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Application of Nanotechnology Liquid Organic Fertilizer in Sustainable Hydroponic Cultivation for Urban Food Security

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ABSTRACT

The demand for vegetables in urban areas is increasing along with the increase in population. New urban development also reduces the land available for farming, making it difficult for farmers to meet the increasing demand for vegetables in society. Efforts made to meet the need for vegetables in urban areas include hydroponic cultivation which is very efficient in limited areas of land. The current study, conducted November 2022-August 2023, used multidimensional scaling (MDS). The data obtained came from the results of questionnaires and interviews with hydroponics practitioners in Padang City. The research results of the three dimensions tested are economic, social and environmental. In the economic dimension, hydroponic cultivation has an index value of 51.29. In the social dimension it has an index value of 52.37 and in the environmental dimension it has an index value of 53.68. The three dimensions tested have quite sustainable values. The hydroponic mapping results show that there are 22 hydroponic cultivators with a total accumulated production of 10,000 planting holes/month, which are then distributed to large-scale supermarkets in Padang City with various types of hydroponic vegetables.

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Keywords: Business; Hydroponic; Sustainable

1. Introduction

Vegetables are an integral part to a balanced and healthy diet. The demand for vegetables in cities is currently quite high. In Indonesia, around 70% of the population lives in urban areas, resulting in the level of food consumption in urban areas to be quite high [1]. The ability to produce vegetables in urban areas is not able to meet the high demand, as agricultural land is decreasing due to the large number of urban developments. The hydroponic planting method is a strategy that can be employed to preserve green spaces in cities, which are increasingly becoming polluted and lacking in cool air. This method is not only a solution to improve the urban atmosphere, but also a potential answer to food security issues [2]. Hydroponics is a planting method that uses water as the planting medium. Hydroponics can be done with limited land area and provides high yields. Hydroponic farming needs to be applied to be able to produce abundant food for sustainable food security, especially in urban environments.

Efforts to increase agricultural production need to be made to meet urban vegetable food needs. The use of nanotechnology in liquid organic fertilizer can further increase productivity and provide long-term benefits in the agricultural sector [3]. Nanotechnology utilizes particles on the nanometer scale that are able to have freer and more controlled movements. Nanotechnology plays a role in reducing the deposition of organic materials so that the ammonia content does not increase [4]. The application of nanotechnology in fertilizer allows plants to absorb nutrients more optimally with an efficiency of around 65-70% [5].

In agriculture, nanotechnology is used to increase crop productivity, product quality, consumer acceptance and efficient use of resources, thus, the application of nanotechnology will help reduce agricultural costs, increase productivity, increase production values and increase farm income, in addition to supporting conservation and improving the quality of natural resources in agricultural production systems. Urban farming presents opportunities for the development of agribusiness-based and environmentally sound farming businesses. Urban agriculture is defined as the cultivation of both food and non-food agricultural products in urban areas. This practice is characterized by limited space, intensive or modern farming techniques, access to market information, and technology-assisted optimization of production, land, and space productivity. It is socially desirable, can improve income, and supports the environment in a sustainable manner.

The hydroponic trend is considered to be part of a healthy lifestyle because most hydroponic farmers prefer to use organic farming methods in lieu of chemical fertilizers and synthetic pesticides. Hydroponics can create a comfortable and healthy environment to live in with various growing systems such as verticulture, hydroponics and aquaponics which can easily be implemented in areas where space is limited. If hydroponics could be adopted by many people, it would be a productive activity to empower the community and support the local economy. Social relations could grow by strengthening the sense of togetherness and creating a culture of mutual cooperation in urban communities.

2. Materials and Methods

This research was conducted in November 2022-August 2023 using the Multidimensional Scaling (MDS) research method, which is one of the procedures used to visually map respondents' perceptions and preferences on geometric maps. The type of data used is data from questionnaires (Table

1) and interviews with hydroponics practitioners in Padang City. The attributes used in the questionnaire consist of three dimensions, namely economic, social and environmental, each dimension consists of 7 sub-dimensions whose scores have been determined.

Table 1. Questionnaire assessment attributes.

