

Research Article



Land Optimization at the Universitas Sains Indonesia to Increase the Percentage of Green Open Space

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Abstract

Bekasi Regency is one of the largest industrial areas in Southeast Asia, resulting in high population density and a decline in environmental quality and air availability. Green open spaces are a solution, namely urban farming, which can be applied to minimal land. This requires an optimal layout design so that efficient urban farming can be developed at the Universitas Sains Indonesia as a provision of green open spaces in the Cibitung subdistrict. This study aims to design an optimal urban farming layout at Universitas Sains Indonesia by optimizing limited land resources to increase the green open space. This study employs a mixed-method approach, combining qualitative site analysis and quantitative approaches, including field observation, land potential analysis, facility relationship analysis, and economic feasibility estimation. The proposed urban farming design integrates three main components: an aquaponic cultivation system, a vertical farming system, and a green-learning park. The aquaponic system utilized a 1000-liter fish tank integrated with hydroponic pipes containing 120 planting holes, whereas the vertical farming system provided an additional 60 planting holes to maximize land productivity. The results indicate that the ARC-ARD approach effectively supports spatial planning by organizing facilities into operational zones. Economic feasibility analysis showed that the system requires an initial investment of approximately Rp 12,270,000, with relatively low operational costs. In addition, the system has the potential to produce 37–45 kg of vegetables per month and 30–40 kg of fish per production cycle. Overall, the proposed urban farming model offers a sustainable strategy for optimizing limited urban land, improving environmental quality, and supporting green campus initiatives.

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1. Introduction

The population in 2050 is estimated to reach 8.9 billion, and food demand will increase by 50%, requiring additional agricultural land that is not available. (FAO, 2020). Limited land area for green open space utilization is a common problem in densely populated areas in Indonesia...(Prabowo & Alif, 2023). This occurred in Bekasi Regency, one of the largest industrial areas in Southeast Asia, home

to 10 industrial parks and over 7,500 companies operating within the region. This phenomenon has affected the population density of Bekasi Regency.

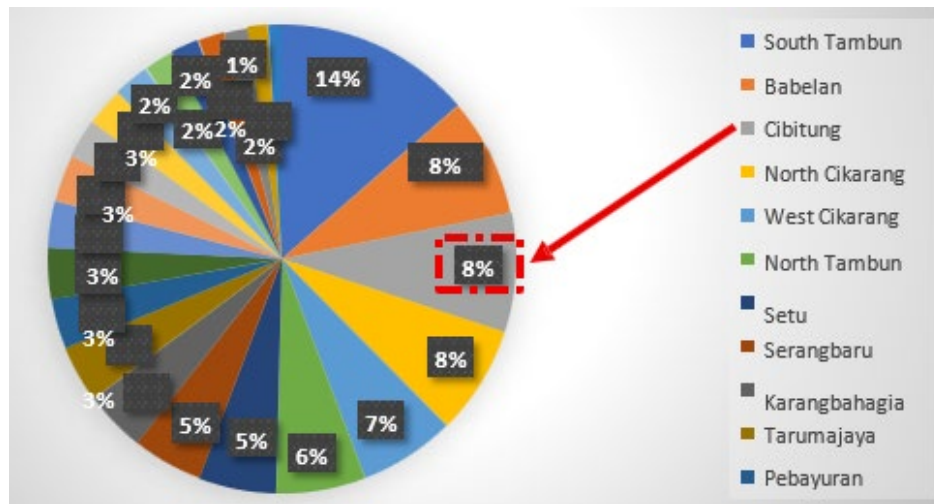


Figure 1. Percentage of Population per District in Bekasi Regency
 (Source: Civil Registration and Population Service Data 2024)

Figure 1. shows that Cibitung sub-district is the third most populous, accounting for 8% of the total population in Bekasi Regency, with a population of 265,964. This has resulted in a drastic decline in environmental quality and the availability of clean air in the Bekasi Regency area, resulting in a reduction in the number of Green Open Spaces. Based on Law No. 26 of 2007 and the Regulation of the Minister of ATR KBPN No. 14 of 2022, the provision of urban Green Land Space must meet a minimum of 30% of the total area of the city or metropolitan area in the regency. Regulation of the Minister of ATR KBPN No. 14 of 2022 further regulates the provision of RTH based on environmental units, which are indirectly determined by population density with a specified service radius. The provision of RTH can be in the form of spatial zones that have the same function as RTH, such as cultural heritage, customary forests, conservation zones, production forests, plantations, agricultural land, and urban farming (Kang et al., 2020; Rahmy & Hoctor, 2021; Rahmy & Rina, 2023).

