Sustainability of Horticulture in Agriculture Era 4.0 in Lembang Sub-district, West Java

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Abstract. Horticulture in Lembang Sub-district seems to be threatened with unsustainability due to urban expansion in Bandung Metropolitan Area. This urban expansion causes a land conversion and puts farmers at risk of losing their arable land. In Agriculture Era 4.0, horticulture management should be integrated with the Internet of Things (IoT), so it can survive amid the urban expansion. Hence, this research aims to analyze the sustainability of horticulture in the current Agriculture Era 4.0 by knowing the spatial distribution of horticulture and land capability class in Lembang Sub-district. The data was collected through field surveys, questionnaires, and in-depth interviews. While the methods were performed by visual interpretation and overlay using ArcGIS and RAP-FARM/MDS. Results showed that 3,079.03 ha was classified as horticulture with vegetables as the dominant cultivated. Based on the horticultural distribution and land capability class, the sustainability index of horticulture were: 54.27 (horticulture in class III), 54.47 (horticulture in class IV), and 44.11 (horticulture in class VI). Horticulture in class III and class IV has quite sustainable status, while class VI has less sustainable status. This study results can be taken into consideration in determining spatial planning for sustainable horticultural development in Lembang Sub-district.

1. Introduction

Various horticultural commodities were cultivated in Lembang Sub-district, ranging from vegetables, fruits, ornamental plants, and medicinal plants. The current condition of horticulture seems to be a particular concern due to urban expansion in Bandung Metropolitan Area. As a result, there was a land conversion from agricultural to non-agricultural land and puts farmers at risk of losing their cultivated land. Especially at this time, Lembang Sub-district became a famous and rapidly growing tourist destination. The development of tourist attractions was followed by the construction of hotels or inns, parking lots, and souvenir shops. Thus, horticulture in Lembang Sub-district threatened with its sustainability.

Sustainability can be seen from various dimensions, namely ecological, social, economic, institutional, and technological [1]. In order to achieve sustainability, it should be adjusted with the current agricultural era, namely Agriculture 4.0, where farm activities are connected to the cloud [2]. Although technology innovation was not a new issue for agriculture, varieties of information and communications technology (ICT) software tools in agriculture had been utilized to assist farmers in
decision making [3]. Various dimensions that describe sustainability should be integrated with the characteristics of Agriculture 4.0. Hence, this research’s objectives were to analyze the sustainability of horticulture in the current Agriculture 4.0 by knowing the spatial distribution of horticulture and land capability class in Lembang Sub-district.

2. Method
This research was conducted in Lembang Sub-district, West Bandung Regency. It is geographically located between 107° 1' 10" - 107° 4’ 40" East Longitude and 6° 3’ 73” - 7° 1’ 31” South Latitude, and consisting 16 villages with 95.56 km² of total area. The study area is presented in figure 1.

Data collected through field surveys and interviews from June until July 2020. Respondents are: (i) horticultural farmers who are randomly selected from overlaying horticultural distribution map and land capability class-map, and (ii) government officers from Agriculture, Fisheries, and Forestry Counselling Center or Balai Penyuluhan Pertanian, Perikanan, dan Kehutanan (BP3K). The methods used in this study are: (i) spatial analysis to determine the distribution of horticulture and land capability class, and (ii) Multidimensional Scaling (MDS) analysis with RAP-FARM method approach.

Spatial distribution is done by digitizing Google Earth Imagery 2019, whereas the land capability class is done by table matching criteria [4]. The procedures of MDS analysis are: (1) determine attributes of each dimension and scoring on a scale of sustainability which obtained through a literature review and discussion with experts, (2) MDS analysis to determine ordination and sustainability status, namely: 0.00-25.00 (unsustainable), 25.01-50.00 (less sustainable), 50.01-75.00 (quite sustainable), and 75.01-100.00 (very sustainable), (3) leverage analysis to determine sensitive attributes, (4) Monte Carlo analysis to detect the source of the error, (5) Calculate the coefficient of determination (R²) and stress value [5, 6]. The MDS analysis was generated based on an assessment of 35 attributes in total covered in 5 dimensions, including ecological (7 attributes), economic (7 attributes), social (7 attributes), institutional (7 attributes), and technological (7 attributes). A comparison of each dimension can be visualized through a kite diagram [7].

