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Sustainability Study of Horticultural Development in Mandailing Natal District With RAPFISH-MDS Analysis

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Abstract. Mandailing Natal district, the second largest district in North Sumatra Province, has great potential for horticultural development. This study aimed to determine the sustainability level of horticultural development in Mandailing Natal district through 5 dimensions: ecological, economic, social, technological, and institutional. The RAPFISH-MDS analysis method was used to measure the index and sustainability status. The results showed that the criteria for the sustainability of horticultural development in Mandailing Natal district was quite sustainable (52.61) with the sustainability index value of the ecological, institutional, social, economic, and technological dimensions, respectively, 58.06; 56.86; 53.76; 51.99; and 51.08. Sensitive attributes supporting sustainability are erosion rate for the ecological dimension, post-harvest management for the economic dimension, extension intensity for the social dimension, land management technology for the technological dimension, and conflicts between farmer groups for the institutional dimension. The improvement of horticultural sustainability in Mandailing Natal district can be done through strengthening input variables, namely perception of the environment, understanding of eco-friendly technology, minimizing the intensity of conflicts, and increasing stakes variables such as education, extension intensity, and government services.
Keywords: horticulture; Mandailing Natal; RAPFISH-MD; sustainability

INTRODUCTION

Mandailing Natal district, as the second largest district in North Sumatra Province, has great potential for developing horticultural crops. Various efforts from the government, private sector and universities including the development of production centers, the provision of assistance for production facilities and infrastructure, increasing the area of production land and increasing the cultivation ability of farmers carried out so far have proven successful even though they are considered not optimal. In 2020, the Mandailing Natal district's agricultural production, particularly that of seasonal and annual fruits and vegetables, increased by 0.91-59.53% with the highest increase in onion and large orange. Meanwhile, petsai, cabbage, spinach, strawberries, chayote, melon and mushroom from the seasonal vegetable and fruit commodity group decreased from 2.83 to 64.66%. Depending on the type of plant, it is known that the harvested area of plants with decreased production decreased by 0.02-50.59% and increased by 55.26-221.15% (BPS, 2021).

Horticultural development has various challenges, mainly driven by the characteristics of its products such as the need for a wide container (*bulky*), *perishable (perishable*), seasonal with a relatively short life, varying quality (Rasyid & Kusumawaty, 2018) and dependence on growing environmental conditions. These challenges include low product competitiveness both in terms of quantity and quality, price, and supply instability, agroecological incompatibilities, breeding and protection of varieties, land limitations, irrigation, facilities, and infrastructure as well as cultivation technology, capital, also the creation and maintenance of strategic linkages both locally, regionally, and internationally (Pitaloka, 2017). The Directorate General of Horticulture (2019) added climate change as one of the significant

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challenges that need to be anticipated because its tendency is not only limited to disrupting the planned development of horticulture but can reduce productivity, quality, and current consumer acceptance. This is related to the contribution of climate change in influencing environmental conditions for plant growth, either through a decrease in soil fertility status, an increase in the occurrence of pests and diseases, as well as changes in host-pathogen interactions or soil microbial populations and pollinator behavior (Prasad & Chakravorty, 2015) which had previously developed due to excessive application of fertilizers and pesticides.

Climate change has a heterogeneous influence on soil properties depending on the contributing climate factors. Acidification or salination of the soil, loss of organic matter levels, leaching of macronutrients N, P and soil bases, decreased CEC, increased availability of toxic nutrients, damage to soil aggregate structures and susceptibility to the risk of erosion are part of the land degradation by climate change (Mondal, 2021). Litskas *et al*., (2019) in the developed model found that climate change would provide a more suitable environment for pests such as tomato mite *Tetranychus urticae* or reduce the effectiveness of biological control agents such as *Phytoseiulus persimilis*. Farmers' cultivation patterns that still need improvement plus climate change with various negative impacts clearly increase the risk of horticultural businesses so appropriate technology is needed as an effective mitigation effort. Based on these challenges, a comprehensive study of horticultural development from various dimensions needs to be carried out by simultaneously assessing the decline in productivity in these dimensions to build a form of sustainable development.

In realizing production stability, sustainability development is a balanced and sustainable integration activity between social, economic, cultural, ecological, legal, and institutional dimensions supported by socialization activities and technology adoption (Saida *et al.*, 2016). Baccar *et al.*, (2018) detailed four factors involved in the development of agricultural sustainability, namely 1) internal factors of farmer families, which include farming objectives, activities outside the agricultural sector, involvement of family members, marketing strategies and length of farming experience; 2) factors of the production system include land area, capital sources, choice of agricultural activities and practices as well as the choice of technological innovations adopted; 3) agricultural environmental factors include the policy establishment or the new species introduction; and 4) global factors such as climate change. More specifically on the development of horticulture, the characteristics of farmers, physical carrying capacity, availability of facilities, infrastructure, and technology; capital ownership, linkage of on and off-farm activities, partnerships, policies, institutions as well as accessibility and marketing are mentioned as factors of the dimensions that affect its sustainability (Sari & Santoso, 2016; Istiqomah *et al.*, 2018). Several studies on sustainability indices in the horticulture, food crops and livestock sectors have been carried out by (Frimawaty *et al*., 2013; Nuraini & Mutolib, 2023; Osak & Hartono, 2016) and revealed that the sustainability index of the socio-ecological dimension is higher than the economic dimension. and technology. Horticulture has the potential to become a leading commodity even though it is cultivated as a side business (Kasmin *et al.*, 2023).