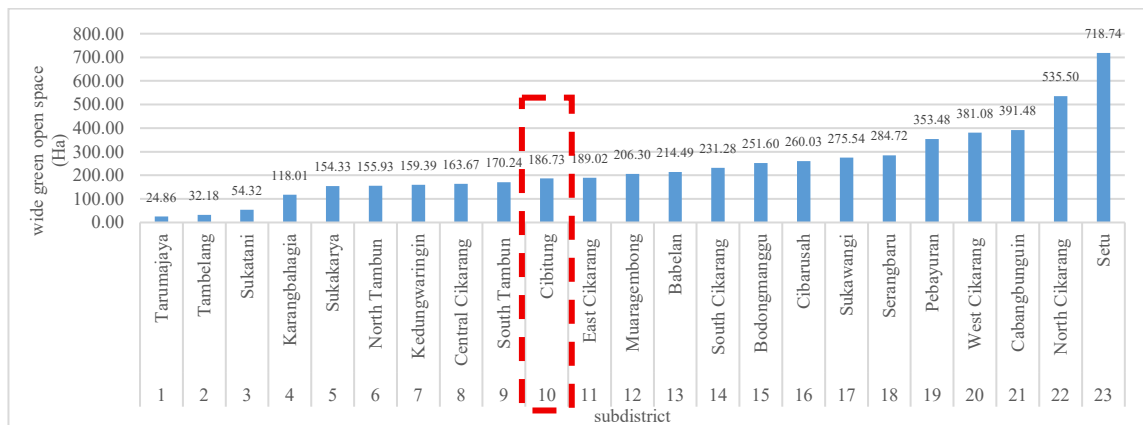


Figure 2. Graph of Existing Green Open Space Area Data per District in Bekasi Regency

Figure 2. Shows a graph of existing green open space area data per sub-district in Bekasi Regency, showing that Cibitung sub-district is the area with the 10th lowest green open space area out of 23 sub-districts in Bekasi Regency. The total area of green open space in Bekasi Regency is 5,512.92 ha out of a total area of 127,586.93 ha, meaning that the green open space area in Bekasi Regency is 4.32%. This is caused by the large number of industries, resulting in a lack of green open spaces in the Cibitung area. If this condition continues, it will increase the risk of declining air quality, as many industries do, but green open spaces as providers of clean air are decreasing. The decline in air quality will impact the health of residents, such as respiratory infections. The results indicate that Bekasi Regency still needs to increase the area of green open space, one of which is Urban Farming by utilizing minimal land to increase the area of green open space in Bekasi Regency. The application of vertical farming began in a university canteen in Wuhan, China, before being implemented in the community (van Delden et al., 2021).

The real challenge to food security today is traditional land-based agriculture, which poses a serious threat because of the scarcity of available land. Modern agriculture can be a more efficient alternative to traditional agriculture (Naikoo et al., 2022). Urban farming in densely populated areas has important benefits for the community, including shortening the supply chain, carbon sequestration, reducing the potential for urban heat, improving mental and physical health, creating jobs, providing habitats for wildlife, and recycling waste (Moraitis et al., 2022). The concept of landless vertical farming is to provide food security and ensure environmental sustainability. The implementation of vertical farming began at universities, which can serve as examples of its large-scale use (Miserocchi & Franco, 2025; SharathKumar et al., 2020)]. Urban farming with limited land provides positive value in terms of food security and environmental sustainability by creating green open spaces in the middle of dense urban settlements (Mahyudin et al., 2025). Urban farming utilizes hydroponic or aeroponic cultivation systems that offer many potential benefits, such as a more

efficient use of space (Oh & Lu, 2023). Urban vertical farming aims to produce food and create ecological, social, and ecosystem centers and improve the quality of green spaces in densely populated urban areas (Zareba et al., 2021).

