Eduvest – Journal of Universal Studies
Volume 6 Number 4, April, 2026
p- ISSN 2775-3735- e-ISSN 2775-3727

Agroforestry as a Policy Instrument for Enhancing Sustainability of Public Green Open Spaces: Integrating MSA-ISM

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Keywords:
Urban Agroforestry,Public Green Open Spaces,Integrated MSAISM,Sustainability,Policy Instrument

ABSTRACT

Rapid urban expansion has intensified pressure on public green open spaces and reduced the ecological functions of urban landscapes. Urban agroforestry has increasingly been *recognized* as a relevant nature-based approach, as it reinforces ecological functions, enhances community well-being, and optimizes the multifunctionality of public green open spaces amid urbanization pressures. However, its sustainability and policy implications in limited urban public green spaces remain insufficiently explored. This study aims to develop evidence-based policy priorities for managing limited and spatially fragmented public green open spaces by integrating agroforestry as a core policy component through the combination of *Multi-Aspect Sustainability Analysis* (*MSA*) and *Interpretive Structural Modeling* (*ISM*). The method employed is a combination of *Multi-Aspect Sustainability Analysis* and *Interpretive Structural Modeling* to assess the sustainability of urban agroforestry systems. A sustainability index of 51.84% indicated a moderately sustainable condition, with strong performance in ecological, social, and infrastructure dimensions but weaker outcomes in economic and legal–institutional aspects. Key drivers included consumer dependence on agroforestry products, the availability of Standard Operating Procedures (*SOPs*) for urban agroforestry management, and the economic value of agroforestry products (vegetables, fruits, timber, honey, livestock). The findings highlight the necessity of integrated, adaptive, and evidence-based policies to ensure the long-term sustainability of urban agroforestry systems and enhance the quality of public green open spaces.

INTRODUCTION

Urbanization is a global phenomenon with consequences for changes in landscape structure and degradation of the urban environment (Mukherjee & Bairwa, 2025; Seifollahi-Aghmiuni et al., 2022). Urbanization has also led to significant changes in the structure of urban landscapes and decreased the capacity of ecosystems to provide environmental services (Dobbs, 2011; Haase et al., 2021). Rapid urbanization in Bogor City and land conversion have triggered increased pressure on open space, environmental quality, and urban ecosystem function.

In a situation of limited space, public Green Open Space (RTH) plays an important role as an ecological buffer as well as a social space for the community. Public RTH is a key element in maintaining the balance of urban ecosystems (Fagerholm, 2016). Public RTH contributes to microclimate regulation, carbon sequestration, and biodiversity conservation (Elmqvist et al., 2015; Kabisch et al., 2017).

Limited area and uneven (fragmented) spatial distribution lead to an increase in surface temperature and disruption of the hydrological cycle (Bolund and Hunhammar, 1999; McPhearson et al., 2016). This condition requires a public RTH management policy that emphasizes quality over mere increases in area, with sustainable practices to realize it (Nugroho, 2020). Therefore, there is a need for a more adaptive, productive, and sustainability-oriented management approach.

Agroforestry as a Policy Instrument for Enhancing Sustainability of Public Green Open Spaces: Integrating MSA-ISM is seen as a relevant approach in that context. Urban agroforestry is developing as a nature-based and sustainable approach that integrates ecological, social, and economic functions in one land management system in public RTH (Suryanto, 2018). Agroforestry also contributes to local food security and increases community involvement in environmental management (Arifin et al., 2018; Fremier et al., 2023).

This system combines woody vegetation with agricultural crops or other components in one space and time, increasing land productivity while maintaining ecological functions (Jose, 2009; Nair, 2011; Hairiah et al., 2023). Various studies show that agroforestry contributes to increasing biodiversity, improving soil quality, sequestering carbon, and strengthening the welfare of urban communities by increasing carbon storage capacity (Arifin and Nakagoshi, 2011; Torralba et al., 2016; Gonçalves et al., 2021; Fremier et al., 2023). As a land management system that combines woody plants with agricultural and/or livestock crops in a single unit of space and time, agroforestry presents ecological, economic, and social benefits simultaneously (Huxley, 1999; Miller et al., 2017). The flexibility of planting and management techniques makes agroforestry adaptive for application on limited urban land and in diverse socio-cultural contexts (King and Chandler, 1979).

Bogor City is one of the urban areas with an area of 11,138 hectares and a rapid population growth rate. The area of built land has exceeded 60% of the total area, while the proportion of public RTH successfully managed by the local government is relatively limited at 4.26% of the total area (Bappenda, 2025). Therefore, strengthening ecological functions in limited space is an urgent need in Bogor City, especially with high rainfall, as evidenced by floods and landslides in several locations.

In the condition of limited space in Bogor City, integrating agroforestry into public RTH is seen as a prospective strategy. This integration offers an alternative approach that combines environmental conservation, social empowerment, and community-based economic value enhancement. It not only strengthens ecological functions but also opens opportunities to enhance social and economic values for the surrounding community. Thus, with agroforestry practices, public RTH evolves from a passive green space into a productive, inclusive, and sustainability-oriented space.

The combination of plants in Bogor City public RTH is quite diverse, consisting of plants that make up agroforestry, but it has not been well managed. This is because almost all stakeholders, except academics, do not understand the meaning of agroforestry. As a result, the benefits have not been felt significantly.

To improve the quality of public RTH, a sustainable agroforestry policy strategy is needed that integrates ecological, economic, social, infrastructure-technological dimensions, as well as laws and institutions. However, comprehensive studies assessing multidimensional agroforestry sustainability in the context of urban RTH remain limited. In fact, a multidimensional approach is important for adaptive and implementable policy formulation.

