JSSEW
Journal of Sustainability, Society, and Eco-Welfare
JSSEW 3(2): 141–163
ISSN 3025-1524

A participatory multi-criteria framework for freshwater ecosystems: Integrating SWOT and AHP for sustainable governance

Safira Rosyada[1,*]
[1] *Department of Environmental Science, Faculty of Postgraduate Studies, Universitas Gadjah Mada, Yogyakarta, DI Yogyakarta 55284, Indonesia.*
*Correspondence: safirarosyada@gmail.com

Received Date: January 8, 2026 Revised Date: January 26, 2026 Accepted Date: January 31, 2026

ABSTRACT

Background: The Telaga Cebong located in the Dieng Plateau of Central Java, play vital role in supporting local agriculture, ecology, and tourism. However, increasing anthropogenic pressures have led to declining water quality and ecological degradation. This study aims to formulate a sustainable management strategy for Telaga Cebong by integrating community perspective, ecological data, and institutional frameworks. Previous studies have identified eutrophication risks and sedimentation as major threats to the lake's functionality, yet a robust, integrated management strategy that incorporates local context and participatory decision-making remains absent. Drawing on principles of the socio-ecological systems framework, this study aims to formulate a sustainable management strategy for Telaga Cebong by integrating community perspective, ecological data, and institutional frameworks. We hypothesize that the successful formulation of a sustainable management strategy for Telaga Cebong requires prioritizing formal institutional and policy interventions (AHP weight >50%) which are supported by strong community engagement. **Methods:** Using a mixed-methods case study approach, the research combines qualitative Strengths, Weaknessess, Opportunities, and Threaths (SWOT) analysis with the Analytical Hierarchy Process (AHP) to prioritize strategic interventions. Data were collected through field observation, in-depth interview, structured questionnaires, and secondary data. **Findings:** The Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS) matrices revealed that strengths and opportunities dominated the strategic landscape. AHP result showed that the Policy and Institutional Strategy received the highest priority weight (53.3%), followed by Human Resource Capacity, Cultural Values, and Government-Community Partnership. **Conclusion:** These findings confirm that formal governance mechanisms, supported by community engagement, are essential for long-term sustainability. **Novelty/Originality of this article:** This study contributes a novel SWOT-based framework that integrates participatory insights with multi-criteria decision-making to guide ecosystem management in rural freshwater context.

KEYWORDS: AHP; freshwater ecosystem management; swot; water quality.

1. Introduction

The volcanic lake is one type of aquatic ecosystem. However, volcanic lakes are vulnerable to environmental changes. Among the primary drivers of these changes are climate change and anthropogenic pressures. This is because human activities can alter the hydrology of the lake ecosystem. Moreover, freshwater ecosystems face growing threats from multiple environmental pressures, including habitat degradation, climate change,

Cite This Article:
Rosyada, S. (2026). A participatory multi-criteria framework for freshwater ecosystems: Integrating SWOT and AHP for sustainable governance. *Journal of Sustainability, Society, and Eco-Welfare, 3*(2), 141-163. https://doi.org/10.61511/jssew.v3i2.2026.2778

invasive species introductions, and pollution (Reid et al., 2019; Cantonati et al., 2020; Soares et al., 2025). Consequently, environmental management within freshwater ecosystems focuses on optimizing the potential and sustainable utilization of aquatic resources while preserving ecological integrity. Law No. 32 of 2009 on the Environment of the Republic of Indonesia defines the concept of the environment as an integrated space encompassing all elements within society, such as forces, conditions, and living organisms that influence nature. that influence nature, the continuity of life, and the welfare of both human and other organisms. Therefore, human activities are deeply connected to environmental dynamics, often driving economic growth but also leading to intensive resource exploitation and potential environment degradation.

This global vulnerability necessitates targeted management strategies at the regional level, particularly in areas recognized for their unique geological and ecological value. The Wonosobo and Banjarnegara Regencies in Central Java have been officially recognized as Geoheritage site under Decree No. 62 of 2023 issued by the Ministry of Energy and Mineral Resources of the Republic of Indonesia. This designation includes 23 geoheritage sites that must be protected, conserved, and utilized for research, education, and geotourism. One of the most significant geosites is Telaga Cebong; located on the Dieng Plateu in Sembungan Village, covering an area of approximately 12 hectares. Telaga Cebong serves as a critical freshwater ecosystem that plays a vital role in both ecological sustainability and the economic development of the local community.

The critical role of Telaga Cebong in supporting local economic development, however places the ecosystem under immense anthropogenic pressure. This pressure is evident as Telaga Cebong has long been essential for irrigating potato farmland, with water pumped throughout the year. Such intensive agricultural activity requires substantial use of organic fertilizers to enhance crop productivity. Approximately 64.5% of the catchment area surrounding Telaga Cebong is used for agriculture, making it the primary contributor of agricultural runoff (Sudarmadji et al., 2017). Surface runoff carries excess nutrients particularly nitrogen (N) and phosphorus (P) into the lake, triggering eutrophication (Glibert et al., 2018). This process, marked by excessive algal growth, significantly degrades water quality and threatens the lake's ecological functions (Jeppesen et al., 2025). Consequently, the sustainability of Telaga Cebong is now critical, as severe eutrophication directly jeopardizes its status as a geological heritage site and the livelihoods of farmers who depend on it for irrigation. The severity of these threats is further compounded by findings from other volcanic lakes, such as Lake Batur in Indonesia, which similarly indicate that intensive agricultural practices and tourism activities are primary drivers of eutrophication, leading to a noticeable decline in water quality and diminished economic value. Therefore, a comprehensive and sustainable management strategy is needed to balance environmental conservation with local economic and socio-cultural interests.

The urgency of this study is driven by the escalating anthropogenic pressures on Telaga Cebong, which have precipitated significant water quality decline and ecological degradation. Given the lake's vital role in supporting regional agriculture, tourism, and ecological stability in the Dieng Plateau, the persistent risks of eutrophication and sedimentation pose a direct threat to local livelihoods and ecosystem services. Without a robust management framework that harmonizes formal institutional interventions with community-based engagement, these environmental threats are likely to result in irreversible ecological loss. Therefore, establishing a prioritized strategic roadmap is not only scientifically necessary but also socially and economically imperative to ensure the long-term resilience of this freshwater ecosystem.

Therefore, robust risk assessment and management frameworks are essential to safeguard the ecological integrity and sustainable use of these aquatic systems (Makanda et al., 2022). Sustainable lake management in complex socio-ecological contexts requires an integrated understanding of ecological conditions and structured tools for action prioritization (Ustaoglu & Williams, 2017). Yet, few studies have systematically combined ecological assessments with strategic planning tools, such as SWOT (Strengths, Weaknesses, Opportunities, Threats) and the Analytic Hierarchy Process (AHP) (Yavuz & Baycan, 2014;

Thungngern et al., 2015; Cacal et al., 2023). This study addresses this gap are to identify key issues with SWOT-AHP analysis to management-oriented approach for Telaga Cebong. SWOT enables qualitative identification of internal and external factors affecting lake ecosystem, while AHP adds quantitative prioritization, enabling objective, transparent decision-making (Saaty, 1980; Chompook et al., 2023). Together, these tools from a hybrid framework capable of linking biological conditions with management priorities. Maintaining a good ecological status services such as water purification, fisheries, and recreation (Lynch et al., 2023; Tolonen et al., 2014), contributing directly to the Sustainable Development Goals (SDGs) (Ho & Goethals, 2019). The SWOT-AHP approach plays a role in the management process. This process involves identifying strengths and weaknesses at the system level, aligning water quality monitoring processes, and supporting the formulation of evidence-based policies with strategic priorities based on environmental, economic, and social criteria.