Universitas Sains Indonesia is located in the Cibitung sub-district, in the middle of an industrial area, making it the first location for urban farming implementation before finally being cultivated in the community. The layout influences the long-term operational efficiency. The goal of the layout is to create a maximum operational system using the Activity Relationship Chart (ARC) method or a work relationship map is The activity in each section based on the proximity of the facilities (Alamsyah & Suhartini, 2021; Fithri Azizah et al., 2023a; Muharni, 2022a; Panjaitan & Azizah, 2020). Facility layout is the activity of designing, conceptualizing, analyzing, and realizing a system that is depicted in a plan to optimize the relationship between workers, material flow, and information flow to achieve efficiency and effectiveness (Barbara & Cahyana, 2021). Based on previous research, the use of ARC and ARD methods is effective for designing layouts (Putri Rahmadani Lubis et al., 2022). Facility layout planning plays an important role in improving operational efficiency by arranging facilities based on their functional relationships. The Activity Relationship Chart (ARC) and Activity Relationship Diagram (ARD) are widely used methods in industrial engineering to determine the closeness relationship between facilities and design efficient layouts. By applying these methods, the arrangement of urban farming facilities can be optimized, even with limited land availability.

Therefore, this research aims to design an urban farming layout at Universitas Sains Indonesia using ARC and ARD methods to increase green open space while integrating ecological, educational, and social functions within the campus environment. However, previous studies on urban farming have primarily focused on cultivation techniques, and limited research has discussed spatial layout optimization using industrial engineering approaches. Therefore, this study applies the Activity Relationship Chart (ARC) and Activity Relationship Diagram (ARD) methods to design an efficient urban farming layout within limited campus land.

2. Material and Methods

2.1 Research Approach

The method used a mixed-method approach that combined qualitative and quantitative analyses. Qualitative data were obtained through field observations and in-depth interviews with members of the Universitas Sains Indonesia academic community to identify potential urban farming locations and their operational requirements. Quantitative analysis was used to estimate the production capacity, resource efficiency, and preliminary economic feasibility of the proposed system, and to analyze the degree of interrelationship between facilities and determine the optimal location for urban farming design.

2.2 Activity Relationship Chart (ARC)

This study uses the Activity Relationship Chart (ARC) method to analyze the degree of relationship between departments for layout optimization that can improve distance and time efficiency (Kolo et al., 2021a; Kovács, 2020; Prayogo & Zusi, 2020; Sonta et al., 2021; Tejaningrum & Hasna, 2024). This approach uses a qualitative assessment by considering objective factors in each facility to achieve efficient facility placement. (Muharni, 2022b; Nurmutia, 2024). The Activity Relationship Chart (ARC) method was applied to analyze the degree of closeness between facilities involved in the urban farming system. The steps to create an ARC are as follows (Gunawan Mohammad, 2023) (Kolo et al., 2021).

- a. List all the facilities used.
- b. Conduct observations and interviews with personnel from each relevant department/facility.
- c. Determine the criteria for establishing closeness between departments/facilities.
- d. Establish relationship values for each facility/department.
- e. Provide opportunities for anyone who provides input to develop a relationship chart.

To design an optimal layout, an analysis using the Activity Relationship Chart (ARC) method is necessary. A layout arrangement that does not match the degree of relationship proximity and importance will result in a suboptimal layout, hindering activities and resulting in waste generation. To determine the relationship between facilities, an Activity Relationship Chart (ARC) analysis is required to determine the degree of relationship and the reasons for the level of relationship between facilities so that a facility layout can be designed based on the level of activity relationship. The Activity Relationship Chart (ARC) is a visual tool used to display the level of relationship between facilities and departments. The Activity Relationship Diagram (ARD) is used to design room layout concepts in the form of diagrams that consider the level of interconnection between facilities (Amelia et al., 2024).

The following are the degrees of relationship between the facilities in the ARC:

- a. Absolutely Important (A): Absolutely necessary proximity
- b. Very Important (E): Very important proximity
- c. Important (I): Important proximity
- d. Ordinary (O): Normal, proximity anywhere is fine
- e. Unimportant (U): Not necessary proximity
- f. Undesirable (X): Absolutely far apart

2.3 Relationship Diagram (ARD)

The Activity Relationship Diagram is an advanced analysis method of the Activity Relationship Chart (ARC), namely a diagram showing the relationship between facilities based on priority levels

of proximity while minimizing processing costs. The purpose of this diagram is to determine the most optimal layout. (Fithri Azizah et al., 2023).

2.4 Land Optimization and Zoning Analysis

To strengthen zoning decisions, additional analyses were conducted, including qualitative land assessment, sunlight exposure analysis, accessibility analysis, and descriptive analysis based on the KRPL (Kawasan Rumah Pangan Lestari) concept. These analyses helped classify the available areas into productive cultivation zones, learning spaces, and supporting infrastructure.

2.5 Agribusiness and Productivity Estimation

A preliminary agribusiness analysis was conducted to estimate the potential production capacity, operational costs, and economic benefits of the proposed urban farming system. This analysis includes the estimation of fish production, vegetable yield, and resource consumption, such as water and electricity.