No	Dimension/Sub dimension	Point				
		1	2	3	4	5
Economic Dimension						
1	Business profit					
2	Productivity					
3	The demand for hydroponic vegetables tends to increase					
4	The price of hydroponic vegetables is higher than other commodities					
5	Business partnership					
6	Business Feasibility					
7	Supply Stability					
Social Dimension						
1	The level of cultivator's knowledge of the environment					
2	Work skills in the field of hydroponics/plants					
3	Obtaining information about hydroponics					
4	Farmer empowerment					
5	Development of cultivating activities					
6	There is cooperation between hydroponic farmers					
7	Public perception of sustainable business					
Environment Dimension						
1	Presence of a water source					
2	Seed varieties					
3	Pest attack intensity					
4	Average temperature					
5	Land availability					
6	Environmental Conservation					
7	Weather conditions					

Description :
1 = Not very influential
2 = No influence
3 = Neutral
4 = Influential
5 = Very Influential

The results of the questionnaire research data were then analyzed with RAPFISH and SPSS software. The results of the MDS analysis are indexes that can be displayed in three indicators, namely Ordination, Leveraging, and Kite Diagrams. Ordination is the placement (mapping) of the analyzed area in terms of bad and good which is then strengthened by anchors. The closer to the good position, the area is said to be sustainable. The sustainability categories used are divided into four, as presented in Table 2.

Table 2. Sustainability status categories based on index values.

Index Value	Category
0 ≤ Index Value ≥ 25	Not sustainable
25 ≤ Index Value ≥ 50	Less sustainable
50 ≤ Index Value ≥ 75	Quite sustainable
75 ≤ Index Value ≥ 100	Sustainable

3. Results and Discussion

3.1 Economic dimension

In the economic dimension (Fig. 1), there are 7 attributes tested, including supply stability, business feasibility, business partnerships, the price of hydroponic vegetables is higher than other commodities, demand for hydroponic vegetables tends to increase, productivity and business profits. Each dimension was analyzed using RAPFISH until the results showed that in leverage analysis of the economic dimension, there are two sensitive attributes that have Root Mean Square (RMS) values. These attributers were supply stability (RMS = 1.02) and productivity (RMS = 1.68), presented below.

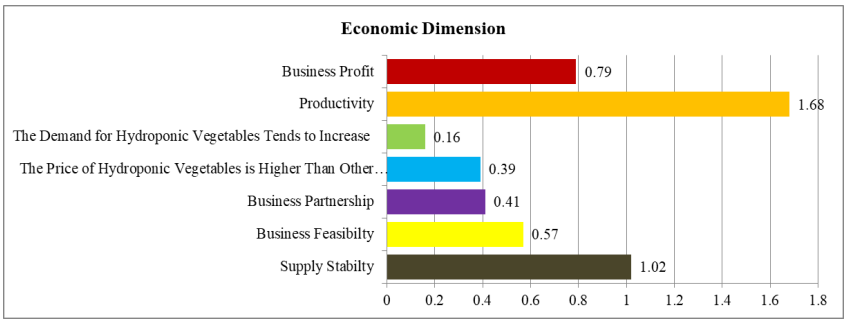

Fig. 1. Rapfish Test on Economic Dimensions.

According to [6], the sustainability index resulting from calculations with the RAPFISH application provides quick assessment results. The determination of scores in RAPFISH comes from three main sources, namely 1: Peer-Review Scoring, which is a score based on a review of scientific documentation by determining the threshold; 2) Grey Literature, which is a score based on the results of previous analyses, both published and unpublished; 3) Expert Judgment, which is the determination of scores made through expert agreement.

As shown in Fig. 1, the dimensions of adjusting supply volume according to consumer needs, is a very important aspect in the economic dimension. For maintaining a stable supply of vegetables on the market, there needs to be an equalization process with appropriate storage facilities so that the quality and freshness of vegetables is maintained [7].

Vegetables cultivated hydroponically can support community food security, because many cultivation activities utilize empty land and ultimately the land produces vegetables. Increasing land productivity can form partnerships between vegetable farmers and traders to market their crops to the community.

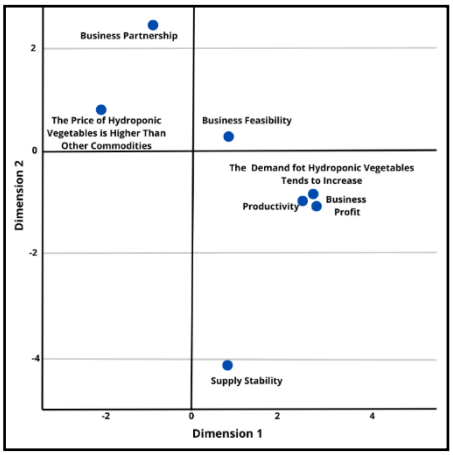

Fig. 2. SPSS Test on Economic Dimensions.

