Strategies for sustainable corn production: a case of South Lampung District, Lampung Province, Indonesia

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Abstract. Demand for corn has been increasing from time to time. However, efforts to increase its production face multidimensional challenges and problems. This study aims to assess sustainability status, analyze leverage and prospective factors, and formulate follow-up strategies for sustainable corn production. Data used primarily were data collected through online focus group discussions and interviews with various related agencies and key informants at provincial and district levels. This study was conducted between May and October 2020 in South Lampung District. Multidimensional Scaling (MDS) and Matrix of Cross Impact Multiplications Applied to Classification (MICMAC) were used to assess the sustainability status and analyze leverage and prospective factors. Then, the Multicriteria Policy (MULTIPOL) was used to formulate the follow-up strategies. The results show that the corn production in South Lampung District is classified as less sustainable, with a sustainability index of 49.30. The sustainability of corn production is influenced by ten leverage attributes, four of which are prospective factors, namely corn prices at the farmer level, the number of water pumps, the use of natural pesticides and fertilizers, and the number of corn shellers. The strategies for sustainable corn production could be carried out by by applying reference purchase prices effectively, strengthening farmer partnerships with the feed industry, supporting environmentally friendly corn farming, and optimization and effective use of pre-harvest and post-harvest machinery. It is necessary to evaluate the effectiveness of various assistance and policies implemented at this time to improve the implementation of programs/policies in the future.

1. Introduction

As one of the strategic food commodities, the demand for corn is increasing, both for food, animal feed, and industrial raw materials. For this reason, the government always strives to increase corn production through various policy programs to meet the growing domestic needs. However, efforts to increase corn production face multidimensional challenges, namely ecological, social, economic, institutional, and technological, which have caused conflicts of interest amongst economic activities.

Various problems and constraints faced in efforts to increase corn production include the following: (1) degradation of land resources and the environment [1] and conversion of agricultural land [2] led to increasingly limited agricultural resources, both quantity and quality, and competition in land use [3]; (2) narrowing of land tenure due to fragmentation factors as a result of increasing population and land inheritance patterns so that it affects farming efficiency [4]; (3) irrigation services are not yet optimal [5]; (4) agricultural production patterns are not yet environmentally friendly [5]; (5) climate change [6,7]; (6) farmer institutions are still weak and there are obstacles in growing institutions in farming
communities [8]; and (7) dissemination and adoption of agricultural technology innovations is still slow [9]. In addition, there are still many other problems and constraints, both ecological, social, economic, institutional, and technological, in corn development.

Increasing corn production, which only focuses on economic aspects, will gradually reduce the capacity and status of the sustainability of the business. Therefore, a thorough and multidimensional study of these various dimensions' leveraging and prospective factors is necessary for sustainable corn production. However, until recently, this area remains relatively under-studied. This study aims to develop the strategies for sustainable corn production based on assessing sustainability status as well as leverage and prospective factors.

2. Materials and methods

2.1. Materials
This study was conducted in South Lampung District, Lampung Province, considering that it represents a corn production center. The conflict of interest in land use there is classified as high, so that it impacts the sustainability of the corn business. The data used in the analysis primarily was obtained through focus group discussions (FGD) and in-depth interviews with various agencies and key informants related to the provincial and district levels (Office of Agriculture/Food Crops and Horticulture, Office of Food Security, Regional Development Planning Agency, Department of Public Development and Spatial Planning, and National Outstanding Farmers and Fishermen Association (KTNA)). The study was conducted between May and October 2020.

2.2. Methods
Multidimensional Scaling (MDS) [10] was used to assess the sustainability status and leverage factor. This method was chosen because it can provide comprehensive, objective, and fast results on sustainability factors, making it easier to determine policies [11]. The stages carried out in the MDS analysis are as follows. First, determining the attributes of each dimension of sustainability (ecological, economic, social, institutional, and technological) (Appendix 1), then each attribute was scored with a range of scores ranging from poor to good in an ordinal scale based on a literature study and FGD with experts. Second, scoring on each attribute from the results of the FGD, in-depth interviews with experts, and secondary data. Third, determining the index and sustainability status according to the index interval as follows: ‘bad’ or ‘not sustainable’ (0.00–25.00), ‘poor’ or ‘less sustainable’ (25.01–50.00), ‘adequate’ or ‘sustainable enough’ (50.01–75.00), and ‘good’ or ‘very sustainable’ (75.01–100.00) [12]. Forth, conducting Monte Carlo analysis to minimize errors at a 95% confidence level. Fifth, employing leverage analysis to determine the sensitive attributes that determine sustainability.

