Jurnal Manajemen & Agribisnis, Vol. 20 No. 2, July 2023
Permalink/DOI: http://dx.doi.org/10.17358/jma.20.2.214

Available online at
http://journal.ipb.ac.id/index.php/jmagr

SUSTAINABILITY OF VEGETABLE HYDROPONIC SYSTEM IN PEKANBARU CITY

Nadia Putri Maisarah[*)1], Anna Fariyanti[*)], Nia Rosiana[*)]

[*)]Department of Agribusiness, Faculty of Economics and Management, IPB University
Jl. Agatis, IPB Dramaga Campus Bogor 16680, Indonesia

Article history:

Received
21 March 2023

Revised
12 June 2023

Accepted
4 July 2023

Available online
31 July 2023

Abstract: The decrease in the harvested area and the reduction in horticultural land caused by the conversion of agricultural land into plantations have prompted farmers to practice vegetable farming using a hydroponic system. This study aims to analyze the level of sustainability in vegetable farming using a hydroponic system, considering various dimensions and farmers' strategies to enhance sustainable hydroponic vegetable farming in Pekanbaru City. The sustainability index was determined using the Rap-Farm Ordination Technique along with the Multidimensional Scaling (MDS) Method, Leverage Analysis, Monte Carlo Simulation, and Analytical Hierarchy Process (AHP) to analyze hydroponic vegetable farming strategies in Pekanbaru City. A saturated sample of 30 hydroponic vegetable farmers from Pekanbaru City was included in this research. The results indicate that vegetable farming using a hydroponic system exhibits a relatively high level of sustainability across different dimensions, including economic, ecological, social, institutional, and technological aspects, with a score of 64.80. The sustainability level for the fifth dimension is moderately good (economic, ecological, social, and technological), whereas the institutional dimension is highly sustainable. Therefore, attributes from the highest-value dimension (institutional) and the lowest-value dimension (social) are given priority. Consequently, these two attributes are combined to enhance the sustainability level. One crucial aspect is improving knowledge of vegetable cultivation using the hydroponic system through training programs to enhance farmers' skills. Additionally, implementing and monitoring hydroponic vegetable farming emerged as a top-ranking alternative strategy to enhance farming practices. This research is expected to assist hydroponic vegetable farmers in enhancing their sustainable farming practices.

Keywords: AHP, hydroponic vegetable, Rap-Farm, sustainable farming, vegetable farming

Abstrak: *Penurunan luas panen dan penurunan luas lahan hortikultura yang disebabkan oleh konversi lahan pertanian menjadi perkebunan memicu para petani untuk berlatih melakukan usahatani sayuran menggunakan sistem hidroponik. Tujuan dari penelitian ini adalah menganalisis tingkat keberlanjutan dan strategi usahatani sayuran menggunakan sistem hidroponik di Kota Pekanbaru. Indeks keberlanjutan menggunakan teknik Rap-Farm dengan metode Multidimensional Scaling (MDS), Analisis Leverage, dan Monte Carlo, serta AHP (Analytical Hierarchy Process) untuk menganalisis strategi usahatani sayuran hidroponik di Kota Pekanbaru. Penelitian ini menggunakan sampel jenuh sebanyak 30 responden petani sayuran hidroponik di Kota Pekanbaru. Hasil menunjukkan tingkat keberlanjutan usahatani sayuran menggunakan sistem hidroponik yang didukung beberapa indikator yaitu dimensi ekonomi, ekologi, sosial, kelembagaan, dan teknologi yang memiliki kategori tingkat keberlanjutan yang cukup baik dengan skor 64,80. Hasil tingkat keberlanjutan dari kelima dimensi memiliki kategori cukup berkelanjutan (ekonomi, ekologi, sosial, dan teknologi) dan tingkat keberlanjutan yang sangat berkelanjutan adalah dimensi kelembagaan. Jadi, beberapa atribut dimensi yang diambil dari dimensi nilai tertinggi (kelembagaan) dan nilai yang terendah (sosial) menjadi prioritas. Kemudian, kedua atribut tersebut dikombinasikan untuk memperbaiki tingkat keberlanjutan yaitu ilmu pengetahuan tentang budidaya sayuran menggunakan sistem hidroponik masih terbatas sehingga dibutuhkan pelatihan untuk meningkatkan skill petani. Selain itu, untuk meningkatkan usahatani diperlukan alternatif strategi, perankingan tertinggi yaitu dengan cara dilakukan penerapan dan pengawasan sayuran hidroponik. Penelitian ini diharapkan mampu membantu petani sayuran hidroponik dalam meningkatkan usahatani yang berkelanjutan.*

Kata kunci: *AHP, sayuran hidroponik, Rap-Farm, usahatani berkelanjutan, usahatani sayuran*

[1] Corresponding author:
Email: nadiaputrim27@gmail.com

INTRODUCTION

Hydroponic vegetables are currently a focal point of Agriculture 4.0 as they are being developed into a sustainable agricultural sector. The advantages of hydroponic vegetables lie in their fresher product quality, absence of chemical pesticides, and healthier attributes compared to conventional vegetables cultivated using soil as a medium.

In addition, there are threats posed by climate change, such as rising temperatures, persistent droughts, unpredictable weather patterns, excessive water resource management for irrigation, uncontrolled water pollution, and declining quality. Moreover, the diminishing availability of arable land and the global increase in population growth have amplified the need for interventions in the demand for fresh food and sustainable agricultural practices (Maluin et al. 2021). Indonesia's population is projected to reach approximately 300.2 million people by 2050 (BPS, 2020), and according to Sohail et al. (2022), consumption is predicted to increase by 59% to 98%. As Indonesia's population grows, the availability of quality land for food production, including horticultural crops like vegetables, diminishes due to urban development and the conversion of agricultural land.

Data from the Ministry of Agriculture (2020) indicates that green vegetable commodities such as mustard greens, spinach, and chickpeas experienced a 0.22% decrease in harvested area in Indonesia between 2018 and 2019. Several cities, including Pekanbaru City in Riau Province, have also witnessed declines in both the harvested area and agricultural land dedicated to vegetable production. This decline can be attributed to increasing urbanization and the conversion of agricultural land into plantation areas.

