Eco. Env. & Cons. 27 (4) : 2021; pp. (1541-1550)
Copyright@ EM International
ISSN 0971–765X

Model of Sustainable Development of Sugarcane Agroindustry in Nusa Tenggara Timur Province

Fahrizal[1], Marimin[2], M. Yani[2], M.Y.J. Purwanto[3] and Sumaryanto[4]

[1]Department of Mechanical Engineering, University of Nusa Cendana, Indonesia
[2]Department of Agroindustrial Technology, Bogor Agricultural University, Indonesia
[3]Department of Civil and Environmental Engineering, Bogor Agricultural University, Indonesia
[4]Indonesian Center for Agricultural Socio-Economic and Policy Studies, Ministry of Agriculture Republic of Indonesia

(Received 22 January, 2021; Accepted 4 March, 2021)

ABSTRACT

Nusa Tenggara Timur (NTT) is one of the provinces in Eastern Indonesia, which has the potential for sugarcane agroindustrial development. NTT has different characteristics compared with regions in Indonesia that have already been developing sugarcane agroindustry, leading to the need for information to look at the sustainability of sugarcane agroindustrial development in this region. The objective of this research was to analyze sugarcane industrial development sustainability in NTT. Sustainability dimensions considered in this study were resources, economic, social, and environment. The performance of each dimension was analyzed by using Multiple Dimensional Scaling and leverage analysis. The weight of each dimension was determined using pairwise comparison method. The multiple dimensional sustainability index was obtained using a weighted average aggregation method. The results showed that all dimensions were at quite a sustainable level. The aggregated sustainable index value was 65.41 which indicates that the sustainability of sugarcane agroindustrial development at Nusa Tenggara Timur Province was at quite a sustainable level. Of the 24 attributes that were analyzed, there were 4 attributes (the availability of agricultural labor, sugarcane yield, health and safety, and utilization of liquid waste) which were very sensitive to the index of sustainability. Therefore, it is recommended to improve these attributes performance to enhance the sustainability of sugarcane agroindustry.

Key words: *Sustainability, Sugarcane agroindustry, Multiple dimensional scaling, Nusa Tenggara Timur Province.*

Introduction

Currently there are 63 cane sugar mills in Indonesia with total production in 2012 reached 2.7x10^6 tons. However, the total production has not been able to meet the needs of national sugar consumption reaching 5.4x10^6 tons (Statistic Berau Centre Republic of Indonesia, 2012a). National sugar consumption is expected to continue to increase along with the population growth rate of 1.49% per year (Statistic Berau Centre Republic of Indonesia, 2012b) and the rate of sugar consumption reaching 66.48 kg per capita (Statistic Berau Centre Republic of Indonesia, 2013). One strategy to increase the national sugar production is the expansion of sugarcane plantations along with the construction of new sugar factories, especially on dry land in Eastern Indonesia reaches 4.0x10^6 ha, in Kalimantan, Sulawesi, Nusa Tenggara, and Papua (Mulyadi *et al*., 2009).

NTT has a comparative advantage for the development of cane plantations. The high intensity of solar radiation and the radiation which leads to high net photosynthetic yield of sugarcane to the maximum, or the increasing yield of sugarcane. Results of experiments with different varieties of cane show on average 12.73% yield of sugarcane (Indonesian Sugar Research Institute, 1985). However, agricultural land in the NTT is dominated by dry land with dominant rainfall in the range of 1000-2000 mm per year (Djaenuddin *et al*., 2002). Associated with sugarcane growing conditions, the availability of water is a major constraint for sugarcane agronidustrial development in the NTT.

Sugarcane is a plant that requires large amounts of water at the beginning of the growth, equivalent to a rainfall of 100 mm per month (Purwono, 2012). Enough supply of water is a necessary condition to achieve good growth and increased productivity of sugarcane. Meanwhile (Choudhary *et al*., 2004) report that to produce 1 ton of sugarcane, as much as 125 tons of water is needed, while to produce 1 ton of sugarcane approximately 5 tons of water is needed. This indicates that the sugarcane agroindustry requires large amounts of water in their production activities. The availability of water for production activities in the on-farm and off-farm production must be taken into consideration in the analysis of sustainability of sugarcane agroindustry in the NTT.

In addition to the availability of water, a critical problem in dryland is low soil fertility, which is characterized by the availability of nutrients, especially phosphorus (P) and very low organic matter content (Purwono, 2012). Low soil fertility will have an impact on the level of use of fertilizers, particularly inorganic fertilizers. Exessive use of inorganic fertilizers will harm the environment. Thus, the use of inorganic fertilizers is taken into consideration in the analysis of the sustainability of sugarcane agroindustry.

