JTEP Jurnal Keteknikan Pertanian,
Vol. 12 No. 2, p 272-283, 2024
P-ISSN 2407-0475 E-ISSN 2338-8439

Available online:
http://journal.ipb.ac.id/index.php/jtep
DOI: 10.19028/jtep.012.2.272-283

Determination of Sustainable Factory Locations for the Lemon Agroindustry using AHP, Mapping and Water Management

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Article Info

Submitted: 10 January 2024
Revised: 23 January 2024
Accepted: 6 May 2024
Available online: 12 August 2024
Published: August 2024

Keywords:
Agroindustry, AHP, lemon, plant factory, water conservations

***How to cite*:**
Prawiranegara, B. M. P., Asdak, C., Octoyne, A., and Kendarto, D. R. (2024). Jurnal Keteknikan Pertanian, 12(2): 272-283. https://doi.org/10.19028/jtep.012.2.272-283

Abstract

This research was conducted in Suntenjaya Village, Lembang, and West Bandung Regency, focusing on lemon agro-industrial development. Research was conducted using the Analytical Hierarchy Process (AHP) approach, area mapping, and water management to determine a sustainable factory location. The main objective is the selection of factory sites by integrating lemon production, considering sustainable agriculture aspects, product aspects, and water conservation programs. The results of this study provide a strong foundation for sustainable agro-industrial development that will support sustainable agriculture, local economy, and environmental protection. The research also combined qualitative and quantitative elements with a mixed approach that included Focus Group Discussion (FGD) and AHP, and the results showed that integrated drainage management was the top priority, followed by sanitation, clean water, reforestation, and sustainable agriculture. Mapping of areas based on geographical characteristics, such as rainfall, slope, and soil type, provided a map of water infiltration rates, which became a key guide in planning water conservation programs. The ultimate location for the lemon agroindustry is half of Desa Suntenjaya, mostly from the center to the northern area, which needs to consider proximity to markets in Bandung Regency and City, easy access to sources of raw materials for lemons, water availability, adequate transportation infrastructure, access to energy sources, suitable climate for lemon growth, and the availability of adequate labor in the region.

Doi: https://doi.org/10.19028/jtep.012.2.272-283

1. Introduction

The development of the lemon agro-industry in Suntenjaya Village, Lembang, focuses on the development of the lemon agro-industry through the Analytical Hierarchy Process (AHP) method, area mapping, and water management to determine the location of a sustainable factory. The main problem that needs to be addressed is how to make factory location decisions that can improve the efficiency and sustainability of the lemon agroindustry by integrating the Analytical Hierarchy Process (AHP) method by considering regional mapping and water management. Through the AHP method, this study aims to combine the results of mapping areas into water conservation priorities with programs on drainage management, sanitation, clean water, sustainable agriculture, and reforestation. In addition, this research will involve a water management analysis to evaluate the availability of water resources in Suntenjaya Village to ensure the continuity of lemon agro-industrial production.

Suntenjaya is a village in the West Bandung Regency, West Java, Indonesia. The region is known to produce lemons, coffee, vegetables, horticulture, and milk. It is located at an altitude of approximately 1290 m above sea level, with temperatures ranging from 16 °C to 21°C, rainfall reaching 2500-3000 mm per year, and land slopes between 15-25% with a slightly coarse soil texture. More importantly, the Lembang region acts as a water absorption area that supplies groundwater to Bandung and its surroundings. In recent years, the lemon agro-industry in Suntenjaya has experienced rapid growth as demand for quality lemon products has increased. Therefore, the choice of plant location is becoming increasingly vital, as it affects the production efficiency, accessibility of raw materials, and environmental impact. In addition, the issue of water availability and its impact on production is a serious concern in the agro-industrial context.