3. Results and Discussion

3.1 Feasibility study

The feasibility study of urban farming at the Universitas Sains Indonesia includes the feasibility of the planning location, objectives, and programs of urban farming at the Indonesian Science University, using SWOT analysis to analyze the strengths and opportunities of the program by considering its weaknesses and challenges.

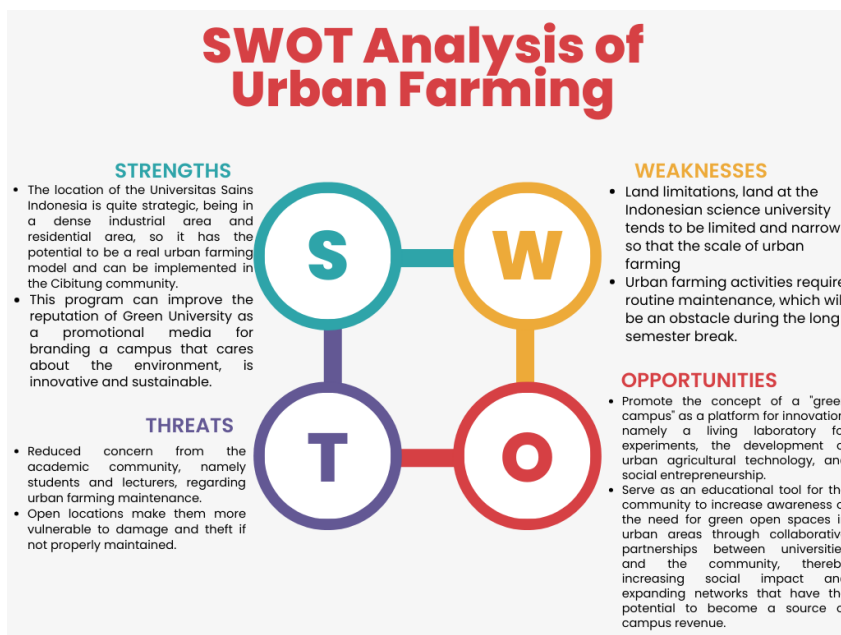


Figure 3. SWOT Analysis of Urban Farming at the Universitas Sains Indonesia

3.2 Identify urban farming locations

To design urban farming, locations with potential for urban farming must be identified. Figure 4. shows the overall layout of the Indonesian Science University (USN). At this stage, areas with potential are identified.

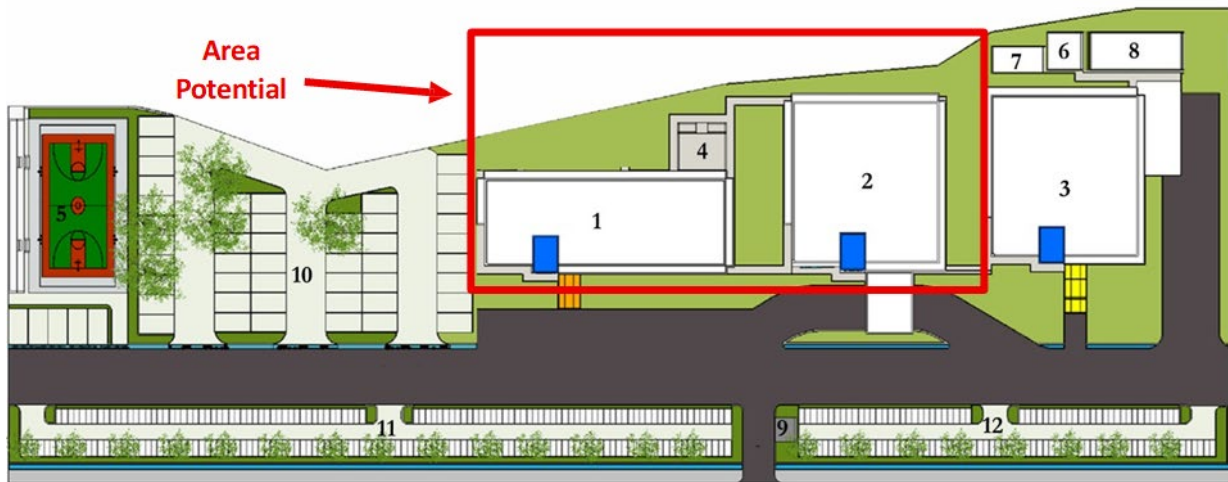


Figure 4. Universitas Sains Indonesia layout.