The study was aimed to determine the level of sustainability of the horticulture sub-sector seen from several dimensions, namely ecological, economic, social, technological, and institutional also knowing the key indicators and technical strategies to improve horticultural sustainability in Mandailing Natal District. The information obtained can then be used as the basis for formulating an appropriate horticultural development strategy as well as policy input for the Mandailing Natal district government as a developer.

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METHODS

The research was conducted at Kabupaten Mandailing Natal District in June to August 2021. Primary data collected through discussion activities, interviews, completing questionnaires, and conducting field surveys are the kind of information required to assess the viability of horticultural commodity development in Mandailing Natal District. A total of 45 respondents were farmers who had at least 5 years of experience in horticulture continuously. Respondents are local farmers with ages ranging from 24 to 61 years and varying levels of education, namely SD, SLTP, SLTA (> 60%), and university. Addition, respondents have also represented each sub-district in Mandailing Natal District. The selected respondents were considered to have represented each sub-district in Mandailing Natal District with the highest number of respondents from the horticulture center sub-district, namely Panyabungan and Kotanopan, respectively 6 and 8 farmers, the remaining 1 to 2 farmers from other sub-districts. The primary data collected are attributes of 5 dimensions of horticultural development sustainability including ecological, economic, social, technological, and institutional dimensions which can be seen in detail in Table 1.

Table 1. Dimensions and attributes of horticultural development sustainability in Mandailing Natal District

No	Dimension	Attribute
1.	Ecology	Land cultivation, slope level, land cover conditions, erosion rate, land suitability level, land conversion rate, use of fertilizers and pesticides, availability of organic fertilizers, availability of water, quality of horticultural products, and productivity.
2.	Economics	Price stability, farm contribution to family income, horticultural product prices, product management, arable land area, loan credit, on farm and off farm income.
3.	Social	The existence of horticultural households, the level of education, the status of land ownership, the presence of government services, intensification of counseling, the intensity of conflicts, perceptions of the environment and understanding of eco-friendly technology.
4.	Technology	The level of technology application, training level, post-harvest management, organic fertilizer technology, mulch technology, land management technology, biopesticide technology, plant cultivation technology, pest control technology and soil and water conservation technology.
5.	Institutional	Microfinance institutions, marketing institutions, production input providers, farmer groups, farmer group associations, agricultural extension workers, conflicts between farmer groups, agricultural business groups and agricultural machinery tools.

The analytical method used to assess the sustainability of horticultural development in Mandailing Natal District is the RAPFISH (Rapid Apraisal for Fisheries) development by the University of British Columbia, Canada, based on multidimensional scaling (MDS) coordination techniques. Data analysis using *the Multidimensional Scaling* (MDS) method through 2 stages of analysis, namely:

1) *Leverage* analysis generates the stress and coefficient of determination (R2) value which serves to inform sensitive attributes or interventions that can be carried out on these sensitive attributes to improve the sustainability status of the region.

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2) *Monte Carlo* analysis was used to estimate the effect of errors in the analysis process performed at a 95% confidence interval. Various calculations in the *Multidimensional Scaling* (MDS) method can be seen in Figure 1.

Standardize the score value of each attribute in order to have a uniform weight and the same measurement scale as the formula:

$$Xiksd = \frac{Xik - Xk}{Sk} \;\ldots\ldots\ldots\; (1)$$

Where:

Xiksd	=	the standard score value of the i-th region on each k-th attribute
Xik	=	the initial score value of the region to i on each k-th attribute
Xk	=	the mid-value of the score on each k-th attribute
Sk	=	the standard deviation of the score on each k-th attribute

↓

Calculation of the closest distance of the *Euclidian distance* according to the equation:

$$d12 = \sqrt{(x1 - x2)^2 + (y1 - y2)^2} \;\ldots\ldots\ldots\; (2)$$

↓

Projection *of the Euclidean* distance between the two points (d12) into the two-dimensional *Euclidean* distance (D12) where *e* as the error value through the equation:

$$d12 = a + bD12 + e \;\ldots\ldots\ldots\; (3)$$

↓

Production of *the* smallest error value with RAPFISH so that the equation is obtained:

$$d12 = bD12 + e \;\ldots\ldots\ldots\; (4)$$

↓

Calculation of stress values with the formula:

$$[Stress = \frac{1}{m}\sum_{k-1}^{m} \frac{\Sigma_i - \Sigma_j\,(D_{ijk} - d_{ijk})^2}{\Sigma_i \Sigma_j d_{ijk}^2}] \;\ldots\ldots\ldots\; (5)$$

Source: Hermawan *et al.*, (2019)

Figure 1. Forms of calculation in the MDS-RAPFISH analysis method

The sustainability index as the output of the MDS-Rapfish calculation is presented in a fixed score between 0% and 100% (Pitcher & Preikshot, 2001). The sustainability index values in this analysis are grouped into 4 categories of sustainability status, namely: 0-25 (unsustainable); 25.10-50 (less sustainable); 50.10-75 (moderately sustainable) and 75.10-100 (sustainable), as done by (Nuraini & Mutolib, 2023) .