The biophysical conditions of Telaga Cebong, particularly concerning the escalating risks of eutrophication and sedimentation that threaten its ecological functionality. However, a significant knowledge gap remains regarding the formulation of a robust and integrated management strategy that harmonizes empirical ecological data with local participatory insights and institutional governance. Current management approaches often lack a multi-criteria decision-making framework capable of prioritizing strategic interventions in a rural freshwater context. The logical framework offers an innovative hybrid approach by integrating SWOT analysis with the Analytical Hierarchy Process (AHP), thereby filling the void between descriptive environmental assessments and actionable institutional policies. By synthesizing community perspectives with institutional frameworks, this study provides a systematic roadmap for ensuring the long-term sustainability of the Telaga Cebong ecosystem. However, a new question arises: how to delineate a sustainable management strategy for Telaga Cebong by synthesizing community-based insights with empirical ecological data and robust institutional frameworks.

Based on the observed pressures from intensive agriculture and the recognized need for strong governance in Geoheritage sites, we hypothesize that the most critical intervention for Telaga Cebong's sustainability will be the implementation of Formal Institutional and Policy Strategy, which will receive the highest priority weight (>50%) when evaluated using the Analytic Hierarchy Process (AHP) against other strategic alternatives. This study uses Lake Cebong as the primary research site to demonstrate the application of the SWOT-AHP method in assessing ecological risks and prioritizing lake management strategies. Through an integrated framework approach, this research identifies the most critical management steps. The research findings highlight the urgency of strategic planning to conserve freshwater biodiversity and achieve sustainable ecosystem management, particularly in small lakes in water-stressed regions.

2. Methods

2.1 Study area and data resource

This study was conducted in the Telaga Cebong ecosystem, Sembungan Village, Kejajar Subdistrict, Wonosobo Regency, Central Java (7°23′635″ N and 109°92′030″ E). Formed from an ancient crater, this lake is flanked by Mount Pakuwojo (3,395 m a.s.l.), Seroja (1,300 m a.s.l.), and Sikunir (2,306 m a.s.l.) (Setiawan et al., 2009). A map of the location and watershed is presented in Figure 1. Lake Cebong was selected based on its status as an eutrophic lake, a condition triggered by the conversion of forest land into potato farming areas (Sudarmadji et al., 2015).

Primary data collection for the SWOT analysis was conducted through field observations and in-depth interviews at the study site in October 2023. Meanwhile, secondary data were collected through literature reviews on ecological assessments (Tsiaoussi et al., 2017; Ntislidou et al., 2018), water quality data, institutional documents, and Focus Group Discussions (FGDs) with stakeholders such as village heads, farmers, and planners. Land use metrics were extracted using spatial data from official GIS and Google Maps (European Environment Agency, 2000).

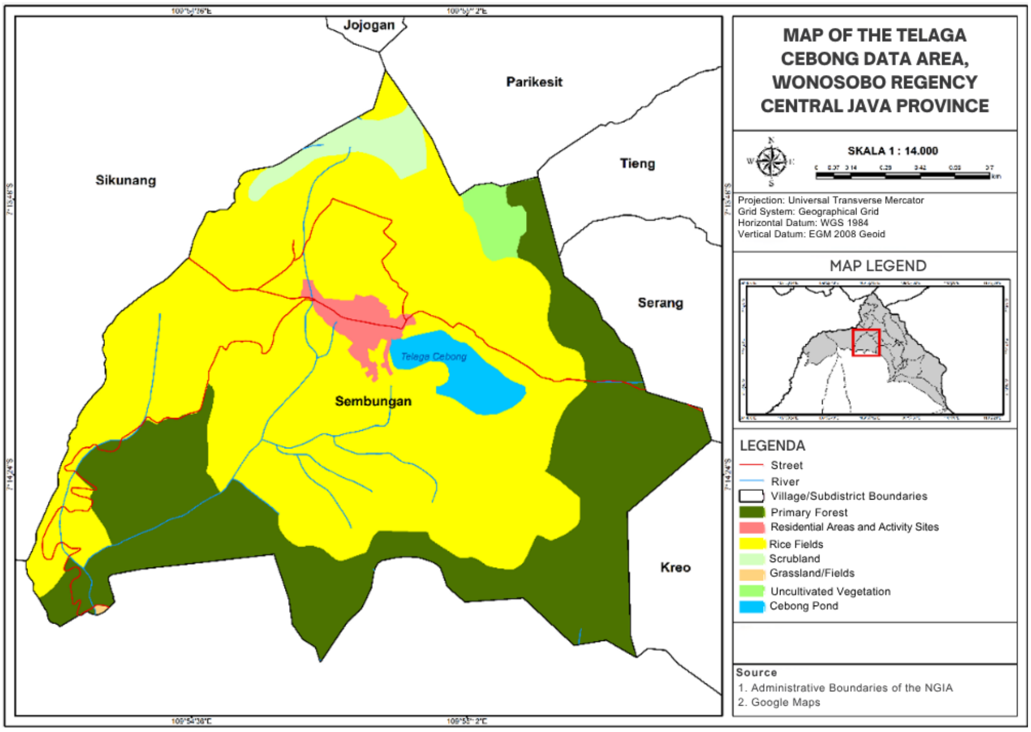

Fig. 1. Research location and water catchment area map

Stakeholders were selected using a purposive sampling technique to ensure a comprehensive representation of the socio-ecological landscape of Telaga Cebong. The selection criteria focused on individuals with direct expertise or significant influence within three primary domains: ecological management, local community interests, and institutional policy-making. To ensure the robustness of the research design, a Focus Group Discussion (FGD) was conducted with these stakeholders to validate the strategic criteria and sub-criteria before their inclusion in the AHP hierarchy. This participatory validation process ensured that the identified factors accurately reflected the local context and institutional realities. Subsequently, these experts provided the qualitative insights for the SWOT analysis and the quantitative assessments required for the AHP pairwise comparisons, facilitating a rigorous synthesis of community-based and institutional perspectives

2.2 The SWOT-AHP method

This study employs a case study approach using the Multi-Criteria Decision Making (MCDM) method with a sequential exploratory design. SWOT analysis is used as a structured decision-support tool to identify and evaluate both internal and external factors in ecosystem management on a qualitative basis. This method helps map the strengths, weaknesses, opportunities, and threats that impact the ecological integrity of lakes (Lee et al., 2008; Leigh, 2009; Ghazinoory et al., 2011; Banihabib et al., 2015). In lake ecosystems, strengths generally include biodiversity, regulatory protection, and minimal anthropogenic disturbance; while weaknesses include a lack of long-term monitoring, the presence of invasive species, or hydrological instability. Opportunities may stem from conservation funding, policy support, or local management, whereas threats include droughts caused by climate change, nutrient accumulation, and land-use conversion. Through integration with ecological assessments, SWOT provides a framework for identifying conservation needs and formulating management strategies that are adaptive to policy (Scolozzi et al., 2014).

These factor then serve as the primary input for quantitative phase ultilizing the Analytical Hierarchy Process (AHP), which involves structuring, weighting, pairwise comparison, and alternative based on expert judgment (Petriki & Bobori, 2025). This research using primary data (questionnaire SWOT and AHP) and secondary data using water quality from literature review and Indonesia Government Standart and Regulation. The integration of both methods ensures that strategy formulation is not based on factor identification but also supported by structured and prioritized expert assessments (Albayrak, 2022). The SWOT analysis is applied by classifying the collected data and information into four strategic dimentions, which are then mapped into a SWOT matrix. The matrix is used to optimize strengths and opportunities while minimizing threats and weakness identified in Telaga Cebong's activities and management practices (Wheelen & Hunger, 1984). Tabel 1 show that the process includes Internal Factor Analysis Summary (IFAS) and External Factor Analysis Summary (EFAS). Internal factors consist of strengths and weaknesses, while external factors include opportunities and threats. Each factor is evaluated, rated, and weighted. The resulting scores are plotted within a SWOT quadrant to illustrate the relationship and positioning of internal and external factors. The final stage of SWOT analysis involves formulating these four core strategies (Thuyen, 2023), which are then refined and prioritized using AHP (Petriki & Bobori, 2025).

