

SYSTEM DYNAMICS MODELING OF SUSTAINABLE ECOTOURISM: A TRIPLE BOTTOM LINE SCENARIO ANALYSIS IN WONOSANTRI, INDONESIA

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Abstract

Background: Ecotourism is a form of natural resource utilization that is oriented towards sustainability. Therefore, its management must take into account environmental, social, and economic aspects in a balanced manner.

Purpose: This study aims to identify the dynamics of ecotourism conditions in the 2030 projection and formulate the best development scenario.

Design/methodology/approach: The data used in this study are primary data obtained from in-depth interviews with key informants and secondary data from internal sources, BPS data, and supporting literature. This study uses a dynamic system analysis method that includes variable identification, the creation of a Cause Loop Diagram (CLD), a Stock and Flow Diagram (SFD), and the determination of the best scenario to recommend.

Finding/Result: The findings indicate that the absence of targeted interventions has caused visitor numbers and revenue to stagnate or decline. With the recommendations of the Environmental and Governance Improvement Scenario, a 162% increase in tourist numbers was recorded in the high scenario. This increase in tourist numbers was followed by an even higher increase in revenue, which reached 178.6%.

Conclusion: These findings indicate that the development of dynamic system scenarios is crucial for maintaining the sustainability of ecotourism from economic, social, institutional, and environmental dimensions, with the Environmental Improvement and Governance Scenario being the most effective scenario in improving the overall performance of the ecotourism system.

Originality/value (State of the art): This study provides an overview of the application of the triple bottom line concept in dynamic ecotourism system modeling. Its originality lies in its ability to model real conditions based on existing data. The findings regarding recommendations for the best management scenarios for ecotourism provide practical contributions that are applicable and can be directly implemented by managers in strategic decision-making.

Keywords: ecotourism, dynamic systems, triple bottom line, governance scenario, development scenario

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INTRODUCTION

The tourism sector supports economic growth by creating jobs for the community (Fadilla, 2024) and contributes to the Gross Domestic Product (Roman and Prus, 2020). According to data from the Badan Pusat Statistik (2025), Indonesian tourism experienced fluctuations between 2019 and 2024, with a contribution of 4.97% and foreign exchange earnings of US\$16.9 million in 2019, declining to a contribution of 4% and foreign exchange earnings of US\$16.7 million with 1.021 billion visitors in 2024. However, many tourism sector developments only focus on economic improvement without considering the existing environmental impacts, such as the potential for environmental degradation due to the number of tourists (Ardhiatma, 2025).

Ecotourism is a form of tourism development that focuses on sustainability by empowering local communities, preserving the environment, and improving economic welfare (Candra & Djunaid, 2025). Ecotourism integrates tourism activities with environmental conservation efforts, where the income generated is reinvested in environmental preservation and improvement (Herman & Supriadi, 2017). The main characteristic of ecotourism is the involvement of local communities as parties who directly implement and utilize it. Malang Regency is one of the regions that has ecotourism supported by natural conditions and the involvement of local communities in its activities. Wonosatri Ecotourism is an example of ecotourism in Malang Regency that has potential as a tourist destination. Wonosatri Ecotourism holds potential for development based on local resources, particularly coffee, which is managed by the Wonosatri Forest Farmers' Group (KTH) in Toyomarto Village. The Arabica and Robusta coffee produced is of high quality and forms part of ecotourism educational activities, while also being supported by a marketing partnership with Kopi Lemar (Lembah Arjuna), which expands access to the market in Malang.

Wonosatri Ecotourism faces several challenges amid increasingly fierce competition among destinations. The first problem is the weak promotional strategy in terms of reach, media used, and consistency in posting, which affects the number of tourists and product sales. On a year-on-year comparison of January-August 2025 with 2024, coffee sales only increased at the beginning of the year, but since March, they have experienced a

significant decrease of more than 80%. This trend is thought to be related to fluctuations in the number of tourists, where a decrease in visits directly impacts declining coffee sales revenue. In terms of month-to-month percentages, revenue experiences sharp fluctuations throughout the year, with the deepest decrease reaching 83% and the highest increase reaching approximately 279% in certain periods. On the environmental side, the degradation of tourist areas due to visitor activity reduces their attractiveness, which has an impact on the instability of the income received. From an institutional perspective, tourism management is still cultural in nature and there is no professional management system in place, with low member involvement in management because the majority of managers have other main occupations (Nasution & Syahputra, 2024).

Although several studies have discussed the application of the Triple Bottom Line concept in tourism development, research specifically addressing ecotourism in Indonesia is still very limited. Some studies have focused on agrotourism development and only discussed influencing factors; however, none have yet used dynamic system analysis and simulation in ecotourism analysis. Harahab et al. (2020) and Ismail et al. (2022), examined ecotourism with a focus on economic development and resilience, yet neither employed dynamic systems as an analytical tool. Meanwhile, Mawengkang (2020) and Putu et al. (2024) examined tourism development using dynamic systems but without a focus on triple bottom line-based ecotourism.