In dimension 1, it can be seen that the further to the right, the greater the value of dimension 1. The attributes that have similarities in the supporting elements, namely the sub-dimension demand for hydroponic vegetables, tend to increase, along with productivity and business profits. Meanwhile, in dimension 2, the partnership sub-dimension has a high value in the economic dimension. In the economic sub-dimension, the demand for hydroponic vegetables tends to increase along with the productivity sub-dimension and business profit sub-dimension.

The productivity of hydroponic vegetables is higher than the productivity of conventional vegetables, around 0.3-0.9 kg/m [8]. Increasing vegetable productivity is also supported by management and management applied in cultivation activites which will have an influence on vegetable productivity. It can be seen that these three sub-dimensions are closely related. Consuming organic vegetables has become a trend in society. This causes many consumers to finally decide to purchase organic vegetables rather than non-organic vegetables. The increase in demand for organic vegetables stems from the fact that many people today realize the importance of consuming nutritious food. Even though the price of organic vegetables is higher than non-organic vegetables, consumers will still buy organic vegetables. The demand for organic vegetables tends to increase. Hydroponic cultivation should also increase productivity and vegetable yields. This can also increase seller's income, as demand in the community increases.

3.2 Social dimension

In the social dimension, there were 7 attributes tested, including cultivator's knowledge level of the environment, work skills in the field of hydroponics/plants, acquisition of information regarding hydroponics, farmer empowerement, fostering cultivitaion activites, cooperation

between hydroponic farmers, and public perception of sustainability. Each dimension was tested using RAPFISH; results showed that in the leverage analysis of the social dimension, there is one attribute that has a Root Mean Square (RMS) value. This attribute is the sub-dimension of work skills in the hydroponics/plants sector.

In the results of the analysis of the social dimension of the hydroponic cultivation system in Padang City, there was one sensitive attribute, namely the sub-dimension of work skills in the field of hydroponics/plants (RMS = 1.37), presented in Fig. 3. The work skills possessed by hydroponics practitioners are important skills that must be aquired. Hydroponic cultivation is still widely carried out by small-scale farmers, so there is a need for basic knowledge about the hydroponic cultivation system in order to increase productivity and the quality of the produce [8].

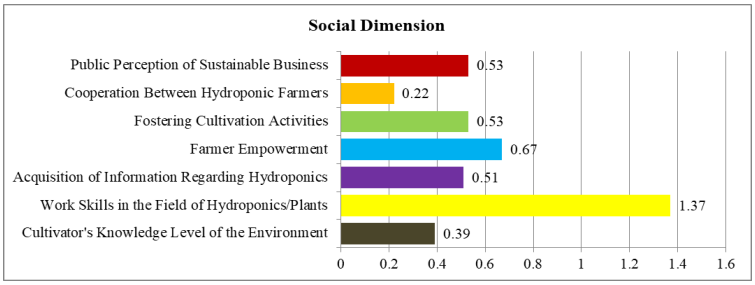

Fig. 3. Rapfish Test on Social Dimensions.

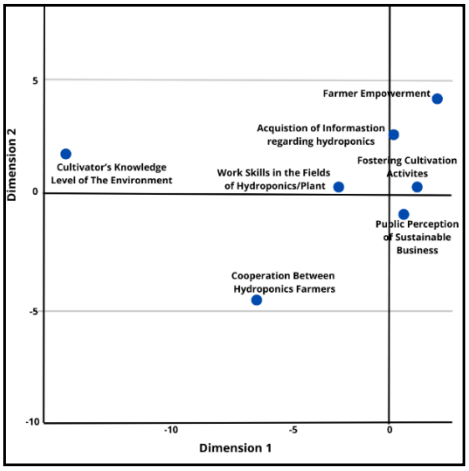

Fig. 4. SPSS Test on Social Dimensions.