Cultivation of dry land sugarcane is not affected by crop rotation, thus enabling repeated ratooning. Besides, the cultivation of ratoon is cheaper than plant cane, as there are no-tillage and seed costs, thus enabling repeated ratooning. However, the higher the number of ratoons, the lower the productivity of sugarcane. Lower ratoon productivity will affect on the non-fulfillment of milling capacity and profitability of sugarcane growers and processing industry (Muchow *et al*., 1998; Salassi and Breaux, 2002; Susila and Sinaga, 2005; Mulyono, 2006). Restrictions on the number of ratoons can be done in the form of consensus among multiple stakeholders who have a conflict of interest in achieving a goal. Conflict resolution to make decisions together or group has been widely described by several studies (Suharjito and Marimin; Lejars *et al*., 2008; Regan *et al*., 2006). Thus, the number of ratoons is taken into consideration in the analysis of the sustainability of the sugarcane industry.

Sustainable agroindustrial development is the construction of an industry that is based on the concept of sustainability, in which the intended agroindustry is built and developed by taking into account aspects of management and conservation of natural resources. The technology used and institutions involved in the development process is geared to meet the interests of human beings in the present and future. The technology used is in accordance with the carrying capacity of natural resources; there is no degradation of the environment, it is economically profitable, and it is socially accepted by society (Soekartawi, 2001).

So far, the approach to the development of sustainable agroindustry is very diverse and depends on the conditions of each region and the characteristics of the agroindustry. (Purnomo *et al*., 2011; Purnomo, 2012) analyze the sustainability of fishery agroindustry resources through a dimensional, economic, social, technological, and environmental approach. Furthermore, (Novita, 2012) examines the sustainability of robusta coffee agroindustry through a dimensional approach on economic, social, environmental, and institutional. Sugarcane agroindustry is an integrated and complex systems, including cultivation, harvesting, transporting, milling, and marketing (Higgins and Muchow, 2003). To find out the status of the sustainability of sugarcane agroindustrial development in NTT, an analysis of sustainability based on the four dimensions, namely resources, economic, social, and environmental dimensions, must be done.

The purpose of this study is to (a) assess the sustainability of sugarcane agroindustrial development status in NTT, (b) identify factors or attributes that sensitively affect the sustainability of sugarcane agroindustrial development in NTT, and (3) formulate policy directives in sugarcane agroindustrial development in NTT.

Materials and Methods

Research Framework

Sugarcane agroindustry is a complex system, requiring integration between the farming sector with the processing industry to increase production, improve profitability, and reduce environmental impacts. Such integration is based on the perspective of sustainable agroindustrial development (Soekartawi, 2001).

Sustainable development perspective is used, by basing sustainability of sugarcane agroindustry in several dimensions that refer to the fundamental pillars of sustainable development perspective including resources, economic, social, and environmental pillars, by not leaving special characteristics of sugarcane agroindustry as a starting point of analysis. The framework underlying the analysis of sustainability of sugarcane agroindustry is presented in Figure 1.

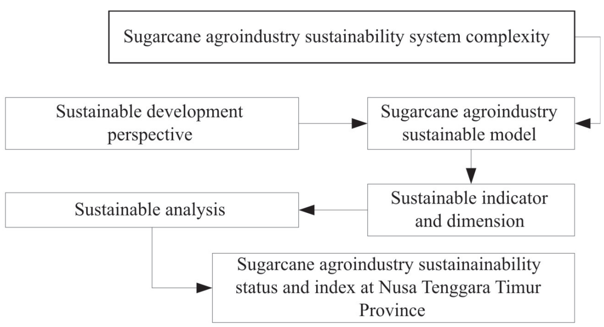

Fig. 1. Research framework

Stages of the Research

Stages of research refer to the methodology of systems approach (Parnell *et al*., 2011; Jaya, *et al*., 2013). This study was designed through systemic, logical, and structured stages, consisting of: (i) a preliminary study; (ii) the design of sustainable system; (iii) continuous modeling; and (iv) development of policy alternatives.

Multiple dimensional scaling (MDS) is used to assess the index and sustainability status as well as to identify the most sensitive attributes of each dimension of sustainability through leverage analysis. The stages of the study on the sustainability of sugarcane agroindustrial development in the NTT is presented in Figure 2.

MDS method is done through several stages. The first stage is the determination of attributes in each dimension of sustainability and definition of the attributes through a literature review, field observations, and discussions with several experts. In this study, the analysis includes 30 attributes in 4 dimensions, namely 6 attributes on resources dimension, 12 attributes on the economic dimension, 6 attributes on the social dimension, and 6 attributes on the environmental dimension. The second stage is an assessment of each attribute in an ordinal scale (scoring) based on the results of field surveys and expert assessment. The third is ordination analysis on MDS to determine the position of the sustainability status in every dimension in the continuity index scale. The fourth is to perform a sensitivity analysis to determine the sensitive variables affecting sustainability. Sensitive attributes are identified through changes in the Root Mean Square (RMS) on the ordinate of the X-axis. The greater the change in RMS, the more sensitive the role of the attribute to increase sustainability status. The last is Monte Carlo analysis to take into account the dimensions of uncertainty (Kavanagh, 2001; Pitcher and Preikshot, 2001). In the analysis employing MDS, the stress value and coefficient of determination (R^2) is also determined. Monte Carlo index value is compared with the MDS index. Stress values and coefficient of determination function to determine whether the addition of attributes is necessary or not, and reflect the accuracy of the dimension examined with the actual situation. Furthermore (Fauzi and Anna, 2005) confirm that the low value of S-stress indicates a good fit, while the high