No statistical distribution assumptions are required because MDS, like cluster analysis, operates directly on dissimilarities. Other crucial assumptions, however, must be made. Multidimensional scaling is, first and foremost, a spatial model. Second, there are some methods for calculating distances from rectangular data that do not adhere to the metric axioms. Finally, all of the objects are expected to fit in the same space [13].

Matrix of Cross Impact Multiplications Applied to Classification (MICMAC) [14] was used to determine prospective factors from leverage factors. The prospective factor is a key factor that influences the sustainability of corn production in the South Lampung District. Multicriteria Policy (MULTIPOL) [15] was employed to formulate a strategy for sustainable corn production based on prospective factors.

3. Results and discussion

3.1. Corn production development in South Lampung District
Lampung Province is the third-largest corn production center in Indonesia after East Java and Central Java, contributing about 8.10% of the total national corn production [16]. Between 2010 and 2017, corn production in Lampung Province showed an increasing trend. The very sharp increase in corn production in the 2015–2017 period (25.82% per year) is suspected to be the success of the UPSUS Corn Program.
through the additional planting area (LTT) activities. The increase in corn production in Lampung Province in this period was almost entirely (96.28%) contributed by the increase in the harvest area. Except for this period, the increase in productivity dominantly contributed to the increase in corn production. Given the increasingly limited land resources, increasing corn production by relying on increasing harvested areas will not continue.

South Lampung District is the largest corn production center in Lampung Province, contributing 31.54% of the total corn production in Lampung province. Both harvested area, production, and corn productivity in South Lampung District between 2010 and 2017 fluctuated from year to year but showed an increasing trend (2.69% per year). In the 2015–2017 period, the increase in corn production rate even reached 10.16% per year. As with Lampung Province, the increase in corn production in the South Lampung District in the 2010–2014 period was dominated by increasing productivity, while in the 2015–2017 period, it was a dominant contribution of increasing harvested area.

3.2. Sustainability status, leverage and prospective factors of sustainable corn production

The results of the MDS analysis covering five dimensions, i.e., ecological, economic, social, institutional, and technological, show that corn production in South Lampung District is classified as less sustainable (MDS index value 49.30). Until recently, there is no study on corn production sustainability in Indonesia employing MDS analysis, so we cannot compare this study result with previous studies. However, a study on the sustainability of corn farming in Grobogan District, Central Java, resulted in the synthetic farm sustainability index of Majewski of 51.15%, referring to as ‘moderate’ [17].

Analysis per dimension shows that there are variations in the index values and sustainability statuses (Table 1 and Figure 1). Out of the five dimensions, only technology was rated as sustainable (MDS index value of 78.47). Farmers carry out corn farming in South Lampung District in monoculture by using new superior hybrid seeds with high productivity and applying good cultivation techniques. This is done because corn farming is the primary source of income. The use of hybrid seeds contributes to higher annual incomes [18]. This makes corn farming in South Lampung District has competitiveness, both competitive and comparative advantages [19]. However, there is a study that highlights the need for enhancing corn tolerance to climate change (drought and heat waves) in pursuing sustainable corn production [7].

Table 1. Statistic parameters, indexes, and sustainability statuses of corn production in South Lampung District.

| Dimension      | MDS index | Monte Carlo | Delta | Stress | R²  | Status  |
|----------------|-----------|-------------|-------|--------|-----|---------|
| Ecology        | 58.57     | 58.13       | 0.43  | 0.12   | 0.95| Adequate|
| Economy        | 46.43     | 46.67       | -0.24 | 0.13   | 0.95| Poor    |
| Social         | 45.14     | 45.41       | -0.27 | 0.13   | 0.95| Poor    |
| Institutional  | 52.65     | 52.79       | -0.14 | 0.16   | 0.94| Adequate|
| Technology     | 78.47     | 75.62       | 2.84  | 0.15   | 0.94| Good    |
| Multidimension | 49.30     | 49.58       | -0.27 | 0.12   | 0.95| Poor    |

The results of the Monte Carlo analysis at the 95% confidence level showed no significant differences between the results of the MDS analysis and those of the Monte Carlo test. This shows that the error in the analysis was very small. In addition, the results of the MDS analysis show that all the attributes studied were quite accurate, so that they provided good and accountable analysis results. This can be seen from the stress value which was only around 0.12 (12%) and the coefficient of determination (R²) was 0.95.
Multidimensional leverage analysis shows that out of 45 attributes analyzed (Appendix 1), ten leverage attributes from the five dimensions affect the sustainability of corn production in the South Lampung District. The ten leverage attributes consist of one attribute belongs to the ecological dimension, three attributes belong to the economic dimensions, three attributes belong to the social dimensions, one attribute belongs to the institutional dimension, and two attributes belong to the technology/infrastructure dimensions (Figure 2).