Agro-industry, which plays a major role in the economies of developing countries, on the one hand makes a significant contribution, but on the other hand creates environmental impacts that need to be addressed throughout the life cycle of its products, from raw materials to disposal (Mustaniroh et al., 2019). Environmental sanitation, which includes aspects such as access to clean water and safe waste treatment, is a crucial goal of the Sustainable Development Agenda (SDG) (Pratama et al., 2019). Furthermore, plant siting is a key factor for ensuring agro-industrial viability. Factors such as distance to markets and marketing, distance to raw material suppliers, and geological and climatic conditions must be considered (Permatasari , 2020). Sustainable agriculture efforts are also very relevant, given the challenges of limited water and land and the need to preserve the environment (Virianita et al., 2019). Forest land conversion limited by reforestation is an important step in maintaining forest cover and sustainable forest management (Mustafa et al., 2020). In addition, understanding water catchment areas in urban areas using computer technology such as Geographic Information Systems (GIS) is an important element in managing water resources effectively (Adibah et al., 2013). Factors such as soil depth and physical characteristics of the land greatly influence crop growth and natural resource management. (Aditiyas et al., 2014). This research also considers the North Bandung area, which is a water conservation area but faces the problem of declining groundwater levels that impact the hydrological cycle and can cause flooding in downstream areas (Nurrochman et al., 2018). Based on previous research, it is important to integrate an understanding of these issues to create a sustainable, efficient lemon agro-industry with positive economic and environmental impacts.

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2. Materials and Methods

Research on the development of lemon agro-industry through a method approach Analytical Hierarchy Process (AHP), area mapping, and water management to determine the location of a sustainable factory to determine the location of a sustainable factory involves several key stages in the order shown in Figure 1. The initial step was the selection of the factors and reasons for determining the critical location. These factors include accessibility to markets, availability of resources, proximity to lemon raw materials, and factors referring to Regulations The law of the land (Permen PU No. 2 in 2013). The research method used was a mixed approach (mixed methods) that combined qualitative and quantitative elements supported by field surveys (Creswell, 1994). A data analysis method using an overlay Geographic Information System (SIG) was used to identify water catchment areas.

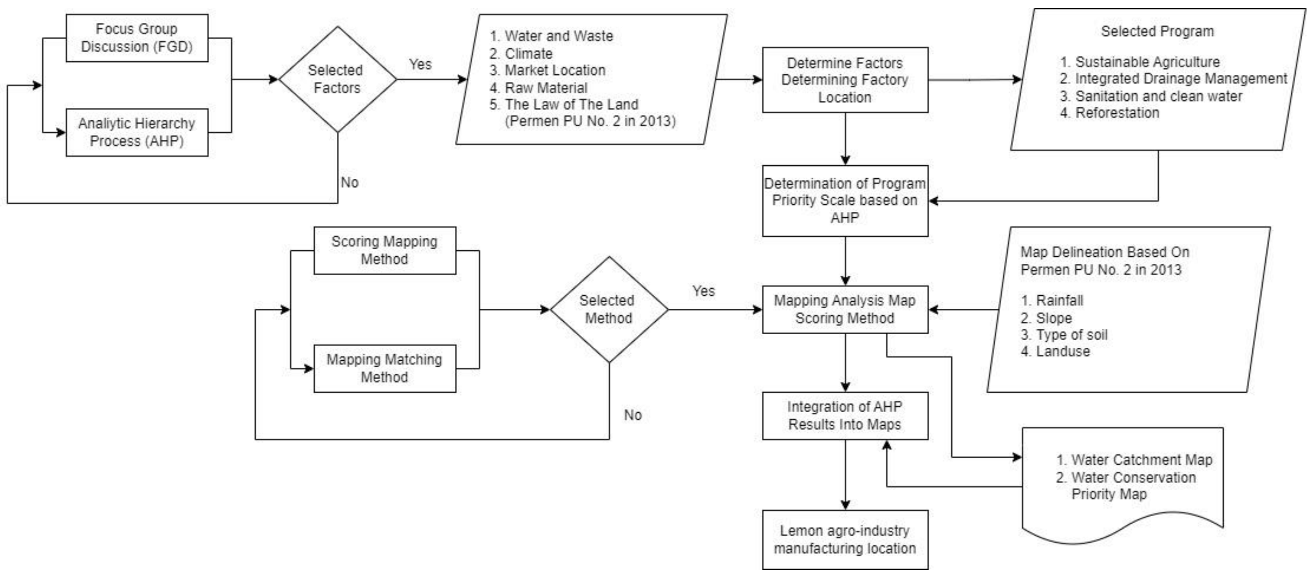

Figure 1. Flowchart of Lemon Citrus Agroindustry Manufacturing Site Determination by Mapping Method

The research began with a qualitative approach through *Focus Group Discussion* (FGD) with *a keyperson*. The FGDs consisted of researchers, community leaders of Suntenjaya Village, and lemon business owners of Suntenjaya Village. FGDs were conducted to understand their views, experiences, and preferences regarding conservation programs, such as integrated drainage management, sanitation, clean water, sustainable agriculture, and reforestation, in the context of lemon agro-industry development in Suntenjaya Village, Lembang. After collecting qualitative data from the FGDs, the research proceeded to a quantitative stage using the AHP (Saaty, 2012). Qualitative data from FGDs, such as keyperson perceptions and preferences, were used as the basis for determining

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the priority scale of conservation programs to be integrated into the decision-making system using the AHP.