Analysis of sustainability status using the Multi-Aspect Sustainability Analysis (MSA) method and the EXimpro application simultaneously assesses the level of sustainability and identifies the main leverage factors affecting the system (Firmansyah, 2022). Integrating MSA with ISM results in an influence-dependency map and element hierarchical structure as the basis for determining policy priorities. Therefore, the focus of this research is to formulate an agroforestry policy strategy in the public RTH of Bogor City through the determination of priority programs to increase sustainability.

The MSA methodology with EXimpro and ISM applications exhibits complementary rather than redundant analytical characteristics. MSA demonstrates strengths in evaluating dimensions of sustainability status and identifying leverage factors that influence sustainability trajectories; however, MSA does not directly specify policy implementation sequencing or provide explicit guidance regarding intervention staging (Sokolova et al., 2024). In contrast, ISM excels at constructing a hierarchy of policy priorities and specifications of implementation stages; however, ISM requires a solid empirical basis for element selection, which MSA analysis can effectively provide.

The integration of the MSA–ISM approach allows the formulation of public RTH agroforestry policy designs that are evidence-based, adaptive, and implementation-oriented (Sudaryanto, Gandarum, and Puspitasari, 2026). Through this integration, sustainability assessment findings can be systematically translated into policy structures that explicitly consider patterns of inter-element influences, systemic dependencies, and field-level implementation readiness. This integrated approach transforms abstract sustainability assessments into actionable policy guidance tailored to specific institutional contexts and stakeholder configurations.

The urgency of this research stems from several converging factors. First, Bogor City's limited public RTH area (only 723.02 hectares or 6.49% of total area per ATR/BPN Ministerial Regulation Number 14 of 2022, with only 474.5 hectares or 4.26% managed) represents a significant gap between policy targets and implementation. Second, the spatial distribution and quality of public RTH are uneven and fragmented, causing suboptimal ecosystem benefits and environmental degradation. Third, government policies related to sustainability aspects (economic, ecological, social) remain compartmentalized rather than integrated. Fourth, stakeholder roles and influences in agroforestry development remain focused on their respective tasks without adequate coordination. Without evidence-based policy priorities, investments in public RTH management may fail to achieve desired sustainability outcomes.

The novelty of this research lies in three interconnected contributions. First, this study integrates Multi-Aspect Sustainability Analysis (MSA) with Interpretive Structural Modeling (ISM) to transform abstract sustainability assessments into actionable policy guidance tailored to specific institutional contexts. This integration addresses the complementary strengths of each method: MSA excels at evaluating sustainability status and identifying leverage factors, while ISM constructs policy priority hierarchies and implementation staging. Second, this research provides the first comprehensive multidimensional sustainability assessment of urban agroforestry in Indonesian public RTH, evaluating ecological, economic, social, infrastructure-technological, and legal-institutional dimensions simultaneously. Third, this study identifies specific key leverage factors (20 attributes across five dimensions) and maps their structural relationships through influence-dependence quadrant analysis and element hierarchy structures, enabling systematic prioritization of policy interventions.

Based on these conditions, this study fills the scientific gap through the integration of urban agroforestry sustainability analysis with multidimensional and structural approaches in evidence-based policy formulation. This study aims to: (1) evaluate the sustainability status of agroforestry in public green open spaces, (2) identify key leverage factors, and (3) formulate policy priorities through evidence-based MSA and ISM approaches.

METHOD

This research was conducted from July 2025 to October 2025 in the Bogor City Administrative Area. Bogor City consisted of 6 sub-districts and 68 villages. The research focused on public RTH throughout Bogor City, sampling 25 public RTH locations successfully managed by the city government, covering 150.71 ha out of a total of 474.13 ha (Table 1). These consisted of urban forests, urban parks, environmental parks, and road green paths, all with potential for development using an agroforestry approach.

This study used a system-based sustainability analysis approach that integrated Multi-Aspect Sustainability Analysis (MSA) and Interpretive Structural Modeling (ISM). This approach was chosen to gain a comprehensive understanding of the dynamics of agroforestry sustainability in public RTH and to formulate policy priorities supporting sustainable management of public RTH. Conceptually, the research was built on the assumption that successful implementation of agroforestry in public RTH was influenced by the interconnectedness of environmental physical conditions, socio-economic performance, infrastructure and technological support, and the legal-institutional framework.

The integration of these two approaches allowed the study not only to evaluate the sustainability status of agroforestry systems but also to identify structural relationships between influencing factors and to formulate systematic policy priorities. MSA analysis determined the sustainability status and identified main leverage factors affecting the system. These leverage factors were then structurally analyzed using ISM to determine cause-and-effect relationships between elements and to formulate policy priorities systematically. The integration of these research methods is shown in Figure 1.

Table 1. Research Object Typology and Area

No	Type	Width (Ha)
1	Urban forests	36,542323
2	City parks	7,042517
3	Sub-district parks	8,098774
4	Sub-district parks	15,338174
5	Community parks	15,883605
6	Neighborhood parks	11,363327
7	Neighborhood association parks	56,441278

Green belts	150,709998

This study uses two main types of data, namely:

1. Primary data was obtained through field observations, questionnaire surveys, and interviews with stakeholders involved in the management of green open spaces in Bogor City. Observations were carried out to identify vegetation conditions, land use structures, and RTH management practices that have the potential to be developed with an agroforestry approach.
2. Secondary data is obtained from various sources such as local government policy documents, research reports, and spatial data on land use.