Out of the ten leverage factors, four prospective factors have a strong influence on the sustainability of corn production, i.e., the price of corn at the farm level, the number of water pumps, the use of natural pesticides and fertilizers, and the number of corn shellers (Figure 3). Meanwhile, a study in Grobogan

**Figure 1.** Kite diagram of the sustainability index values and statuses by dimension of corn production in South Lampung District, 2020.

**Figure 2.** Multidimensional corn production leverage factors in South Lampung District, 2020.
District, Central Java [17] highlighted the importance of facilitating deep wells and input price subsidies, including seed price subsidies to achieving sustainable corn farming in the mentioned location.

**Figure 3.** Key/dominant factors that influence the strategy for increasing sustainable corn production in South Lampung District, 2020.

| No. | Symbol | Description |
|-----|--------|-------------|
| 1.  | organic | Use of natural pesticides and fertilizers |
| 2.  | agworker | Number of agricultural workers |
| 3.  | small | Percentage of smallholder farmers (<0.5 ha) |
| 4.  | educ | Farmer's formal education |
| 5.  | farmerhh | Percentage of corn farmer households |
| 6.  | manag | Corn farming management pattern |
| 7.  | waterpump | Number of water pumps |
| 8.  | comprice | Corn prices at farmer level |
| 9.  | budget | Proportion of local government budget for food crops subsector |
| 10. | sheller | Number of corn shellers |

### 3.3. Strategies for sustainable corn production

The program for sustainable corn production is carried out based on intensification and extensification. From this program, policy strategies and operational steps are then drawn up to be implemented in the short, medium, and long term. There are five policy strategies: the development of agricultural tools and machinery, institutional strengthening and farm financing, development of environmentally friendly corn production, stabilization of supply and prices, and increasing product competitiveness (Table 2).

The five policy strategies are prepared based on the priority of their potential impact on corn production sustainability. Mapping of machinery, especially corn shellers and hand tractors, is needed to increase agricultural machinery's effectiveness. From these results, it is possible to redistribute the agricultural machinery to farmer groups. In addition, corporation-based farming should be carried out to increase farming efficiency and profits and environmentally friendly farming practices. An increase in farming efficiency, productivity, added value, and income can be achieved through land consolidation, corporate farming, and modern agriculture due to increased economies of scale [20]. Implementing Field School-Integrated Crop Management (FS-ICM) for more environmentally friendly farming practices will make a higher comparative advantage in producing corn [21], so it is expected
that the practices will increase corn competitiveness in South Lampung District in particular and Indonesia in general.

Table 2. Policy strategies and its operational steps for sustainable corn production.

| No. | Policy strategy                                      | Operational steps                                                                 |
|-----|------------------------------------------------------|------------------------------------------------------------------------------------|
| 1.  | Development of agricultural tools and machinery (alsintan) | • mapping of the availability and needs of alsintan (corn sheller and hand tractor)  |
|   |                                                      | • increasing the effectiveness of alsintan utilization                               |
| 2.  | Institutional strengthening and farm financing        | • application of corporate-based farming                                             |
|   |                                                      | • strengthening partnership between corn farmers and feed mills                     |
|   |                                                      | • expansion of people’s business credit (KUR) guarantee support                     |
| 3.  | Development of environmentally friendly corn production | • expansion of organic fertilizer support                                             |
|   |                                                      | • increasing area and effectiveness of the implementation of integrated pest control |
|   |                                                      | • expansion of environmental conservation practices                                 |
| 4.  | Stabilization of corn supply and price               | • construction of silos in corn business centers                                     |
|   |                                                      | • control and adjustment of import tariffs                                          |
|   |                                                      | • increasing the effectiveness of applying the reference purchase price             |
| 5.  | Increasing competitiveness of corn/corn products      | • increasing productivity, quality, and added value                                 |
|   |                                                      | • expansion of mechanization application (tractor, transplanter, sheller, dryer)     |

4. Conclusions

Multidimensionally, corn production in South Lampung District shows a ‘poor’ sustainable status. Ten leverage attributes influence sustainable corn production in South Lampung District, and four key factors play an essential role: the price of corn at the farm level, the number of water pumps, the use of natural pesticides and fertilizers, and the number of corn shellers.