Table 1. SWOT strategy matrix

Internal / External	Strenghts	Weaknesses
Opportunities	S-O Strategies are strength based strategies designed to capitalize on external opportunities	W-O strategies aim to minimize internal weakness in order to take advantage of external opportunities
Threats	S-T strategies utilize internal strength to mitigate or overcome external threats	W-T strategies focus on reducing internal weakness and avoiding potential external threats

The Analytical Hierarchy Process (AHP), introduced by Thomas L. Saaty in the 1970s, is a robust and systematic multi-criteria decision-making method. Its strength lie in its structured, straightforward, and practical nature. In the context of Telaga Cebong's ecosystem management, AHP is effective for objectively wighing and prioritizing stategic alternatives across environmental, economics, and socio-institutional dimentions. The AHP procedure involves four key steps: hierarchy structuring; pairwise comparison; weight index calculation; consistency testing. Furthermore, The AHP method operates through three main stages: criterion decomposition, comparison of decision alternatives, and criterion prioritization. This approach utilizes the eigenvalue method to construct a decision hierarchy that links each criterion to the available alternatives. Ishizaka & Labib, (2009), weight allocation in AHP enables the formation of a criterion hierarchy that facilitates decision-makers in focusing on both primary and sub-criteria. Furthermore, a comparison matrix can be developed to enhance precision in the decision-making process. Criteria assessment is crucial because overly complex structures can yield insignificant results. Although there are challenges related to rank reversal on the inverse scale during the eigenvalue process when formulating priorities, the application of AHP remains a complex yet essential tool. This method plays a vital role in simplifying dynamic models and ensuring the accuracy of decisions related to hierarchy and scaling.

The key elements of the SWOT analysis were identified through a combination of field ecological assessments, a literature review, and focus group discussions (FGDs) with stakeholders. Each identified factor was then entered into a pairwise comparison matrix using the Saaty scale of 1–9. Referring to Table 2, a score of 1 indicates equal importance, while a score of 9 represents the absolute importance of one element relative to another based on expert judgment.

The priority weight vector for each matrix was calculated by normalizing each column (i.e., dividing each element by the total sum of the column) and calculating the row mean.

This process yields the relative weights of each element within the matrix. To ensure the comparisons are logically consistent, a consistency test is performed. The initial step is to calculate the Weighted Sum Vector (WSV) by multiplying the comparison matrix (A) by the priority weight vector (W), formulated as (i.e., WSV = A × w). Subsequently, each now of the WSV was divided by its corresponding priority weight to yield the consistency vectors $\lambda i = \frac{WSVi}{wi}$ and then the principal eigenvalue $\lambda max = \frac{\Sigma\lambda i}{n}$ was estimated. The above was used to estimate the Consistency Index ($CI = \frac{\lambda max - n}{n-1}$) with n the number of rows and finally the Consistency Ratio ($CR = \frac{CI}{RI}$). This ratio is computed to measure to consistency of pairwise comparisons. A CR below an acceptable threshold (typically 0.1) confirms that the comparisons are logically consistent and reliable for decision-making (Cacal et al., 2023; Kurttila et al., 2000; Saaty, 2008; Ho, 2008). A CR value exceeding 0.1 necessitates a re-evaluation of the judgments by the respondents to ensure data reliability.

Table 2. Scale of comparative importance in pairwise comparisons between SWOT factors, using Saaty's 1-9 scale

Intensity of Important	Definition	Explanation
1	Equal importance	Both elements contribute equally to the goal.
3	Moderate importance	The experience and assessment lean slightly more toward one element than the others.
5	Strong importance	The experience and assessment are heavily biased toward one element over another.
7	Very strong importance	One element is preferred over the others; its dominance is clearly evident in practice.
9	Extreme importance	Evidence supporting one element over another has the highest possible degree of certainty.
2,4,6,8	Intermediate values	The midpoint between two adjacent scores.
1/3,1/5,1/7,1/9	The inverse of the ratio.	

(Saaty, 2008)

The SWOT-AHP approach was applied at Telaga Cebong to formulate priorities for sustainable management. The weighted results of these calculations were then integrated into a final decision matrix as the basis for managerial action planning. Based on an ecological review combined with input from stakeholders, this process yielded several outputs: first, the SWOT categories were ranked by level of importance (e.g., threats and weaknesses > strengths > opportunities); second, each factor within the SWOT quadrants is weighted; and third, management strategies are evaluated and prioritized based on the three main AHP criteria: environmental impact, feasibility, and level of urgency.

3. Results and Discussion

3.1 Identification of environmental issues in Telaga Cebong

3.1.1 Water quality

The findings from Telaga Cebong reveal a complex interplay between hydrological limitation, anthropogenic pressures, and nutrient dynamics. The main water input of the lake is from rainwater, meaning that the watwer availability of the lake relies solely on the precipitation in the rainy season. The catchment area of the lake is particularly small, which implies a limited amount of water potential. Since Telaga Cebong receives most if its water from the rain, the water quality is presumed to be similar to the quality of the rainwater. In other words, the lake is expected to contain no excessive substances. Telaga Cebong has no inlet from river. However, since Telaga Cebong is extensively used as the source of irrigation water in the surrounding agricultural land, a considerable amount of its water is extracted continuously. The water scarcity endangers Telaga Cebong, especially in dry season.

Regarding to Table 3, it shows that water quality assessment of Telaga Cebong from 2018 to 2023 indicate a progressive decline. The pH of Telaga Cebong was fluctuated. Rosyada (2023) mentioned pH in Telaga Cebong was in 2.6. Based on monitoring data from Conservation Department, when dry season pH was very acid (1-2) due to the dry up water. Furthermore, water quality measurement on volcanic lake in Azores Archipelagos also showed that physical condition of water quality on volcanic lake is quite different with research area. From 13 volcanic lake from that certain area, pH is ranging from 4.2 to 9.9. The acidic conditions in Telaga Cebong are likely driven by reduced water volume and concentration of solutes during droughts. During this period, concentrations of total nitrogen and total phosphate exceeded the thresholds established by the Indonesian Water Quality Standards (Government Regulation No. 22 of 2021). Based on Indonesian water quality standard regulation number 22/2021 about criteria of water quality for spesific purposes. Class I used for source of drinking water, Class II used for recreation, live stock and fish farming, Class III used for live stock, fish farming and agriculture, and Class IV used for agriculture. Elevated concentration to pH, dissolved oxygen (DO), total nitrogen (TN), total phosphate (TP), and clorophyll-a (Cl-a) concentration higher than Indonesian water quality standard and suggest ongoing eutrophication.

Table 3. Water quality of Telaga Cebong

Physical Parameters	Measured Water Quality Parameters				Indonesian Water Quality Standards (Government Regulation No. 22 of 2021)			
	(Dilazuard, 2018)	(Falah, 2020)	(Rosyada, 2021)	(Rosyada, 2023)	Class 1	Class 2	Class 3	Class 4
Temperature (°C)	18	18.21	19.82	23.27	Deviation 3	Deviation 3	Deviation 3	Deviation 3
pH	5	5.47	6.02	2.6	6-9	6-9	6-9	6-9
DO (mg/L)	6.9	8.21	12.19	8.08	6	4	3	1
TDS (g/L)	-	-	233.6	-	1000	1000	1000	1000
COD (mg/L)	-	-	-	63.4	10	25	40	80
BOD (mg/L)	-	-	-	9.4	2	3	6	12
TN (mg/L)	70.45	-	-	47.69	15	15	25	-
TP (mg/L)	2.9	-	-	1.35	0.2	0.2	1.0	-
Cl-a (mg/m^3)	-	-	-	253.75	10	50	100	200

