Sustainability assessment of chili farming in the highlands of Pacet Sub District, Regency of Cianjur, West Java

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Abstracts. Chili farming in the highlands is facing the problem of decreasing land fertility due to the loss of soil top layer, high humidity and rainfall that causes more pests and disease. Therefore, soil conservation, pests and plant diseases controlling are the priority in management of chili farming and these efforts are practically in line with the goal of sustainable agricultural development. This study aims to analyze the sustainability status of chili farming in the Highlands of Pacet Sub district, Region of Cianjur, West Java Province. Method of sustainability assessment using multidimensional scaling approach with RAP-Chili technique that includes 34 attributes on dimension of environment, economic, social, technology, and institution. The results show that chili farming in highlands of Pacet was quite sustainable with an index about 54.39 percent. Out of five dimensions, environment and economic dimension had the highest index in moderately sustainable category while other dimensions were less sustainable. Thus, improvement toward sustainable chili farming could be prioritized on less sustainable dimension which were social, technology and institution by considering leverage attributes of those dimensions, namely extension program, application of bio pesticide and pest trap, post harvesting technology and availability of marketing institution.

1. Introduction
Chili is a vegetable commodity with high economic value due to the increasing of population and industries that require chili as raw material. Consumption per capita of chilies in 2016 was about 1.55 kg/capita, and increased in 2017 to 1.56 kg/capita and increased again to 1.58 kg/capita in 2019. With a total population of 267 million peoples, the need for chili in 2019 reached 421.8 thousand tonnes. This total demand requires an increase in the chili production. Wandschneider et al. [1] mentioned that the harvested area of chilli ranges between 230,000- 245,000 ha annually. Meanwhile according to data of Ministry of Agriculture, large chili production in 2019 was about 1.26 million tonnes with a harvest area of 144,391 ha and productivity of 8.77 ton/ha. Meanwhile, production of cayenne pepper in the same year was 1.37 million tonnes with a harvest area of 177,581 ha and productivity of 7.8 ton per ha. However, this average productivity is still lower than the potential productivity at 12 ton/ha [2].

In recent years, the increase in vegetable production, including chilies, was constrained by limited agricultural land, which made an upland land become a choice for planting chilies other than in the...
lowlands [3]. However, chili farming in the highlands faces the challenges of erosion, high pest and disease attack as well as the low productivity. Slope and high rainfall increase the chance of erosion, especially on land that highly used for vegetable cultivation [4, 5, 6]. High humidity and rainfall causes more pest and disease attacks such as roting fruit caused by the fungus Colletotrichum spp. and late blight phytoftora caused by the fungus Phytophthora capsici [7]. In addition, the productivity of vegetable crops including chilies in the highlands is lower than agricultural land in the lowlands because the land fertility decreases rapidly as the loss of topsoil that is more fertile [8]. Therefore, efforts to conserve the soil and control the pest and disease attack are the priority for the management of chili farming in the highlands. This effort basically supports the sustainability of chili farming as well that able to maintain environment, social and economic resources for the farmer welfare.

Farming sustainability is an application of sustainable development that must be able to integrate resources and information from ecological, social and economic aspects [9, 10]. Furthermore, [11] mentioned that agricultural development is not only aimed at increasing or maintaining productivity or production but at the same time it must be able to protect and preserve agricultural resources and long-term economic growth. It requires appropriate technology, policies and resource management in line with comparative and competitive advantages of a region. The pillars of sustainable development as stated in [12] on which most of nowadays term refer to [13]. The same concept was explained by [14] that sustainable development is an effort to synchronize and integrate three aspects of development, namely environmental, economic and social aspects. Despite many method to assess the sustainability of development programs and farming systems, a multidimensional scaling approach using the Rapid Appraisal for Fisheries (RAP-FISH) technique is familiar to be used since this technique is able to provide information on sustainability indices and important attributes that is sensitive to the sustainability indices [15, 16].

Related to the previous description, this study aims to assess the sustainability of chili farming in the highland of Pacet, Cianjur District using the Rap Chili Sustainability technique and to arrange recommendations for the future development of upland chili farming. The benefit of this assessment is that it becomes a reference for developing the chili farming systems in the highland by optimizing the contribution of sensitive attributes that affect each dimensions of the sustainability.

2. Methodology

The research was conducted from November 2019 to February 2020 in Cipendawa and Cugenang Villages, Pacet District, Cianjur Regency, West Java. Primary data collection was carried out by survey method through in-depth interviews with 40 farmers using a questionnaire and direct observation of farming activities in the research location. Secondary data obtained from literature studies and research results relevant to the research objectives.