This study adopts the Triple Bottom Line theory as the conceptual basis for addressing ecotourism issues. Pranicevic and Peterlin (2015) desktop research and secondary data were used in the study. Findings – Case study's results indicate the means, such as e-mail services, webpage interactive capabilities, Facebook as social networking site and printed media that are mostly used communication tools. "Personal touch" is an emphasized code that was stated as the reason why web communication is most often directed to email or phone call communication. Blogs as social media equivalent of personal web pages are used as a trend tracking tool. YouTube channel as content community media is scarcely used, with intention to be used more for presenting in-situ accommodation and surroundings. There is a lack of resources (financial and human explained that the Triple Bottom Line (TBL)

concept integrates economic, social, and environmental dimensions as pillars of sustainability. These aspects are interrelated, with changes in one dimension affecting the other dimensions. The authors argue that this concept is relevant as a conceptual basis for ecotourism development, as it reconciles the interests of the community and managers with environmental stewardship to improve economic outcomes.

This study aims to analyze the development of ecotourism based on the Triple Bottom Line principle by identifying interrelated factors in ecotourism development. These factors were used as the basis for formulating a dynamic model and simulating various policies. Simulations were used to determine the best alternative scenarios. The results of this study are expected to provide a basis for formulating more effective ecotourism management policies.

METHODS

This study was conducted at Wonosantri Ecotourism, Malang Regency, East Java, employing a mixed-methods approach with a descriptive design to characterize relationships based on empirical data to address the research question regarding the selection of the optimal scenario for ecotourism development (Syahrizal & Jailani, 2023). The data were obtained from key informants, namely, ecotourism managers. Key informants serve as core sources of information, considering that the information they provide is valid for the research object (Pamungkas et al. 2021).

This study involved a single respondent as a key informant, selected through purposive sampling based on their active role, relevance, and ability to provide information that aligned with the study's objectives. The findings were supported by secondary data that were accessible and validated through in-depth interviews with the informant. The informant is a manager and one of the founders of Wonosantri Ecotourism, possessing a deep understanding of tourism activities and coffee management. The questions provided contain qualitative indicators that cannot be obtained from the ecotourism database. Annual data were obtained from secondary data of the 2022-2025 ecotourism annual

report and data from the BPS of Malang Regency. The research stages were carried out by identifying existing problems and determining the key variables used based on literature and in-depth interviews in the field.

The data analysis method employed in this study was system dynamics. A dynamic system is a system analysis method characterized by the interrelationships between various variables and the existence of a time delay effect in the change process (Widayanti et al. 2025). These variables were analyzed for cause-and-effect relationships using Causal Loop Diagrams based on literature and field data. The CLD was then translated into a quantitative model in the form of a Stock and Flow Diagram (SFD) that explains the accumulation (stock) and rate of change (flow) of each main variable. Next, various policy scenarios were simulated to analyze the impact of interventions on the sustainability of the system, with the simulation results used as a basis for formulating policy recommendations for ecotourism development that is economically, socially, and environmentally balanced. The policy scenarios in this study include institutional strengthening and promotion, environmental and governance improvements, and land and institutional expansion. These scenarios were selected because they represent the environmental, social, and economic aspects of the triple bottom line approach and are based on the conditions and challenges facing Wonosantri Ecotourism. The analysis method used is descriptive analysis, which provides a detailed description using a dynamic system approach to simulate systems with complex interactions in a cause-and-effect model using the Vensim application.

Figure 1 shows the research framework for understanding the potential for ecotourism development to improve the local economy. However, several challenges, such as insufficient promotion and potential land degradation, affect visitor and income fluctuations. Dynamic system modeling covers three things: the creation of a Causal Loop Diagram (CLD), a Stock and Flow Diagram (SFD), and the creation of time-based simulations based on assumptions to provide a realistic picture of the impact of interactions between variables (Hamzah et al. 2025).