In dimension 1 (Fig. 4), it can be observed that the further to the right, the greater the value. The attributes that have similarities in their supporting elements include the sub-dimension of community perception of business continuity and the sub-dimension of cultivating activities development. Additionally, the sub-dimension of obtaining information about hydroponics and the sub-dimension of work skills in the field of hydroponics also share similarities in their supporting elements. While in dimension 2, the sub-dimension of farmer empowerment has a high value in the social dimension. In the social dimension, it can be seen that the sub-dimension of public perception of business continuity with the sub-dimension of fostering cultivation activities has similarities in their supporting elements. Finally, the sub-dimension of obtaining information about hydroponics with the sub-dimension of work skills also has similarities with each other.

3.3 Environmental dimension

In the environmental dimension, there are 7 attributes tested, including presence of water source, seed varieties, pest attack intensity, average temperature, land availability, environmental conservation, and weather conditions.

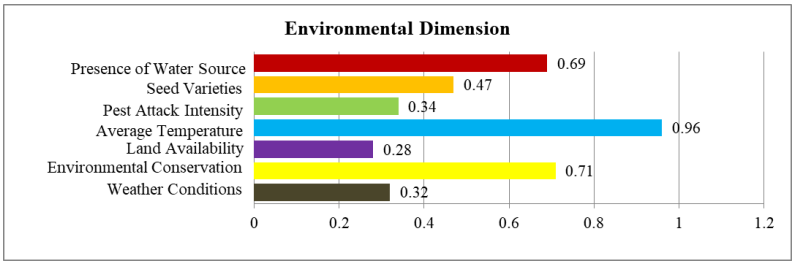

Fig. 5. Rapfish Test on Environmental Dimensions.

Public knowledge of organic vegetable farming has experienced a lot of development. In previous research [9] it was found that 85.71% of respondents had sufficient knowledge regarding information on the advantages and benefits of cultivating organic vegetables. Coaching activities that have been carried out a lot in the community provide information and knowledge related to the benefits of hydroponic vegetables. In fact, 92.86% of farmers who were respondents in Windirah's research (2021) had the perception that there is a lot of land that is suitable for cultivating organic vegetables, so these farmers are very confident that cultivating organic vegetables has quite good business sustainability. Farmer empowerment has the highest score in the sustainability test results, which is one of the important sub-dimensions for better business sustainability.

Each dimension was tested using RAPFISH. The results showed that in the leverage analysis on the environmental dimension, there were three attributes that had RMS values, namely the sub-dimension of the existence water sources, sub-dimension of average temperature, and the sub-dimension of environmental preservation. In the analysis of the environmental dimensions of the hydroponic cultivation system in Padang City, there were three sensitive attributes, namely the presence of water sources (RMS = 0.69), the average temperature sub-dimension (RMS = 0.96) and the environmental preservation sub-dimension (RMS = 0.71), presented in Fig. 5. Based on research [10] water is the main element in the success of hydroponic cultivation. The water source is supplied continuously with maximum usage. Water helps plants to carry out photosynthesis effectively. The agricultural sector in Indonesia is very dependent on water resources. In the planting process, temperature is one of the abiotic factors that greatly influences the growth of hydroponic plants. This is because the planting medium uses water which keeps the temperature in line with the surrounding environment.

The liquid organic fertilizer used will be directly absorbed by the plants through the planting medium, so soil contamination will not occur. Hydroponic cultivation is one way to preserve the environment. Cultivated plants can produce oxygen so can reduce pollution [11]. Additionally, the use of land in hydroponic cultivation systems can maximize land use to produce plants and products that have sales value to meet the dietary needs of the community.

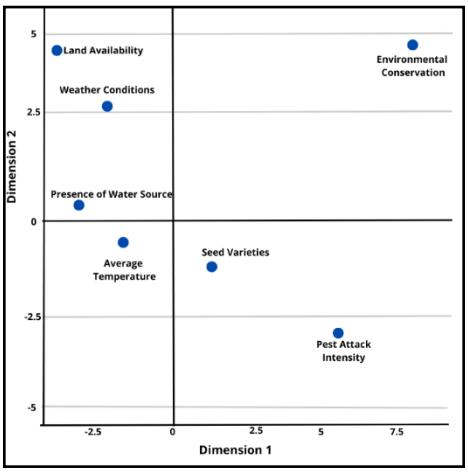

Fig. 6. SPSS Test on Environmetal Dimensions.