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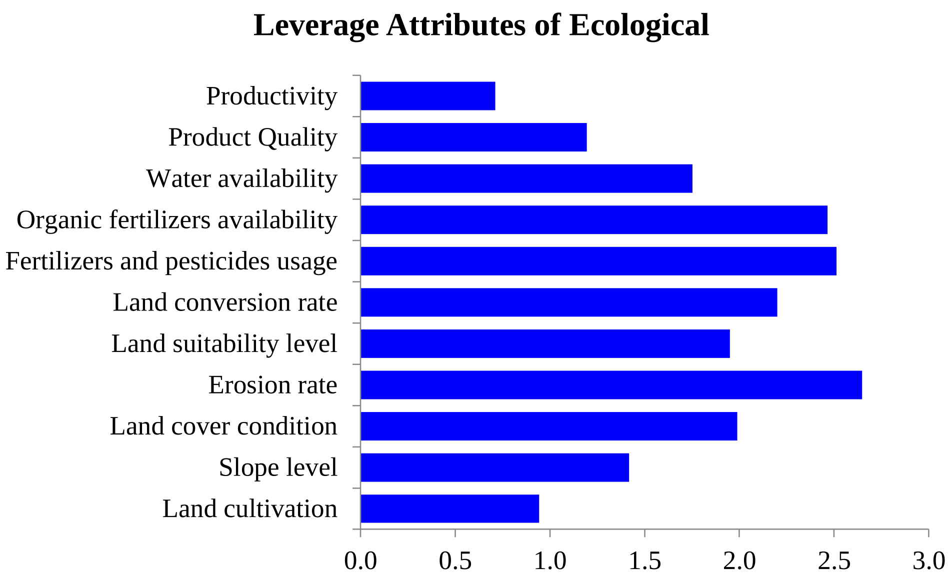
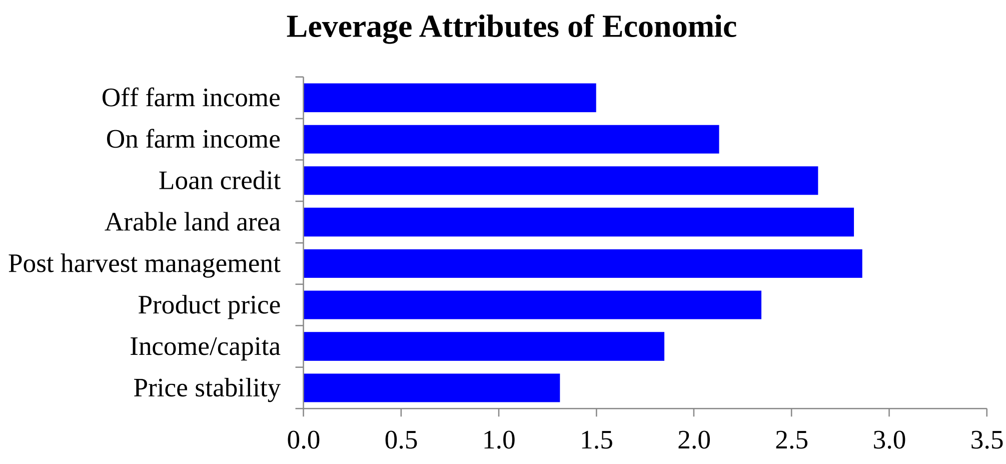
Further analysis was carried out to determine the development action plan based on knowledge of the degree of influence of the 10 leverage variables obtained from the previous multidimensional results with MICMAC analysis. According to (Fauzi, 2019), the MICMAC approach relies on analytical thinking through problem solving. MICMAC can help identify influential and influential (dependent) variables that are important for a system so that it is effective as a tool for sustainability analysis, both in sectoral and regional contexts.

RESULTS AND DISCUSSION

Sustainability Value and Leverage Attributes of the Horticultural Subsector

The results of the leverage analysis for the sustainability of ecological, economic, social, institutional and technological dimensions are presented in Figure 1. The analysis results clearly inform the main *leverage* attributes that significantly influence the sustainability index of horticultural development in Mandailing Natal district for each dimension.