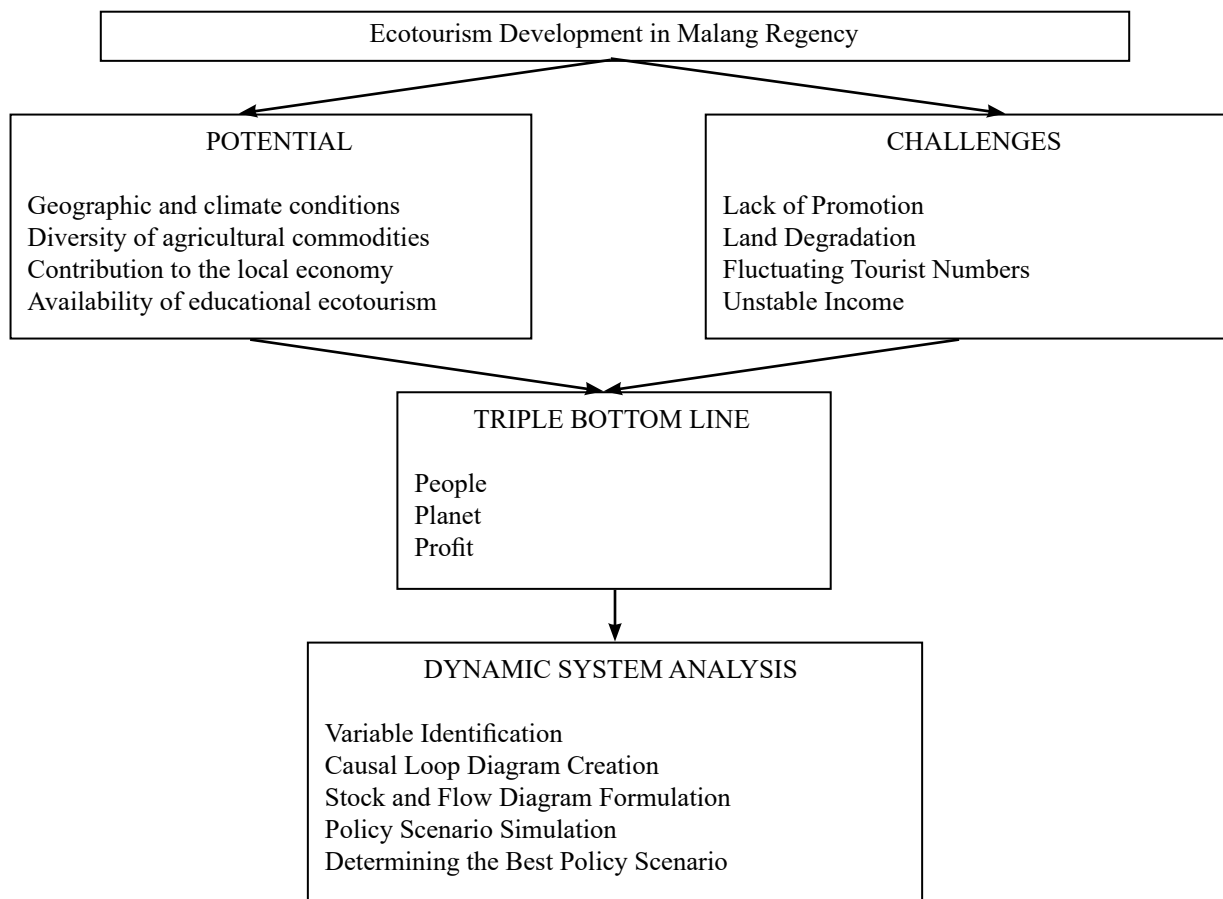


Figure 1. Research framework of ecotourism development

RESULTS

Dynamic system modeling in ecotourism development focuses on the Triple Bottom Line concept (People, Planet, and Profit). Variable selection was based on theory and field conditions. The variables included external factors such as rainy days and holidays, as well as internal factors such as promotion, policy, institutional involvement, wages, operational costs, labor, production, land area, environmental damage, and environmental improvement. The ultimate goal is to examine their collective effects on tourist numbers and ecotourism revenue.

Causal Loop Diagram (CLD) Model for Ecotourism Development

Causal Loop Diagram (CLD) is a qualitative tool in dynamic systems and is used to map the cause and effect structure between variables (Apsari et al. 2023;

Arini et al. 2024). R.Toubes et al. (2020), stated that rainy days can cause a decline in the number of tourists. On the other hand, Zhang et al. (2016) and Fazrina (2017) explained that leave and holiday policies are factors contributing to the surge in tourist travel and affect revenue in the tourism sector. In terms of the environment, Aguilar Calderón et al. (2025) and Njoya et al. (2022) demonstrate that land area affects the number of tourists, which could potentially affect labor wages due to increased demand for tourism workers. Alkamalia et al. (2017) and Han et al. (2024), explain that land area is related to land degradation and can affect productivity and ecosystem function, reduce environmental quality, and trigger land conversion. From a social and institutional perspective, Khan et al. (2020) and Kimmell et al. (2023) explain that strong institutional capacity to support sustainable ecotourism encourages environmental improvement through conservation and land restoration activities, which can positively influence tourist numbers.

A balancing loop is a feedback mechanism that stabilizes the system by holding back or reducing changes to maintain a balanced state. In Figure 2, there are two balancing loops, namely Balancing 1 (B1), which includes (+) wages (+) operational costs (-) agrotourism income (-) wages. Balancing 2 (B2) includes (+) number of workers (+) wages (+) operational costs (-) ecotourism income (-) number of workers. A reinforcing loop is feedback that reinforces changes in a system so that a variable can continue to increase or decrease continuously. Reinforcing 1 (R1) includes (+) land area (+) ecotourism production (+) ecotourism income (+) land area. This figure also has three reinforcing loops, such as Reinforcing 2 (R2), which includes the number of workers (+), ecotourism production (+), ecotourism income (+), and number of workers (+). Reinforcing 3 (R3) includes (+) environmental improvement, (-) environmental damage, (-) land area, (+) number of tourists, (+) ecotourism income, and (+) environmental improvement.