The stages of this research include:

1. Multi-Aspect Sustainability Analysis (MSA)The evaluation of agroforestry sustainability in public green open spaces is carried out using Multi-Aspect Sustainability Analysis (MSA) which is operationalized through the EXIMPRO (Expert-based Integrated Multi-criteria Process) tool.
2. Interpretive Structural Modeling (ISM)

Interpretive Structural Modeling (ISM) is a system analysis method used to understand the structural relationships between elements in a complex system. This method allows the preparation of relationships between factors in the form of a hierarchical structure so that it can be known which factors have the greatest influence on the system.

The integration of this research method is shown in the diagram in Figure 1. This diagram shows the integration flow between multidimensional sustainability evaluation and policy structural modeling to formulate agroforestry management strategies in public RTH in Bogor City.

RESULT AND DISCUSSION

Current Condition of Bogor City Public RTH

Public RTH in Bogor City is very limited in area. Referring to the typology regulated in the Ministerial Regulation of ATR/BPN Number 14 of 2022, public RTH in Bogor City has an area of only 723.02 hectares or around 6.49% (Bapperida, 2025) of the total area of Bogor City. However, until now the Bogor City Government has only managed public RTH covering an area of 474.5 hectares or 4.26%, with the wide distribution shown in Figure 2. There is a gap between policy and actual implementation on the ground.

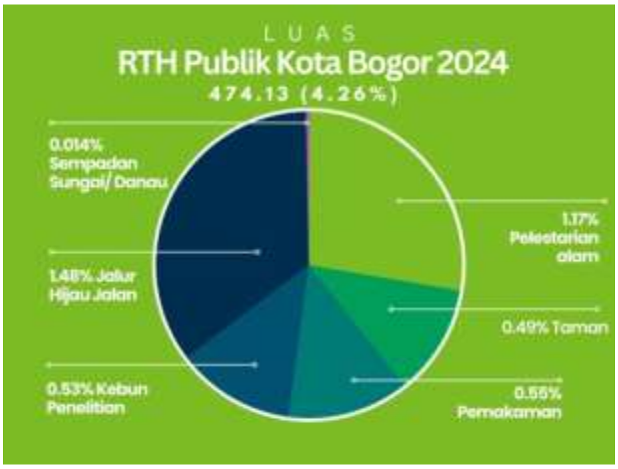

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Table 2. Bogor City Land Cover Area 2025

No	Land Cover Classification	Wide	
		hectares	Presses
1	Bushes	641,32	5,76
2	Plantation	78,62	0,71
3	Built Land	7.499,79	67,33
4	Dryland agriculture	1.029,99	9,25
5	Mixed dryland farming	876,88	7,87
6	Rice Fields	162,84	1,46
7	Open ground	185,26	1,66
8	Water bodies	204,06	1,83
	Total	10.678,75	

Land cover in Bogor City as seen in the map in Figure 3 where the built land cover is increasingly pressuring green land in Bogor City.

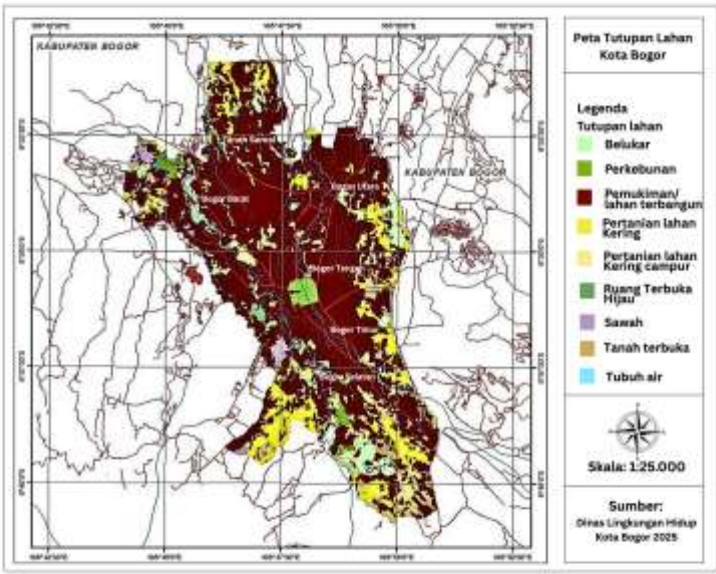

Figure 2. Bogor City Land Cover Map (DLH 2025)

The condition of land pressure built on green land (public RTH) in Bogor City. The map of land use change in Bogor City shows that in a span of 10 years, the pressure on land built up in Bogor City is getting greater (Figure 4). This condition is an even tougher challenge in meeting the needs of public RTH to be able to serve more than one million people in Bogor City.