Sustainability assessment used a multidimensional scaling (MDS) approach with the RAP-Chili technique as a modification of the fisheries system assessment technique. This MDS approach carried out a multidimensional transformation into 2 dimensions and determines the relative position of sustainability between 2 extreme points in the bad (0 percent) and good (100 percent) ordination for each dimension as well as the combined dimensions.

In this MDS principle, a distance measurement called eucliden distance was carried out with the following equation:

\[ d = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2 + (Z_1 - Z_2)^2 + \cdots} \]  

(1)

The RAP ordination analysis is complemented by the arrangement of a sustainability index of chili farming through the assessment stage of each attribute on an ordinal scale based on the sustainability criteria in each dimension. The index value and sustainability status are grouped into two groups whereas a sustainability index of 0 to 50 percent called as unsustainable and an index above 50 percent called as sustainable farming [10].

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Leverage or sensitivity analysis is carried out to see which attribute is the most sensitively affects the sustainability index in each dimension. Sensitive attributes are obtained by changing the ordination Root Mean Square (RMS) on the sustainability scale. The greater the change in RMS due to the loss of certain attributes, the more sensitive the role of these attributes will be for sustainability. Attributes that are located in the middle value are taken for policy recommendation.

The MDS technique also calculates the S-stress value to determine the goodness of fit of the model. A good model has an S stress value that is smaller than 0.25 [10]. Furthermore, factors that are sensitive to sustainability are characterized based on the results of the attribute leverage that has the largest root mean square (RMS) value when one of the attributes is omitted in ordination [17]. The greater the value of changes in the RMS, the greater the role of these attributes or the more sensitive it is in shaping the sustainability value. Besides, Monte Carlo analysis is used to evaluate the effect of random error. The Monte Carlo analysis also aims to determine the effect of the attribute scoring error, the effect of scoring variations, the stability of the repeated MDS analysis process and the incorrect entry or missing data. The low value difference between Rap Analysis and Monte Carlo shows that the MDS method analysis has a high level of confidence because errors in the analysis can be minimized.

3. Results and discussion

3.1. Multidimensional sustainability
Multidimensional scaling result with RAP-Chili shows that chili farming in the highland of Pacet was sustainable with sustainability index about 54.39 percent. The sustainability index was obtained from an assessment of 35 attributes covered in five dimensions, namely environment, economic, social, technology and institution (figure 1). These results indicate that chili management in the highlands of Pacet has integrated the resources for the current balance and has the potential to provide prosperity in the future.

![Figure 1. Sustainability index of chili farming in the highland of Pacet, Cianjur, West Java.](image)

The multidimensional sustainability index of chili farming is also presented in figure 2 in the kite diagram of Rap Chilli Farming. As presented on figure 2, out of five dimensions, only institutional dimension was unsustainable with a sustainability index of 48.20 percent, while the other four dimensions, namely environmental, economic, social and technological dimension were sustainable with a sustainability index ranged from 50.59 - 61.59 percent. Therefore, this result indicated that institutional dimension must be improved to increase the sustainability of chili farming by focused on the leverage
attributes that affect the sustainability of chilli farming significantly. Meanwhile, other dimension should be managed optimally to maintain their sustainability and even improved it to reach the highest sustainability status.

![Kite diagram of multidimensional sustainability index of chili farming.](image)

Table 1. MDS. Monte Carlo with 95 percent confidence interval and statistical parameters of the analysis.

| Dimension        | Sustainability Index | Statistics         | Determination (R²) |
|------------------|----------------------|---------------------|--------------------|
|                  | MDS                  | Monte Carlo         | Stress Values      |                     |
| Multidimensional | 54.39                | 54.30               | 0.13               | 95.61               |
| Environment      | 61.59                | 60.44               | 0.15               | 94.42               |
| Economic         | 59.29                | 59.19               | 0.16               | 93.73               |
| Social           | 52.51                | 52.43               | 0.16               | 93.51               |
| Institutional    | 48.20                | 47.76               | 0.15               | 94.16               |
| Technology       | 50.39                | 50.59               | 0.15               | 94.18               |

Furthermore, both of the statistical parameters indicated that all attributes were used in each dimension has been good enough to explain the sustainability of chili farming in the highland. Stress value for multidimensional and five dimensions were less than 0.25 ranged from 0.13-0.16 percent. This means that the effect of error in the assessment of an attribute was very small and can be ignored. Further, the value of determination coefficient (R²) in each dimension and multidimensional were close to 1 which ranged from 93.42 - 95.61 percent. It indicated that there was a close correlation between attributes in a dimension that was tested since more than 93 percent data could explain the model. Some parameters of this statistical test showed that the method RAP-Chili good enough to be used as one technique to assess the sustainability of chili farming in the highland of Pacet District.