In dimension 1, it can be seen that the further to the right, the greater the value for dimension 1, the intensity sub-dimension pest attacks have the highes value. While in dimension 2, the land availability sub-dimension has the highest value. Concerning environmental dimensions, it can be seen that the sub-dimensions of pest attack intensity and land availability have the highest value in the sustainability test using SPSS. Cultivated plants are susceptible to pest attacks that can damage plants. Pests that attack plants can make plants unfit for consumption. Pest control must be carried out from the preparation stage until the plants enter harvest time, this can be done by spraying pesticides to reduce pest attacks [12]. Apart from that, land availability is also one of the subdimensions that has the highest score in in the sustainability test. Cultivation using the hydroponic method can be done while maximizing the use of land, as a variety of hydroponic planting methods can be done on narrow land.

3.4 Multidimension test result

Multidimensional sustainability results indicate index values for the economic, social, and environmental dimensions as 51.29, 52.37, and 53.68, respectively. In the fly diagram (Fig. 7), it can be seen that each dimension has a different sustainability index value, based on the test results using RAPFISH. This shows that the three dimensions have a fairly sustainable status.

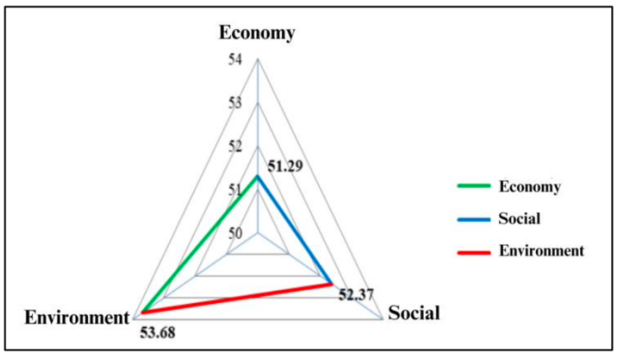

Fig. 7. Multidimensional test results.

Each dimension tested in this study also has an average stress value of 0.16 > 0.25. T his indicates that the effect of the error on the assessment of each sub-dimension is very small So the application of nanotechnology liquid organic fertilizer in the hydroponic cultivation system has the potential to be sustainable enough to be applied by the hydroponic planting method to support the food security of Padang City.

The results of the sustainability analysis based on the three dimensions are quite sustainable; the stress value for each dimension is > 0.25 (Table 3).

This indicates that all the sub-dimensions tested have good enough scores for testing the application of hydroponic planting methods to support urban food security.

Table 3. Sustainable Index Value.

Dimension	Stress value	R^2	Index	Description
Economi	0.1650	0.9355	51.29	Quite sustainable
Social	0.1646	0.9358	52.37	Quite sustainable
Environment	0.1638	0.9361	53.68	Quite sustainable

3.5 Location map of hydroponic cultivators in Padang city

There are 22 hydroponic vegetable cultivators in Padang City with locations spread across the city. The mapping of hydroponic cultivators in Padang City (Fig. 8) includes hydroponic farmers who also act

as distributors and seller of vegetables. The results show mapping hydroponic cultivation factors spread throughout Padang City. The amount of production for each cultivator is different. Based on the results of an interview with Alfi, a hydroponics farmer in Padang City, the accumulated production of the hydroponic vegetables he cultivates is 10,000 planting holes every month. Based on research [13] Greens Guru Hydroponic as a hydroponic practioner can produce hydroponically grown vegetables in a total of around 930 holes every month. Hydro Garden hydroponic practitioners can produce around 344 kg of total vegetables (Winda et al., 2020). In previous research [14], the West Sumatra Hydroponic Community, which consists of 10 hydroponic practitioners, can produce around 1500-2500 planting holes every month.