So, this will certainly affect the quantity and quality of production and productivity in the vegetable business. Additionally, it also has an impact on food security. Therefore, in order to maintain stable food availability, an agricultural system is needed that minimizes land use while still ensuring optimal production. Several studies have suggested that cultivating crops using less land can be an alternative to traditional agricultural systems, addressing issues associated with conventional farming such as low profitability (Melgarejo et al. 2007). Thus, conventional agriculture needs to be supplemented by modern agriculture, which is more productive and ecologically sustainable (Lambin and Meyfroidt, 2011). Moreover, to support sustainable agriculture in terms of quality and healthiness for consumption, the concept of sustainable development needs to be applied. Sustainable development, as proposed by the United Nations' World Commission on Environment and Development (WCED), also known as the Brundtland Commission (1987), defines development as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. The economic, ecological, and social aspects are essential components of this development concept, and they must work together to support sustainable development.

The concept of sustainable development can be approached from various dimensions, including economic, ecological, social, and technological aspects (Zartha Sossa et al. 2022). According to Greenland et al. (2022), the importance of sustainable development can be assessed through five dimensions: social, political, environmental, institutional, and economic. In order to achieve sustainable development goals (SDGs), it is crucial to have sustainable agricultural development. A hydroponic system is an agricultural system that supports sustainable development.

According to Li et al. (2018), hydroponics is an innovative, environmentally friendly, and sustainable food production technology. Hydroponic systems for growing vegetables are considered a suitable solution to address the aforementioned challenges. Martinez-Mate et al. (2018) state that hydroponic systems contribute to increased yields, improved water productivity, and reduced greenhouse gas emissions compared to conventional cultivation methods. Moreover, hydroponic systems are in high demand due to their ability to control environmental temperature, even in hot climates (Grewal et al. 2011).

Considering the significance of ensuring food availability in urban areas, the capital city is deemed an ideal location to realize sustainable development and urban and community sustainability, particularly in achieving successful implementation of sustainable agricultural smart technologies (ST) (Parra-Domínguez et al. 2022). However, it is unfortunate that certain smart farming (SF) technologies, such as hydroponic systems, remain relatively unexplored in urban areas. Consequently, the research on the sustainability of vegetable farming using a hydroponic system aims to analyze the level of sustainability and strategies for enhancing hydroponic vegetable businesses across five dimensions: economic, ecological, social, institutional, and technological.

METHODS

This research was conducted in Pekanbaru City, Riau Province, and the selection of the location was purposeful. Pekanbaru is an area where hydroponic vegetable farming activities are carried out, and some farmers are still engaged in this practice. The research was conducted over a period of three months, from December 2021 to May 2022.

To determine the level of sustainability, a linkage was established between the sustainability aspect and the indicators used for its assessment. Analyzing farmer strategies for increasing hydroponic vegetable farming using the AHP method was a key objective of this research. The quantitative data were processed using Microsoft Excel, while SuperDecisions software was utilized as an analytical tool. A saturated sample, also known as saturation sampling, was employed as the sampling method. This technique is applied when the entire population is included in the sample (Sugiyono, 2017). The sample consisted of 30 vegetable farmers who utilize the hydroponic system in Pekanbaru City.

Sustainability Analysis

The analysis aims to measure the level of sustainability based on specific indicators. The measurement scale used to analyze sustainability is a five-dimensional approach, including economic, ecological, social, institutional, and technological aspects. The sustainability index scale in Table 1 is used to categorize the level of sustainability in this research, ranging from 0% to 100%.

Table 1. Index criteria and sustainability status

Index Value	Category
0 – 25	Poor (Not sustainable)
26 – 50	Less (Less sustainable)
51 – 75	Sufficient (Sufficiently sustainable)
76 – 100	Good (Highly sustainable)

Source: Kavanagh and Pitcher (2004)

Rapfarm

Rap-Farm (Rapid Appraisal of Farming) is a modified version of Rapfish (Rapid Appraisal for Fisheries) tailored to fit the context of each study's commodity. In this research, Rap-Farm employs Multi-dimensional Scaling (MDS), Leverage Analysis, and Monte Carlo methods to analyze the dimensions and attributes of sustainability.

Multidimensional Scaling (MDS)

The MDS method, integrated with Rap-Farm, is utilized in sustainability research to analyze multiple dimensions, including economic, ecological, social, institutional, and technological aspects.

Leverage Analysis

Leverage analysis is computed based on the discrepancy in calculated standard errors between two scores, excluding the attributes Pitcher and Preikshot (2001), to determine attribute intervention. Ratnaningtyas et al. (2016) suggest that the analysis prioritizes determining sensitive attributes by assessing changes in the leverage of the root mean square (RMS) on the X-coordinate axis. A higher RMS score indicates a more pronounced sensitivity of the attribute's role in enhancing sustainability.

Monte Carlo

This research employs Monte Carlo analysis as an analytical model to measure the impact of random errors. In Monte Carlo Analysis, a standard error of less than 5% or a confidence interval of less than 95% is considered acceptable. Kavanagh and Pitcher (2004) indicated that the results of Monte Carlo analysis remain consistent in terms of the multidimensional index value for each dimension. If the difference between MDS and Monte Carlo is <1, the MDS model is considered valid and error-free.

Farmer's Strategy in Increasing Sustainable Hydroponic Vegetable using AHP

The Analytical Hierarchy Process (AHP) is a general theory of measurement based on psychological and mathematical foundations. AHP is a mathematical method for analyzing complex decision problems involving multiple criteria. It treats decision elements hierarchically, where the importance or preferences of decision elements are compared pairwise with the elements preceding them in the hierarchy. Numerical techniques are used to derive quantitative values from verbal comparisons (Kurttila et al. 2000). AHP was initially developed by Saaty (1977-1980). Dos Santos et al. (2019) emphasized the importance of the AHP method in pairwise comparisons of elements on a ratio scale. Assessment results are presented in a matrix using pairwise comparison matrices.