The policy strategies for achieving sustainable corn production could be carried out by guaranteeing corn prices produced by farmers by applying reference purchase prices effectively. The government facilitates the strengthening of farmer partnerships with the feed industry and establishes a policy that the feed industry and BULOG should buy farmers’ corn according to the reference purchasing prices that have been established. In order to maintain corn productivity, land structure improvement should be carried out sustainably through environmentally friendly farming practices. Implementing FS-ICM and expansion of organic fertilizer supports should be done. Government assistance such as the organic fertilizer processing unit (UPPO) should be expanded in number and use, including in corn cultivation. Agricultural machinery and equipment assistance provided to farmers needs to be mapped between current needs and availability. Mapping should be done by region (subdistrict/district/province). Suppose it is excessive in one location, the machinery and equipment can be relocated to another area. These mapping results are also used as a guide to determine the number and types of agricultural machinery and equipment assistance to distribute to farmers at the next stage.

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Appendix 1. Dimensions and attributes used in the sustainability analysis of corn production in South Lampung District, 2020.

| Dimension          | Attribute                                                                 |
|--------------------|---------------------------------------------------------------------------|
| I. Ecology         | 1. Use of chemical fertilizers                                           |
|                    | 2. Use of organic fertilizers                                            |
|                    | 3. Use of chemical pesticides                                            |
|                    | 4. Use of natural pesticides                                             |
|                    | 5. Amount of rainfall per year                                             |
|                    | 6. Number of dry months per year                                          |
|                    | 7. Irrigation system                                                       |
|                    | 8. Corn productivity                                                      |
|                    | 9. Land conversion                                                        |
|                    | 10. Corn land construction                                                |
|                    | 11. Harvest failure due to drought/flood/pest attack                       |
|                    | 12. Pressure of industrial and residential land use                       |
| II. Economy        | 1. Economic efficiency (RC)/average income of farmers relative to the district minimum wage |
|                    | 2. Corn production                                                        |
|                    | 3. Farmer's exchange rate                                                 |
|                    | 4. Corn prices at farmer level                                             |
|                    | 5. Changes in real wages of farm workers                                  |
|                    | 6. Percentage of smallholder farmers (<0.5 ha)                            |
|                    | 7. Number of agricultural workers                                          |
|                    | 8. Access to capital for farming                                           |
|                    | 9. Yield of corn farming compared to total family income                   |
|                    | 10. Marketing institutions that accommodate corn production                |
|                    | 11. Relative advantages of corn farming compared to its competitors        |
| III. Social        | 1. Percentage of corn farmer households                                   |
|                    | 2. Farmer's formal education                                               |
|                    | 3. Farmer households who have participated in agricultural extension       |
|                    | 4. Motivation of farmers to do corn farming                                |
|                    | 5. Frequency of corn land use conflicts                                   |
|                    | 6. Proporsi bagi hasil tanah garapan                                      |
|                    | 7. Family participation in corn farming activities                         |
|                    | 8. Corn consumption per capita                                            |
|                    | 9. Alternative business other than corn farming (other/non-agricultural commodities) |
|                    | 10. Perceptions of the sustainability of corn farming                     |
|                    | 11. Corn farming management pattern                                        |
| IV. Institutional  | 1. Liveliness of corn farmer groups in agricultural activities             |
|                    | 2. Presence of extension workers                                           |
|                    | 3. Consistency of land use with RTRW (Regional Spatial Plan)              |
|                    | 4. Perpetual land status for agricultural land (Perda)                     |
|                    | 5. Proportion of local government budget for food crops subsector          |
| V. Technology/     | 1. Number of 2-wheel and 4-wheel tractor                                  |
| infrastructure     | 2. Number of water pumps                                                  |
|                    | 3. Number of corn shellers                                                |
|                    | 4. New superior variety technology adoption by the farmer                  |
|                    | 5. Post-harvest technology application                                     |