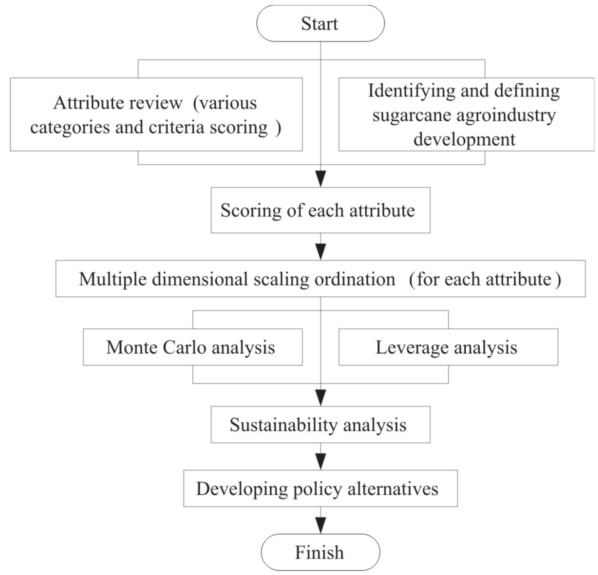

Fig. 2. Stages of the research

value of S-stress suggests the other way around. According (Kavanagh and Pitcher, 2004), a good model (quite good results of analysis) is obtained when the value of S-stress is less than 0.25 (S<0.25), and R^2 close to 1 (100%).

Sustainability index scale systems studied have a range of 0 percent to 100 percent, as shown in Table 1 (Hidayanto *et al*. 2009).

Table 1. Index category and sustainability status

Index value	Category
0.00-25.00	Bad (unsustainable)
25.01-50.00	Low (less sustainable)
50.01-75.00	Fair (quite sustainable)
75.01-100.00	Good (sustainable)

Data Collection

The source of data was the primary and secondary data. The primary data was in the form of biophysical and socio-economic data obtained through field survey activities in the NTT. Primary data was also obtained through benchmarking at Sindanglaut Sugar Factory and Subang Sugar Factory, West Java, Indonesia. Secondary data were obtained from the results of studies, reports, and programs of departments and related agencies.

Results and Discussion

System Analysis

System analysis is performed through the analysis of the needs of the components related to the sustainability of sugarcane agroindustrial development. Based on expert opinion and literature review, there are four dimensions, namely resources, economic, social, and environmental. (Purnomo, 2012; Novita, 2012; Jaya *et al*., 2013) state that these fourth dimensions are the main pillar in the sustainability of agroindustry. The dimension and attributes included in the analysis of the sustainability of the development of sugarcane agroindustry are presented in Table 2.

Sustainability Index of Sugarcane Agroindustrial Development

Based on the analysis using MDS, it is known that the sustainability index on resources dimension is 62.69% (quite sustainable); economic dimension is 70.85% (quite sustainable); social dimension is 67.18% (quite sustainable), and environmental dimension is 55.89% (quite sustainable). For all these dimensions to be sustained in the future, then the sensitive attributes (existing condition) of each dimension need intervention or improvement. The value of each dimension of sustainability is presented in Figure 3.

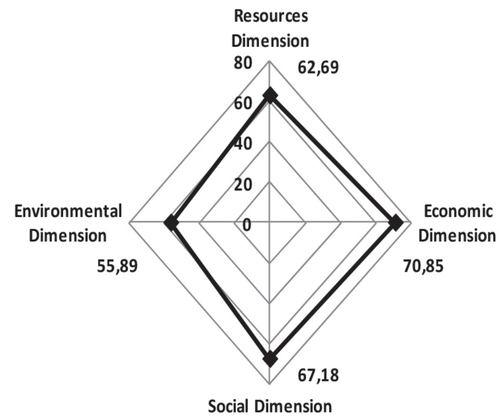

Fig. 3. Kite diagram of sustainability index in sugarcane agroindustrial development

To find out multiple dimensional sustainability index, the index of each dimension is aggregated using weighted average aggregation method (Purnomo, 2012). Meanwhile, the weight of each dimension was determined using the pairwise comparison method (Saaty, 1998). Multiple dimensional sustainability index is 65.41. It indicates that the sustainability of sugarcane agroindustrial development at NTT is quite sustainable. The determination of multiple dimensional sustainability index is presented in Table 3.

Resources Dimension

The analysis shows a sustainability index of 62.69% (quite sustainable), a stress value of 0.152, and an R^2 value of 0.994. According to Kavanagh (2001), the allowed stress is less than 0.25. A stress value of 0.152 indicates that the result of the analysis is quite good, and R^2 of 0.944 indicates that the model using variables has explained 94.4% of the existing model.