The hierarchy is constructed by identifying the main elements, as shown in Table 2, and dividing them into sub-elements. Each hierarchical level is assessed through pairwise comparisons, assigning a scale of 1-9 to consider the comparisons between pairs and elements at each level.

Table 2. Scores and definition of qualitative's opinion with a comparison scale

Score 1	: Vertical factor is of equal importance as a horizontal factor
Score 3	: Vertical factor is of moderate importance as a horizontal factor
Score 5	: Vertical factor is of solid importance as a horizontal factor
Score 7	: Vertical factor is extreme importance as a horizontal
Score 9	: Vertical factor is of extreme importance as a horizontal factor
Score 2,4,6,8	: Comparison between the above values

Source: Saaty (2004)

AHP measures the consistency ratio (CR) by comparing the consistency index (CI) with the random index (RI) using the following formula:

$$CR = CI/RI$$

$$CI = (\lambda max - n)/(n-1)$$, where λ max is an eigenvalue by matrix

The variable 'n' represents the number of criteria/ alternatives being compared. If CI is zero, the assessment decision is perfectly consistent, where λ max is equal to the number of comparisons made, which is 'n'. Therefore, higher CI values indicate lower levels of decision-making consistency. Comparisons made with a CI of less than or equal to 0.1 (10%) are considered good if the resulting CR is not greater than 0.1. However, if the CR exceeds 0.1, the quality of information must be improved by correcting or repeating inconsistent questions to obtain more valid and consistent answers, enabling meaningful pairwise comparisons.

RESULTS

This study examines the level of sustainability in hydroponic vegetable farming in Pekanbaru City. The objective is to assess the sustainability level supported by attributes and indicators across the economic, ecological, social, institutional, and technological aspects.

The Rap-Farm Ordination analysis, utilizing the Multidimensional Scaling (MDS) model, serves as an analytical tool to measure the sustainability of hydroponic vegetable farming. The feasibility of the Rap-Farm analysis is evaluated based on Stress and R-square values for each of the five dimensions, as shown in Table 3. A Stress value of <0.25 indicates a good fit, according to Malhotra (2006), and R-square values close to 1 suggest that the model effectively explains the attributes in the research model. If the Stress and R-square values are not valid, the researcher should repeat the attribute analysis.

Table 3. Statistical values from the MDS analysis of the sustainability of vegetable farming using a hydroponic system in Pekanbaru City

Dimensions	S-stress (< 0,25)	R2
Economy	0.19	0.93
Ecology	0.17	0.94
Social	0.17	0.94
Institutional	0.16	0.95
Technology	0.16	0.94

Table 4 displays the Monte Carlo and MDS analysis, demonstrating the validation of the sustainability index. The small difference in average scores between Monte Carlo analysis and MDS analysis, within a difference of less than 5% or a confidence interval of 95%, indicates minor discrepancies. This suggests that the MDS model accurately analyzes the level of sustainability (Kavanagh and Pitcher 2004).

The Level of Sustainability of Vegetable Farming Using a Hydroponic System Has an Economic Dimension

The MDS results for the six attributes indicate that the economic dimension has a sustainability index value of 63.97. This suggests that hydroponic vegetable farming in Pekanbaru City has a relatively sustainable level of economic sustainability, as depicted in Figure 1. The leverage analysis reveals that the most influential attribute in the sustainability of hydroponic vegetable farming is the economic feasibility of the hydroponic system. The profitability of hydroponic vegetable farmers significantly impacts the sustainability of their farming practices. Borges and Dal'Sotto (2016) state that the demand for hydroponics leads to increased plant diversity, resulting in higher profits for farmers. Therefore, diversifying plants in hydroponic vegetable farming can enhance profitability. Another attribute affecting the sustainability of hydroponic vegetable farming is ease of market access. Based on interviews conducted with farmers, it is still challenging to access markets, such as selling vegetables to modern markets. Distributors require a constant supply of hydroponic vegetables, and some farmers struggle to meet the demands of modern market distributors. The neoclassical theory suggests that companies maximize profits by setting commodity quantity and price based on market constraints.

Research conducted by Wiryawan et al. (2020) shows a sustainability index score of 81.69 for the economic dimension, categorizing it as highly sustainable. The attributes considered in their research include the appropriateness of competitive fresh-cut vegetable products developed based on demand (ACFV), cut vegetable prices, sustainability, profit of contract farmers, as well as market share and opportunity.

Table 4. Differences in average sustainability values from Rap-Farm ordination and Monte Carlo Analysis of different dimensions for sustainability of vegetable farming using a hydroponic system in Pekanbaru City

	Economic	Ecology	Social	Institutional	Technology
Rap-farm (%)	63.97	64.53	56.86	75.78	62.89
Monte-Carlo (%)	63.42	63.38	56.59	74.99	62.22
Difference	0.55	1,15	0.27	0.79	0.67