The fluctuating dissolved oxygen (DO), ranging from 6.9 to 12.19 mg/L with average 8.84 mg/L. This figure is slightly lower than that of Lake Warna, which has a DO level of 9.03 mg/L (Soeprobowati et al., 2017). The greater the intensity of the photosynthetic process or the higher the level of phytoplankton development, the greater the productiin of DO. Nitrogen and phosphorus growth via photosynthesis (Søndergaard et al., 2017; Jiang & Nakano, 2022). TN and TP in Telaga Cebong is highest in 2018 (70.45 mg/L and 2.9 mg/L), according to 2023 TN, TP and Cl-a (47.69 mg/L, 1.35 mg/L, and 253.75 mg/m^3). This surge in N and P concentrations directly stimulates phytoplankton productivity, which in turn boosts secondary production, including zooplankton and fish populations. Until now, local communities have generally welcomed these eutrophication conditions because the increased fish population has been economically beneficial to them. One of the most deleterious consequences of eutrophication is formation of algae that are typically dominated by blue-green algae (Boyd, 2015; Akinnawo, 2023). When the algal bloom phase ends due to nutrient depletion, the algae die en masse. The decomposition process of this dead algal biomass requires a very large amount of dissolved oxygen, leading to oxygen depletion (a drastic drop in oxygen levels) that has the potential to trigger mass fish deaths in the lake. Consequently, it is essential to consider the impact of excessive nitrogen and phosporus concentrations in lake water (Prentice, 2021; Elser et al., 2022) in Table 3.

This finding is supported by previous studies Dilazuardi (2019), classified the trophic status of Telaga Cebong as mesotrophic, while Rosyada (2023) identified it as mesotrophic to eutrophic using Trophic Status Index (TSI) Method. These classification reflect increasing nutrient enrichment and signal a shift toward more pronounced eutrophication. Previous studies have demonstrated the interdependence of key limnological parameters water transparency, chlorophyll-a concentration, and total phosphorus in assessing trophic status. Cloutier & Sanchez (2007), in their study of 154 lakes in Quebec, Canada, found a strong correlation between water clarity and chlorophyll-a, with chlorophyll-a also closely linked to total phosphorus, particularly in southern Quebec lakes. These findings support the use of transparency as a reliable indicator in future trophic status monitoring. Similarly, Tibebe et al. (2019), applied Carlson's Trophic State Index (TSI) to Lake Tana in Ethiopia and found consistent results when compared to OECD standards: the lake was classified as eutrophic based on chlorophyll-a and total phosphorus, while transparency indicated a hypereutrophic condition. Carlson's TSI has been widely adopted globally for trophic classification due to its integrative nature. Given the interconnectedness of these parameters, Carlson's TSI provides a robust and accurate representation of Telaga Cebong's trophic status, making it a suitable tool for long-term ecological monitoring and management. Eutrophication has led to degradation of lake ecosystem and biodiversity in approximately 40% of the total number of lake worldwide while 83% of freshwater species have been disappeared since 1970. Furthermore, 90,000 cases of illnesses occur in the US alone due to microbial contamination from activities related to lake each year (Ho & Goethals, 2019)

The ecosystem of the lake is prone to significant shocks and stresses despite the implementation of some conservation efforts. The conservation is however different from the one that is implemented in a large lake (Sudarmadji et al., 2019). A large lake requires much-complicated conservation. International Lake Environment Committee (ILEC) Foundation has intoduced several guidelines of the conservation efforts. However, some adjustments are required in order to suit the condition in Indonesia. The conservation efforts will not work properly when they focus only on the lake itself because the water in the lake is also influenced by the condition of the catchment area. They have to consider the participation of the local community. Therefore, a comprehensive concept of conservation in Telaga Cebong becomes necessary in order to sustain the exixtence of the lake especially focusing on water use regulation or irrigation.

3.1.2 Land-use change in buffer zone

This section critically analyzes the research findings concerning the land-use transition in Telaga Cebong buffer zone form intensive potato cultivation to tourism accomodation, specifically glamping and supporting infrastructure. Secondary data confirms that the Telaga Cebong's catchment area is overwhelmingly dominated by potato agriculture (up to 65.4% of the catchment area), leading to high rates of erosion and sedimentation that have caused significant lake shallowing (Telaga Cebong's area has shrunk from 18 Ha to 12 Ha (Sudarmadji et al., 2015).

Agricultural activities surrounding Telaga Cebong, particularly potato farming, have significantly impacted the lake's water quality. Fertilizer runoff into the water body and the extraction of lake water for irrigation are the primary stressors. The catchment area (DTA) spans approximately 186.71 hectares, with agricultural land occupying 156.96 hectares vastly exceeding the lake's surface area of only 8.47 hectares. During the dry season, when rainfall is scarce, farmers rely heavily on pumping water from the lake to irrigate their fields. Field observations recorded the daily use of approximately 150 diesel-powered pumps operating in rotation. This practice not only reduces the lake's water volume but also poses a pollution risk due to potential fuel spills, further threatening the ecological integrity of Telaga Cebong.

While potato farming caused gradual erotion, glamping construction-involving the clearing of remaining vegetation, sol compaction, and foundation placement inflicts acurate structural damege on the riparian zone. This construction increases the Impervious Surface Area, drastically accelerating the volume and velocity of surface runoff. Crucially, this runoff now carries not just sediment and materials directly into the lake permanently eliminating the natural filterung funtion of the sempadan. This structural infringement directly violates the mandated minimum buffer distance (50 meters from the lake edge) as stipulated in national regulation (Permen PUPR No.28/2014).

3.1.3 Socio-economic welfare and the sustainability dilemma

The degradation observed in the Telaga Cebong riparian zone, primarily driven by the transition form potato farming to glaming tourism, creates a significat paradox concerning socio-economic welfare in Sembungan Village. While conservation regulation mandate buffer protection, local communities often perceive the economic benefits derived from tourism infrastucture development as having higher immediate value compared to the long-term ecological services provided by the lake (Sinulingga et al., 2024). Although the majority of the economic-driven targets aim to dissociate environmental deprivation from economic growth, the indirect impacts of human activity to obtain the economic growth can ve extensive on the lake sustainability as this was the case in the past. A noticeavle example is that the correlation between the higher amount of untreated wastewater and the increasing per capita income was found in higher pollution-generating economic activities (Flörke et al., 2019).

This financial incentive for short-term gain often supersedes local awareness and environmental law enforcement (Harris & Shahriyani, 2024). Landowners are financially incentivized to violate conservation law because the profitability of an accommodation unit drastically out weights the income potential of the same plot used for potato cultivation. While economic benefit (job creation, revenue) temporarily boost community welfare, this prosperity is built on a foundation of ecological debt. The continuation of structural degradation threatens to destroy the lake's natural aesthetic and water quality (the core tourism asset). This will inevitably lead to a severe, long-term decline in local economic welfare, impacting livelihoods more drastically than fluctuating agricultural income.

The real economic growth rate data for Wonosobo Regency, benchmarked against the constant prices of the 2010 base year (2010=100), indicates a net expansion of the total regional economy (Gross Regional Domestic Product) across the period. Specifically, the growth rates of 3.68% in 2021, 5.02% in 2022, anad 4.30% in 2023 signify a continuous increase in the volume of goods and services produced, net of inflationary effects (Badan Pusat Statistik Kabupaten Wonosobo, 2024). The robust expansion in 2022 likely reflects post-pandemic economy recovery, followed by a slight moderation in 2023, yet the overall trajectory supports the underlying premise a short-term financial incentive. These growth figures validate the existence of short-term financial incentives driving land-use change, as economic prosperity largely fueled by directly profitable sectors like tourism and accomodation structurally outweighs and displaces income from traditional sectors such as potato cultivation, thus substantiating the claim that the current boost in community welfare is bulit upon the consumption of the core ecological assets.