Table 1. Description of the name of the layout room at Universitas Sains Indonesia.

No	Description
1	Building A (Laboratory and Library)
2	Building B (Rectorate Foundation)
3	Building C (Lecture and student affairs room)
4	Mosque
5	Basketball court
6	Canteen
7	Generator
8	PLN Substation room
9	Security pos
10	Car park
11	Motorcycle park

Based on Figure 5. After location identification, it was found that four zones could be used for urban farming. The following is an analysis of the four zones.



Figure 5. Potential areas for urban farming.

Table 2. Analysis of the four zones of urban farming.

No	Zone	Description	Zone
1	Zone 1	<p>Located behind Building A, it is safer for plants that require care, as they are protected from damage</p> <p>The high intensity of sunlight makes this location very suitable for urban farming, aquaponics, and hydroponics, which require sunlight for the growth of plants and fish farming.</p> <p>The sun moves from east to west, so from morning to noon, the sunlight is full, and in the afternoon, it is covered by the building. This helps hydroponic growth because if the sunlight is too hot and long, it will cause the plants to wilt and eventually die.</p> <p>Close to water sources</p> <p>The space is spacious</p>	Aquaponic
2	Zone 2 & 3	<p>It is an area between two buildings with road access and is not used as a parking spot.</p> <p>Become a path to the mosque and canteen</p> <p>It is a gathering spot for students but there are no seats provided and it tends to be very hot during the day</p>	Green Learned Park
3	Zone 4	<p>It is the rear part of Building A-C, which forms the boundary with the buildings behind the campus.</p> <p>an area that has a narrow width of only 3 meters</p>	Vertical Hydroponic

Based on the zoning analysis conducted and the type of urban farming that will be designed according to the location conditions, there are three types of urban farming:

- a. Aquaponics, a combination of aquaculture (fish farming) and hydroponics (soilless plant cultivation), utilizes minimal land resources. Waste from fish farming serves as a fertilizer and nutrient source for plants. A location with a highlighted intensity is required.
- b. Vertical aquaponics is similar to aquaponics, except that the hydroponic pipes are arranged vertically. This is particularly suitable for use in Green Open (Zone 4) because of the long and limited space behind the building. The nutrient tank was integrated with the aquaponic fish tank.
- c. Green Learning Garden: A place for student discussions surrounded by vertical plants, providing shade due to reduced sunlight and fresh air due to being under the plants.

Location identification showed that four potential zones were previously not optimally utilized. With a design approach using the Activity Relationship Chart (ARC), the layout of urban farming can be arranged more efficiently, even with limited land. The ARC helps determine the level of proximity between facilities so that activity flows, such as maintenance, harvesting, and distribution, can run more effectively without wasting space or time.

3.3 Activity Relationship Chart

To design an urban farming layout, in this case using an aquaponic system on limited land, the University of Science Indonesia analyzed the degree of close relationships obtained from interviews with the Universitas Sains Indonesia community as respondents. The following are the results of the ARC.

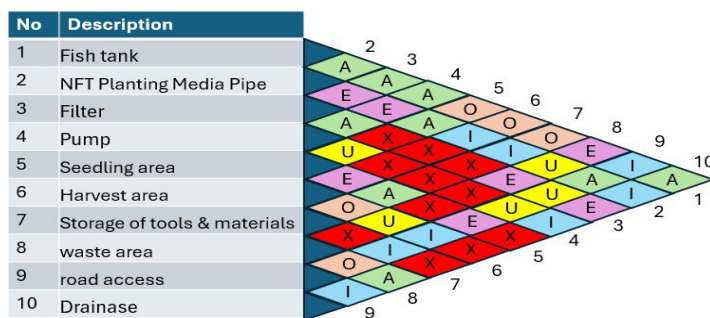


Figure 6. Activity Relationship Chart Aquaponic

for creating aquaponic and vertical-aquaponic systems. The Activity Relationship Chart analyzes the level of proximity between facilities to design a facility layout that facilitates maintenance access. This analysis is important to be carried out at the beginning, before designing the layout, so that the urban farming created is optimal even on minimal land.

3.4 Activity Relationship Diagram

Table 3 presents the results of the Activity Relationship Diagram worksheet, which is a continuation of the ARC, containing the level of relationships between activities and facilities. The worksheet results were compiled based on the Activity Relationship Chart.