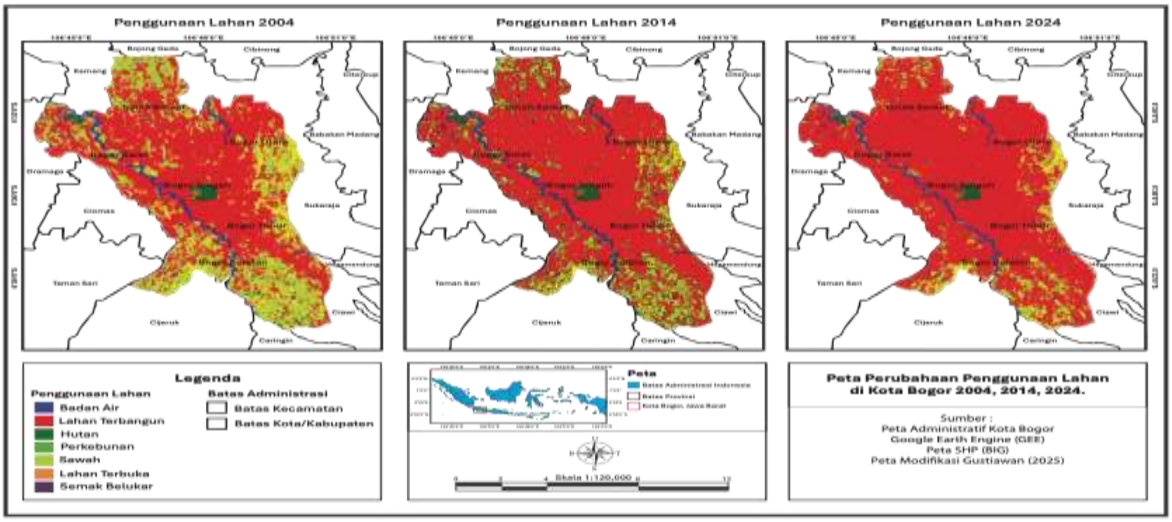

Figure 3. Bogor City Land Cover Map (DLH 2025)

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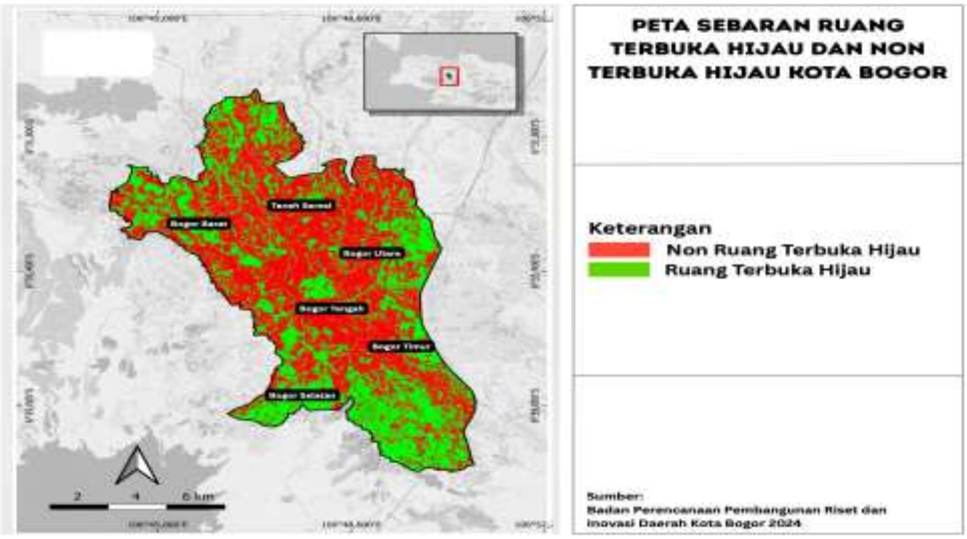


Figure 4. Green Open and Non-Open Space Distribution Map

Agroforestry practices in public RTH in Bogor City have been seen, although they have not been managed systemically and have not been supported by an adequate policy framework. The government's policy focus related to sustainability aspects (economic, seculogical, social) is currently still compartmentalized in their respective focuses, not yet integrated with each other. The role and influence of key stakeholders in the development and management of agroforestry in public RTH is currently identified as still focusing on their respective tasks, there has been no coordination with each other.

Management with agroforestry practices in the public RTH of Bogor City can be seen from the variety of plant types and strata, as well as the combination of constituent components in it. Almost all public RTH in Bogor City currently meet the combined components of agriculture and forestry, and there are more than 4 out of 8 types of agroforestry plants with diverse strata ranging from strata 1-5. The combination of plant types, components and strata that make up agroforestry is shown in the graph in Figures 6 and 7.

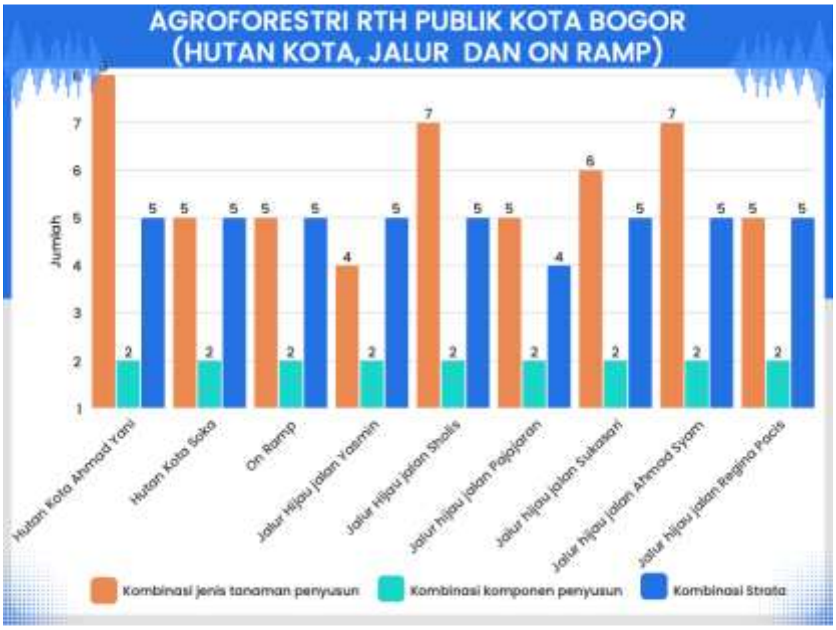
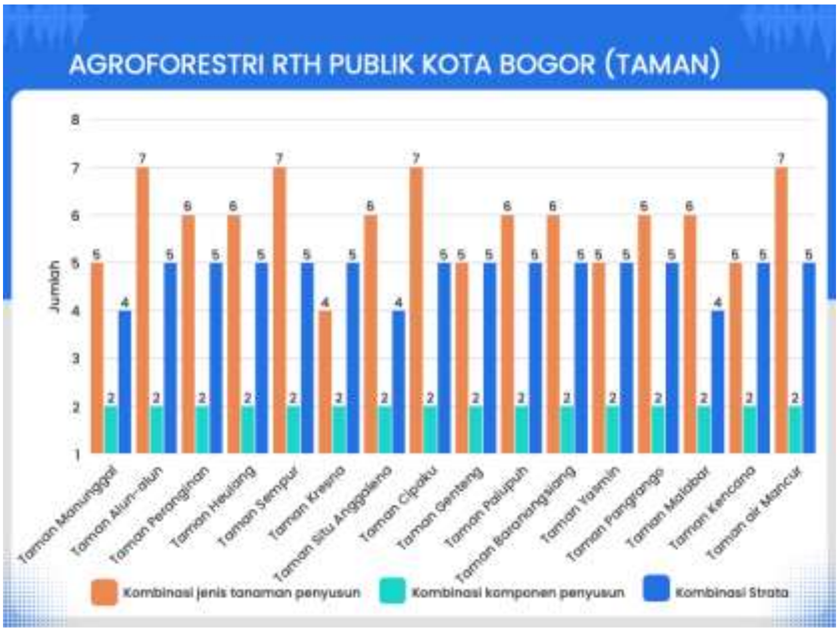