Leverage analysis results indicate that the main leverage factors for resource dimension are (1) the availability of agricultural labor, (2) the availability of dry land sugarcane cultivation technology, and (3) the existence of dry land research institutes. These attributes must get a major concern in the development of sugarcane agroindustry, which is expected to improve the sustainability status. The

Table 2. Dimension and attributes

Dimensions		Attributes
Resources	1.	Suitability of land and agro-climatic conditions
	2.	Varieties and quality of seeds
	3.	The availability of agricultural labor
	4.	Dryland sugarcane cultivation technology
	5.	Dryland research institutes
	6.	Infrastructure
Economic	1.	Profit gained by the sugarcane industry
	2.	Profit gained by sugarcane farmers
	3.	Sugarcane credit
	4.	Transportation of sugarcane
	5.	The number of ratoon
	6.	Productivity of sugarcane
	7.	The yield of sugarcane
	8.	Competitiveness of sugarcane to other commodities
	9.	Market share
	10.	Contribution to local revenue
	11.	Farm management
	12.	The cost of labor
Social	1.	Employment
	2.	The participation of farmers in partnership
	3.	Health and safety
	4.	Linkages with the livestock sector
	5.	Land tenure
Environmental	1.	Utilization of waste
	2.	Utilization of CO_2 in the purification of juice sugar
	3.	Wastewater management
	4.	The use of water
	5.	The use of chemical fertilizers
	6.	Fire in sugarcane plantation

Table 3. Determination of multiple dimensional sustainability index

Dimension of sustainability	Index Value	Weight	Index Value*Weight
Resources	62.69	0.489	30.65
Economic	70.85	0.327	23.16
Social	55.89	0.074	4.13
Environment	67.18	0.111	7.54
Multiple dimensional sustainability index		65.41	

sustainability index and leverage analysis results on the resources dimension are presented in Figure 4.

Availability of agricultural labor is the most sensitive attribute. The results of the field survey show that agricultural labor especially for sugarcane was not yet available; this was due to the unavailability of the sugarcane industry in the NTT until now. Sugarcane has not been widely known by farmers. Socialization by agricultural counselors has not covered the sugarcane commodity. Farmers plant crops such as corn, beans, cashew and other dryland commodities based on what they learn from their parents. Existing research institutions in the NTT such as the Institut for Agricultural Technology of Nusa Tenggara Timur and the Research Institut of the University of Nusa Cendana have not yet conducted many studies on sugarcane cultivation technology.

Intervention or improvement on the attributes to be done to improve the sustainability index is the introduction of sugarcane and the introduction of manufacturing technology of sugar. Thus, farmers are indirectly familiar with the technology of cultivation and processing of sugarcane, although in its simplest way. Research institutes must also develop

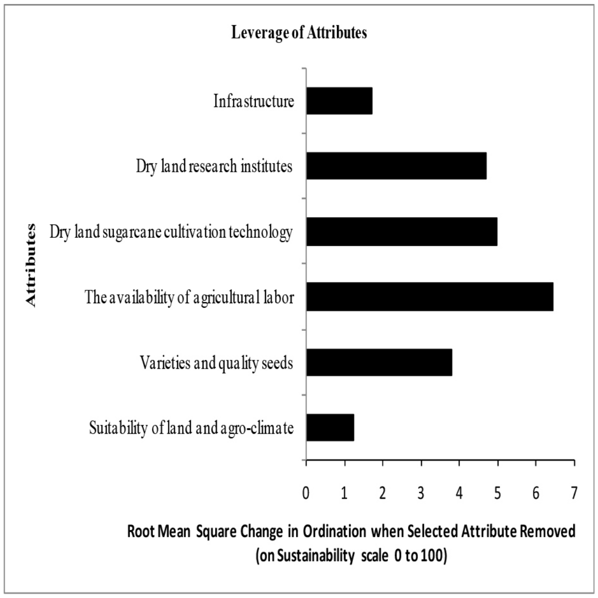

Fig. 4. Attributes sensitive to the sustainability of resources dimension

research on sugarcane cultivation technology on dry land that is more suitable to the condition of the local area.

Economic Dimension

The MDS analysis results in a sustainability index of 70.85%, a stress value of 0.136, and an R^2 value of 0.95. Leverage analysis results indicate that there are three main leverage factors for the economic dimension, namely (1) the yield of sugarcane, (2) the competitiveness of sugarcane against other commodities, and (3) the number of ratoons. These attributes have to get a major concern in the development of sugarcane agroindustry, which is expected to improve the sustainability status. The sustainability index and leverage analysis results on the economic dimension are presented in Figure 5.