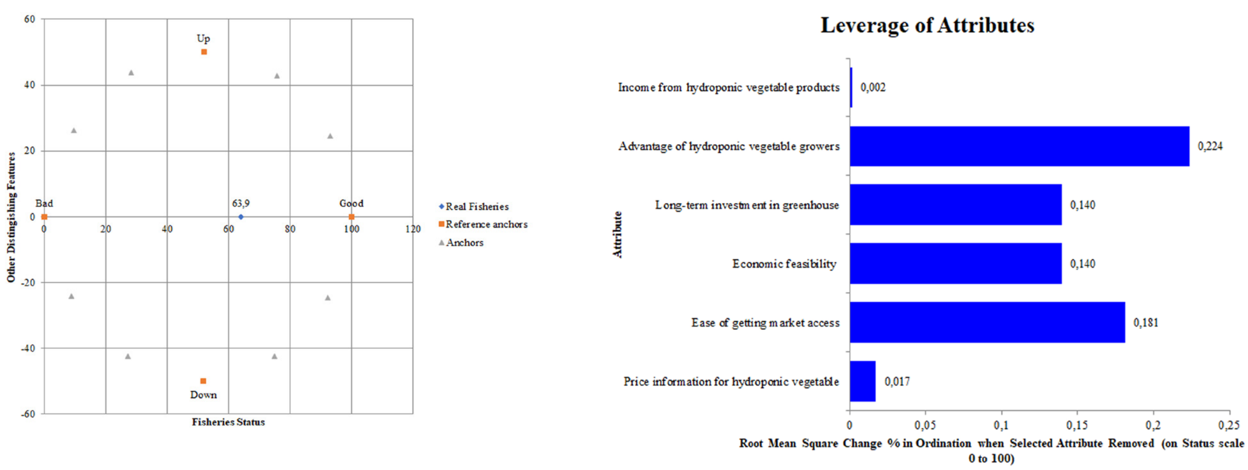


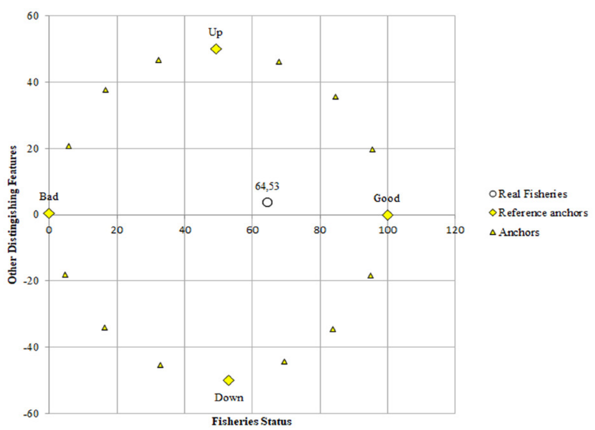
Figure 1. The result of Rap-Farm analysis and leverage analysis in economic dimension

Another attribute that influences the economic sustainability of hydroponic vegetable farming is long-term greenhouse investment. Economic feasibility is the third most significant attribute affecting economic sustainability. The study results indicate that investing in greenhouses for hydroponic vegetable farming is economically feasible based on the analysis of Net Present Value (NPV), Internal Rate of Return (IRR), and Equivalent Annual Value (EAV). The NPV result of Rp308,715,049.37 suggests that the benefits of using a greenhouse outweigh the costs, making greenhouse utilization profitable for hydroponic vegetable farming. The IRR calculation of 52% indicates the return on investment for using greenhouses, which is considered feasible if IRR exceeds the Discount Rate (DR). Additionally, Souza et al. (2019) determined that projects utilizing greenhouses are acceptable if the IRR is higher than the Minimum Acceptable Rate of Return (MARR). Economic feasibility is also measured using an EAV of Rp30,872,504.83. Consequently, investing in greenhouses for hydroponic vegetable farming in Pekanbaru City is deemed profitable and viable in the long run.

The Level of Sustainability of Vegetable Farming Using a Hydroponic System Has an Ecology Dimension

The sustainability index of the ecological dimension in hydroponic vegetable farming, as depicted in Figure 2, has an MDS score of 64.53, indicating a fairly sustainable level. The ecological dimension demonstrates better performance compared to the economic dimension. Hydroponic vegetable farming in the ecological dimension is known for its environmentally friendly practices and ability to achieve higher production compared to conventional farming methods. According to Gumisiriza et al. (2022), the hydroponic system offers advantages over traditional farming by providing a climate-smart farming approach that allows control of air humidity, reduction of pests and diseases, and increased production even in less fertile land areas.

The leverage analysis results reveal that three sensitive attributes significantly impact sustainability in the ecological dimension. Majid et al. (2021) mentioned that the discharge of hydroponic wastewater into the environment can lead to groundwater pollution and have negative effects on the surrounding ecosystem and environment. Conversely, based on field research, some farmers utilize hydroponic waste as a fertilizer medium, leading to excessive plant growth. Narine et al. (2014) explained that hydroponic plants have a higher mineral composition compared to conventional plants, resulting in faster growth and increased productivity in hydroponic vegetable production compared to soil-based cultivation. Hydroponic systems offer benefits such as higher productivity, efficient use of water and nutrients, and reduced environmental pollution (Yang and Kim, 2020). Moreover, the use of a hydroponic system contributes to sustainable renewable energy sources, as supported by research (Chen et al. 2020). The level of hydroponic vegetable production can be controlled by adjusting the production settings. Consistent with previous research, the hydroponic system proves to be feasible for development in Pekanbaru City as it promotes environmental protection, strengthens small-scale agriculture, and enhances local food availability.



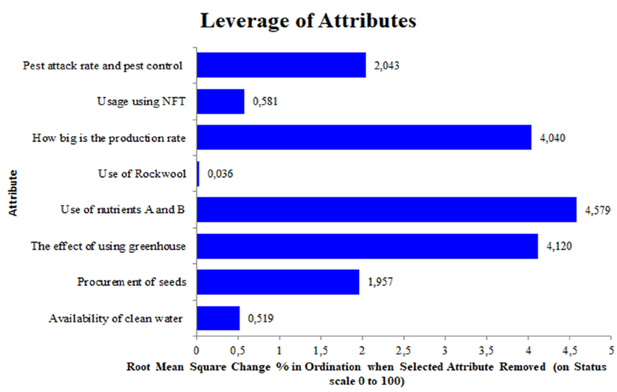


Figure 2. Results of Rap-Farm analysis and ecological dimension leverage analysis

The Level of Sustainability of Vegetable Farming Using A Social Dimension Hydroponic System

The sustainability index for vegetable farming using a hydroponic system in the social dimension is relatively sustainable, as indicated by a score of 56.86 in the MDS analysis (Figure 3). This index value is lower than the values observed in the economic and ecological dimensions. To enhance the sustainability index in the social dimension, it is crucial to address the attributes identified as sensitive factors affecting the sustainability of hydroponic vegetable farming in the social dimension.

The leverage analysis conducted on the social dimension of vegetable farming using a hydroponic system reveals that the most sensitive attribute among the eight attributes is the level of knowledge and experience in hydroponic vegetable farming. The average hydroponic farmer often does not possess expertise in agriculture, highlighting the need for improvement in knowledge regarding vegetable cultivation using a hydroponic system.