Stock and Flow Diagram (SFD) Model for Ecotourism Development

The Stock and Flow Diagram (SFD), known as the “Forrester Diagram,” is an advanced stage in the modeling process that quantitatively describes dynamic systems (Baez et al. 2023). A Stock Flow Diagram (SFD) is an advanced stage in system dynamics analysis, which is carried out by compiling stock flow diagrams and currents to illustrate the relationships between variables in the system (Schoenenberger et al. 2021). Figure 3 shows a stock and flow diagram of the research model in ecotourism with three main stocks, namely land area, number of tourists, and income, which are influenced by supporting variables. As derived from Figure 3, the variables were classified into three distinct aspects: social-institutional, environmental, and economic.

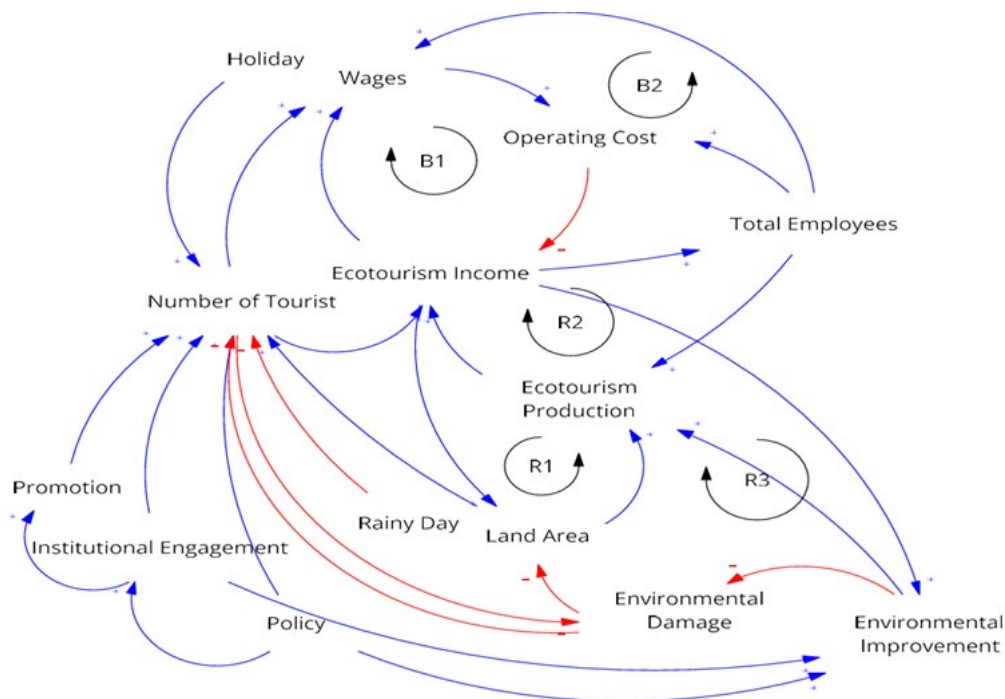


Figure 2. Causal loop diagram model of ecotourism development

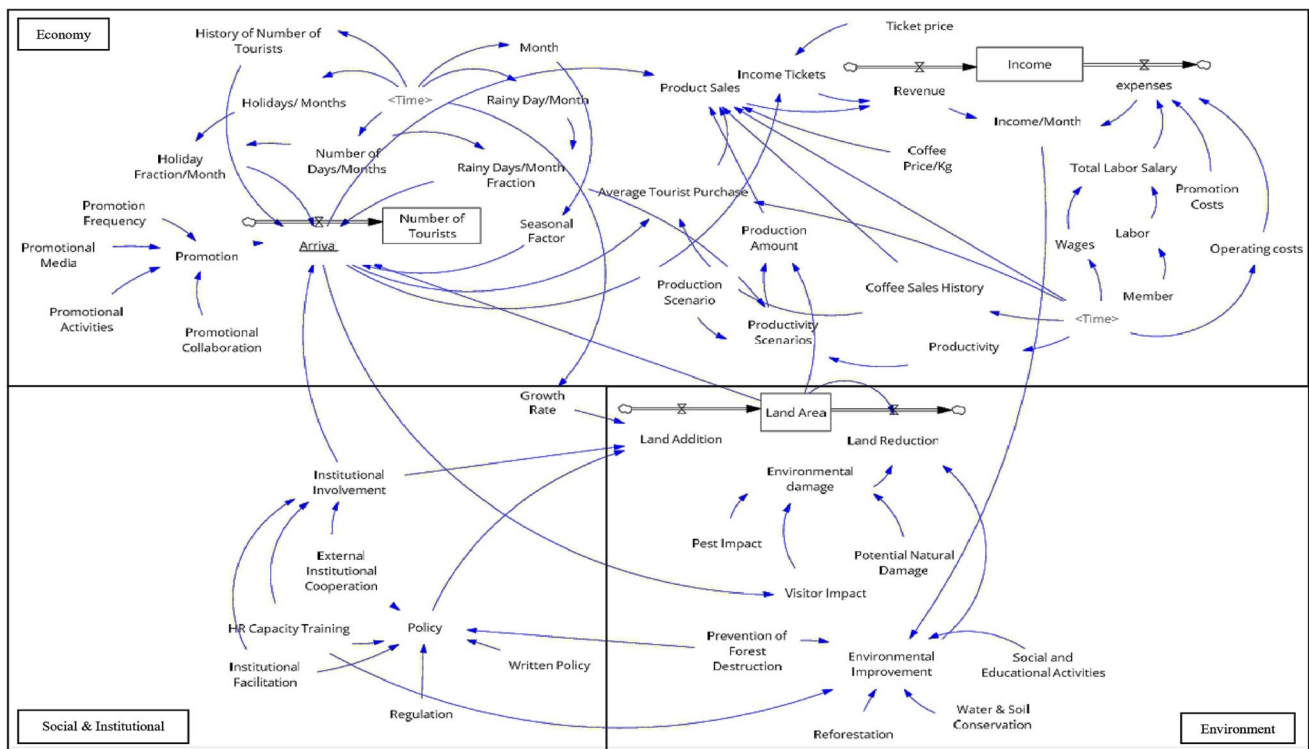


Figure 3. Stock and flow diagram model of ecotourism development

Based on Table 1 and the Stock Flow Diagram, policy support and strong institutional capacity strengthen the structure and function of tourism management, which affects the land area and tourist numbers, thereby promoting stability and sustainability in tourism development. In terms of social and institutional aspects, institutional capacity is influenced by institutional cooperation, training, and facilitation, which play a role in formulating and implementing policies consisting of policy recognition and policy. In the formation of social and institutional sub-models, institutional capacity is influenced by training and facilitation that supports policy formulation and implementation (Lucrezi et al. 2019).

Based on Table 2 and the Stock Flow Diagram, the variables that are expected to influence visitor numbers include production volume, land area, holidays, rainfall, environmental improvements, and damage, which encourage an increase in tourists and affect income (Chang et al. 2024; Wang et al. 2024; safeguards the ecosystem, and enhances risk resilience. However, existing TEA research has shortcomings regarding methodology and research scales. This study constructed a TEA index system to address these deficiencies. The index system comprises two subsystems, tourism industry adaptation (TIA Zulvianti, et al. 2022). Income