Figure 5. Classification of Agroforestry in Bogor City Public RTH (City Forests, on Ramp and Road Green Paths)



This study assesses the sustainability of agroforestry in the public green open space (RTH) of Bogor City with a focus on ecological, economic, social, infrastructure, and legal aspects. The ecological aspect obtained a score of 66.71%, which is classified as sustainable, with key factors including air temperature, vegetation canopy density, biodiversity, and groundwater pollution. Sensitivity analysis shows that air temperature and biodiversity have a major influence on ecological quality. Groundwater pollution remains a serious threat if not managed in conjunction with vegetation and water quality management.

The economic aspect obtained a score of 26.14%, indicating less sustainable conditions. Low consumer dependence on agroforestry products and lack of market integration limit the economic contribution of agroforestry systems. Improving the marketing system and downstream products can significantly improve economic sustainability. On the social side, this aspect obtained a score of 60.71%, which shows that agroforestry provides benefits in public health, participation, environmental education, and public awareness. However, there is still a need to increase education about agroforestry so that community participation is based on sustainable ecological awareness.

The infrastructure and technology aspects obtained a score of 60.50%, with limited spatial data that hindered the effective planning and management of agroforestry RTH. Finally, the legal and institutional aspects obtained a score of 45.14%, which shows that weak institutions and the absence of special SOPs for agroforestry management are the main obstacles. Institutional strength and adequate legal support are needed to optimize agroforestry systems. The overall sustainability index of 51.84% shows that agroforestry in the Bogor City RTH makes a positive contribution, but there needs to be a balance between ecological, economic, social, and institutional functions to achieve more optimal sustainability.

Key Leverage Factors to Improve Performance

Based on the previous analysis using EKsimpro, there are a number of leverage attributes that need to be considered to increase the sustainability of agroforestry in public green open spaces (RTH) in Bogor City. These leverage factors are identified in each aspect of sustainability and are summarized in Table 4. Factor analysis is used to determine attributes that have a dominant influence on an aspect of sustainability, so that it can be used as a basis for determining the priority of system improvement or intervention. The dominance of an attribute is determined based on its level of sensitivity to changes in sustainability values compared to other attributes in the same aspect. Attributes with higher sensitivity are considered to be the key factors that affect the sustainability performance of the system the most.

The number of leverage factors identified may vary depending on the distribution of sensitivity values of each attribute in that aspect. Some attributes may have similar sensitivity values, and to improve the accuracy of interpretation, uncertainty error analysis and random iteration are used to more accurately determine the difference in influence between attributes. The results of the analysis show that some attributes have higher sensitivity than others, so they can be categorized as the main leverage factors. Therefore, agroforestry management policies in public RTH in Bogor City need to be focused on these attributes, with interventions that are expected to have a significant impact on improving system sustainability.

Table 3. Leverage Factors Between Aspects

Agroforestry RTH Audience

No.	Leverage Factors	Aspects
1	Temperature Udara	Ecology
2	Headline Density	
3	Biodiversity	

4	Groundwater Pollution Around Agroforestry	
5	Managing Tourist Visits in Urban Agroforestry	Economy
6	The level of consumer dependence on agroforestry agricultural products	
7	Agroforestry products (vegetables, fruits, wood, honey, livestock) have economic value	
8	Market Reach	
9	Health	Social
10	Community Participation in Agroforestry Management	
11	Urban Agroforestry Education for the Community	
12	Community Knowledge of RTH and Agroforestry Model	
13	Product quality standardization	Infrastructure and Technology
14	Availability of Produce Processing Industry	
15	Limited spatial data on protected areas and RTH in Bogor City	
16	Condition of irrigation channels	
17	Availability of Operational Standards for Urban Agroforestry Management	Law & Institutions
18	Availability of Agroforestry Management Institutions	
19	Law Enforcement/ Enforcement of Conversions	
20	Marketing Agencies	