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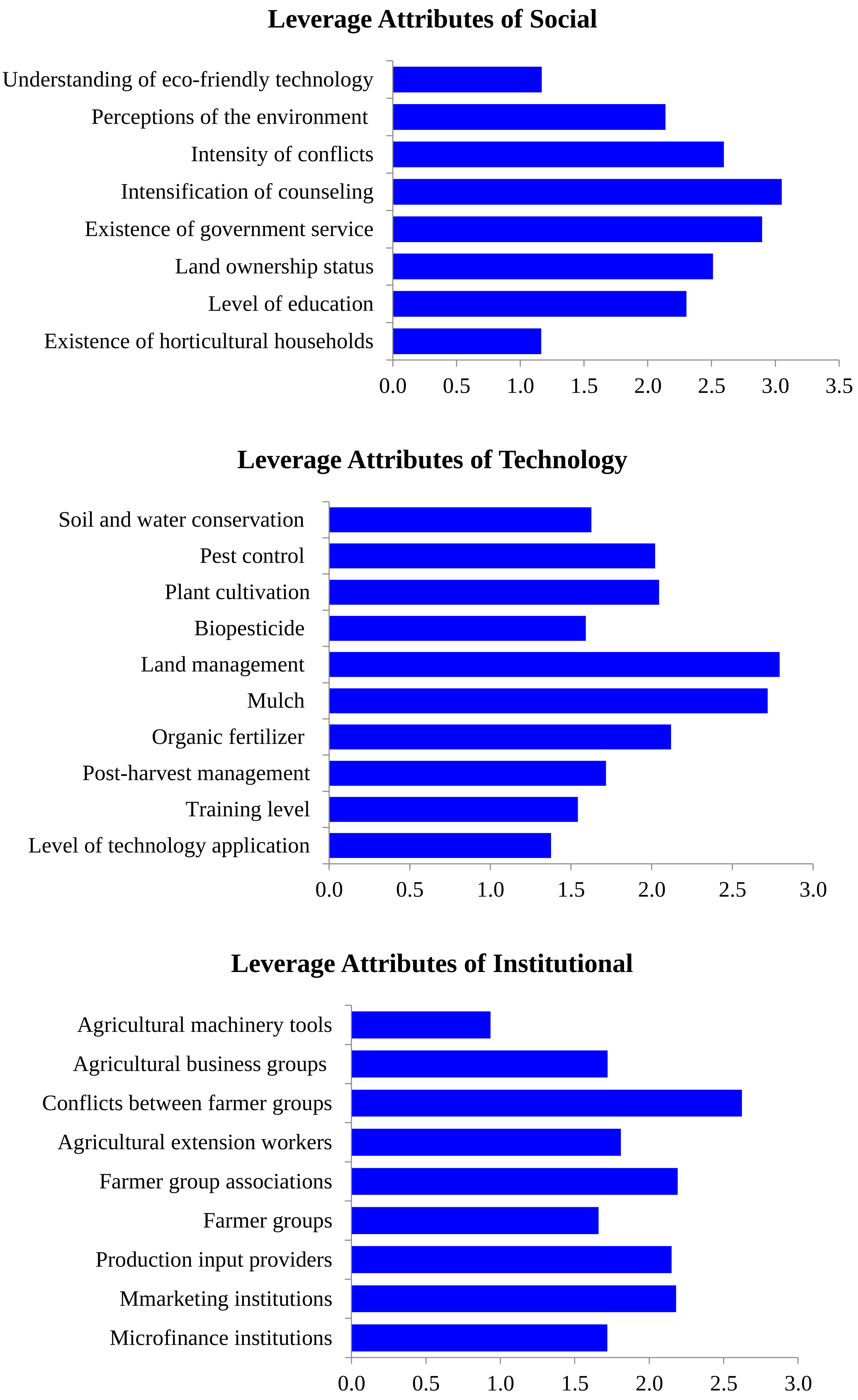

Figure 2. Leverage attributes of ecological, economic, social, technological, and institutional dimensions of horticultural sustainability in Mandailing Natal District

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Sustainability of horticultural subsector on ecological dimension

Leverage attribute for the ecological dimension consist of the erosion rate (2.65), the use of fertilizers and pesticides (2.51), and the availability of organic fertilizers(2.41). Erosion as one of the main causes of land degradation, especially on agricultural dry lands (Wahyunto & Dariah, 2014) is an event of d*etachment*, transportation, and deposition of soil material by water which is influenced by the function of climatic factors including rainfall, soil, topographic vegetation, and humans (Huda *et al.*, 2020). The exposure of soil material is in line with the loss of nutrients N, P, K, Ca, and Mg with the largest loss found in Ca of 6459 kg Ha^{-1} (Didjajani, 2012). The loss of soil bases (K,Ca, Mg) will acidify the soil and disrupt the availability of nutrients for plants resulting in additional production costs for improvement efforts such as liming or adding organic matter to the soil. To anticipate the risk of production loss due to erosion, it is necessary to apply specific soil conservation techniques to prevent erosion and runoff and create good drainage conditions. Various technologies such as building of bench terraces, beds in the direction of the slopes interspersed with contours mound, regulation of cropping patterns, planting of cover crops, use of crop residue mulch, cultivation of perennial crops, application of integrated and eco-friendly agriculture also vegetative conservation techniques will effective to reduce the erosion impact on horticultural land (Rusdi *et al.*, 2013; Sutrisno & Heryani, 2013; Arifin *et al.*, 2017).