3.2. Dimension of environment
Sustainability assessment for environmental dimension used seven attributes which were land fertility, plant disease and pest attack, availability of organic material, erosion rate, water availability, wind speed
and land elevation. Result of RAP Chili for sustainability of the environmental dimension shows that environmental dimension was sustain with index at 61.59 percent (figure 3). It means that chili farming in the highland of Pacet has considered the environmental preservation and balance as well.

Further, result of the leverage attributes analysis for environmental dimension shows that water availability, land fertility and wind speed were sensitive to the sustainability of chili farming in the dimension of environment. Therefore, management on those attributes must be improved properly to reach the high status of sustainability.

![Figure 3. Sustainability of environmental dimension and the leverage attributes.](image)

3.3. Dimension of economic

Using six attributes of economical dimension, sustainability assessment give the result that economical dimension was sustainable at index of 59.29 percent. Those attributes were productivity increase, price stability, quality of chili crop, marketing collateral, income increase and production cost saving. Out of 6 attributes, price stability, marketing collateral and production cost saving were the leverage attributes toward the sustainability of chili farming since those attributes were sensitive to the sustainability on economical dimension. Price stability as the leverage attributes of sustainability also mention by [18]. Meanwhile, the production cost saving as the leverage attributes also mention by [19].

![Figure 4. Sustainability of economical dimension and the leverage attributes](image)
3.4. Dimension of social

Result of the ordination for social dimension sustainability reach an index of 52.51 percent or in category of quite sustainable. Comparing with other dimension, sustainability index of social dimension was the third highest index among the five dimensions. This result shows that social contribution to the sustainability of chili farming was quite good.

Analysis result of social dimension sustainability leverage in Figure 5 presented that of the six attributes were analyzed, three attributes were sensitive affect the chili farming sustainability, namely extension intensity, training intensity and formal education of farmers. Extension intensity influences the chili farming significantly because this attribute could change the farmer’s knowledge and behavior on the management of chili farming especially the farming management, fertilizer and pesticide usage as well marketing aspect. This result is in accordance with study result of [20] that stated extension, training and demonstration plot were required to further enhance the social sustainability on the dairy and horticultural farming integration system. Intensity of training also become the sensitive attribute on the potato farming sustainability as explained by [21].

![Figure 5. Sustainability of social dimension and the leverage attributes.](image)

3.5. Dimension of technology

Multidimensional analysis for technological dimension showed that this dimension was quite sustainable with index about 50.59 percent. Improvement on this dimension could be focused on the leverage attribute that significantly affect the chili farming sustainability. As presented in figure 6, out of nine attributes were analyzed, understanding the benefit of bio pesticide, use of processing technology, use of pest trap, and use of rain shelter were sensitively influenced the sustainability of chili farming. When farmers understand the benefit of bio pesticide, they were aware and motivated to combine the application of bio pesticide with the chemical pesticide. The application of bio pesticide has decreased the production cost since bio pesticide also has the function as fertilizer and growth regulator.
3.6. Dimension of institution
Institutional dimension was not sustainable since the sustainability index of this dimension was less than 50. This result indicated that institutional dimension should be prioritized to be improved to achieve the chili farming sustainability and intervention on this dimension could be focused on the leverage attributes. Based on figure 7, leverage attributes on institutional dimension that influence the sustainability of chili farming were the availability of marketing institution, cooperation and partnership, the role of farmer group, and the role of extension worker. It means that enhancing on the marketing institution, partnership and role of farmer group was required to reach the sustainability development on chili farming especially in the highland of Pacet, Cianjur. Similar point stated by [22] that efforts that can be made to support the implementation of a sustainable agricultural system includes strengthening the institutions and improving land and crop management systems.

4. Conclusion
Multidimensional scaling with RAP-Chili technique give the result that chili farming in the highland of Pacet District was sustainable with sustainability index about 54.39 percent. These results indicated that
chili farming in the highlands of Pacet has integrated the resources for current balance and potentially use in the future. Out of five dimensions, only institutional dimension was unsustainable with an index about 48.20 percent while other dimensions, namely environmental, economic, social and technological dimension were sustainable with a sustainability index ranged from 50.59 - 61.59 percent. Therefore, improvement on the chili farming sustainability should be prioritized for the institutional dimension by focused on the leverage attributes that affected significantly the sustainability index. Leverage attributes on the institutional dimensions that sensitively affect the sustainability of chili farming were the availability of marketing institution, cooperation and partnership, the role of farmer group, and the role of extension workers.

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