variables can be influenced by the number of workers, wages, operational costs, and production volume, which considers environmental impacts because it affects the amount of land used (Jin et al. 2022).

Based on Table 3 and the Stock Flow Diagram, in terms of the environment, land area is a stock variable that is influenced by environmental damage and restoration, institutional capacity, and policies implemented (Foster and Bell-James 2024). Inflows, such as increased tourist visits, can boost ecotourism revenue, but they also impact environmental quality due to increased land-use intensity (Ndhlovu and Dube 2024; Fernandes 2020). Environmental improvement efforts can restore ecosystems and increase tourist appeal (Torsney and Buckley, 2025).

Model Validation (Behavioral Testing)

Behavioral testing of the model was conducted to ensure that the dynamic system model produced logical trends and output patterns consistent with real phenomena. Model validation was performed using the Mean Absolute Percentage Error (MAPE) as an indicator of the error rate between the simulation results and actual data.

Table 1. Variables in the social institutional aspect of ecotourism development

Variables	Name	Reference	Unit	Description
Auxiliary	Policy	Juvitasari et al. (2025)	Indeks	Regulations that support development
	Institutional Facilitation		Activities	Number of activities carried out by institutions
	Regulations		Regulation	Number of regulations implemented
	Written Policy	Sulmiah et al. (2024)	Indeks	Number of official recognitions from authorities regarding KTH
	Social Education Activities		Activities	Number of community awareness activities on the importance of conservation
	Institutional Engagement		Indeks	Level of participation of external institutions
	External Cooperation		Indeks	Number of partnerships
HR Capacity Building Training	Activities	Number of activities to improve the skills and knowledge of KTH managers and members		
External Factors	Rainy Days	Irawan et al. (2021)	Day	Number of rainy days each month
	Holidays	R.-Toubes et al. (2020)	Day	Number of public holidays