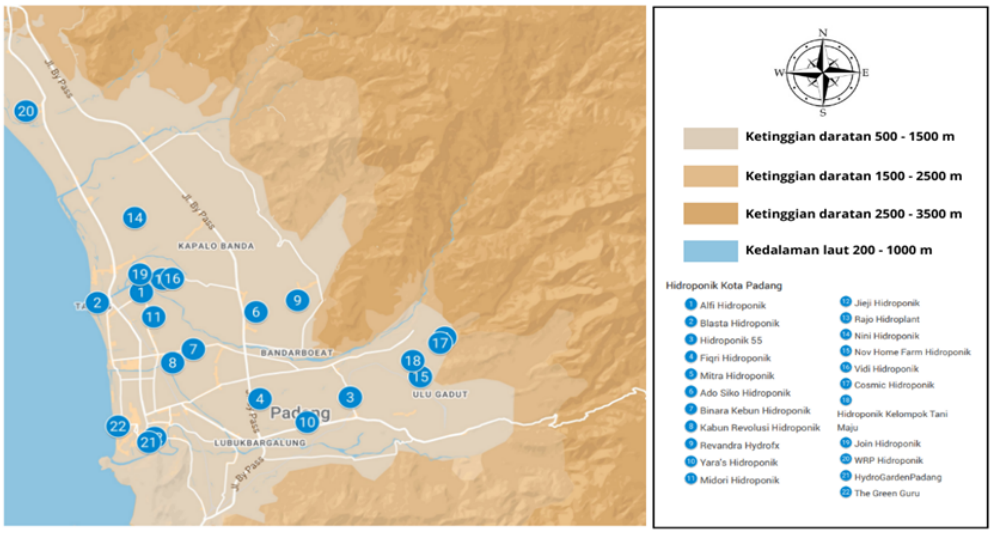

Fig. 8. Location of hydroponic cultivation in Padang city.

Table 5. Location for selling hydroponic vegetables in Padang city.

Location	Vegetable	Consumer
Basko Grand Mall	Pakcoy	Housewife
	Green lettuce	Government employees
	Kale Nero	Student
	Brazil spinach	
	Green spinace	
	Romaine lettuce	
	Kailan	
Transmart Padang	Pakcoy	Housewife
	Bayam Hijau	Government employees
	Curly lettuce	Household assistant
	Caisim	Student
Budiman Ulak Karang	Pakcoy	Housewife
	Green lettuce	Government employees
	Kale	Student
	Malay spinach	
Budiman Gunung Pangilun	Pakcoy	Housewife
	Green lettuce	Government employees
		Student
SJS Plaza	Pakcoy	Housewife
	Kailan	Government employees
	Green lettuce	Student
	Kale	Household assistant
	Mustard green	
	Brazil spinach	
	Romaine lettuce	
	Mint	
Ramayana Padang	Pakcoy	Housewife
	Green lettuce	Government employees
	Mint	Student
		Household assistant
Dalas Swalayan	Pakcoy	Housewife
	Green lettuce	Government employees
		Student
		Household assistant

The results of hydroponic vegetable production are then distributed to sales locations or marketed directly to consumers (Table 5). Based on the results of an interview with one of the hydroponic cultivation practitioners, namely Mr. Alfi, many of the products are marketed in supermarkets, traditional markets, and to friends, relatives and residents around the cultivation location. Based on the results of the field survey, it was found that 7 large-scale supermarkets sell hydroponic vegetables, namely Basko Grand Mall, Transmart Padang, Budiman Ulak Karang branch, Budiman Gunung Pangilun branch, SJS Plaza, Swalayan Ramayana Padang and Dalas Swalayan. Supermarkets that sell hydroponic vegetables sell various types of hydroponic vegetables such as pakcoy, green lettuce, kale nero, Brazilian spinach, green spinach, romaine lettuce, kailan, caisim, mala spinach and mint. Based on the results of field observations, the average consumer who buys hydroponic vegetables is housewives with an age range of 27-35 years, civil servants, students and household assistants. Based on the results of an interview with Mr. Alfi as a hydroponic cultivator in Padang City, the types of vegetables that are most in demand by consumers include bok choy, green lettuce, kale nero, kale, basil and Brazilian spinach. The trend of hydroponic vegetables is increasing every year and increasing sales due to more and more consumers.

4. Conclusion

Research on sustainable hydroponic farming in Padang City found linkages between three important dimensions: environmental, economic and social. Plant productivity in the environment has a positive impact on the economic dimension, which is influenced by factors affecting the sustainability of hydroponic farming. In addition, the skills of hydroponic practitioners and other social aspects were also assessed in this study. The results of the mds test show the index values for each dimension: economic (51.29), social (52.37), and environmental (53.68). In addition, the environmental dimension is the most influential dimension for the sustainability of hydroponic businesses in Padang City, while the most influential sub-dimension is job skills in hydroponics in the economic dimension. This data confirms that hydroponic farming plays a role in supporting food security in Padang City. There are 22 hydroponic farming sites in the city with a total production of around 10,000 pots/month that have the potential to increase economic income and create food stability. These measures are expected to ensure food security and economic development for hydroponic cultivators in the region.

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