Structural Relationship between Leverage Factors and Policy Hierarchy Structure

Table 4. Leverage Factors That Become Policy Recommendations

No.	Leverage Factors	Code
1	Temperature Udara	E1
2	Headline Density	E2
3	Biodiversity	E3
4	Groundwater Pollution Around Agroforestry	E4
5	Management of Tourist Visits in Urban Agroforestry	E5
6	The level of consumer dependence on agroforestry agricultural products	E6
7	Agroforestry products (vegetables, fruits, wood, honey, livestock) have economic value	E7
8	Market Reach	E8
9	Health	E9
10	Community Participation in Agroforestry Management	E10
11	Urban Agroforestry Education for the Community	E11
12	Community Knowledge of RTH and Agroforestry Model	E12
13	Product quality standardization	E13
14	Availability of Produce Processing Industry	E14
15	Limited spatial data on protected areas and RTH in Bogor City	E15
16	Condition of irrigation channels	E16
17	Availability of Operational Standards for Urban Agroforestry Management	E17
18	Availability of Agroforestry Management Institutions	E18
19	Law Enforcement/ Enforcement of Conversions	E19
20	Marketing Agencies	E20

Determination of implementation based on leverage factors is useful in providing agroforestry policy recommendations to public RTH. This is in the form of analyzing the relationship between leverage factors, especially about the ease of implementation in accordance with the condition of natural resources, infrastructure, technology, and community culture. The relationship analysis produced an influence-dependence quadrant matrix, and an element hierarchy structure using the ISM method. The matrix visualizes the capabilities of each of the interdependent elements and their dependence on this agrofrorestri system, while the hierarchy structure diagram shows the stages of its implementation in the field.

The matrix of the power of agroforestry influence and dependence on public RTH in Bogor City is shown in Figure 8.

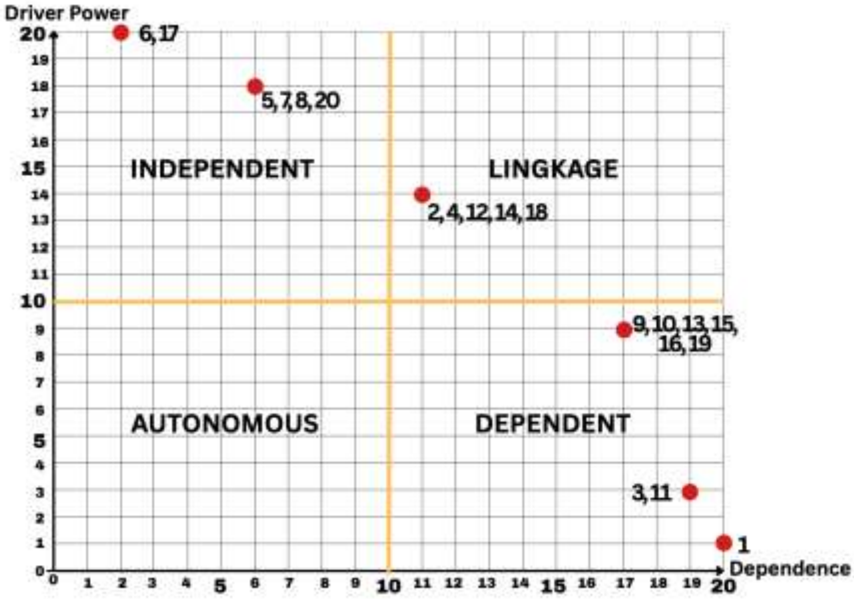


Figure 7. Structural Impact Relationship Matrix of Agroforestry

The sustainability of agroforestry in protected areas and green open spaces (RTH) in Bogor City is divided into three categories: Dependent, Linkage, and Independent. This system measures the strength of influence and dependence of elements in agroforestry sustainability based on coordinate points. The higher the horizontal value (x-axis), the greater the dependence on other elements, while the vertical value (y-axis) shows a greater influence. The Dependent Quadrant includes elements with high dependency and low influence, such as Health, Community Participation, Product Quality Standardization, and several others. These elements should be a priority to implement due to their low dependency.

The Linkage quadrant includes elements with high influence and dependence, such as Crown Density, Groundwater Pollution, and Community Knowledge. These elements have equal influence and dependence, so they require balanced attention. The Independent Quadrant includes elements with high influence and low dependency, such as Tourism Visit Management, Economic Value of Agroforestry Products, and Marketing Institutions. These elements are a key factor and a top priority due to their great influence and low dependency. The implementation hierarchy is determined based on the location of the elements in the quadrant, starting with the Independent quadrant as the top priority, then continuing to the Linkage, Dependent, and Autonomous quadrants.

The results of the hierarchy of each element based on the previous criteria can be reviewed in Figure 9.

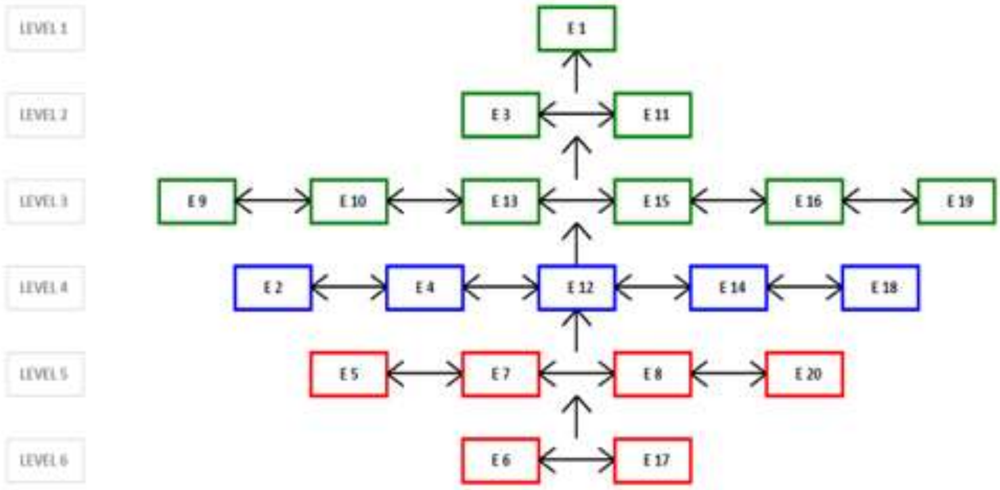


Figure 8. Structural Hierarchy of ISM Elements

The key elements in the public RTH agroforestry system in Bogor City are determined from the relationship of each element that is a problem of sustainability in its implementation. The key elements in question are found at the sixth and fifth levels in Figure 9 of the ISM Element Structural Hierarchy. These key elements need to be prioritized to be improved or improved, thus affecting the performance of each element of this agrofrettri system.