3. Results and discussion
The results and discussion will be discussed in 3 subsections, namely the spatial distribution of horticulture, land capability class, and sustainability index.

3.1. Spatial distribution of horticulture
Horticultural distribution in Lembang Sub-district covering 3,079.03 ha. The most widely cultivated horticulture is vegetables, such as broccoli, tomato, cauliflower, lettuce, chili, chayote, bean, and cabbage. The distribution of horticulture in Lembang Sub-district is presented in figure 2.
3.2. Land capability class

Evaluation of land capability is one of the efforts in utilizing land according to its potential. From the result, four land capability classes were found, namely: class III (1,834.95 ha), class IV (1,636.72 ha), class VI (3,627.94 ha), and class VII (498.39 ha) (figure 3). Most of the land in Lembang Sub-district is classified into class VI. Some of the limiting factors are located on a rather steep slope, the threat of severe erosion, severely eroded, and the root area is very shallow [8].

As the second-largest area, land in class III can be used for annual crops and plants that require special processing, grass plants, production forests, protected forests, and wildlife reserves [8]. In comparison, soils in class IV is suitable for occasional cultivation in rotation with hay or pasture, or orchards protected by permanent cover crops [8]. The last is class VII, which is unsuitable for annual crop farming, and it is only suitable for pasture or forestry. If it is used for pasture and production forest, there must be a severe erosion prevention effort. However, based on the field survey, horticultural cultivation was in land capability class III, IV, VI, and class VII.

3.3. Sustainability index

The area for sustainability analysis was an overlay result between the distribution of vegetable horticulture and the land capability class presented in figure 4. Due to a tiny area of horticulture in land capability class VII, horticulture in that area was not counted in sustainability analysis.

Based on MDS analysis, sustainability indexes of horticulture in land capability class III, class IV, and class VI in Lembang Sub-district were 54.27, 54.47, and 44.11 (figure 5). Horticulture in land capability class III and IV was categorized as quite sustainable, whereas horticulture in land capability
class VI was less sustainable. The kite diagram and MDS sustainability index of horticulture in Lembang Sub-district are presented below.

![Kite diagram and MDS sustainability index of horticulture in Lembang sub-district](image)

**Figure 5.** Kite diagram and MDS sustainability index of horticulture in Lembang sub-district

3.3.1. Ecological dimension. The results showed that MDS ordination value for the ecological dimension of horticulture in land capability class III, IV, and VI, namely: 58.19, 52.29, and 51.48 and all classified as quite sustainable (figure 5). The most sensitive attribute in horticulture in class III was an irrigation technique, while in class IV and VI was the availability of organic material sources (figure 6). Some horticultural areas had fairly good irrigation techniques. On the other hand, the other farmers still rely on rainwater in the rainy season. When in the dry season, some farmers made irrigation by using a pump that draws water from a nearby river. The average length of the pipe was 100-500 m. The farmers watered their plants by using a hose or sprayer of the water that had been collected.

Regarding the availability of organic material sources, farmers purchased the supply of manure from outside Lembang Sub-district, except farmers who had a side job as a breeder, so that they will take its manure as fertilizer. As a sensitive attribute, irrigation repair and maintain the availability of organic material sources needs to be done to increase the sustainability index.

![Leverage chart of the ecological dimension](image)

**Figure 6.** Leverage chart of the ecological dimension

3.3.2. Economic dimension. Horticulture in land capability class III, class IV, and class VI were less sustainable with 43.25, 41.94, and 49.27 as the MDS ordination values (figure 4). The leverage factor that affected was market availability (figure 7). Horticultural farmers believe that the market availability in Lembang Sub-district was easy to find, although they were not much involved in the market. The non-involvement of farmers was also the reason why farmers’ ability to access the market was the second most sensitive attribute in horticulture class III and IV. Farmers’ ability to access the market was related to the selling price. Some farmers were able to choose which collectors to sell their products. They can
negotiate about the price as well. However, some farmers were already tied to one collector who provided them with planting capital. So, after harvesting, the farmers sell their products to this collector and pay their debts.