3. Results and Discussion

In the process of selecting factors and reasons for determining the location of a factory, 16 factors were identified that could potentially influence location decisions (Apple, 2018). It should be emphasized that in the context of the lemon agro-industry, the most crucial aspects are water resource management and industrial waste management. Water plays a central role in lemon production, making the conservation of water resources and the sustainability of the lemon agro-industry a top priority. Furthermore, the priority scale for water conservation programs was determined using the AHP method, based on the FGD results. The process of determining the priority scale of water conservation programs involves several stages. The first stage was a paired comparison of statements conducted by the keyperson during the FGDs, where each program was compared in terms of how important it was compared with the other programs. The comparison scale ranges from 1 to 9, where 1 indicates that the two programs are of equal importance and 9 indicates a very high level of importance. The second stage involves the creation of a pairwise comparison matrix. The 4 × 4 matrix reflects all comparisons between the programs and is used as the basis for the calculations in the AHP method. The third stage involved normalizing the pairwise comparison matrix. This process allows for the determination of which programs will receive a higher priority in the context of water resource conservation.

Table 1. Comparison Matrix

Criteria	Integrated Drainage Management	Sanitation and Clean Water	Reforestasi	Sustainable Agriculture
Integrated Drainage Management	1	3	5	2
Sanitation and Clean Water	0,333	1	4	1
Reforestasi	0,2	0,25	1	0,50
Sustainable Agriculture	0,5	1	2	1
Total	2,033	5,25	12	4,5

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The fourth stage involved the calculation of the eigenvectors. The eigenvector is the average of each row of the normalization matrix, as presented in Table 2. This was used to identify the relative weight of each prioritized water conservation program, and the fifth stage was the calculation of the eigenvalue (λmax). The eigenvalue (λmax) is the sum of the product of the eigenvectors and normalization matrix. In this study, the eigenvalue (λmax) was approximately 3.024. This value is important for determining the level of consistency of pairwise comparisons conducted in water-conservation programs. The sixth stage is the calculation of consistency using CR. Consistency (CR) is the ratio between the CI and the random consistency index (RI). The determination of an appropriate CR requires an RI value to match the matrix size. This level of consistency refers to the extent to which the pairwise comparisons made by the key person during the FGDs conform to the principles of consistency in AHP. The results of this stage help determine which programs should receive a higher priority to achieve the goal of sustainable water conservation. Next, we calculated consistency (CI) using the following equation:

$$CI = \frac{(\lambda max - n)}{(n - 1)} \tag{1}$$

$$CI \approx \frac{(3{,}024 - 4)}{(4 - 1)} = -0{,}3253$$

Next, CR is calculated using the following equation:

$$CR = \frac{CI}{RI} \tag{2}$$

$$CR \approx \frac{-0{,}3253}{0{,}9} \approx -0{,}3614$$

Where CI denotes the consistency index, n denotes the number of criteria, and denotes the average number of consistency vectors. The value is generated from the average value of vector consistency (Setyoningty et al., 2022) The level of consistency in the decision-making process is very important. In this study, the resulting CR value of -0.3614 was smaller than 0.1; thus, it can be considered consistent. A CR value close to zero illustrates a high level of consistency in determining priority water conservation programs (Padmowati, 2009). This consistency is important for ensuring that the decisions taken are effective and suitable for achieving sustainable water conservation.

As explained in Table 2, the results of this calculation show the priority level for water conservation programs that can be carried out in Suntenjaya Village. Integrated drainage management is the top priority, with a weight of 48.1%, followed by sanitation and clean water, with a weight of 22.7% being the second priority. Furthermore, reforestation with a weight of 20.6% was the third priority and sustainable agriculture with a weight of 8.5% was the fourth priority. Thus, the priorities

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in the water conservation program that should be implemented in Suntenjaya Village were determined based on AHP analysis.