The yield of sugarcane in NTT is high enough, due to high radiation intensity and duration, reaching 93.76% (Climatology Meteorology and Geophysics Agency of NTT, 2012). The experimental results obtained the average yield of sugarcane of 12.73% (Indonesian Sugar Institute, 1985). High sugar yield correlates with the high production of sugar and high profits to be obtained. Farming on dry land shows that sugarcane provides greater revenue compared to other dryland crops. Sugarcane in dry land is more prospective for farmers, especially in the areas of climate belongs to the D and E type as a

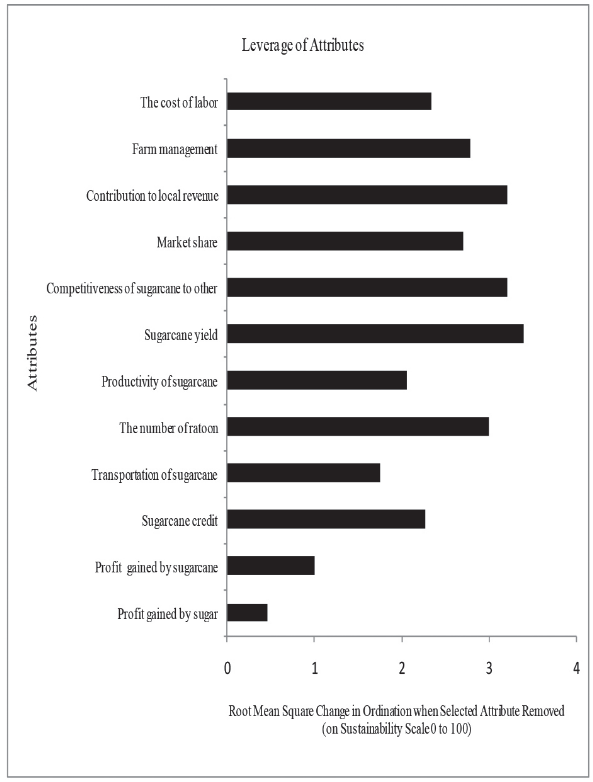

Fig. 5. Attributes sensitive to the sustainability of economic dimension

classification based on the Oldeman. This is because other crops have certain conditions of soil and climate to meet (Hafsah, 2003). Therefore, the factors that affect the yield of sugarcane should be taken into account so that the yield of sugarcane remains high.

Dryland cultivation of sugarcane is not affected by crop rotation, thus enabling repeated ratooning. However, the high number of ratoons decreases the production of sugarcane and leads to the non-fulfillment of the milling capacity of the sugar factory. The profits gained by cane sugar mills reduce as a result of the cost of idle capacity. The number of ratoons at farm level should be limited to the optimum, as to provide maximum profits to farmers and cane sugar mills. These attributes need to be managed properly to increase the sustainability index.

Intervention on the attributes to be done to improve the sustainability index is planning the planting properly and selection of varieties of sugarcane in accordance with the conditions of the local area, supported by efforts to maintain and improve soil fertility and the provision of sufficient irrigation water, as to provide maximum sugarcane growth and to help improving productivity and yield. Other activities that can be done is the involvement of central and local governments in protecting and maintaining the price of sugar so that farmers' willingness to grow sugarcane remains high. To improve sugarcane production and profits of farmers and the sugarcane industry, consensus on restrictions on the number of ratoons should be made.

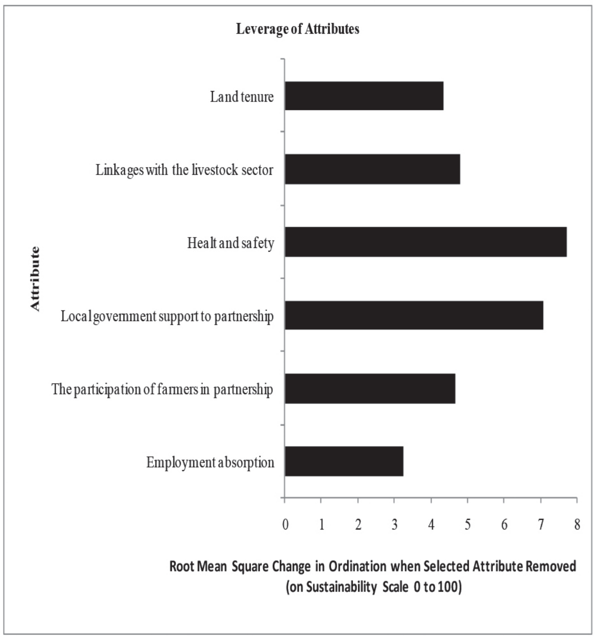

Fig. 6. Attributes sensitive to the sustainability of the social dimension

Social Dimension

The MDS analysis results in a sustainability index of 67.18% (quite sustainable), a stress value of 0.145, and an R^2 value of 0.945. Leverage analysis results indicate that there are three main leverage factors for the social dimension, namely (1) health and safety, (2) local government support to partnership, and (3) linkages with livestock sector. These attributes have to get a major concern in the development of sugarcane agroindustry, which is expected to improve the sustainability status. The sustainability index and leverage analysis results on the social dimension are presented in Figure. 6.