The second and third leverage attributes, namely the level of use of chemical fertilizers and pesticides and the availability of organic fertilizers are interrelated. Excessive and continuous use of chemical fertilizers and pesticides will leave residues on agricultural products and the environment which will have an impact on ecosystem health and the sustainability of agriculture itself. The solution to minimizing the excessive use of pesticides is the application of integrated pest control, which is a multi-disciplinary environmental pest control method that combines various effective control techniques and economically feasible practices (Wedastra *et al.*, 2020; Alam *et al.*, 2016). In terms of the use of chemical fertilizers, farmers are expected to use inorganic fertilizers wisely and increase the use of organic fertilizers. To support the wise use of inorganic fertilizers, farmers can use various test kits offered such as Upland Soil Test Kit (PUTK), Paddy Soil Test Kit (PUTS), Wetland Soil Test Kit (PUTR) and Leaf Color Chart (BWD) to determine fertilizer requirement according to field/crop conditions. Regarding the use of organic fertilizers, socialization and agricultural waste management practices can increase organic matter inputs to the field without burdening farmers with exorbitant buying costs.

Sustainability of horticultural subsector on economic dimensions

Leverage attributes in the economic dimension that most influence the horticultural sustainability index in Mandailing Natal district are post harvest management (2.86), arable land area (2.82), and loan credit (2.64). Post harvest management is one of the activities that can increase the competitiveness of horticultural products and reduce the risk of farmers losing production and income. Post harvest management can contribute to extending the shelf life of products, producing value-added derivative products and improving product quality so that they are eligible to penetrate the export or modern market with higher prices. The processing of Raja Siam and Ambon bananas into sale bananas at the farmer level, for example, is reported to be able to provide an additional profit of IDR 1,075/kg banana and an R/C ratio of up to 4.08 (Hasanah *et al.*, 2015 and Palisuri, 2016). Meanwhile, Shiddieqy & Widiani (2012) informed that improved post-harvest handling of carrots in fostered farmers for sales to modern markets increased income by

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144 and 94%, respectively, compared to post-harvest handling for sales to middlemen and traditional markets.

The next leverage attribute is the arable land area and loan credit with leverage values of 2.82 and 2.64 respectively. This value reflects the change in the root mean square if the attribute is omitted. In a sense, the value of arable land area will increase the RMS sustainability index by 2.82 on a scale of 0-100. In the Mandailing Natal district, most horticultural farmers only have access to land smaller than 1 Ha. That small area of arable land is considered not to meet the economic scale (Mawardati, 2013) so it is necessary to increase the area of arable land which will increase the income of individual farmers and regional income. The increase in the area of arable land is in line with the increase in the value of farming efficiency (Pradnyawati & Cipta, 2021) but along with the potential risks and large capital requirements, good management is needed by first examining specifically the downstream subsystem of agribusiness development in Mandailing Natal district. Regarding large capital needs, farmers can take advantage of the government's low-interest credit program in agriculture, namely the Kredit Usaha Rakyat, which will be more profitable than borrowing from middlemen. However, the long and complicated process and administrative requirements made most farmers not interested in participating in the program. On the other hand, farmers who have successfully obtained KUR capital loans are expected to make the program more effective by focusing the allocation of capital loans for farming activities not for other activities (Hafsah *et al*., 2019; Dharmawan & Karyani, 2018).

Sustainability of horticultural subsector on the social dimension

Social *sustainability* is one of the sustainability indicators of a development activity (including agriculture and agribusiness) which is contained in the triangular framework of the concept of sustainable development (Rivai & Anugrah, 2011). The results of the analysis show that the intensity of counseling (3.05), the existence of government services (2.90), and the intensity of conflict (2.60) are the leverage attributes in the social dimension. The intensity of extension activities be expected to change farmers' behavior and perceptions towards agriculture on a large scale, including in the horticulture sub-sector by providing an understanding of land management that pays attention to environmental sustainability and long-term benefits. The change needs to go through several stages and takes a long time due to the underlying background and experience factors. The stages of perception consist of introduction, persuasion, decision, implementation, and confirmation (D'Antoni *et al.*, 2012). The decision and implementation of farmers to adopt a technology varies and is influenced by various factors such as 1) the activity and methods of assisting extension workers in carrying out their functions as liaisons, organizers, dynamists, technicians, and mentors; 2) awards or rewards received by farmers when adopting a technology; 3) assistance received; 4) the relative advantage received; 5) technological suitability; 6) farmers' perceptions of the influence of media/interpersonal information and 7) farmers' economic level related to capital to adopt the technological innovations offered (Indraningsih, 2011; Putri & Safitri, 2018; Mangundap *et al.*, 2020).

Government services include supporting subsystems that serve as catalysts by creating accelerated development of agribusiness systems. Existence is intended to be a recognition of the community that the service is felt to be beneficial and is followed voluntarily by the farming community. This is closely related to changes in people's perceptions of existing government services or assistance that have been carried out. Finally, for the attributes of conflict intensity, conflicts at the farmer level between farmers, the government, and the private sector

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(Dharmawan, 2006) can be minimized to facilitate horticultural development so that the benefits of its development can be felt equally by the three parties.