Table 3. Worksheet Activity Relationship Diagram Aquaponic

Code	Description	A	E	I	U	O	X
1	Fish Tank	2,3,4,10	8	6,7,9	-	5	-
2	NFT Planting Media Pipe	1, 5,6,7,9	3,4	10	8	-	-
3	Filter	1,4	2,8,10	-	9	-	5,6,7
4	Pump	1,3	2	10	5	-	6,7,8
5	Seeding Area	2,7	6,9	-	-	-	3,4,8,10
6	Harvest Area	2	-	1,9	8	7	3,4,5,10
7	Storage of tools & materials	2,5	-	1,9	-	6	3,4,8,10
8	Waste Area	10	1,3	-	2,6	9	4,5,7
9	Road Access	2	5	1,6,7,10	3,4	8	-
10	Drainage	1,8	3	2,4,9	-	-	-

Table 4. Result analysis of ARC and ARD

No	Facility Name	Degree of Closeness
1	Fish Tank	<p>(A= Absolutely necessary proximity) with NFT growing media pipes, pump, filter and drainage</p> <p>(E= Very important proximity) with Waste area</p> <p>(I= Important proximity) with Harvest area, Storage of tools & materials, and road access</p> <p>(O= Normal) with Seedling area</p>
2	NFT growing media pipe	<p>(A= Absolutely necessary proximity) with a fish tank, a seedling area, a Harvest area, a Storage of tools & materials, and road access</p> <p>(E= Very important proximity) with NFT growing media pipes, Waste area dan drainage</p> <p>(I= Important proximity) with Drainage</p> <p>(U= Not necessary proximity) with Waste area</p>
3	Filter	<p>(A= Absolutely necessary proximity) with a fish tank and a pump</p> <p>(E= Very important proximity) with a pump, filter</p> <p>(U= Not necessary proximity) with road access</p> <p>(X= Absolutely far apart) with Waste area</p>
4	Pump	<p>(A= Absolutely necessary proximity) with fish tank and filter</p> <p>(E= Very important proximity) With NFT growing media pipes</p> <p>(I= Important proximity) with Drainage)</p> <p>(U= Not necessary proximity) with the seedling area</p> <p>(X= Absolutely far apart) with Harvest area, Storage of tools & materials, waste area)</p>
5	Seeding Area	<p>(A= Absolutely necessary proximity) With NFT growing media pipes dan Storage of tools & materials</p> <p>(E= Very important proximity) with Harvest area and Road access</p> <p>(X= Absolutely far apart) with filter, pump, Waste area, Drainage</p>

No	Facility Name	Degree of Closeness
6	Harvest Area	(A= Absolutely necessary proximity) With NFT growing media pipes
		(I= Important proximity) with a Fish tank, road access
		(U= Not necessary proximity) with Waste area
		(O= Normal) with Storage of tools & materials
7	Storage at tools & materials	(X= Absolutely far apart) with filter, pump, Seedling area, Drainage
		(A= Absolutely necessary proximity) With NFT growing media pipes dan seedling area
		(I= Important proximity) with a Fish tank, road access
		(O= Normal) with the Harvest area
8	Waste Area	(X= Absolutely far apart) with filter, pump, Waste area, Drainage
		(A= Absolutely necessary proximity) with Drainage
		(E= Very important proximity) with the Seedling area
		(U= Not necessary proximity) With NFT growing media pipes and Harvest area
9	Road access	(O= Normal) with road access
		(X= Absolutely far apart) with pump, Seedling area, Storage of tools & materials
		(A= Absolutely necessary proximity) With NFT growing media pipes
		(E= Very important proximity) with the Seedling area
10	Drainage	(I= Important proximity) with a Fish tank, Harvest area, Storage of tools & materials, drainage
		(U= Not necessary proximity) with filter and pump
		(O= Normal) with Waste area
		(A= Absolutely necessary proximity) with Fish tank and Waste area
		(E= Very important proximity) with filter
		(I= Important proximity) with NFT growing media pipes, pump, and road access

The ARD results were used to develop the final layout design of the urban farming system. The layout ensures an efficient flow of maintenance activities, harvesting processes, and waste management while minimizing unnecessary movement between facilities.

3.5 Area Allocation Diagram (AAD)

At this stage, the layout that was analyzed using ARC and ARD was designed. The following is the layout design for urban farming at Universitas Sains Indonesia.