Table 2. Variables in the economic aspect of ecotourism development

Variables	Name	Reference	Unit	Description	
Stock	Number of Tourists	Bicer & Gunawan (2018)	Person	Number of tourists visiting	
Flow	Ecotourism Revenue	Widayanti et al. (2025)	Rupiah	Total net eco-tourism revenue	
	Arrivals		Person	Number of tourists arriving	
	Income		Rupiah	Total money received	
Auxiliary	Expenses	Mulyana & Muslih (2020)	Rupiah	Total money spent on eco-tourism	
	Labor		Person	Number of workers involved	
	Operating Costs		Rupiah	Total expenditure on eco-tourism	
	Wages		Rupiah	Remuneration received by workers	
	Coffee Prices		Rupiah	Average selling price of coffee	
	Product Sales		Kg	Total coffee products sales	
	Ecotourism Production		Ayu et al. (2021)	Kg	Total production from ecotourism activities
	Productivity		Irawan et al. (2021)	Kg/Ha	Level of production efficiency compared to the area of land used
	Tourist Purchases			Kg/Person	Average tourist expenditure
	Ticket Prices			Rupiah	Entrance fees set for tourists
	Promotion	Indeks		Accumulation of efforts to introduce tourism	
	Promotional Cooperation	Irawan et al. (2021)	Indeks	Number of collaborations in promotional	
	Promotional Media		Media	Number of communication channels used	
	Promotional Frequency		Indeks	Level of promotional activity intensity	

The results of the model validation test showed that all variables were valid because they had a MAPE value of less than 10% (Zhang et al. 2025)(Table 4). In this test, key variables such as the Number of Tourists, Land Area, and Revenue are observed during the simulation period, and the resulting patterns are compared with relevant historical data or theory.

Business as Usual Projection for 2030

In the 2030 projection, the model was simulated to predict possible scenarios for that year based on the available historical data. In this simulation, no policy interventions were applied because the projection was based solely on the observed historical data. The results of this simulation are predictive and represent potential scenarios rather than certainties. Business as Usual (BAU) conditions indicate that the number of tourists is

at a relatively stable level, which is approximately 100 people per period, reflecting ecotourism management conditions without intervention (Table 5). With this number of visits, tourism activities are operating at a limited capacity and have not shown significant improvement. The BAU condition shows that the land used is approximately 63.4 hectares (Table 5). The area of this land is relatively constant and has not undergone significant changes; therefore, the carrying capacity of tourists and ecotourism activities still depends on existing conditions. Suboptimal land use has the potential to limit the increase in the number of visits and economic activities that can be generated (Sipahutar, 2024). Ecotourism revenue under BAU conditions is recorded at IDR16,755,960 (Table 5). This value reflects the economic contribution generated by the current level of visits and land use.

Table 3. Variables in the environmental aspect of ecotourism development

Variables	Name	Reference	Unit	Description
Stock	Land Area	Ayu et al. (2021)	Ha	Total area of land used for activities
Flow	Land Addition		Ha	Amount of productive land
	Land Reduction		Ha	Amount of degraded land
Auxiliary	Expenditures		Rupiah	Total money spent on ecotourism
	Impact of Pests		Indeks	Amount of impact from organism attacks
	Impact of Visitors		Indeks	Impact of tourist activities on the environment
	Forest Protection Activities		Activities	Amount of monitoring and prevention activities for environmental damage
	Environmental Damage	Darmawan et al. (2016)	Indeks	Accumulation of disturbance levels due to human or natural activities
	Environmental Improvement	Dahu et al. (2021)	Activities	Number of forest rehabilitation and restoration efforts
	Potential Natural Damage		Indeks	Number of environmental damage risks that may occur due to external factors
Water & Soil Conservation	Water & Soil Conservation		Activities	Number of activities to maintain the quality and availability of water and soil resources
	Reforestation		Trees	Number of tree replantings
	Prevention of Forest Damage		Activities	Number of anticipatory activities to avoid forest damage

Table 4. Behavior model test of dynamic system

Stock	Value	%
Land	2.544	2.5
Revenue	9.615	9.6
Number of Visitors	0.09	0.09

Table 5. Business as usual condition of ecotourism

Condition	Business as Usual
Number of Tourism (People)	100
Land Area (Ha)	63.4
Income (IDR)	16,755,960

Simulation of Intervention in the 2030 Projection

Simulations of interventions in the 2030 projection were conducted to analyze the extent to which the designed management policies or strategies could influence the key variables in the ecotourism system. The form and magnitude of the interventions were determined based on assumptions that represented actual conditions with previously identified variables. Intervention levels of 10% and 20% were used to represent moderate and high policy scenarios, respectively. These values were determined as reasonable assumptions to explore the sensitivity of the system to different levels of intervention (Suryani et al. 2021). Quantitative variables were increased by adding numbers according to the intervention percentage. Increased institutional involvement was achieved by providing training to managers and strengthening external cooperation. Policy improvements were made by creating and implementing new policies that were not previously in place and were appropriate to the conditions. Promotion was improved by adding social media, increasing the frequency of promotions, and collaborating with external parties.

In the Institutional Strengthening and Promotion Scenario, the number of tourists increased by 116% at the low-intervention level and rose to 157% at the high-intervention level (Table 6). Along with this increase, revenue also rose significantly, by 123.8% in the low scenario and 180.8% in the high scenario. However, the land area in this scenario did not change significantly,

showing only a very small decrease of approximately 0.3%, so that the increase in performance was more influenced by non-land factors. Graph of scenario results for land area variables in Figure 4.