Sustainability of Horticultural Subsector on Technology Dimension

Leverage attributes in the technological dimension are focused on land resources management (2.79) which in detail consists of tillage technology, the use of mulch, and organic fertilizers. Efforts to increase land productivity in the long term can be carried out with land use management that is balanced with knowledge of environmental sustainability. To achieve this, farmers with the help of extension workers and other related parties need to work together in choosing technology that is appropriate to the type and land condition by utilizing surrounding natural resources to save technology implementation costs. No tillage, minimum *tillage* and *mulch tillage* as part of a conservation tillage system can be farmers' choice to realize sustainable agriculture. Minimizing soil mechanical disturbances in the three tillage practices will positively impact the environment, plant growth and production, and improve the soil's physical, chemical and biological properties. In detail, the positive impacts include increased aggregation, porosity, water holding capacity and water use efficiency; improvement of soil nutrient cycles related to increased levels of organic matter and nutrients such as N, P, K, Ca and Mg; increasing soil pH and CEC; increasing the population and activity of organisms; changes in the composition of soil microorganisms; minimize the impact of erosion; reducing emissions of carbon dioxide (CO2) and greenhouse gases such as nitrous oxide (N2O) and methane (NH4) (Busari *et al*., 2015). In addition to those mentioned above, the use of mulch can also suppress weeds in the crop and eliminate the residual effects of pesticides, fertilizers, and heavy metals in the soil (Iqbal *et al*., 2020). The choice of mulch material needs to be a concern for farmers, the use of organic mulch by utilizing resources in the environment around farmers is considered safer and supports sustainable agriculture than inorganic mulch such as plastic which in the long run can cause environmental pollution, threats to soil biodiversity and decreased land ecosystem function (Ngosong *et al*., 2019).

Sustainability of Horticultural Subsector on Institutional Dimensions

Farmers need an institution that regulates *both on and off farm* activities. In practice, the institution functions as a formal association that connects external parties and interacts with fellow farmers to obtain resources such as production inputs. These interactions sometimes lead to conflicts between farmers and farmers groups in the group farmers association. Conflicts between farmer groups leverage attributes of the institutional dimension. The success of group farmers associations in resolving conflicts, both horizontally and vertically, is related to their ability as facilitators and accommodate the aspirations of members (Maharani & Laksmono, 2021) so that a careful attitude is needed in managing management and relying on deliberation in making every decision. Other attributes that become leverage in the institutional dimension are group farmers association and marketing institutions. These two attributes are interrelated because sometimes group farmers association has a function as a marketing institution for farmer groups. Group farmers association needs to minimize its role in farming activities managed by individuals and farmer groups (Pujiharto, 2010) to be able to focus more on carrying out its role as a marketing institution and get more benefits for Group farmers association and member farmers. Group farmers association as a marketing agency is responsible for creating relationships with formal and informal business partners, grading and packing members' agricultural products, and providing alternative market networks for farmers whose products do not meet the qualifications (Demmallino *et al.*, 2018).

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Table 2. Sustainability index dimensions and potential for horticultural development in Mandailing District Natal 2021

No	Subdistrict	Sustainability Index Value Per Dimension					Horticultural Development Sustainability Index	
		Ecol	Eco	Soc	Tech	Inst		
1	Batahan	42,5	37,9	60,4	42,9	52,0	49,23	LS
2	Sinunukan	62,9	54,3	54,2	50,2	51,4	52,32	QS
3	Christmas Bar	55,8	51,3	51,9	44,5	53,7	49,21	LS
4	Lingga Bayu	63,3	56,3	59,3	61,8	48,6	57,17	QS
5	Ranto Baek	48,3	40,8	52,4	51,1	53,7	48,97	LS
6	Kotanopan	54,7	48,7	47,6	47,7	53,0	49,65	LS
7	Ulu Pungkut	57,1	53,2	55,9	50,2	61,1	52,97	QS
8	Mining	75,7	61,2	50,5	43,4	51,5	52,52	QS
9	Sorik Marapi Valley	64,8	44,6	46,8	47,9	51,8	48,26	LS
10	Sorik Marapi Peak	59,8	57,1	63,4	64,3	60,8	59,49	QS
11	Sipongi Estuary	51,5	52,9	47,0	57,2	58,0	52,95	QS
12	Pakantan	43,1	47,8	39,1	41,0	40,2	42,62	LS
13	Panyabungan	59,6	47,4	49,8	43,9	50,5	49,20	LS
14	South Panyabungan	65,4	44,6	47,0	47,9	51,8	49,10	LS
15	Panyabungan Barat	74,7	79,9	71,7	77,7	87,6	75,27	S
16	North Panyabungan	53,2	49,4	54,2	46,2	56,7	51,37	QS
17	East Panyabungan	56,9	50,2	47,1	53,6	42,3	49,18	LS
18	Huta Bargot	49,5	56,0	46,9	48,6	56,7	48,24	LS
19	Christmas	44,4	46,1	55,2	43,6	56,4	48,64	LS
20	Estuary Stem Girl	66,4	55,6	51,5	47,9	56,2	53,18	QS
21	Siabu	61,2	47,5	59,8	50,9	61,9	54,26	QS
22	Malintang Hill	59,1	52,0	58,0	54,3	64,4	54,39	QS
23	Fighting Dragon	65,7	61,1	67,3	58,3	87,8	61,91	QS
Total		**58,06**	**51,99**	**53,76**	**51,08**	**56,86**	**52,61**	**QS**