Table 2. Eigen value

Criteria	Integrated Drainage Management	Sanitation and Clean Water	Reforestasi	Sustainable Agriculture	Total	Average
Integrated Drainage Management	0,492	0,571	0,417	0,444	1,924	0,481
Sanitation and Clean Water	0,164	0,190	0,333	0,222	0,910	0,227
Reforestasi	0,098	0,048	0,083	0,111	0,340	0,085
Sustainable Agriculture	0,246	0,190	0,167	0,222	0,825	0,206

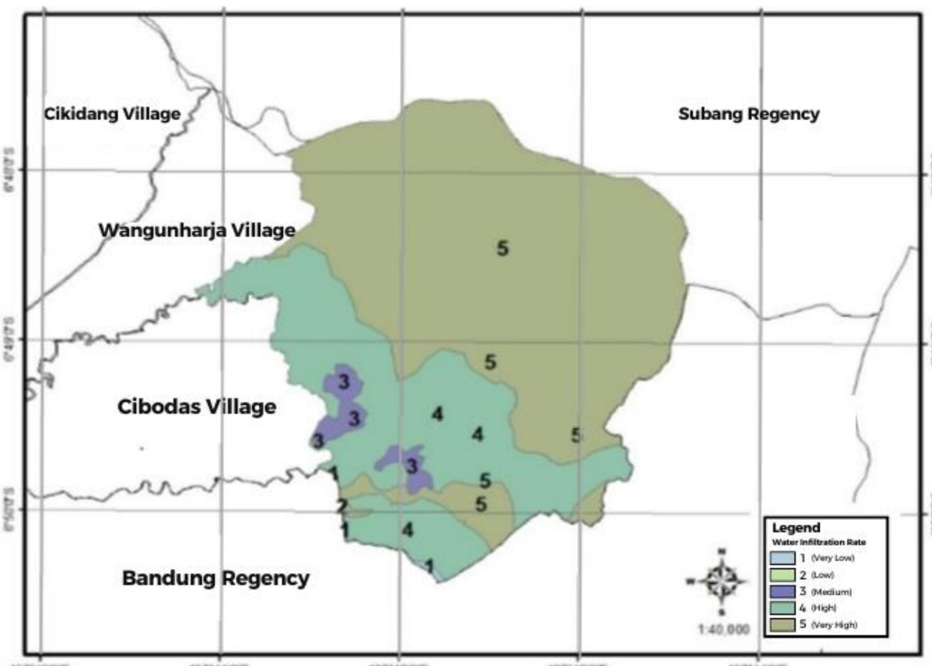

Figure 2. Village Water Infiltration Rate Map Suntenjaya

The map in Figure 2. makes it possible to identify areas in Suntenjaya Village that have different levels of water infiltration. The results can be determined in more detail with precision, where water conservation programs such as integrated drainage management, sanitation and clean water, sustainable agriculture, and reforestation are the main activities in the area. Areas with low or very low water infiltration rates (Categories 1, 2, or 3) have a higher priority in water resource conservation programs. This is because these areas tend to be more vulnerable to water-related problems such as drought and insufficient water supply. Predetermined water conservation programs, such as integrated drainage management, sanitation and clean water, sustainable agriculture, and reforestation, will focus more on areas with low water infiltration rates to maximize their benefits. The program includes efforts to safeguard water resources, sustainably manage water, and minimize negative impacts on the environment.

The results of the AHP method are important in determining the priority scale of water conservation programs. The integration stage of the AHP results is a key stage that combines two critical aspects in this research, namely, the analysis of water conservation program priorities with AHP and geographical mapping for water infiltration levels in Suntenjaya Village. The results of this integration are shown in the Suntenjaya Village Water Conservation Prioritization Map in Figure 3. This provides a more comprehensive picture of the areas that require water resource protection. Considering the priority level based on AHP results and accurate mapping data, water conservation programs can be implemented more efficiently and effectively.