3.2 Multi-criteria decision-making (MCDM)

This stage represents the decision-making phase, built upon insights from the input and matching stages. According to (Kumar & Osuri, 2014), the decision-making process encompasses the subject input from decision makers and provides an appropriate output alternative. The decision-making process also develops a single altervative or a set of alternatives. There are three essentials processes involved in decision-making; define the decision problem based on goal, identify criteria, and identify alternative, hierarchy of decision-making for Telaga Cebong management show in Figure 2. When the alternatives are chosen in the process, the overall objective depends on two or more criteria based on the goal (s).

The MCDM method has been a useful research area since the 1960s, generation numerous conceptual and applied books and articles (Mladenovi´c-Ranisavljevi´c et al., 2018). It also a helpful tool for resolving problems and related to conflicting criteria, to help people and aid in water resource management issues. A review of the MCDM method used for water management and planning was conductes by (Hajkowicz & Collins, 2007). Therefore, MCDM methodologies have been proposed to define a better alternative, identify alternatives into several small classes, and rank alternatives into a subjective order of importance (Amorocho-Daza et al., 2019)

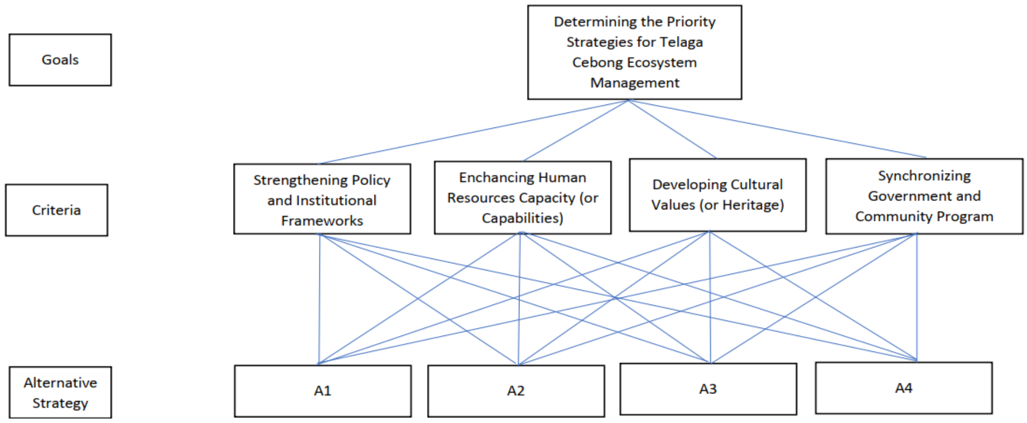

Fig. 2. Hierarchy of decision making of Telaga Cebong

This study examines the application of two Multi-Criteria Decision Making (MCDM) methods—namely SWOT and AHP—in parameter weighting and variable evaluation. The integration of these two methods simplifies the formulation process and minimizes the margin of error, as their effectiveness has been demonstrated in various ecosystem management scenarios (Sarkar & Majumder, 2021). Therefore, this study aims to integrate the SWOT and AHP frameworks to produce a calculation model that is more time-efficient while also offering higher accuracy. Broadly speaking, this approach follows four main stages: selection of criteria and alternatives based on stakeholder needs, ranking of criteria and alternatives according to their level of importance, and comparison of alternatives against these criteria (Figure 3). The relevance of this method is supported by prior research; for example, Walangitan et al. (2024), who combined SWOT-AHP to analyze management strategies for the Tondano Lake ecosystem in North Sulawesi, Indonesia. Additionally Petriki & Bobori (2025), also applied the integration of ecological assessment and SWOT-AHP to formulate sustainable freshwater management in the Mediterranean region.

3.2.1 SWOT analysis

Regarding to Figure 3, it shows that of the literature review and stakeholder interviews, several internal strengths were identified in the management of Telaga Cebong. These include the establishment of local irrigation regulations by Sembungan Village, active community participation in lake stewarship, strong cultural values that encourage conservation, significant ecotourism potential. These social and cultural assets particularly participatory human resources and local regulatory frameworks serve as key drivers for sustainable lake management (Zayim, 2024; Ni et al., 2025).

Consersely, notable weakness were obeserved. These include the absence of regular water quality monitoring by both village authorities and local government, extensive use of the catchment area for agriculture leading to nutrient runoff during the rainy season, limited oversight and support from regional institutions, ecological degradation merked by lake shrinkage from 18 to 12 hectares due to sedimentation and peat growth. This degradation has diminished the lake's ecological function, aesthetic value, and tourism appeal. Without improved monitoring and institutional support, these weakness pose significant challenges to tong term sustainability (Đurić et al., 2025; Yang & Rahim, 2025).

Key opportunities for managing Telaga Cebong include strong community awareness of the lake's ecological and cultural value, active support from the Central Java Provincial Government for establishing the Dieng Plateau as a National Geopark as a camping destination. These factors present strategic momentum for integrating sustainable tourism and strengthening local stewardship (He et al., 2025). However several threats jeopardize the lake's sustainability, seasonal droughts and continuous water extration for irrigation reduce water volume, while agricultural runoff (rich in fertilizers and accelerates eutrophication). Farmers also express concern over erosion and nutrient loading, and the village's vulnerability to landslides further compounds ecological risks. Collectivelly, the pressures threaten the long-term functionality of Telaga Cebong as both a natural and economic resource.

Table 4. The internal and external factors

Internal Factor			
Strengths (S)		Weakness (W)	
S1	Sembungan Village has established local irrigation water regulations	W1	Regular water quality monitoring of the lake is currently inadequate or non-existent, both by the Village and the local government
S2	Sembungan Village possesses participatory human resources for lake management	W2	The Lake Cebong catchment area (DTA) is used for agriculture, leading to fertilizer runoff, especially during the rainy season, which increases the lake's nutrient load
S3	Strong cultural heritage fosters a continuous commitment among the community, especially farmers, toward preserving the lake	W3	Guidance and supervision from the local government are not yet optimal
S4	Sembungan Village holds significant tourism potential that can be enchanced to attract visitors	W4	Lake Cebong has experienced shrinkage, reducing its area from 18 Ha to 12 Ha
External Factors			
Opportunities (O)		Threats (T)	
O1	The Sembungan community is aware that Lake Cebong is vital Village asset whose functional sustainability must be maintained	T1	The dry season and the continuous pumping of lake water for irrigating agriculture fields cause a reduction in Lake Cebong's water volume
O2	The Central Java Provincial Government and related parties are actively supporting the designation of the Dieng Plateau as a National Geopark	T2	Farmers are concerned about fertilizers use and erosion, which threaten the functional sustainability of the lake
O3	The local government is beginning to provide guidance and training to Sembungan Village farmers	T3	Declining Lake Cebong water quality, due to fertilizer use and other influencing activities, leads to lake eutrophication
O4	Lake Cebong is known as a camping spot, presenting a significant opportunity for developing an integrated and sustainable tourism concept	T4	Sembungan Village is an area prone to landslide disasters

The internal factors used to assess performance represent the strengths and weaknesses relevant to achieving the research objectives. Meanwhile, external factors focus on existing conditions and emerging trends outside the system that influence the management of Telaga Cebong. The internal and external factors influencing the development of Telaga Cebong's management can be observed in the following Table 4. However, Following the identification of internal and external factors, the researcher assigned ratings and weights based on questionnaire data. The results of this weighting and rating process are presented in Table 5.

Table 5. Internal factor analysis summary (IFAS)

No.	Internal Strategic Factors (IFAS)	Significance Level	Weight (Bi)	Rating (Ri)	Score (Bi x Ri)
Strength (S)					
1	Village regulations	3	0.13	5	0.68

2	Community resources for lake management	3	0.13	4	0.54
3	Local Wisdom	2	0.09	3	0.27
4	Sembungan Village as a tourism village	3	0.13	5	0.68
Total		11	0.5	17	2.18
Weakness (W)					
1	Inadequate lake water quality monitoring	3	0.13	3	0.40
2	Water pollution due to fertilizer runoff	3	0.13	5	0.68
3	Suboptimal guidance and supervision from local government	2	0.09	2	0.18
4	Reduction/shrinkage of lake area	3	0.13	1	0.13
Total		11	0.5	11	1.40

Based on the processing of the Internal Factor Analysis Summary (IFAS) matrix for Lake Cebong's management strategy, the resulting difference between the total weighted scores for Strengths and Weaknesses is 1.4. This positive value indicates that the internal strategic factors for Lake Cebong's management are in a favorable position. Similar to the IFAS matrix calculation, following the identification of external factor comprising opportunities and threats, the researchers proceeded to assign ratings and weights based on the data acquired from respondents. Table 6 shows the results of the weighting and rating process.