However, it is worth noting that the average farming experience among hydroponic farmers is approximately six years, indicating a certain level of skill. Some farmers actively participate in private training sessions and seminars to enhance their knowledge and skills in cultivating vegetables using a hydroponic system. Nonetheless, hydroponic vegetable farmers still encounter challenges in effectively managing pest infestations and plant diseases, especially when dealing with a large number of plants.

The Level of Sustainability of Vegetable Farming Using An Institutional Dimension Hydroponic System

The results of the sustainability assessment for vegetable farming using a hydroponic system in Pekanbaru indicate that the institutional dimension has the highest index value of 75.78, reflecting a highly sustainable level. The statistical analysis of sustainability using the dimension of institutional sustainability demonstrates a Stress value of 0.16 (<0.25) and a coefficient of determination (R2) of 0.95, which is close to 1. These statistical findings indicate that the attributes and dimensions applied in the field have been properly implemented. Figure 4 displays the MDS score for the institutional dimension, which has the highest value among the dimensions, categorizing it as very sustainable.

The leverage analysis of attributes reveals that the socialization of new technologies in hydroponic vegetable cultivation is a sensitive indicator affecting the sustainability of hydroponic vegetable farming. The government and paid self-training programs provide hydroponic vegetable cultivation training for farmer groups.

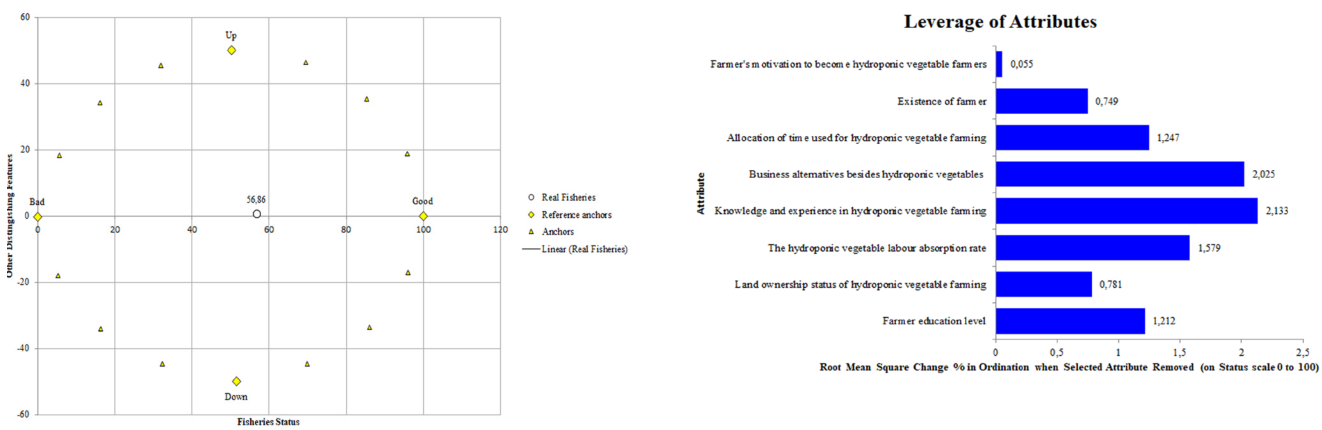


Figure 3. Rap-Farm analysis results and social dimension leverage analysis

Since the farmers involved in this study are smallholders, there is a need to improve their knowledge of the hydroponic system, and training on hydroponic cultivation is crucial. However, such training programs are still relatively limited, both from the government and private sectors. A significant obstacle in the field is the farmers' limited knowledge in effectively controlling pests and plant-disturbing organisms (OPT). Consequently, farmers often struggle when faced with pest attacks. The presence of pests and OPT can significantly impact the quantity of hydroponic vegetable production. Gumisiriza et al. (2022) highlight the importance of technical knowledge in hydroponic cultivation for farmers. Insufficient technical knowledge about hydroponics may hinder farmers from adopting this technology. For instance, Sharma et al. (2018) found that only 6% of hydroponic farmers utilize advanced technologies such as climate control systems and proper regulation of pH and temperature in nutrient solutions. Failure to operate these systems correctly can lead to plant damage.

The Level of Sustainability of Vegetable Farming Using A Technological Dimension Hydroponic System

The sustainability index of hydroponic vegetable farming in Pekanbaru is 62.89, indicating a fairly sustainable level. While the technological dimension's score is lower than the economic and ecological dimensions, it is still higher than the social dimension. The leverage analysis (Figure 5) identifies the availability of databases as a crucial attribute influencing the sustainability of hydroponic vegetable farming in the technological dimension. Farmers are accustomed to recording information, such as production results and monitoring the production system from upstream to downstream. Jandl (2020) suggests that the adoption of IoT-based hydroponic verticals can revolutionize agriculture and address existing challenges. The use of IoT provides time optimization and technical benefits to farmers. By implementing IoT sensors in hydroponic farming, continuous monitoring of plant health and status can be achieved. This allows for effective application of nutrients and water at regular intervals, optimizing crop growth. Thus, the development of a hydroponic system using IoT technology has the potential to increase crop productivity even in limited land areas.

Overall, the sustainability index values obtained from each dimension indicate that the institutional dimension has the highest index value, while the social dimension has the lowest index value. However, on average, each dimension demonstrates a fairly sustainable level, with a score of 64.80.