Note:
1) US (unsustainable)= 0-25; LS (less sustainable)= 25.10-50; QS (quite sustainable)= 50.10-75; and S (sustainable)= 75.10-100 (Pitcher & Preikshot, 2001)
2) Ecol (Ecology); Eco (Economy); Soc (Social); Tech (Technology); and Inst (Institutional)

Sustainability index and potential development of horticultural subsector in Mandailing Natal District

The index values and sustainability criteria of each dimension and the potential for horticultural development in Mandailing Natal district can be seen in Table 1. Overall, it is known that the value of the sustainability index is on the criteria of less sustainable (LS) to sustainable (B). Based on the value of the sustainability index, the sustainability criteria are found in the Tambangan subdistrict for the ecological dimension; West Panyabungan subdistrict for economic and technological dimensions; also West Panyabungan and Naga Juang sub-districts for the institutional dimension. Especially for the social

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dimension, no sub-districts with index values are included in the sustainability criteria.

Based on the average value of the sustainability index of each dimension, it is known that the technological dimension has the lowest average value (51.08). In order from low to high, above the technological dimension there are economic (51.99), social (53.76), institutional (56.86), and ecological (58.06) dimensions. This value indicates that increasing the sustainability of horticulture in Mandailing Natal district needs to prioritize technological improvements for economic development, followed by social acceptance and institutional strengthening.

The total sustainability index value of horticultural development in Mandailing Natal district was obtained by mapping the overall value of the sustainability index of the five dimensions. The average value of the horticultural development sustainability index in Mandailing district is 52.61 which is included in the quite sustainable (QS) criteria with the lowest sustainability value found in Pakantan subdistrict (42.62) and the highest in West Panyabungan subdistrict (75.27). Of the total 23 subdistricts, only 1 subdistrict is on the sustainable criteria while the remaining 22 sub-districts are on the criteria of less sustainable (11) and quite sustainable (11).

Horticultural Development Action Strategy in Mandailing Natal District

The results of the sustainability index analysis with multidimensional RAPFISH show that at least 10 leverage variables can improve the sustainability of horticultural development in Mandailing Natal district. In detail the position and relationship of these variables are presented in Figure 2 below. The variables of conflict intensity (ints_kflk), perception of the environment (pers_ling) and understanding of eco-friendly technology (pem_tekRL) from the social dimension are in quadrant I as input variables. The input variable is independent and affects the output variable through the stakes variable, so it can be used to make technical policies.

The variables of the technological dimension consisting of the level of post-harvest mastery (psca_panen), the level of application of technology (tgk_tek), and the level of training (training) are in quadrant IV as output variables. The output variable can be said to be a variable that is influenced by other variables, so that it becomes a parameter or goal of the success of a technical policy. Meanwhile, in quadrants II and III there are variables from the social dimension, namely the level of education (pddkn), the intensity of extension (ints_pylh), and the existence of government services (lynan_pem) as *stakes variables* that connect *input* and *output* variables also land status (stat_ lhn) as *an autonomous* variable that has no influence and dependence on horticultural development in Mandailing Natal district. The improvement of one dimension requires the contribution of other dimensions, this can be seen from the results of *multidimensional scaling* analysis where increasing the dimension of technology that is prioritized because it has the lowest average value requires the role of the social dimension by increasing farmers' perception of the environment and understanding of eco-friendly technology.

The three input variables affect the level of technology use. Environmental perception has a strong influence on the understanding of eco-friendly technology. The eco-friendly technology itself affects 2 variables, both end up on the of technology use variables. In different directions, the variables of environmental perception and the intensity of extension influence each other which further affects the output variable of technology use. The conflict intensity variable has a moderate effect on the intensity of extension, education level, and government services, all three of which lead to the variable use of technology. The last input variable, namely the understanding of eco-friendly technology, has a moderate effect on the variables of technology use but has a strong effect on the use of post-harvest technology which further

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affects government services and the use of technology.

Variabel *stakes* namely education connects the variables of perception to the environment and affects the level of technology, the utilization of post-harvest technology, and the level of training. The education variable also links the variables of perception of the environment and the intensity of counseling with the use of technology. Meanwhile, the intensity of counseling connects education and environmental perceptions with the use of technology.