Table 6. External factor analysis summary (EFAS)

No.	External Factor Analysis (EFAS)	Significance Level	Weight (Bi)	Rating (Ri)	Score (Bi x Ri)
	Opportunities (O)				
1	Village community awareness	3	0.15	4	0.6
2	Collaboration with academia, agencies, and relevant institutions	1	0.05	3	0.15
3	Local government attention/support	2	0.1	3	0.3
4	Development of tourism conceps	3	0.15	4	0.6
Subtotal		9	0.45	14	1.65
	Threats (T)				
1	Decreasing water volume	3	0.15	1	0.15
2	Farmer anxienty/concerns	3	0.15	2	0.3
3	Decline in water quality	3	0.15	2	0.3
4	Landslide prone area	2	0.1	4	0.4
Total		11	0.55	9	1.15

This stage provides essentials input for strategy formulation through the Internal Factor Analysis Summary (IFAS) dan External Factor Analysis Summary (EFAS) matrices. Based on the weighted scores of the SWOT components, the result ranked as follow strengths 2.2, opportunities 1.6, weaknesses 1.4, and threats 1.15. Regarding to Figure 4, it shows that the determined strategic coordinates are X = 2.18 and Y = 1.65 with both the internal (X-axis) and external (Y-axis) factors being positive. These findings indicate that the management of Telaga Cebong in Sembungan Village is primarily driven by leveraging internal strengths and external opportunities (S-O strategy) of the Cartesian diagram (Petriki & Bobori, 2025). This result, which prioritize the maximizztion analyses in othe hight-potential, yet ecologically sensitive, regions (He et al., 2025).

Based on the research conducted by Mandari et al. (2024), the SWOT analysis revealed that the management strategy for Sepunjung Lake is positioned in Quadran I. Consequently, the adopted strategy is the S-O (Strength – Opportunities) strategy. The strategic position of Sepunjung Lake management in Quadrant I supports an aggressive strategy. This implies that the implemented strategy aligns with an aggressive growth-oriented policy. The management strategy for Sepunjung Lake can be elaborated as follows: establishing village regulations to protect the biophysical quality of the lake waters, the vegetation cover surronding the lake and the biodiversity, managing ecotourism based on local wisdom, and developing the potential for freshwater fisheries. Moreover, research by Amal et al. (2024), on Poso Lake, Pasir Putih Village, placed its management in Quadrant I (S-O strategy) based on IFAS and EFAS analysis.

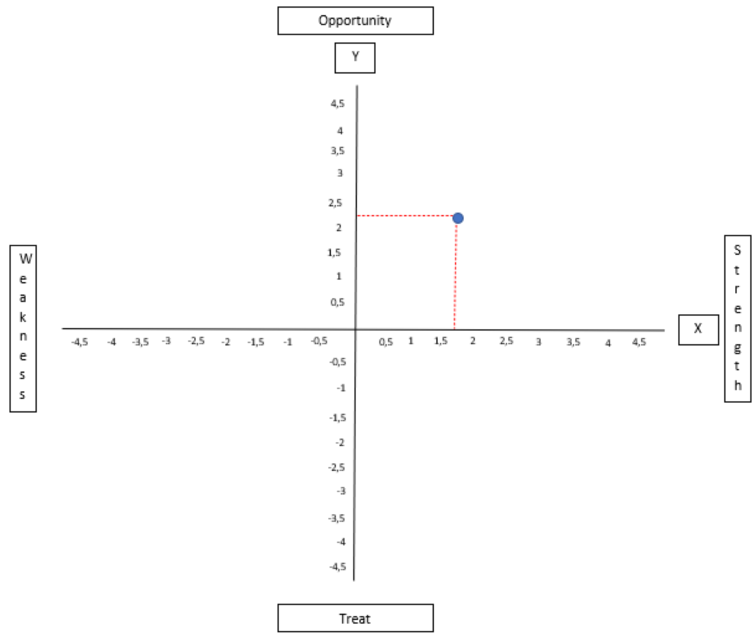

Fig. 4. The Cartesian quadrant SWOT diagram

The main strategic priorities for Poso Lake include: Maximizing natural beauty by developing distinctive tourist attractions, leveraging cultural and traditional wisdom to create compelling tourist appeal and stimulate alternative community enterprises, and fostering partnerships and cooperation among the government, community, and private sector for the development of the Poso Lake coastal tourism area. This positioning implies a significant capacity for maximizing growth and achieving substantial advancement. Following the determination of the internal and external factors, the subsequent step involves converting the IFAS and EFAS analysis result into the SWOT matrix. Table 7 shows that matrix yields several strategiec alternatives.

Table 7. Matrix SWOT

Internal / External	Strenghts(S)	Weaknessess (W)
	1. Sembungan Village has established irrigation water regulation, serving as a clear legal basis for the supervision and utilization of water, thereby optimizing usage 2. The participatory Human Resources (HR) of Sembungan Village ensure community involvement and local ownership for local-wisdom-based and sustainable lake management and maintenance 3. Strong cultural heritage fosters an emotional bond and collective commitment among the community,	1. Regular monitoring of lake water quality remains inadequate or is not conducted periodically, both by the Village and the local government 2. Farmers express concerns regarding fertilizer use and erosion, which threaten the functional sustainability of the lake 3. Guidance and supervision provided by the local government are currently suboptimal

	particularly farmers, toward preserving the lake, establishing it as a shared identity that ensures sustainable management based on tradition	
	4. The tourism potential of Sembungan Village is an asset that can be developed into a new source of income, simultaneously encouraging environmental preservation and cultural protection as elements of sustainable tourism attraction	4. Lake Cebong has shrunk from 18 hectares to 12 hectares due to sedimentation and peat growth around the perimeter, consequently diminishing its aesthetic, ecological function, and tourist appeal
Opportunities (O)	SO	WO
1. The Sembungan community is aware that Lake Cebong is a vital village asset whose functional sustainability must be preserved	1. Engage Academia for Scientific Regulation Drafting: Collaborate with academic institutions to formulate specific Village Regulations (Perdes) regarding lake zoning and water quality standards, supported by scientific legitimacy and legally enforced	1. Immediately Establish Formal Collaboration with Academia/Universities: Partner to train local Human Resources and implement a routine, scientific water quality monitoring protocol for the lake
2. The Central Java Provincial Government and related parties are actively supporting the designation of the Dieng Plateau as a National Geopark	2. Strengthen Dissemination of Village Regulations through Local Wisdom Values: Ensure conservation rules (e.g., prohibitions on littering) are readily accepted and adhered to by the community and tourists, thereby supporting the designation of the Dieng Plateau as a National Geopark	2. Mobilize Community Awareness for Active Participation in the Lake Cebong Watershed Conservation Movement (DAS): Initiate activities such as terracing and planting high-yielding vegetation in agricultural lands upstream
3. The local government is beginning to provide guidance and training to Sembungan Village farmers	3. Utilize Existing Local HR to Form a Special Lake Conservation Unit (under Pokdarwis/BumDes): This unit will be tasked with controlling weeds/algae and maintaining the lake's buffer zone (sempadan), fully supported by collective community awareness	3. Leverage Community Awareness to Conduct Intensive Socialization and Training: Focus on organic farming practices and the use of environmentally friendly pesticides and fertilizers, specifically targeting farmers upstream of the lake.
4. Lake Cebong is known as a camping spot, presenting a significant opportunity for developing an integrated	4. Establish Sembungan Village's Image as an "Ecotourism" Destination: Package local rites/traditional wisdom	4. Transform Weaknesses into Attractions by Developing an Educational Tourism Concept: Tourists can be actively invited to participate