![Figure 7](image-url) **Figure 7.** Leverage chart of the economic dimension

On the other hand, the second most sensitive attribute in class VI is creating added-value products. Some farmers in class VI were able to access markets and create added value. The creation of added value was not only able to increase selling prices but also able to absorb new jobs and drive research and product development activities [9]. In connection with this matter, training about adding value products and the ease of loan capital can be implemented smoothly in situations that can be met by farmers. Those were important things to increase the economic condition of farmers and the value of the sustainability index.

3.3.3. **Social dimension.** The social dimension was closely related to the institutional dimension because several attributes are about farmer groups, which were the institutional dimension’s dominant attributes. Figure 4 showed that the MDS ordination value of horticulture in land capability class III, class IV, and class VI were, namely; 72.73 (quite sustainable), 87.31 (sustainable), 52.66 (quite sustainable). The most sensitive attribute of horticulture in land capability class III was the intensity to attend counselling/training. The training was needed to support farmers to achieve sustainability in the era of agriculture 4.0. Training for farmers had a positive impact on production and profit on farming, which was also supported by levels of education and experience of farmers [10].

![Figure 8](image-url) **Figure 8.** Leverage chart of the economic dimension
While in capability class IV, perception about participatory means farmers who had known about the benefit of involving in farmer groups to cooperate with other farmers, but they were still not engaged in farmer groups. Sometimes this issue can lead to social conflict, which was jealousy towards farmers who received government assistance. The most sensitive attribute in land capability class VI was the communication and cooperation between farmers (figure 8). That cooperation would occur more frequently if these farmers were involved in farmer groups.

3.3.4. Institutional dimension. The institutional dimension more described the existence and farmers’ involvement in farmer groups. The results showed that the institutional dimension of horticulture in land capability class III, class IV, and class VI were 54.11 (quite sustainable), 64.08 (quite sustainable), and 28.45 (less sustainable). Regarding the leverage analysis, the most sensitive attribute was farmer groups’ existence (figure 9). The existence of farmer groups can be an effort to improve food consumption by its members by increasing farm production and income [11]. Based on data in Agriculture, Fisheries, and Forestry Counselling Center or Balai Penyuluhan Pertanian Perikanan, dan Kehutanan (BP3K), there were 16 farmer group associations in 16 villages in Lembang Sub-districts. In one farmer group association, there were approximately 15-20 farmer groups. In fact, not all farmers in Lembang Sub-district are involved in the farmer group, including most of the respondents who were asked in the interview.

![Figure 9. Institutional dimension leverage chart](image-url)

3.3.5. Technological Dimension. The seven attributes used in the technological dimension analysis are related to agriculture 4.0, which is digitalization. Various digitalization types are big data, robotics, sensors, artificial intelligence, and the Internet of Things (IoT) [12]. Optimization of agricultural production systems, value chains, and food systems are expected to be the output of digitization in agriculture. The implementation of agricultural digitalization can be conducted during the on-farm and off-farm processes and also a digital marketing [13].

Digital marketing arises from the development of information technology that quickly happened. It changed some aspects of human life, such as fulfilling the necessities of life that can be completed online or digital. Future marketing in agriculture are no longer conventional but will be platform-based by utilizing the IoT, which is one of agriculture 4.0’s characteristic. Consumers of agricultural products will use the platform via smartphones or other gadgets to buy products. This situation will benefit farmers in maximizing production and minimizing the distribution chain [14].

Related to agricultural technology 4.0 in Lembang Sub-district, the analysis result showed that the MDS ordination value of horticulture in land capability class III was 52.77 and classified as quite sustainable. While MDS ordination value of horticulture in land capability class IV and class VI were
30.56 and 35.50, which classified as less sustainable. The leverage factor affected in all areas was smartphone usage following by easy internet access (figure 10).

