of the RAP-DAFARM analysis and the value of Monte Carlo analysis

Sustainability dimension	MDS	Monte Carlo	Difference
Economic	51.08	51.08	0.00
Social	49.86	49.48	0.38
Environmental	38.51	39.28	0.77

Sources: Outputs of RAP-DAFARM analysis, 2020

Table 4. Strategies to increase scores of attributes that are sensitive to sustainability status

No	Attribute	Strategy to improve score
1.	Market coverage	In terms of market coverage of agricultural products, there occurs lag of market for produce (Giller et al., 2009). Improvement of infrastructure by the government is highly vital in marketing agricultural products (El-Beltagy et al., 1997). A broader market coverage can streamline marketing where market selling prices will benefit farmers leading to commercial farmers (Dillon et al., 2010).
2.	The role of capital supporting institution	Market prospect is one of the keys to develop farming management (Jama et al., 2008). Capital is a factor that limits dryland farming (Knutson et al., 2011). Increasing capital can upsurge farm management capacity with the availability of adequate credit (Singh et al., 2004). Taking this condition into account, the most affordable capital institution for farmers is in cooperative.
3.	Mutual co-operation	Collaboration between farmers, either in farmer groups or between farmer groups (Whitbread et al., 2010), is commonly called “mutual cooperation”. Mutual cooperation is one of social capitals in agriculture. To improve the sustainability status, mutual cooperation needs to be nurtured and developed by members of farmer groups and farmers cultivating spread-out lands (El-Beltagy et al., 1997).
4.	Role of agricultural insurance	The government should prioritize policies on determining agricultural incentives/ subsidies/ insurance in the studied area to deal with the risk of crop failure (Bowers, 1995; Singh et al., 2004). If agricultural insurance policy is implemented, farm management will be more sustainable (Knutson et al., 2011).
5.	Dryland management pattern	Dryland management pattern is commonly managed individually. This contributes to limited ability to manage dry land. Therefore, to streamline the management of dryland farming, farmers need to manage the land in groups, both the investment and the resources. Manager capacity is very important to achieve sustainability and increasing dryland farming manager capacity requires human capital investment (Berhanu et al., 2007).
6.	Agricultural waste utilization	The limited knowledge and skills in the utilization of agricultural and livestock waste is the obstacle. Therefore it is necessary to increase human resources in using agricultural technology (El-Beltagy et al., 1997). The role of AFEO and farmer groups in the dissemination of knowledge and skills in the use of waste as organic fertilizer is very significant. The synergy of the integration between farming and animal husbandry is a key factor in providing sources of soil nutrient (Singh, 1998).
7.	Pesticide use	Threats that appear for farming sustainability are pests and plant diseases (Goldman, 1995). This contributes to frequent crop failures. To support sustainability, AFEO and farmer groups play an important role in making vegetable pesticides for diffusion and adoption processes (Fowler & Rockstrom, 2001).
8.	Land suitability	Mapping land suitability for drought-tolerant crop cultivation and increasing planting index in suitable areas (Miyan, 2015) are necessary to practice.
9.	Land conservation	Land conservation is carried out individually or in groups with civil engineering or vegetation building approaches that are affordable for farmers, including water harvesting. Land and water conservation can improve the sustainability of dryland management (Bowers, 1995; Fowler & Rockstrom, 2001).

Sources: Outputs of RAP-DAFARM analysis, 2020

Table 5. The results of leveraging the value of sustainability in each dimension

Dimension of sustainability	MDS	Leverage results		
		MDS	*S-Stress*	Squared Correlation (RSQ)
Economy	51.08	61.54	0.1400147	0.9413424
Social	49.86	61.33	0.1330773	0.9527943
Environment	38.51	61.52	0.1333331	0.9545442

Source: Outputs of RAP-DAFARM analysis, 2020

On the environmental dimension, the difference between MDS and Monte Carlo values are more than 0.5 (> 0.5) and considered relatively unfavorable. Difference in value > 0.5 is likely caused by an error due to lack of understanding or differences in opinion (Pitcher et al., 2013).

Key factors in improving sustainable management of dryland farming in the future are considered from the attributes that have an RMS value of more than half in each dimension of sustainability. The score is raised 1 level to achieve a moderately sustainable status. Strategies undertaken to increase the score of sensitive attributes are presented in Table 4.

Strategies to increase scores on sensitive attributes need to be comprehensive. The government, field extension workers, farmer groups, community leaders, farmers and stakeholders work together according to their respective roles in the implementation of these strategies. Attributes that are sensitive to improve the sustainability status after being raised one level are demonstrated in Table 5.

The results of multidimensional RAP-DAFARM analysis on the increase of sensitive attribute scores show a sustainability index of 61.8 (quite sustainable). Building farmers' care and awareness on the importance of sustainable farming needs to be done before these strategies are implemented. When socialization on the importance of sustainable agriculture is carried out at farmer group level meetings or community meeting more often, the farmers's level of understanding will be better. This is because farmers are faced with a variety of limitations, and thus, to carry out strategies that serve as sustainability leveraging factors is not easy.

Conclusion

In managing dryland farming, farmers are faced with various internal and external limitations. They apply indigenous knowledge to adapt to the situation in order to respond to the environmental, economic and social conditions. Dryland farming focuses on the production of corn and upland rice to support the availability of staple foods at the household level. Farming is also combined with livestock but it has not been well integrated. Based on MDS sustainability analysis modified using RAP-DAFARM, it is obvious that the dryland farming management in food-insecure areas is considered less sustainable. Based on these findings, the efforts to improve dryland farming sustainability are made by applying the strategies to the key factors of the attributes that have RMS value of more than half of each sustainability dimension. The successful implementation of the strategies requires synergy and joint commitment from stakeholders in the food insecure areas of East Nusa Tenggara in terms of policies, programs, budgeting and facilities.

The strategies that are implemented to achieve a fairly sustainable status include 1) expanding market coverage, 2) increasing the role of capital supporting institutions, 3) increasing mutual cooperation activities, 4) agricultural insurance programs, 5) patterns of grouped dryland management, 6) agricultural waste utilization, 7) plant-based pesticide use, and 8) land suitability and land conservation. The strategies are implemented comprehensively by all concerned parties.

Acknowledgements

We would like to express our sincere gratitude to Universitas Sebelas Maret for funding this research through the Dissertation Research Grant and Indonesian Ministry of Research, Technology and Higher Education for granting Beasiswa Pendidikan Pascasarjana Dalam Negeri. Our sincere appreciation is also extended to all parties who have provided information to complete this article.

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Received: October, 16, 2020; *Accepted:* February, 2, 2021; *Published: October,* 2021