and sustainable tourism concept	as educational ecotourism attractions, emphasizing the importance of maintaining the lake's ecosystem as a cultural heritage asset	or learn firsthand about water quality monitoring methods and the importance of the lake ecosystem
Threaths	ST	WT
1. The dry season and the pumping of lake water for irrigation of agricultural fields reduce Lake Cebong's water volume	1. Legalization and Strengthening of Conservation and Community-Based Management Programs: Strictly enforce conservation regulations and local rules to control the use of chemical fertilizers and irresponsible farming practices in the surrounding area	1. Prioritize the Activation of Water Quality Monitoring Programs and Geohydrological Studies: Conduct studies and inventories to obtain robust baseline data for formulating village regulations (Perdes) aimed at controlling agricultural runoff
2. Farmers are concerned about fertilizer use and erosion, which threaten the functional sustainability of the lake	2. Ecosystem Degradation & Disaster Vulnerability Reduction: Reinforce the internalization of conservation values and integrate culture into ecotourism as a non-physical defense mechanism to ensure community and visitor compliance, thereby reducing ecosystem pressure	2. Expedite the Facilitation of Structured and Massive Organic Fertilizer Subsidies: This is crucial for reducing farmers' dependence on chemical fertilizers, which are the root cause of eutrophication
3. Declining Lake Cebong water quality, due to fertilizer use and other influencing activities, leads to lake eutrophication	3. Seasonal Water Management and Technical Training: Utilize conservation training and the role of the Special Water Unit to master efficient water management (hydrology) and irrigation techniques, mobilizing the community for integrated watershed management (DAS) actions	3. Establish Environmental Standard Operating Procedures (SOPs): Develop binding SOPs for tourism activities and ensure strict enforcement to prevent tourism activities from placing excessive pressure on the Lake Cebong ecosystem

3.3 Analytical hierarchy process (AHP)

Saaty (1980), proposed an AHP method that depends on the MCDM method, which splits the issue based on decisin criteria, sub-criteria, and alternatives to achiecve specific purpose. AHP is discussed as an appropriate alternative to the non-physical measurable requirements, which integrates the difficulty in decision-making with the use of the ratio scale, and can be used in group and individul decision-making (Lai et al., 1999). This approach is used to examine the relative weights of available alternatives, and also applies to different fields of study, including energy, education, fishery, supply chain, food, banking, etc (Sutadian et al., 2017). Moreover, this prosess has been acepted throughout the world due to is multifunctional characteristics described by (Forman & Gass, 2001), who started the distribution resources, quality measurement, and forecasting. Furthermore, the AHP method has been used for the an analytical hierarchy process approach for prioritization of objective and parameters for an intergrated urban water management. Also Sancak et al. (2022), it is aimed to reveal the relationship between the subject judgement of the decision-makers and the objective hydrological factors by synthesizing “water important values” obtained with AHP and measurement data.

The AHP framework was constructed using the selected Strengths-Opportunity (S-O) strategy identified in the preceding SWOT analysis (Ni et al., 2025). This hierarchical model enables structured prioritization of strategic alternatives by intergrating expert judgment across environmental, economic, and socio-institutional dimentions, ensuring that choosen strategy aligns with both internal capabilities and external opportunities (Yang & Rahim, 2025). This stucture enabled systematic pairwise comparisons and prioritization based on expert input. Following the identification of internal and external factors through SWOT analysis and their quantification IFAS and EFAS matrices, the selected Strengths-Opportunities (S-O) strategies were classified into four strategic categories within the AHP framework. This classification process transforms the broad strategic directions formulated in the SWOT matrix into discrete alternatives suitable fot quantitative comparison in AHP (Zayim, 2024) These categories are shown in Table 8, reflecting tarteged interventions aligned with stakeholder preferences and resource contraints.

Table 8. The weakness-opportunity strategies classified as alternatives within the AHP framework

Strengths-Opportunities (SO)	
Institutionalization of Conservation Programs (S1, O2) Enforcement of Conservation Regulation (S1, O3) Internalization of Conservation Values (S3, S1, O1) Scientific Documentation of Local Wisdom (S3, O3)	Policy and Institutional Strategy (A1)
Strenghtening Community-Based Management (S2,O1) Technical Conservation Training (S5, O2) Local Ecotourism Guides (S2, O4)	Human Resource Capacity Strategy (A2)
Cultural Integration in Ecotourism (S3, O4) Development of Green Marketing (S4, O4)	Cultural Values Strategy (A3)
Conservation Budget Acceleration (S4, O3)	Government-Community Partnership Strategy (A4)

The questionnaire data collected from the experts was transformed into a pairwise comparison matrix to obtain the relative weights of each criterion. The matrix was then tabulated and normalized to facilitate the computational process. Next, the Consistency Index and Consistency Ratio were calculated to validate the reliability of the expert assessments. The results of the comparison matrix calculations for both the criteria and the alternative strategies are further detailed in tabular form. In the context of its application, lake management policies must absolutely be site-specific. This is because each lake has unique characteristics, utilization objectives, and priority scales, thus requiring different optimization approaches in its management plan. Nevertheless, there are several essential parameters that must generally be accommodated in such policies. These aspects include the control of invasive aquatic species, wildlife and fisheries management, nutrient load regulation, water quality maintenance, and the management of recreational areas and watersheds (DAS). Ultimately, action recommendations must be designed in accordance with local conditions and the lake’s priority issues, while still considering economic efficiency and the implementation timeline.

Table 9. Alternative strategy of Telaga Cebong

Alternative Strategy	Value
Policy and Institutional Strategy	0.533
Human Resource Capacity Strategy	0.223
Cultural Values Strategy	0.165
Government-Community Partnership Strategy	0.078

Table 9 shows that final priority for each management strategy were obtained by multiplying the eigenvalue of its corresponding main criterion. The result on the eigenvector result from the AHP analysis, the highest priority weight was assigned to the Policy and Institutional Strategy with score of 0.533 (53.3%). This indicates that respondents primarily local stakeholders favor policy and institutional interventions as the most effective strategy for managing telaga Cebong. This was followed by the Human Resource Capacity Strategy at 0.223 (22.3%), the Cultural Values Strategy at 0.165 (16.5%), and the Government-Community Partership Strategy at 0.078 (7.8%). These findings reflect a strategy preference for formal governance mechanisms supported by capacity building and cultural engagement. Furthermore, as with Kalmah et al. (2022) , the content of policy can be the key to sustainable lake management in Indonesia because reportedly there has been positive changes in Rawapening condition. Moreover, the multifuntional exploitations of these stagnan water challenge the determination of specific operation and restoration action and need multidisiplinary research and multi-stakeholder approaches (Tallar & Suen, 2017).

The empirical results of this study underscore a pivotal shift in ecosystem management paradigm, where the heavy prioritization of institutional and policy interventions (53.3% AHP weight) signifies that ecological restoration is fundamentally a governance challenge rather than a purely technical one. In the long term, this strategic orientation institutionalizes a proactive governance architecture, replacing fragmented, reactive responses with a streamlined, multi-sectoral framework that integrates agricultural, environmental, and tourism mandates. By embedding community-based insights into this formal structure, the strategy transcends traditional 'top-down' models, fostering a participatory empowerment dynamic that aligns local economic survival specifically in irrigation-dependent agriculture with rigorous conservation goals. Consequently, the framework acts as a socio-ecological buffer; it bolsters ecosystem resilience by codifying environmental thresholds into enforceable policy, thereby insulating Telaga Cebong from irreversible degradation caused by escalating anthropogenic pressures. Ultimately, this synthesis of high-level policy weighting and local engagement offers a robust, replicable blueprint for addressing the 'wicked problems' of freshwater management in rural global contexts. In conclusion, the case study at Telaga Cebong demonstrates the essential role of integrating ecological assessments with structured decision-support tools, namely SWOT and AHP. This comprehensive approach not only identifies key conservation priorities but also provides a framework for sustainable lake management that can be replicated in similar freshwater ecosystems. For future development, this study recommends the need for more precise methodologies in follow-up research, particularly through the implementation of long-term ecological monitoring and more inclusive and participatory stakeholder engagement.