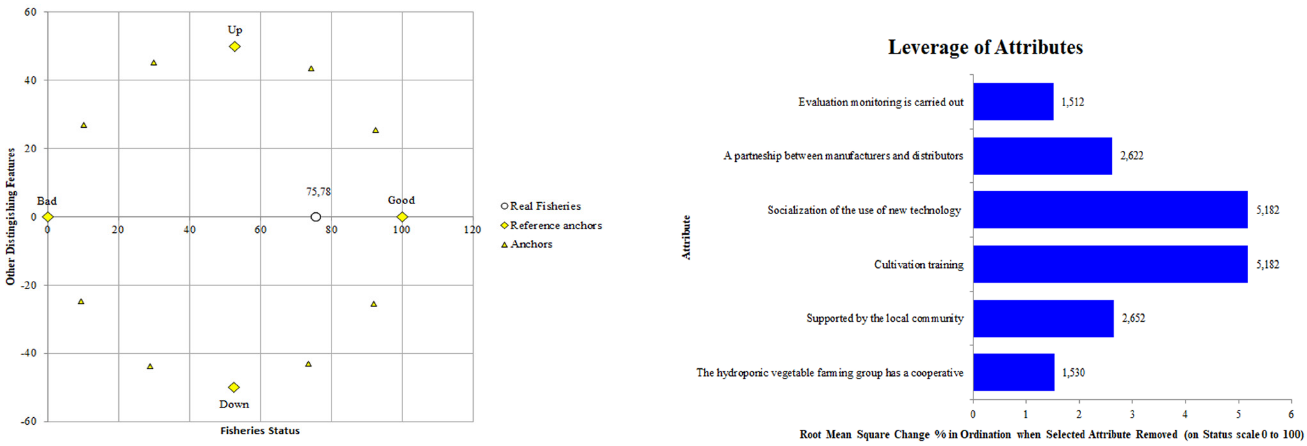


Figure 4. Rap-Farm analysis results and institutional dimension leverage analysis

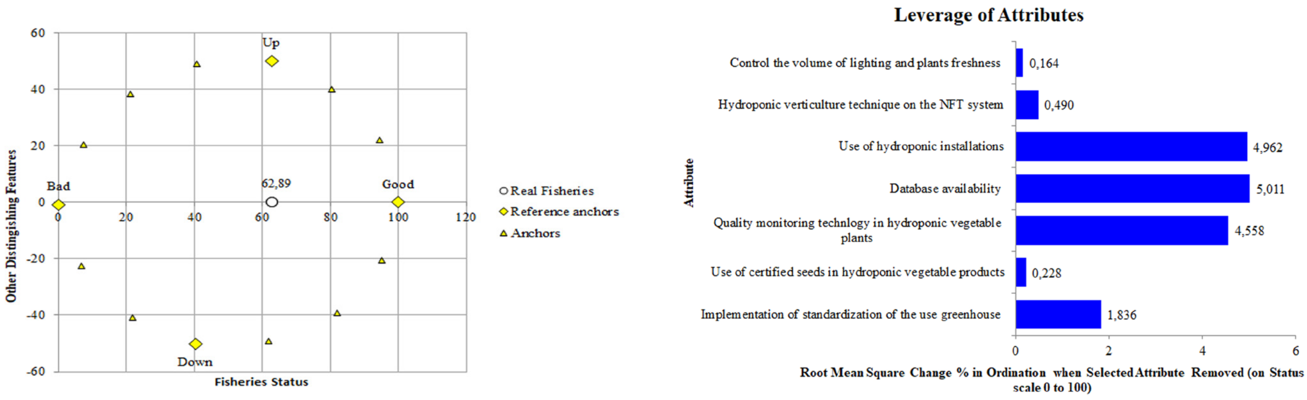


Figure 5. The results of the Rap-Farm analysis and the analysis of the technology dimension leverage

Strategies Farmers to Enhance Vegetable Farming using a Hydroponic System Sustainability

Therefore, the results of each dimension level obtained from the sustainability index of hydroponic vegetable farming are derived from the five dimensions, with the institutional dimension having the highest index value and the social dimension having the lowest index value. However, the average score for each dimension indicates a fairly sustainable level of 64.80. The Analytical Hierarchy Process (AHP) method is used to formulate alternative strategies for improving vegetable farming using a sustainable hydroponic system in Pekanbaru City. Weighting is conducted based on expert opinions to prioritize the alternative strategies in each dimension (economic, ecological, social, institutional, and technological).

Based on the analysis results (Figure 6), certain aspects require attention to enhance vegetable farming using a sustainable hydroponic system. First, in terms of weaknesses, the most sensitive factor affecting sustainability is the control of plant-damaging organisms (OPT). Farmers often face challenges in controlling OPT attacks, particularly during the summer when pests tend to increase in the greenhouse. If pest infestation persists, it becomes difficult for farmers to manage them even with the use of organic pesticides. Inadequate pest control can lead to plant damage, resulting in decreased production and lower product quality.

The role of hydroponic farmers is crucial for achieving sustainability in vegetable farming using a hydroponic system, as indicated by the highest AHP score of 0.323. Farmers need to enhance their skills in hydroponic cultivation through training. Additionally, to boost sales, implementing effective marketing strategies is necessary. Research by Nurjanah et al. (2022) suggests involving consumers in product development, collaborating with partners for product improvement and increasing sales through e-commerce and endorsements. Promotions via social media, such as creating engaging content on platforms like Instagram and WhatsApp, can also be beneficial.

One alternative strategy to enhance vegetable farming using a hydroponic system in Pekanbaru City is the implementation and monitoring of hydroponic vegetables. This strategy involves selecting high-quality inputs, including certified seeds, as they significantly impact the sustainability and success of the farming business (Table 5).

Moreover, optimizing the pH value of the nutrient solution in the hydroponic system, ranging from 5.5 to 6.5, is essential for plant growth. Magwaza et al. (2020) suggest that the optimum pH level for nutrient release is between 6.5 and 8.5. It is crucial to ensure the pH level remains within the recommended range to avoid negative effects on nitrification and denitrification. Additionally, the use of greenhouses also plays a role in the production of hydroponic vegetables.