In the Environmental and Governance Improvement Scenario, the number of tourists increased by 120.0% in the low scenario and 162% in the high scenario (Table 7). This increase in tourist numbers was followed by a higher increase in revenue compared to the Institutional Strengthening and Promotion Scenario, namely, 241.8% in the low scenario and 178.6% in the high scenario. The land area in this scenario is relatively stable with a very small increase of approximately 1.4%; therefore, it can be concluded that the increase in revenue is mainly driven by improvements in environmental quality and the strengthening of policies and institutions. Graph of scenario results for number of tourism variables in Figure 5.

The Land and Institution Addition Scenario, which involves intervention in the form of land expansion, shows an increase in land area of 9.3% compared to business-as-usual conditions (Table 8). This increase in land capacity drives a 137% increase in the number of tourists in the low scenario and a 149% increase in the high scenario, respectively. Revenue in this scenario also experiences a significant increase, namely, 203.8% in the low scenario and 222% in the high scenario. These findings indicate that the addition of land area increases the tourist carrying capacity. Graph of scenario results for income variables in Figure 6.

Table 6. Institutional strengthening and promotion scenario result of dynamic system

Scenario	Variable	Intervention	Year	Number of Tourists (People)	Land Area (Ha)	Revenue (IDR)
Institutional Strengthening and Promotion Scenario (A)	Involvement of institutions, policies, workforce, promotion	10%	2026	175	63.4	27,287,068
			2027	195	63.4	32,212,783
			2028	216	63.3	37,394,828
			2029	237	63.2	42,683,703
			2030	258	63.1	47,937,275
			Average	216	63.2	37,503,131
			2026	209	63.3	34,919,236
		20%	2027	232	63.2	40,776,119
			2028	257	63.2	46,935,632
			2029	282	63.1	53,219,725
			2030	307	63.0	59,458,608
			Average	257	63.2	47,061,863

Table 7. Environmental improvement and governance scenario result of dynamic system

Scenario	Variable	Intervention	Year	Number of Tourists (People)	Land Area (Ha)	Revenue (IDR)
Environmental Improvement and Governance Scenario (B)	Environmental improvements, policies, institutional involvement, promotion	10%	2026	178	64.5	36,290,149
			2027	198	64.4	41,300,515
			2028	219	64.4	46,571,616
			2029	241	64.3	51,951,391
			2030	262	64.2	57,295,241
			Average	220	64.3	57,268,218
			2026	213	64.5	44,897,926
		20%	2027	237	64.4	50,864,623
			2028	262	64.3	57,139,616
			2029	287	64.3	63,541,541
			2030	313	64.2	69,897,383
			Average	262	64.3	46,681,783

Table 8. Land and institution expansion scenario result of dynamic system

Scenario	Variable	Intervention	Year	Number of Tourists (People)	Land Area (Ha)	Revenue (IDR)
Land and Institution Expansion Scenario (C)	Land area, environmental improvement, policy, institutional involvement, promotion	10%	2026	191	69.4	39,713,171
			2027	213	69.4	45,108,356
			2028	236	69.3	50,784,258
			2029	259	69.2	56,577,233
			2030	282	69.1	62,331,492
			Average	237	69.3	50,902,902
			2026	201	69.5	42,176,163
		20%	2027	224	69.4	47,845,407
			2028	248	69.3	53,809,117
			2029	272	69.3	59,895,208
			2030	296	69.2	65,939,817
			Average	249	69.3	53,933,142

Determining the Best Scenario

The best scenario was determined based on calculations using a sensitivity analysis. Based on Table 9, the High Environmental and Governance Improvement Scenario yielded the best performance compared to the other scenarios. Grzn et al. (2024), assert that sensitivity analysis can serve as a basis for decision-making by identifying variables with the greatest influence on the model. This can be observed from the highest average sensitivity value of 1.349, indicating that this scenario has the greatest influence on improving the overall system performance. A higher value indicates that this scenario has a greater influence on the ecotourism system (Putu et al. 2024).

In the Environmental Improvement and Governance Scenario, improvements in ecotourism performance are achieved through a 20% intervention in environmental improvement, policy, institutional involvement, and promotion without emphasizing land expansion. This intervention aims to improve the overall quality of management and attractiveness of the area, thereby significantly increasing the number of tourists and revenue. In terms of environmental improvement, this scenario increases the number and scale of environmental education, water and soil conservation, and reforestation activities. The addition of environmental education activities aims to increase the awareness of managers and visitors of the importance of environmental preservation, while the increase in

conservation and reforestation activities contributes to the physical and ecological improvement of the area. These efforts are intended to enable communities and managers to take proactive measures against forest and land fires rather than relying solely on action from government authorities (Ambarita, 2021).