The Suntenjaya Village Water Conservation Prioritization Map, shown in Figure 3, plays an important role in prioritizing sustainable water resource management. This map provides a clear view of areas that require urgent water conservation measures. Categories 1, 2, and 3 indicate low to moderate levels of water infiltration; therefore, conservation measures are particularly important in these areas. Although the area of very low water catchment (category 1) is only approximately 2.56%, conservation prioritization in this area remains important, as water supply shortages and drought risks can have significant impacts on residents and ecosystems in the region. On the other hand, the areas with high and very high water infiltration rates (categories 4 and 5) reached approximately 97.44%, which means that nature's ability to infiltrate water in this area is relatively good. However, this does not diminish the importance of maintaining the sustainability and quality of water resources in this area in the long term.

The water conservation priority map, created by considering the water infiltration rate, provides important guidance for planning water conservation programs and ensuring that the water resources in Suntenjaya Village are well maintained. Water conservation prioritization should be based on a combination of the size of the affected area and the urgency of the problem, so that various aspects of water conservation can be carried out efficiently and effectively.

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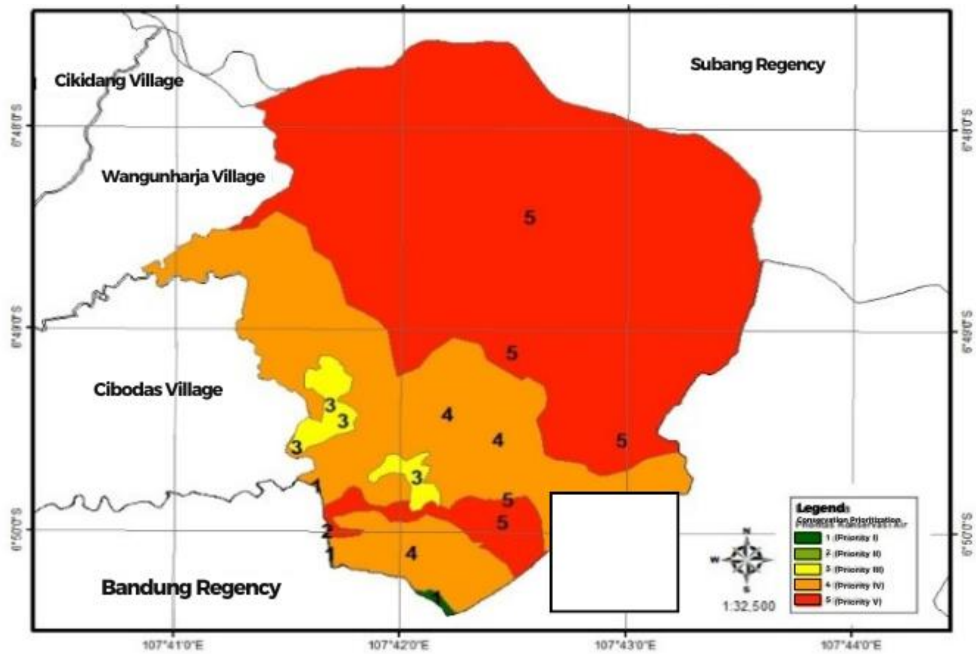

Figure 3. Suntenjaya Village Water Conservation Priority Map

Table 3. Area based on water catchment area and conservation priority level

Conservation Prioritization	Extensive(Ha)
Very Low	2,94
Low	0,078
Medium	43,63
High	650,41
Very high	1.118,78

The research also focused on determining the optimal location of the lemon agro-industrial factory in Suntenjaya Village. To achieve this objective, a Lemon Citrus Plantation and Manufacturing Land Suitability Map (Figure 4) was used to determine four land suitability categories: Highly Suitable (S1), Moderately Suitable (S2), marginally suitable (S3), and unsuitable (N). The determination of plant location is based on several key factors, including market accessibility, availability of raw materials, transportation, energy sources, climate, and labor resources. The location decision should also consider the proximity to lemon plantations and availability of water sources, which are crucial

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aspects of the lemon product industry. This land suitability map provides a visual view of potential sites that meet these requirements. As a result, factory sites that are compatible with lemon resources can be more clearly identified, enabling efficient and sustainable planning for the lemon agro-industry in Suntenjaya Village.