![Figure 10. Technology dimension leverage chart](image)

Based on the field survey, all farmers interviewed had a smartphone to communicate with other farmers or discuss horticulture problems. Easy communication was supported by a good internet signal in all areas, including remote villages. However, only a few farmers use smartphone to run digital marketing, while others still rely on collectors.

Seeing the current conditions, education about agriculture 4.0, especially in the technological dimension, is needed by farmers. Limited knowledge is a factor that hinders the pace of technology from penetrating the agricultural sector at large. The role of the government and other stakeholders is needed to provide adequate education for farmers to adapt agriculture 4.0 in terms of technology such as how to run digital marketing.

### 3.4. Validation of sustainability index

Validation of the sustainability index carried out by Monte Carlo analysis and statistical parameters such as the coefficient of determination ($R^2$) and stress value. Monte Carlo analysis at a 95% confidence interval was used to estimate the effect of errors in the statistical analysis process [15]. Table 1 showed that the difference between MDS value and Monte Carlo was relatively small, ranging from 0.20 to 2.45. It indicates that the error in making each attribute score is relatively small and the output produced with high-level confidence [16][17].

| Class | Ecological | Economic | Social | Institutional | Technology |
|-------|------------|----------|--------|---------------|------------|
|       | Monte Carlo Difference | Monte Carlo Difference | Monte Carlo Difference | Monte Carlo Difference | Monte Carlo Difference |
| III   | 57.67      | 0.52     | 43.83  | 0.58          | 71.56      | 1.17        | 51.67      | 2.44        | 52.28      | 0.49        |
| IV    | 52.06      | 0.23     | 42.86  | 0.92          | 84.86      | 2.45        | 62.90      | 1.19        | 32.81      | 2.25        |
| VI    | 51.28      | 0.20     | 49.41  | 0.14          | 52.47      | 0.19        | 30.63      | 2.18        | 36.45      | 0.95        |

The coefficient of determination ($R^2$) in each dimension was ranged from 0.909 to 0.944 (table 2), which are sufficiently high value and close to 1. This means that the number of attributes used to assess a dimension is accurate enough. While the stress value in each dimension (table 2) showed a small value. The smaller the stress value, then the better output of the analysis [18]. Both of these statistical parameters showed that the analysis results are sufficiently good.
Table 2. Statistical parameters of the sustainability index analysis

| Class | Dimensional Ecological R² | Dimensional Economic R² | Dimensional Social R² | Dimensional Institutional R² | Dimensional Technology R² |
|-------|---------------------------|-------------------------|-----------------------|-----------------------------|--------------------------|
|       | Stress                    | Stress                  | Stress                | Stress                      | Stress                   |
| III   | 0.942                     | 0.151                   | 0.941                 | 0.141                       | 0.930                    | 0.142                    |
| IV    | 0.940                     | 0.158                   | 0.940                 | 0.142                       | 0.939                    | 0.139                    | 0.909                    | 0.151                    |
| VI    | 0.943                     | 0.152                   | 0.942                 | 0.146                       | 0.942                    | 0.151                    | 0.931                    | 0.141                    | 0.937                    | 0.142                    |

4. Conclusion

The sustainability index of horticulture in the agriculture era 4.0 especially vegetables in Lembang Sub-district, can be described in three areas of land capability, which are land capability class III, class IV, and class VI. In multidimensional, sustainability indexes in class III and IV are 54.27 and 54.47. Both are classified as quite sustainable. While the sustainability index for horticulture in land capability class VI was 44.11 and classified as less sustainable. Related to this matter, increasing the value of sustainability can be done concerning sensitive attributes obtained from leverage analysis in each dimension (ecological, economic, social, institutional, and technological).

The characteristics of agriculture 4.0 that integrate with the IoT should also be applied in terms of development so that horticulture can survive amid the urban expansion. Digital marketing or online-based sales is one of the methods in 4.0’s characteristic. This requires an internet signal and a smartphone or other gadgets. In fact, almost all farmers in Lembang Sub-district have these tools. However, only a few farmers use this method, while others still rely on collectors to sell their products. Therefore, the role of the government and other stakeholders is needed to provide adequate education for farmers in order to adapt agriculture 4.0 from all dimensions, especially technology.

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