Agroindustrial development in a region will provide a positive and negative impact on the surrounding community. The positive impacts are work opportunities or employment and increased economic activities. The negative impacts are in the forms of environmental pollution due to industrial waste generated, either solid, liquid, or gas produced. Environmental pollution caused by the waste will adversely affect the health of the people around the industry. Public rejection will appear if the existence of the industry does not provide health insurance for employees and especially communities around the industry. The positive impact of employment and an increase in economy activates is the increase in people's income. Levels of community income distribution are measured through the Gini Ratio Value (Gini Index) (Rustiadi *et al.*, 2011). The smaller the Gini Index, close to zero, means the better the distribution of incomes. Conversely, high Gini Index is usually followed by a high degree of social inequality and could trigger social unrest.

NTT Province is also known as one of the centers of national cattle production. Sugarcane agroindustrial development in the NTT should be integrated with the livestock sector, especially in the supply of animal feed. Integration of the beef cattle industry and sugarcane plantations in Tanegashima Island, Japan can reduce the input for feed and fertilizer costs (Gradiz *et al.*, 2007). Therefore, the attributes of health and safety, local government support on partnership, and linkages with the livestock sector must be maintained and cared properly, thus increasing the sustainability index.

Intervention or improvement on the attributes to be done to improve the sustainability index is the

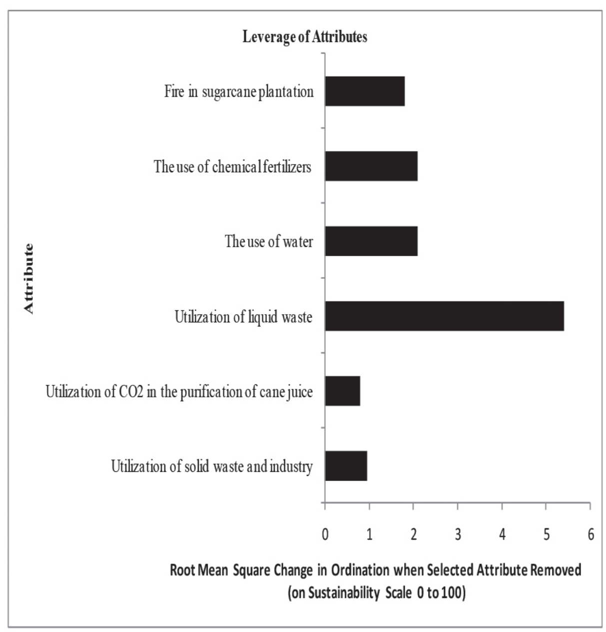

Fig. 7. Attributes sensitive to the sustainability of the environmental dimension

utilization of sugarcane waste leaves and top cane for animal feed, as well as utilization of livestock manure for fertilizer of sugarcane. This integrated activity can reduce the cost of sugarcane production inputs and livestock production. It is also important for the industry to create employment. Also, the proper management of industrial waste can reduce the negative impact on public health around the industry.

Environmental Dimension

The MDS analysis results in a sustainability index of 55.89% (quite sustainable), a stress value of 0.162, and an R^2 value of 0.939. Leverage analysis results indicate that there are three main leverage factors for the social dimension, namely (1) the management of industrial wastewater, (2) the use of water, and (3) the use of chemical fertilizers. These attributes have to get a major concern in the development of sugarcane agroindustry, which is expected to improve the sustainability status. The sustainability index and leverage analysis results on the environmental dimension are presented in Fig. 7.

Sugarcane agroindustry produces liquid waste such as contaminated and uncontaminated water. The contaminated water is wastewater mixed with chemicals in the processing of sugar. Unlike the uncontaminated water, the contaminated water is not recycled and is used again in the processing of sugar. The contaminated water is discharged into the environment (rivers) or sugarcane plantations after treatment processes in Wastewater Treatment Plants (WWTP). Liquid waste discharged into the river would harm public health around the industry if the processing of waste is not done based on the defined standard operating procedures.

Other attributes that must be considered are the use of water, use of chemical fertilizers, and the use of CO_2 gas waste. The main obstacle for dryland agriculture is water availability and soil fertility. Water is needed not only for the processing of sugarcane, but also for other sectors. Wastewater recycling can conserve water usage. Also, recycling of solid waste into organic fertilizer can reduce the use of chemical fertilizers.

CO_2 waste is generated by the result of burning bagasse at boiler station. CO_2 can be purified and used for cane juice purification process. Currently, some sugarcane industry in Indonesia is developing defecation remelt carbonation process. This process can reduce the negative impact of CO_2 on the environment.

Table 4. The differences between the sustainability indexes of MDS and Monte Carlo

Sustainability dimensions	Sustainability indexes (%)		Differences
	MDS	Monte Carlo	
Resources	62.69	61.81	0.88
Economic	70.85	69.23	1.62
Social	67.18	65.81	1.37
Environmental	55.89	55.18	0.71

Intervention or improvement on the attributes to be done to improve the sustainability index is the application of drip irrigation technology. This technology can minimize water used for sugarcane cultivation. Further, the application of water recycling technology in the processing industry is also very important, as it can help industrial wastewater to be recycled and reused for processing sugarcane. It is also very important to well-utilized the wastewater, so it does not bring a bad impact on the environment.