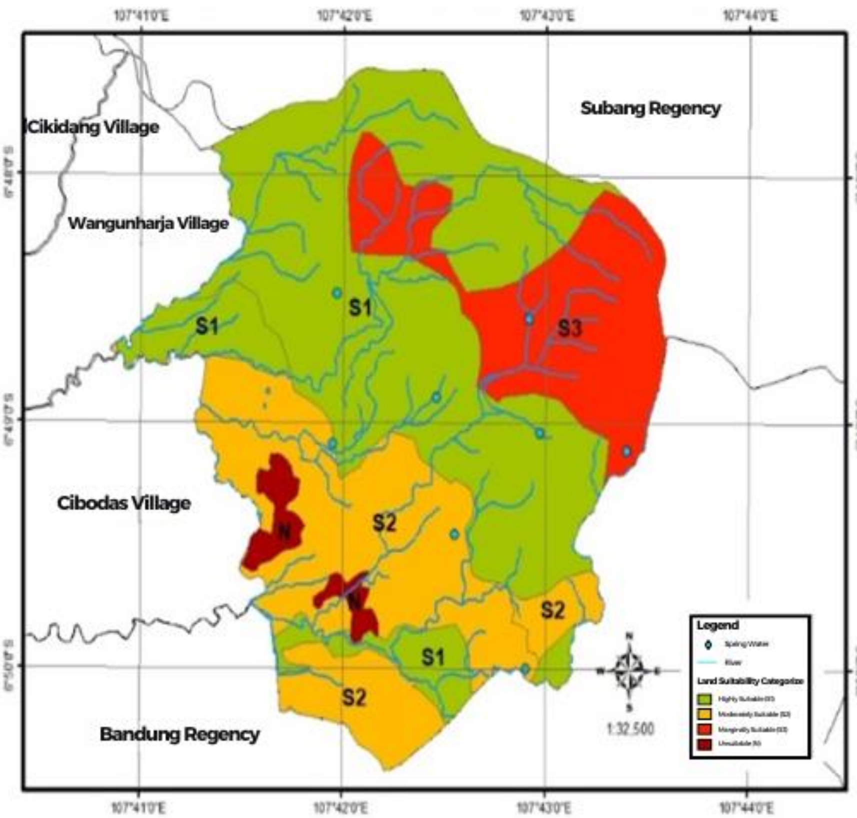

Figure 4. Suntenjaya Village Lemon Plantation and Manufacturing Land Suitability Map

The results of this study can identify the ideal location for lemon agroindustry manufacturing in Suntenjaya Village, which is in the S1 category area, as illustrated in Figure 4. This decision was based on several considerations, including proximity to the market (Bandung Regency and City), ease of access to sources of raw materials for lemons, sufficient water availability and support by water conservation programs that have been established in its priorities, adequate transportation infrastructure to support the distribution of lemons and their products, good access to energy sources, a suitable climate for lemon growth, and adequate labor availability in the region. As shown in Table 4, the area suitable for lemon agroindustry manufacturing is approximately 832.53 hectares or 52.16% of the total area of Suntenjaya Village, which confirms that this area is the optimal choice for establishing a lemon agroindustry factory. Therefore, the selection of this location is expected to

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support the efficiency of sustainable lemon production, while still considering environmental aspects and water conservation.

Table 4. Area Based on Land Suitability For Lemon Trees

Suitability Level	Extensive (Ha)
Highly Suitable (S1)	832,53
Moderately Suitability(S2)	437,04
Marginally Suitable (S3)	288,18
Unsuitable(N)	38,32

4. Conclusion

The development of the lemon agro-industry in Suntenjaya Village, Lembang, has great potential to support various interrelated aspects. The production of processed lemon products can be integrated into a sustainable agro-industrial system through conservation programs, such as integrated drainage management, sanitation, clean water, sustainable agriculture, and reforestation. In addition to providing significant economic benefits, the development of this agroindustry supports sustainable agriculture in the region.

The selection of agro-industrial factory locations involves map analysis, product distribution efficiency, and resource optimization, with priority water conservation programs using the AHP method. This helps develop a sustainable agro-industry in Suntenjaya Village, West Bandung Regency.

The implication of this study is that the development of the lemon agro-industry in the Suntenjaya Village area, Lembang, has the potential to provide significant economic benefits in supporting sustainable agricultural practices. The results of the AHP analysis and area mapping provide guidance for the development of a lemon agro-industry factory location decision-mapping model for more efficient resource allocation and environmental sustainability protection in the development of the agro-industry.

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