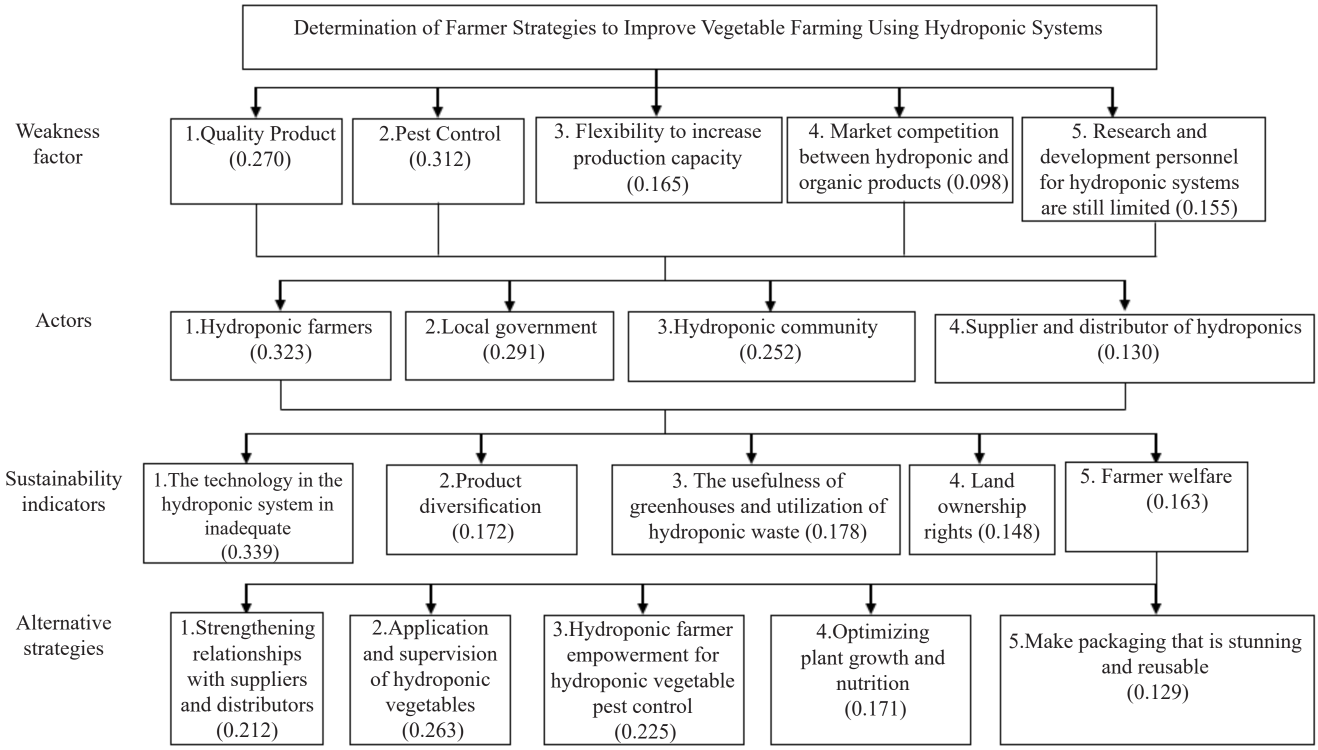


Figure 6. Determination of the hierarchy for farmer strategies to improve vegetable farming using sustainable hydroponic systems

Table 5. The results of a series of alternative farmer strategies to increase vegetable farming using a sustainable hydroponic system

Alternatives	Normal	Ranking
Strengthening relationships with suppliers and distributors	0.2116	3
Application and supervision of hydroponic vegetables	0.2625	1
Hydroponic farmer empowerment for pest control on hydroponic vegetables	0.2254	2
Optimize plant growth and nutrition	0.1715	4
Making packaging stunning and reusable	0.1289	5

Managerial Implication

Based on the results of research on the sustainability level of hydroponic vegetable farming and the strategies to ensure its continued sustainability, it is crucial for farmers to prioritize the institutional and social dimensions. This can be achieved by organizing training programs and activities aimed at enhancing farmer skills and knowledge regarding the latest hydroponic technologies. To further support the sustainability of hydroponic vegetable farming, several alternative strategies can be implemented. These include the application and monitoring of hydroponic vegetables, empowering hydroponic farmers to effectively control pests on their crops, strengthening relationships with suppliers and distributors, optimizing plant growth and nutrition, and utilizing appealing and reusable packaging.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The assessment results of indicators on sensitive attributes affect the level of sustainability as measured by five dimensions: economic, ecological, social, institutional, and technological. The results of the indicators for the dimensions of sustainability show that the sustainability level of vegetable farming using hydroponic systems is, on average, highly sustainable in the economic, social, ecological, and technological dimensions. The institutional dimension, in particular, exhibits a very high level of sustainability. To further enhance the sustainability of hydroponic vegetable farming, it is important to implement strategies that have been ranked based on their influence. The strategy that ranks the highest is the application and monitoring of hydroponic vegetables.

Recommendations

Since the sustainability levels vary across dimensions, it is recommended to prioritize the dimensions with the highest and lowest values in order to improve overall sustainability. Combining the institutional and social dimensions is expected to further enhance sustainable hydroponic vegetable farming. Additionally, attention should be given to the alternative strategy of using attractive and reusable packaging, as it has the potential to attract buyers and contribute to the overall sustainability of the farming practice.

FUNDING STATEMENT: This research did not receive any specific grant from funding agencies in the public, commercial, or not - for - profit sectors.

CONFLICTS OF INTEREST: The authors declare no conflict of interest.

REFERENCES

Borges R, Dal'Sotto TC. 2016. Análise econômico-financeira de um sistema de cultivo hidropônico. *Custos e @gronegócio line* 12(3):217–239.

Chen P, Zhu G, Kim HJ, Brown PB, Huang JY. 2020. Comparative life cycle assessment of aquaponics and hydroponics in the Midwestern United States. *Journal of Cleaner Production* 275:122888. https://doi.org/10.1016/j.jclepro.2020.122888

Greenland S, Saleem M, Misra R, Mason J. 2022. Sustainable management education and an empirical five-pillar model of sustainability. *The International Journal of Management Education* 20(3):1–18.

Grewal HS, Maheshwari B, Parks SE. 2011. Water and nutrient use efficiency of a low-cost hydroponic greenhouse for a cucumber crop: An Australian case study. *Agricultural Water Management* 98(5):841–846. https://doi.org/10.1016/j.agwat.2010.12.010

Gumisiriza MS, Kabirizi JML, Mugerwa M, Ndakidemi PA, Mbega ER. 2022. Can soilless farming feed urban East Africa? An assessment of the benefits and challenges of hydroponics in Uganda and Tanzania. *Environ Challenges*. 6 November 2021:100413. https://doi.org/10.1016/j.envc.2021.100413

Jandl A. 2020. IoT and Edge Computing Technologies for Vertical Farming from Seed to Harvesting. *Thesis*., siap terbit.