Monte Carlo Analysis

Monte Carlo analysis was performed to assess the uncertainty dimension in MDS. The results of Monte Carlo analysis showed that on the confidence level of 95%, there is not much difference for each dimension (the difference is relatively small). These circumstances indicate that simulation using MDS has a high confidence level (Jaya *et al*., 2013). The differences between the sustainability indexes of MDS and Monte Carlo are listed in Table 4.

Table 5. The stress values and the coefficient of sustainability determination for sugarcane agroindustrial development in NTT.

Parameter	Sustainability Dimensions			
	Res.	Eco.	Social	Environ.
Stress	0.152	0.136	0.145	0.162
Determination coefficient	0.944	0.950	0.945	0.939

The difference between MDS and Monte Carlo sustainability indexes is relatively small, showing that MDS uses multiple attributes: (1) it shows a relatively small mistake in scoring on each attribute, (2) it shows the relatively low variation of scoring errors due to differences in opinion, (3) MDS has high stability, (4) it can avoid errors in entering data or missing data, (5) it can avoid the S-high stress value, (6) the system understudied has a high confidence level, (7) MDS method is quite good as one evaluation tools for sugarcane agroindustrial development in the NTT.

Based on the results of MDS analysis, it can be seen that each attribute is quite accurate, visible from the stress value and the determination coefficient. According to Kavanagh and Pitcher (2004), a stress value of less than 0.25 and a determination value close to 1.0 is quite accurate and is accountable. It shows that the model employing the four sustainability dimensions are already using good variables or attributes. The stress values and the coefficient of determination are presented in Table 5.

Conclusion

The sustainability status of sugarcane agroindustrial development in Nusa Tenggara Timur Province in each dimension was as follows: (a) resources dimension was quite sustainable (62.69%), (b) economic dimension was quite sustainable (70.85%), (c) social dimension was quite sustainable (67.18%), and (d) environmental dimension was quite sustainable (55.89%).

Attributes that were sensitive or affect the sustainability for each dimension were as follows: (a) resources dimension, namely the availability of agricultural labor, the availability of dry land sugarcane cultivation technology and the availability dry land institutions/research institutions; (b) economic dimension, namely the yield of sugarcane, the competitiveness of sugarcane against other commodities, and the amount of ratoon; (c) social dimension, namely health and safety, local government support on partnership, and linkages with the livestock sector; (d) environmental dimension, namely the utilization of industrial liquid waste, water management, and the use of chemical fertilizers.

Recommendations

It was recommended for the sugarcane agroindustry to be developed in Nusa Tenggara Timur Province to apply good agricultural practices through the use of quality seeds, varieties structuring, water management, and plant disease management, as well as waste and pollution minimization. Good profits must be realized through the use of waste to reduce the cost of production inputs, and a good manufacturing process must be realized through the overall efficiency of the sugarcane production process. Local governments can facilitate partnerships between farmers and the industry by issuing rules and regulations that govern partnerships.

This study can be continued by using a dynamic systems approach, given that many variables and attributes related to the sustainable sugarcane industry development are dynamic in nature.

Acknowledgments

This research is part of the writer's dissertation in the Agroindustrial Technology Ph.D. Program at Bogor Agricultural University and supervised by Prof. Marimin, M.Sc., as the promotor, by Dr. Mohammad Yani, M.Sc., Dr. M.Y.J. Purwanto, and Dr. Sumaryanto, as co-promotor. We would like thank to Ir. Ibnu Haris Parwata (General Manager of PG. Subang), Ir. Chafsul Jaskandi (General Manager of PG. Sindanglaut Cirebon), and Dr. Wayan R. Susila (Advisor in Indonesian Sugar Association), who have also assisted this research.

References

Adam, M. and Ghaly, A.E. 2007. Maximizing sustainability of the Costa Rican coffee industry. *J. of Cleaner Production*. 15(17) : 1716-1729.

Choudhary, O.P. Jason, S., Bajwa, M.S. and Kapur, M.L. 2004. Effect of sustained sodic and saline-sodic irrigation and farmyard manure on yield and quality of sugarcane under semi-arid conditions. *Field Crops Research*. 87(2-3) : 103-116.

Climatology Meteorology and Geophysics Agency of East Nusa Tenggara Province, 2012. *Monthly Rainfall Data*. Kupang.

Djaenudin, D., Sulaeman, Y. and Abdurachman, A. 2002. Pendekatan pewilayahan komoditas pertanian menurut pedo-agroklimat di Kawasan Timur Indonesia. *J. Lit. Pertanian.* 21(1) : 1-10.

Fauzi, A. and Anna, S. 2005. *Pemodelan Sumber Daya Perikanan dan Kelautan*. PT. Gramedia Pustaka. Jakarta.

Gradiz, L., Sugimoto, A., Ujihara, K., Fukuhara, S. and Kahi, A.K. 2007. Beef cow-calf production system integrated with sugarcane production: simulation model development and application in Japan. *Agricultural Systems*. 94(3) : 750-762.

Higgins, A.J. and Muchow, R.C. 2003. Assessing the potential benefit of alternative cane supply arrangement in the Australian sugar industry. *Agricultural System*. 76(2) : 623-638.