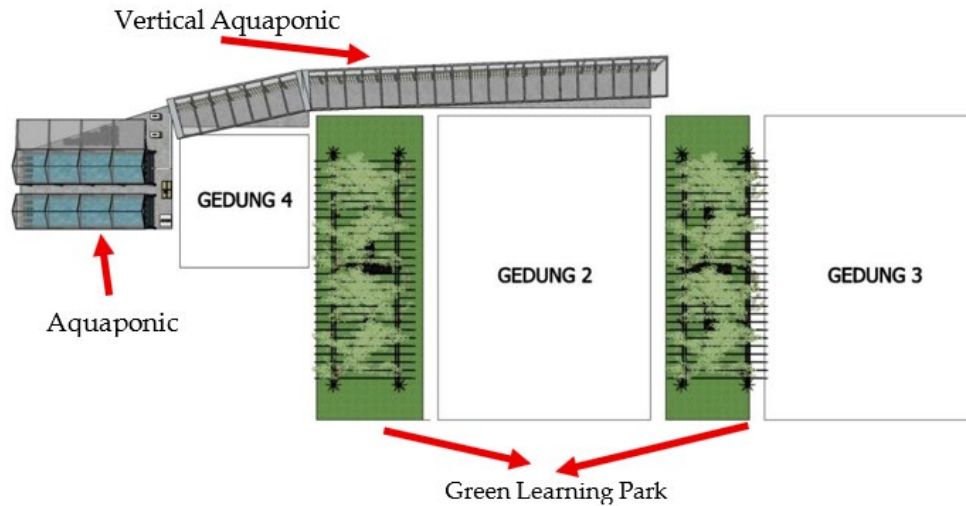


Figure 7. Urban farming layout design at Universitas Sains Indonesia.

Figure 7. shows the layout design of urban farming. There are four zones: zone 1 is aquaponics, zones 2 and 3 are green learning gardens, and zone 4 is vertical aquaponics that connects to zone 1.



Figure 8. Aquaponic at Zone 1.

Figure 8. The aquaponic design consists of 10 facilities and is designed in accordance with the results of the activity relationship chart analysis.



Figure 9. Green Learning Park in Zones 2 and 3.

Figure 9. shows the green learning park in zones 2 and 3, which was previously just vacant land used as road access to the rear of the building, but has now been turned into a park that can be used as a learning area for students with a green learning park atmosphere.



Figure 10. Vertical aquaponics in Zone 4.

Figure 10. shows the vertical aquaponics system connected to the aquaponics system in Zone 1. The area behind the university building is not used for anything, so it is vacant. Although narrow, it can be used for vertical aquaponics, thereby adding green open spaces to the campus.

The implementation of three types of urban farming, namely aquaponics in Zone 1, a Green Learning Park in Zones 2 and 3, and vertical aquaponics in Zone 4, can integrate ecological, social, and educational functions in one area. In addition to improving the quality of the campus environment, this design also provides added value in the form of space for student interaction in a green atmosphere. Weaknesses related to land limitations and threats to sustainability can be minimized by forming a special student activity unit tasked with maintaining and developing the system. Thus, the ARC-based urban farming design has proven to be relevant for application in densely industrialized areas with minimal open spaces.

3.6 Activity and Resource Efficiency Analysis

The aquaponics system was designed using fish tanks with a capacity of approximately 1,000 liters that can hold approximately 80–100 tilapia fish. With a cultivation cycle of 4–5 months, the harvest is estimated to reach 30–40 kg per cycle. The NFT hydroponic system in Zone 1 can accommodate approximately 120 planting holes for leafy vegetables, such as lettuce, pak choi, and spinach. With a planting cycle of 30–40 days, production is estimated to reach 25–30 kg per month. The vertical aquaponics system in Zone 4 added approximately 60 planting holes, increasing the production capacity while effectively utilizing limited space. The aquaponics system also demonstrates significant resource efficiency by reducing water use by up to 90% compared to conventional agriculture, owing to continuous water circulation.

3.7 Economic Feasibility Estimation

An economic feasibility analysis was conducted to evaluate the financial viability of implementing the proposed urban farming system at Universitas Sains Indonesia. The analysis includes an estimation of the initial investment cost, operational expenses, and potential economic benefits generated from the integrated urban farming system consisting of aquaponic cultivation, vertical farming, and green learning park areas.

Urban farming design integrates three main components. The aquaponic system serves as the primary production unit, combining fish cultivation with hydroponic vegetable production. The vertical farming system is designed to maximize land utilization through vertical planting structures, and the green learning park functions as an educational and ecological space that supports campus sustainability programs. The estimated investment costs for each system are presented in the following tables.

Table 5. Estimated Investment Costs for Urban Farming.