Kavanagh P, Pitcher TJ. 2004. Implementing Microsoft Excel Software For. *The Fisheries Centre Research Reports* 12(2):75.

Kementerian Pertanian. 2020. Statistik Konsumsi Pangan 2020. *Cent Agric Data Inf Syst*., siap terbit. http://epublikasi.setjen.pertanian.go.id/arsip-perstatistikan/163-statistik/statistik-konsumsi/751-statistik-konsumsi-pangan-tahun-2020.

Kurttila M, Pesonen M, Kangas J, Kajanus M. 2000. Utilizing the analytic hierarchy process (AHP) in SWOT analysis - A hybrid method and its application to a forest-certification case. *Forest Policy and Economics* 1(1):41–52. https://doi.org/10.1016/S1389-9341(99)00004-0

Lambin EF, Meyfroidt P. 2011. Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences* 108(9):3465–3472. https://doi.org/10.1073/pnas.1100480108

Li G, Tao L, Li X li, Peng L, Song C feng, Dai L li, Wu Y zi, Xie L. 2018. Design and performance of a novel rice hydroponic biofilter in a pond-scale aquaponic recirculating system. *Ecological Engineering* 125 May:1–10. https://doi.org/10.1016/j.ecoleng.2018.10.001

Magwaza ST, Magwaza LS, Odindo AO, Mditshwa A. 2020. Hydroponic technology as decentralised system for domestic wastewater treatment and vegetable production in urban agriculture: A review. *Science of The Total Environment* 698:134154. https://doi.org/10.1016/j.scitotenv.2019.134154

Majid M, Khan JN, Ahmad Shah QM, Masoodi KZ, Afroza B, Parvaze S. 2021. Evaluation of hydroponic systems for the cultivation of Lettuce (Lactuca sativa L., var. Longifolia) and comparison with protected soil-based cultivation. *Agricultural Water Management* 245 August: 106572.https://doi.org/10.1016/j.agwat.2020.106572

Maluin FN, Hussein MZ, Nik Ibrahim NNL, Wayayok A, Hashim N. 2021. Some emerging opportunities of nanotechnology development for soilless and microgreen farming. *Agronomy* 11(6):1–28. https://doi.org/10.3390/agronomy11061213

Martinez-Mate MA, Martin-Gorriz B, Martínez-Alvarez V, Soto-García M, Maestre-Valero JF. 2018. Hydroponic system and desalinated seawater as an alternative farm-productive proposal in water scarcity areas: Energy and greenhouse gas emissions analysis of lettuce production in southeast Spain. *Journal of Cleaner Production* 172:1298–1310. https://doi.org/10.1016/j.jclepro.2017.10.275

Melgarejo P, Martínez JJ, Hernández F, Salazar DM, Martínez R. 2007. Preliminary results on fig soil-less culture. *Scientia Horticulturae* 111(3):255–259. https://doi.org/10.1016/j.scienta.2006.10.032

Narine LK, Ganpat W, Ali A. 2014. Consumers' willingness to pay for greenhouse-hydroponic tomatoes in Trinidad, W.I. *Tropical Agriculture* 91(4):266–283.

Nurjanah AS, Nurhayati P, Ramadanti A. 2022. Marketing Strategy Development for Green House Karamba Hydroponic Vegetables. *Jurnal Manajemen & Agribisnis* 19(1):69–78. https://doi.org/10.17358/jma.19.1.69

Parra-Domínguez J, Gil-Egido A, Rodríguez-González S. 2022. SDGs as One of the Drivers of Smart City Development: The Indicator Selection Process. *Smart Cities* 5(3):1025–1038. https://doi.org/10.3390/smartcities5030051

Pitcher TJ, Preikshot D. 2001. RAPFISH: A rapid appraisal technique to evaluate the sustainability status of fisheries. *Fisheries Research* 49(3):255–270. https://doi.org/10.1016/S0165-7836(00)00205-8

Ratnaningtyas NA, Ma'ruf WF, Agustini TW, Hutabarat J, Anggoro S. 2016. Prospect and Adversity the Downstream of "Softbone Milkfish" in Semarang City, Indonesia. *Aquat Procedia*. 7:166–176. https://doi.org/10.1016/j.aqpro.2016.07.023

Dos Santos PH, Neves SM, Sant'Anna DO, Oliveira CH de, Carvalho HD. 2019. The analytic hierarchy process supporting decision making for sustainable development: An overview of applications. *Journal of Cleaner Production* 212:119–138. https://doi.org/10.1016/j.jclepro.2018.11.270

Sharma N et al. 2018. Hydroponics as an advanced technique for vegetable production: An overview. *Journal of Soil and Water Conservation* 17(4):364. https://doi.org/10.5958/2455-7145.2018.00056.5

Sohail S et al. 2022. Organic Vegetable Farming; A Valuable Way to Ensure Sustainability and Profitability. *Vegetable Crops - Health Benefits and Cultivation* January. https://doi.org/10.5772/intechopen.101095

Souza SV, Gimenes RMT, Binotto E. 2019. Economic viability for deploying hydroponic system in emerging countries: A differentiated risk adjustment proposal. *Land use policy*. 83 March 2018:357–369. https://doi.org/10.1016/j.landusepol.2019.02.020

Wiryawan FS, Marimin, Djatna T. 2020. Value chain and sustainability analysis of fresh-cut vegetable: A case study at SSS Co. *Journal of Cleaner Production* 260. https://doi.org/10.1016/j.jclepro.2020.121039

Yang T, Kim HJ. 2020. Comparisons of nitrogen and phosphorus mass balance for tomato-, basil-, and lettuce-based aquaponic and hydroponic systems. *Journal of Cleaner Production* 274:122619. https://doi.org/10.1016/j.jclepro.2020.122619

Zartha Sossa JW, Gaviria Suárez JF, López Suárez NM, Rebolledo JLS, Orozco Mendoza GL, Vélez Suárez V. 2022. Innovation systems and sustainability. development of a methodology on innovation systems for the measurement of sustainability indicators in regions based on a colombian case study. *Sustainability* 14(23):1–24. https://doi.org/10.3390/su142315955