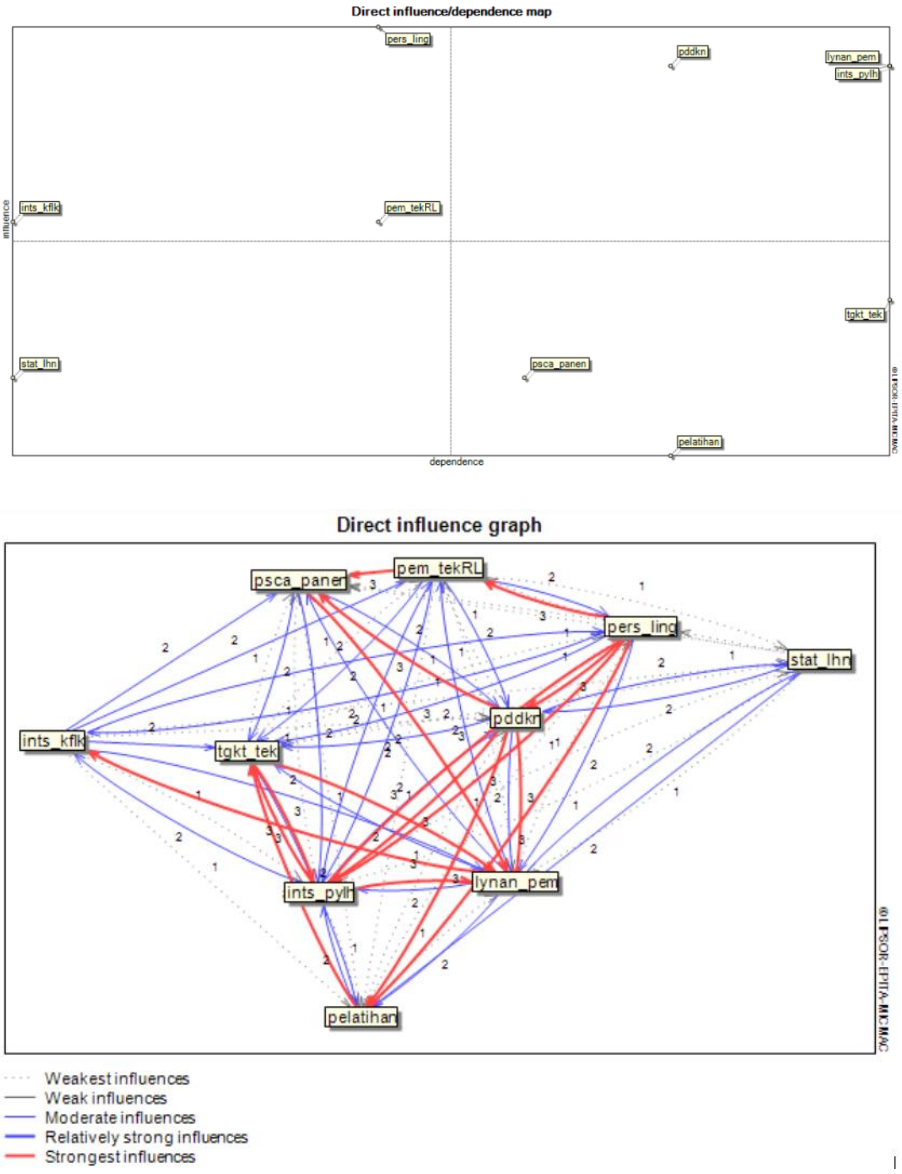

Figure 3. Mapping variable leverage sustainability development of horticultural areas (a) and Graph of the degree of influence of variable *leverage* on horticultural development of Mandailing Natal district (b)

The results of the MICMAC analysis indicate that of the 10 leverage variables, changes in people's perceptions of eco-friendly horticulture become the priority focus variable for horticulture development in Mandailing Natal district. The use of eco-friendly technology needs to be disseminated through extension services or government programs. This indicates that the government needs to develop various programs that will

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increase farmers' perceptions of the environment and eco-friendly technology through the intensity of extension.

Increasing farmers' perceptions of the environment can be done through various action plans such as 1) Dissemination of organic and eco-friendly technologies; the use of pesticides and insecticides in the right dose and time; utilization of resources in the production of organic pesticides and fertilizers; understanding of chemical residues; information technology to increase productivity that is eco-friendly; 2) Emphasis on understanding the balance of the environment and ecosystem; 3) Implementation of government programs in the form of organic production input support.

CONCLUSION

The technological and economic dimensions have a relatively low sustainability value compared to the social, institutional, and ecological dimensions. Sustainability index improvement can be done by improving attributes on the technological and economic dimensions. These efforts include: improving tillage technology, increasing the use of mulch, and the use of organic fertilizers. Meanwhile, sustainability index improvement in the economic dimension can be done through improving post harvest management, increasing the arable land area, and use of credit loans.

The improvement of horticultural sustainability in Mandailing Natal district can be done through strengthening input variables, namely perception of the environment, understanding of eco-friendly technology, and minimizing the intensity of conflicts as well as increasing stakes variables such as education, extension intensity, and government services. Increasing farmers' perceptions of the environment itself can be realized through action plan that focuses on disseminating various eco-friendly information and technologies that support sustainable agriculture, emphasizing understanding related to environmental and ecosystem balance and implementing government programs in the form of organic production input support.

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