Estimated Investment Cost for Aquaponic System			
No	Component	Estimated Cost (Rp)	
1	Fish tank (1000 L)	Rp	1.800.000
2	Aquaponic support frame	Rp	800.000
3	Water pump	Rp	350.000
4	Biofilter and filtration media	Rp	400.000
5	NFT hydroponic pipes (120 planting holes)	Rp	1.200.000
6	Net pots and planting media	Rp	150.000
7	Electrical installation and timer	Rp	200.000
8	Tilapia fish seedlings	Rp	300.000
9	Vegetable seedlings	Rp	100.000
	Total	Rp	5.300.000

Estimated Investment Cost for Aquaponic System			
No	Component	Estimated Cost (Rp)	
Estimated Investment Cost for Vertical Farming System			
1	Vertical farming frame structure	Rp	1.500.000
2	Vertical hydroponic pipes	Rp	720.000
3	Water pump	Rp	300.000
4	Nutrient water tank	Rp	250.000
5	Net pots and planting media	Rp	120.000
6	Vegetable seedlings	Rp	80.000
7	Pipe fittings and installation	Rp	200.000
	Total	Rp	3.170.000
Estimated Investment Cost for Green Learning Park			
No	Component	Estimated Cost (Rp)	
1	Garden benches	Rp	1.500.000
2	Ornamental plants	Rp	600.000
3	Plant pots	Rp	500.000
4	Garden paving and pathway	Rp	1.200.000
	Total	Rp	3.800.000
Total Urban Farming		Rp	12.270.000

3.8 Environmental Sustainability Analysis

Environmental sustainability is a key objective of the proposed urban-farming system. The integration of aquaponic cultivation, vertical farming, and green learning park areas aims to improve environmental quality, optimize limited land resources, and contribute to the expansion of green open spaces within the campus environment.

One of the primary advantages of aquaponic systems is their efficient water utilization. Unlike conventional agriculture, which requires large volumes of irrigation water, aquaponic systems operate using a closed-loop recirculation system. Water from the fish tank was continuously circulated through the hydroponic plant beds and returned to the tank after filtration. This process significantly reduces water consumption while maintaining nutrient availability for plant growth. Previous studies have indicated that aquaponic systems can reduce water usage by up to 70% compared to conventional soil-based agriculture, making them highly suitable for urban areas with limited water resources.

In addition to water efficiency, aquaponic systems minimize the use of chemical fertilizers. The nutrients required by plants are naturally supplied by fish waste, which is converted into plant-available nutrients through biological filtration processes. This natural nutrient cycle reduces

environmental pollution caused by excessive fertilizer application and supports the development of a sustainable food production system.

The implementation of vertical farming further enhances environmental sustainability by maximizing the use of limited land. Through vertical planting structures, a larger number of plants can be cultivated in a relatively small area. In this study, the vertical farming system increased planting capacity by adding 60 additional planting holes, thereby improving land productivity without requiring additional horizontal space.

Furthermore, the development of the green learning park contributes to the improvement of microclimate conditions within the campus. Vegetation can reduce urban heat effects, improve air quality, and create a more comfortable outdoor environment for students and campus visitors. The green learning park also functions as an educational space in which students can learn about sustainable agriculture, environmental management, and green technology applications.

4. Conclusion

This study aimed to design an optimal urban farming layout at Universitas Sains Indonesia to increase the availability of green open spaces by utilizing limited land resources. Industrial engineering approaches were applied using the Activity Relationship Chart (ARC) and Activity Relationship Diagram (ARD) methods to determine the spatial relationships and optimal zoning of urban farming facilities. The proposed design integrates three main components: the aquaponic cultivation system, vertical farming system, and green learning park, which together support ecological, educational, and productive functions within the campus environment.

The results indicate that the ARC-ARD approach can effectively optimize land utilization by organizing urban farming activities into efficient zones. In addition, the proposed system demonstrates potential economic and environmental benefits through efficient water use, increased vegetation coverage, and the ability to produce vegetables and fish in a limited area. Therefore, the proposed urban farming model can serve as a sustainable strategy for increasing green open spaces and supporting green campus initiatives in densely populated urban areas such as Bekasi.

Future research should explore the integration of automated monitoring systems, optimization of production capacity, and long-term operational management strategies to improve the sustainability and scalability of urban farming systems in urban environments.

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6. AI Writing Statement

The author uses AI tools to check for grammatical errors and rephrase sentences. All process of model development, calculations, data analysis, and interpretation was conducted and verified by the author, who bears full responsibility for the content of this manuscript.

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