In terms of policy, this scenario is characterized by the addition of forest damage prevention activities, formulation of new written policies, and implementation of internal environment-based regulations. Strengthening these policies provides certainty in area management, clarifies the direction of ecotourism development, and increases stakeholder and visitor confidence in the sustainability of area management. Efforts to develop a five-year conservation plan and a conservation tourism zoning map are expected to help achieve these goals (Samosir et al. 2024). Institutional involvement increased through additional cooperation with external institutions, improved institutional facilitation, and strengthened human resource capacity through advanced training. The expansion of cooperation networks and institutional support has strengthened ecotourism governance,

improved service quality, and opened up opportunities for broader product development and marketing. In terms of promotion, Risyanti et al. (2024) highlighted that institutionalization and effective management are central to the successful development of tourism villages. Accordingly, this scenario increases the frequency and diversity of promotional media, including the adoption of additional social media channels, direct promotional activities, and collaborative promotional efforts with external parties to broaden the reach of information.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The main and supporting factors that can shape the Wonosantri ecotourism system consist of endogenous variables, including internal factors that directly affect system performance, such as the number of tourists, number of workers, operational costs, wages, land area, ecotourism production, ecotourism income, and policies. The exogenous variables included rainy days and holidays.

Table 9. Sensitivity analysis results from dynamic system scenarios

Scenario	Intervention	Number of Tourists	Land Area (ha)	Revenue (IDR)	Average
Policy Strengthening Scenario	Low	1.158	-0.006	1.238	0.797
	High	1.570	-0.008	1.809	1.123
Environmental Improvement Scenario	Low	1.195	0.011	1.786	0.997
	High	1.618	0.010	2.418	1.349
Land Expansion Scenario	Low	1.364	0.089	2.038	1.164
	High	1.485	0.090	2.219	1.264

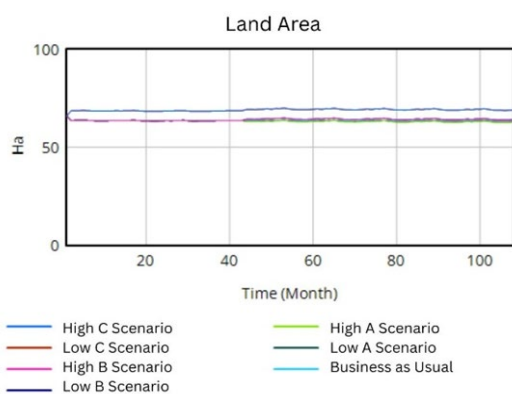


Figure 4. Graph of scenario results for land area variables

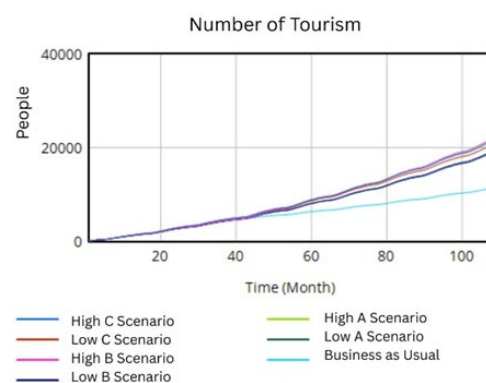


Figure 5. Graph of scenario results for number of tourism variables

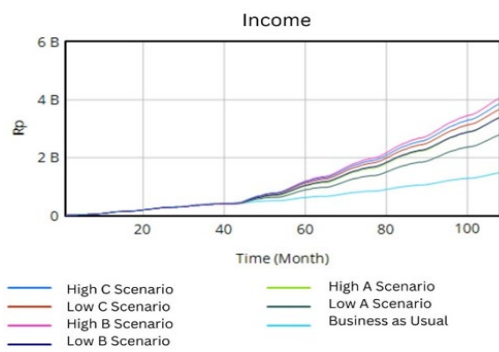


Figure 6. Graph of scenario results for income variables

The Environmental Improvement and Governance Scenario was the most effective for improving the overall performance of the ecotourism system. In this scenario, the number of tourists reaches 204, the land area increases to 64 ha, and the income is the highest, at approximately IDR38 million.

Recommendations

Ecotourism managers are advised to implement integrated policies, as outlined in the Environmental Improvement and High Governance Scenario, with a 20% improvement in policy, environmental improvement, institutional involvement, and promotion. Institutional strengthening can be achieved by increasing cooperation with tourism agencies and coffee communities and increasing the number of training sessions for managers and communities. Environmental improvements must focus on concrete activities, such as planting erosion-control vegetation, constructing infiltration wells, increasing the number of plant seedlings, and providing environmental education to managers and visitors. Promotion can be enhanced by adding digital promotional media (TikTok and Facebook), increasing the frequency of posts, and participating in tourism events through booths and direct promotional activities. Promotional cooperation with other tourism operators should also be strengthened to increase the number of visits. Managers need to add practical training, such as advanced digital marketing and tourism hospitality. Improving human resource capabilities will directly impact the quality of service and tourist comfort.

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