Hafsah, M.J. 2003. *Bisnis Gula di Indonesia*. Mulia Sari. Jakarta.

Hidayanto, M., Supriadi, S., Yahya, S. and Amien, L.I. 2009. Analysis of the sustainability of the cocoa plantations of the people in the Border Region Sebatik Island, East Kalimantan Province. *Jurnal Agro Ekonomi*. 12(2) : 213-229.

Indonesian Sugar Research Institut. 1985. *Keragaan dan Masalah Tanaman Tebu Kebun Percobaan Anakalang Sumba Barat Nusa Tenggara Timur*. Pasuruan, Indonesia.

Jaya, R., Machfud, Raharja, S. and Marimin. 2013. Sustainability analysis for gayo coffee supply chain. *International Journal on Advanced Science Engineering Information Technology*. 3(2) : 24-28.

Kavanagh, P. 2001. *Rapid Appraisal of Fisheries (RAPFISH) software description (for Microsoft Excel). Rapid appraisal for fisheries project*. University of British Columbia, Fisheries Centre, Vancouver.

Kavanagh, P. and Pitcher, T.J. 2004. Implementing Microsoft excel software for fish: A technique for the rapid appraisal of fisheries status. *Fisheries Centre Research Reports.* 12(2).

Lejars, C., Le Gal, P.Y. and Auzoux, S. 2008. A decision support approach for cane supply management within a sugar mill area. *Comput. Electron. Agric.* 60(60) : 239-249.

Mulyadi, M., Toharisman, A. and Mirsawan, 2009. *Identifikasi Potensi Lahan untuk Mendukung Pengembangan Agribisnis Tebu di Wilayah Timur Indonesia*. Pasuruan: Indonesian Sugar Research Institut.

Muchow, R.C., Higgins, A.J., Rudd, A.V. and Ford, A.W. 1998. Optimizing harvest date in sugar production: A case study for the Mossman Mill Region in Australia. II. Sensitivity to crop age and crop class distribution. *Field Crops Research.* 57(3) : 243-251.

Mulyono, D. 2006. Analisis usaha tani tebu di lahan tegalan kasus di Kabupaten Bondowoso. *Jurnal Sains dan Teknologi.* 8(1) : 51-56.

Novita, E. 2012. *Processing design at robusta coffee agroindustry using modified wet process technology based on cleaner production.* Ph.D. thesis. Bogor Agricultural University.

Pitcher, T.J. and Preikshot, D. 2001. RAPFISH: A rapid appraisal technique to evaluate the sustainability status of fisheries. *Fisheries Research*. 49(3) : 255-270.

Purnomo, B.H., Machfud, Hermawan, A. and Wiyono, E.S. 2011. A model prediction of resources and economic sustainability on chirimen agroindustry. *Jurnal Teknologi Industri Pertanian*. 21(3) : 163-175.

Purnomo, B.H. 2012. *A design of sustainability predictive model for capture fishery agroindustry.* Ph.D. thesis. Bogor Agricultural University. Indonesia,

Parnell, G.S., Driscoll, P.J. and Henderson, D.L. 2011. *Decision Making in System Engineering and Management*. John Wiley & Sons, Inc. USA.

Purwono. 2012. *Efisiensi penggunaan air pada budidaya tebu lahan kering.* Ph.D thesis. Bogor Agricultural University. Indonesia.

Regan, H.M. Colyvan, M. and Markovchick-Nicholls, L. 2006. A formal model for consensus and negotiation in environmental management. *Journal of Environmental Management*. 80(2) : 167-176.

Rustiadi, E., Saefulhakim, S. and Panuju, D. 2011. *Perencanaan and Pengembangan Wilayah*. Yayasan Pustaka Obor Indonesia. Jakarta.

Saaty, T.L. 1988. *Decision Making for Leader: The Analytical Hierarchy Process for Decision in Complex World*. RWS Publication. Pittsburgh.

Soekartawi, 2001. *Pengantar Agroindusti*. PT Raja Grafindo Persada. Jakarta.

Salassi, M.E. and Breaux, J. 2002. Economically optimal crop cycle length for major sugarcane varieties in Lousiana. *Journal American Society of Sugarcane Technologist*. 22(53) : 53-62.

Susila, W.R. and Sinaga, B.M. 2005. Pengembangan industri gula indonesia yang kompetitif pada situasi persaingan yang adil. *J. Lit. Pertanian*. 24(1) : 1-9.

Suharjito and Marimin. 2012. Risk balancing model of agry-supply chain using fuzzy risks utility regression. *Journal of Theoretical and Applied Information Technology*. 41(2) : 13-23.

Statistic Berau Centre Republic of Indonesia,2012. *Statistik Tebu*. Jakarta.

Statistic Berau Centre Republic of Indonesia, 2012. *Statistik Penduduk*. Jakarta,

Statistic Berau Centre Republic of Indonesia, 2013. *Survey Sosial Ekonomi Nasional 2009-2013*. Jakarta.