The rest of the elements will be upgraded according to the second (blue) and third (green) priorities. The division of priorities is based on the strength of influence and dependence of each element and is structurally mapped at the level. The higher the level value, the higher the priority of the elements in it.

At level one, it is filled by the elements of the Level of Consumer Dependence on Agroforestry Agricultural Products (E6), and the Availability of Operational Standards for Urban Agroforestry Management (SOP) (E17) are key elements of Urban Agroforestry management efforts. Consumer dependence (E6) reflects the ability of urban communities to depend on agroforestry products, such as vegetables, fruits, honey, and livestock products as sources of food, income, and local ecological connections. Exploratory studies show that urban agriculture significantly reduces people's dependence on food supplies from outside the city or country, while strengthening local food availability and community resilience (Grebitus et al., 2020)

On the other hand, the availability of SOPs (E17) is the technical backbone in urban agroforestry operations. SOPs ensure that every stage from planting, maintenance, to distribution is carried out effectively and efficiently. Research on the development of SOPs in agro-tourism based on integrated agricultural systems confirms that the existence of structured and standardized SOPs is very important to support efficient, organized, and quality activities (Jovanda & Irdana, 2021).

The synergy between E6 and E17 is known when consumer demand for quality agroforestry products triggers the need for adaptive and responsive SOPs. Solid SOPs not only improve product quality and operational efficiency, but also strengthen consumer confidence in the agroforestry system. Conversely, increased consumer demand is driving SOP updates to reflect the quality and sustainability standards the market expects

The next element that needs to be built is the element located at the fifth level, namely Tourist Visit Management in Urban Agroforestry (E5), Agroforestry products have economic value (vegetables, fruits, wood, honey, livestock) (E7), Market Reach (E8), and Marketing Institutions (E20). These four elements can be optimized simultaneously in one integrated intervention scheme simultaneously over a single period. The management of agroforestry tourism visits (E5) can function as a vehicle for education, conservation, and experience-based promotion, thereby simultaneously encouraging ecological and economic added value.

Research by Astarini et al. (2024) on the Batur Geopark shows that the development of agroforestry ecotourism generates significant NPV and IRR, strengthening the sustainability and attractiveness of agroecological tourism. In addition, a study by Widjaja et al. (2021) emphasizes the importance of integrating agroforestry tourism planning with landscape management to increase the social value and economic sustainability of the region. Agroforestry products with economic value (E7) such as vegetables, fruits, honey, wood, and livestock, are the main sources of income for farmers and incentives to maintain agroforestry practices.

In a study by Ine Tiga et al. (2024), the contribution of agroforestry to household income reached 98.74% in Ende, showing the central role of agroforestry products in local economic development. The same thing was emphasized by Mardhia et al. (2022) that the processing of agroforestry products such as honey and local medicinal plants provides high added value if supported by appropriate training and SOPs. Market Reach (E8) is a key factor in distributing agroforestry products to the regional markets of Bogor City and Bogor Regency, West Java Province, as well as nationally. According to Ulya et al. (2023), strengthening distribution networks and cooperative-based business schemes greatly determines the success of agroforestry coffee marketing in Sumatra and Java. In addition, research by Kurniawan and Marhaeni (2020) shows that the use of digital technology and collaboration between farmers can significantly expand market access for agroforestry products. Meanwhile, Marketing Institutions (E20) have a role as a bridge between producers and consumers.

A study by Wibowo et al. (2021) stated that strengthening institutions such as cooperatives and farmer groups is very important to encourage price transparency and distribution efficiency. A global study from Samaniego et al. (2022) also shows that the existence of inclusive and community-based marketing institutions supports forest bioeconomics and agroforestry systems that are adaptive to climate change and markets. The elements at the fourth level are Crown Density (E2), Groundwater Pollution Around Agroforestry (E4), Community Knowledge of Protected Forests and Agroforestry Models (E12), Availability of Yield Processing Industries (E14), Availability of Agroforestry Management Institutions (E18). These five elements can be implemented after completing the elements in the previous level.

These five elements have high influence and dependency capabilities, so they have high sensitivity, and instability when applied. The density of the canopy (E2) represents vegetation conditions that affect the microclimate, soil stability, and biodiversity. Research in Bogor City reported that vegetation density (% NDVI) is strongly correlated with carbon stocks and tree diversity in community agroforestry (Hartoyo et al., 2025). Wiley et al (2022) add that optimal shade crowning improves soil fertility and water retention. Groundwater pollution (E4) is an environmental indicator that is vulnerable to being affected by agroforestry practices if not managed. Agroforestry can minimize erosion and runoff through organic absorption and natural filtration thereby improving water quality (Propagate AG, 2025).

Forest vegetation of agroforestry systems helps reduce sedimentation and increase groundwater infiltration (Castle et al., 2022). Public knowledge (E12) about public RTH and agroforestry models is the key to participation and sustainability. Agroforestry models based on local knowledge show significant contributions to community well-being and conservation (Dako et al., 2024). Research in North Luwu also highlights that social capital in the form of networking, trust, and the value of togetherness will have a major influence on the adoption of agroforestry practices and food security (Yusriadi, 2025). Furthermore, the yield processing industry (E14) has a role in increasing the added value of agroforestry products. Efforts to diversify products such as honey, processed wood, and herbs are very potential if supported by the local processing industry (Mardhia et al., 2022). Integrated agroforestry practices according to agent-based simulations in Indonesia show that post-harvest processing capabilities strengthen economic and environmental outcomes (Noldeke et al., 2021).

Finally, the Agroforestry Management Institute (E18) serves as a liaison between the community and policy, functioning as a facilitator, provider of SOPs, education, and access to institutional resources. Landscape-based governance that integrates conservation and agricultural actors has proven effective in the context of restoration and community participation (Zinngrebe et al., 2020). A social study of community forestry in Lampung shows that management institutions strengthen land ownership, practice supervision, and economic outcomes (Putraditama, 2021). The elements located at the third level are Health (E9), Community Participation in Agroforestry Management (E10), Product Quality Standardization (E13), Limited Spatial Data of Public RTH in Bogor City (E15), Irrigation Channel Conditions (E16), and Law Enforcement/Implementation of Conversion (E19). These six elements have an important role in sustainable agroforestry management.

Health (E9) is closely related to environmental quality and access to food produced by agroforestry systems. Degraded environments and low food availability can directly affect public health, especially in urban areas with limited green open space such as Bogor City (Dawson et al., 2022; Li et al., 2021). In addition, community participation in agroforestry management (E10) occurs as a result of educational encouragement, the dissemination of local knowledge, and the existence of management institutions that facilitate the process.

Increasing environmental literacy for the community has been proven to encourage active community involvement in conservation and agroecological practices (Rahman et al., 2023; Nugroho, 2020). Furthermore, the standardization of agroforestry product quality (E13) is highly dependent on the existence of standard operating procedures (SOPs), the agricultural product processing industry, and connections with the market that can guarantee product added value. Non-conformance of standards is often a major obstacle in integrating agroforestry products into formal market chains (Sari et al., 2021; Putri & Abdullah, 2023).

The limitation of public RTH spatial data in Bogor City (E15) is a major challenge in evidence-based policy planning, because decision-making without accurate geospatial data can cause land use conflicts (Susilowati et al., 2020; Pratama et al., 2022). The condition of irrigation channels (E16) also plays an important role because this physical system is the infrastructure that supports production sustainability in agroforestry. The existence and quality of irrigation have an effect on water utilization efficiency and plant resilience to climate change (Fitriani et al., 2021; Handoko & Widiastuti, 2023). Finally, law enforcement and the implementation of land conversion (E19), especially the conversion of public RTH into other functions, is a form of regulation that is not only influenced by the availability of data, but also by the active participation of the community and the transparency of government institutions. Without strong law enforcement, land degradation and tenure conflicts are increasing (Yuliana et al., 2022; Widodo et al., 2021).

At the second level, two main problems were found, namely biodiversity (E3) and urban agroforestry education for the community (E11). Biodiversity is an indicator of the ecological success of agroforestry systems, because the presence of various species of flora and fauna indicates ecosystem stability and resistance to external disturbances such as climate change and pests. Agroforestry designed with species diversity (E3) in mind is able to create microhabitats, increase nutrient cycles, and support other ecosystem services (Jose et al., 2020). The decline in biodiversity in urban areas such as Bogor City shows ecological pressure due to land conversion and the lack of multistrata vegetation that supports ecosystems (Widodo & Subrata, 2022). Meanwhile, agroforestry education to the community (E11) is an important aspect in social capacity building and institutional strengthening. Proper education can encourage active participation of residents in agroforestry management, increase environmental awareness, and strengthen the sustainability of the system from a socio-ecological perspective (Mulyani et al., 2023).

The dissemination of knowledge and direct community involvement in agroforestry activities will strengthen collaboration between communities, governments, and the private sector in managing food-based green spaces and conservation (Santosa & Fitri, 2021). On the other hand, the last level contains the element of air temperature (E1) as an indicator of the final impact of the ecological system formed through vegetation, biodiversity, and urban spatial planning around the location of agroforestry. The decrease in local air temperature is one of the real benefits of the existence of agroforestry through the cooling effect of vegetation and increased evapotranspiration. Multistrata vegetative systems built in agroforestry have been shown to be able to reduce the urban heat island effect (Rahmawati et al., 2021) and increase temperature comfort (Lee & Kim, 2020).

CONCLUSION

The study revealed that agroforestry sustainability in Bogor City's public RTH is not solely determined by ecological performance but is significantly hindered by weak integration of economic and legal-institutional aspects, underscoring the need for a systemic shift from sectoral to holistic management that simultaneously addresses ecological, social, economic, and governance dimensions. This gradual, integrated approach can elevate agroforestry from a passive ecological role to a strategic tool for inclusive, adaptive, and long-term urban development. Key recommendations for the Bogor City government include developing a special SOP for urban agroforestry to guide production-based RTH management, establishing dedicated agroforestry management units to strengthen local institutions, fostering markets and product downstreaming via partnerships with MSMEs, cooperatives, and tourism, enhancing community capacity through urban agroforestry training, and bolstering GIS-based spatial databases for public RTH. For future research, longitudinal studies could track the long-term impacts of these interventions on sustainability metrics and urban resilience in other Indonesian cities facing similar RTH constraints.

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