4. Conclusions

This study demonstrates that the sustainable management of Telaga Cebong, a geosite and vital freshwater ecosystem within the Dieng Plateau, necessitates an integrated, strategic, and policy-driven approach. Using a hybrid framework that combined qualitative SWOT analysis with the quantitative Analytic Hierarchy Process (AHP), we identified the key leverage points for long-term sustainability. The SWOT analysis revealed that the management context is optimally positioned for an aggressive Strengths-Opportunities (S-O) strategy. This is driven by internal assets, such as existing local irrigation regulations, strong cultural values, and community participation, aligning with external opportunities, particularly governmental support for the Dieng National Geopark and ecotourism potential. However, these strengths are critically challenged by pressing weaknesses, including insufficient long-term water quality monitoring, ecological degradation (lake shrinkage due to sedimentation), and limited institutional oversight.

The subsequent AHP analysis provided a structured prioritization of management alternatives. The results conclusively confirm that the Policy and Institutional Strategy holds the highest strategic importance with a priority weight of 53.3%. This is followed by the Human Resource Capacity Strategy (22.3%), Cultural Values Strategy (16.5%), and Government-Community Partnership Strategy (7.8%). These findings underscore the importance of formal governance mechanisms supported by community engagement and capacity building to ensure the long-term sustainability of Telaga Cebong.

Acknowledgement
Appreciation is extended to the supervisors, experts and informants who assisted in this research.

Author Contribution
S.R conceptualized the study, wrote, reviewed, and edited the article.

Funding
This research received no external funding.

Ethical Review Board Statement
Not available.

Informed Consent Statement
Informed consent was obtained from all subjects involved in the study.

Data Availability Statement
Not available.

Conflicts of Interest
The author declares no conflict of interest.

Declaration of Generative AI Use
During the preparation of this work, the author(s) used Grammarly to assist in improving grammar, clarity, and academic tone of the manuscript. After using this tool, the author(s) reviewed and edited the content as needed and took full responsibility for the content of the publication.

References
Akinnawo, S. O. (2023). Eutrophication: Causes, consequences, physical, chemical and biological techniques for mitigation strategies. *Environmental Challenges*, *12*, 100733. https://doi.org/10.1016/j.envc.2023.100733

Albayrak, K. (2022). A hybrid fuzzy decision making approach for sitting a solid waste energy production plant. *Soft Computing*, *26*(2), 575–587. https://doi.org/10.1007/s00500-021-06563-x

Amal, M. I. L. ., Najib, M., Awalia, R., & Andresi, B. (2024). Strategi Pengembangan Kawasan Wisata Pesisir Danau Poso Desa Pasir Putih Kabupaten Poso. *Journal Of Urban And Regional Planning Of Tadulako*, *3*(1). https://doi.org/10.22487/peweka.v3i1.29

Amorocho-Daza, H., Cabrales, S., Santos, R., & Saldarriaga, J. (2019). A new multi-Criteria decision analysis methodology for the selection of new water supply infrastructure. *Water (Switzerland)*, *11*(4). https://doi.org/10.3390/w11040805

Badan Pusat Statistik Kabupaten Wonosobo. (2024). *Kabupaten Wonosobo dalam angka 2024*. Badan Pusat Statistik Indonesia.

Banihabib, M. E., Azarnivand, A., & Peralta, R. C. (2015). A new framework for strategic planning to stabilize a shrinking lake. *Lake and Reservoir Management*, *31*(1), 31–43. https://doi.org/10.1080/10402381.2014.987409

Boyd, C. E. (2015). *Water Quality*. Springer International Publishing. https://doi.org/10.1007/978-3-319-17446-4

Cacal, J. C., Taboada, E. B., & Mehboob, M. S. (2023). Strategic Implementation of Integrated Water Resource Management in Selected Areas of Palawan: SWOT-AHP Method. *Sustainability*, *15*(4), 2922. https://doi.org/10.3390/su15042922

Cantonati, M., Poikane, S., Pringle, C. M., Stevens, L. E., Turak, E., Heino, J., Richardson, J. S., Bolpagni, R., Borrini, A., Cid, N., Čtvrtlíková, M., Galassi, D. M. P., Hájek, M., Hawes, I., Levkov, Z., Naselli-Flores, L., Saber, A. A., Cicco, M. Di, Fiasca, B., Znachor, P. (2020). Characteristics, Main Impacts, and Stewardship of Natural and Artificial Freshwater Environments: Consequences for Biodiversity Conservation. *Water*, *12*(1), 260. https://doi.org/10.3390/w12010260

Chompook, P., Roemmontri, J., & Ketsakorn, A. (2023). The Application Of Analytic Hierarchy Process (AHP) For Selecting Community Problems: Multicriteria Decision-Making Approach On Environmental Health Aspects. *Journal of Sustainability Science and Management*, *18*(10), 138–149. https://doi.org/10.46754/jssm.2023.10.009

Cloutier, R. G., & Sanchez, M. (2007). Trophic Status Evaluation for 154 Lakes in Quebec, Canada: Monitoring and Recommendations. *Water Quality Research Journal*, *42*(4), 252–268. https://doi.org/10.2166/wqrj.2007.028

Dilazuardi, M. (2018). *Kualitas Air Telaga Cebong Dieng Jawa Tengah Berdasarkan Struktur Komunitas Diatom Bentik*. Universitas Diponegoro.

Đurić, Z., Cvijanović, D., Petek, V., & Potočnik Topler, J. (2025). Sustainability Struggle: Challenges and Issues in Managing Sustainability and Environmental Protection in Local Tourism Destinations Practices—An Overview †. *Sustainability (Switzerland)*, *17*(15). https://doi.org/10.3390/su17157134

Elser, J. J., Devlin, S. P., Yu, J., Baumann, A., Church, M. J., Dore, J. E., Hall, R. O., Hollar, M., Johnson, T., Vick-Majors, T., & White, C. (2022). Sustained stoichiometric imbalance and its ecological consequences in a large oligotrophic lake. *Proceedings of the National Academy of Sciences*, *119*(30). https://doi.org/10.1073/pnas.2202268119

European Environment Agency. (2000). *Corine Land Cover; European Environment Agency*. EEA.

Flörke, M., Bärlund, I., van Vliet, M. T., Bouwman, A. F., & Wada, Y. (2019). Analysing trade-offs between SDGs related to water quality using salinity as a marker. *Current Opinion in Environmental Sustainability*, *36*, 96–104. https://doi.org/10.1016/j.cosust.2018.10.005

Forman, E. H., & Gass, S. I. (2001). The Analytic Hierarchy Process: An Exposition. *Source: Operations Research*, *49*(4). https://www.jstor.org/stable/3088581

Ghazinoory, S., Abdi, M., & Azadegan-Mehr, M. (2011). SWOT Methodology: A State-Of-The-Art Review For The Past, A Framework For The Future/SSGG Metodologija: Praeities Ir Ateities Analizė. *Journal of Business Economics and Management*, *12*(1), 24–48. https://doi.org/10.3846/16111699.2011.555358

Glibert, P., Heil, C., Wilkerson, F., & Dugdale, R. (2018). Nutrients and Harmful Algal Blooms: Dynamic Kinetics and Flexible Nutrition. In: Glibert, P., Berdalet, E., Burford, M., Pitcher, G., Zhou, M. (eds) *Global Ecology and Oceanography of Harmful Algal Blooms . Ecological Studies*, vol 232. Springer. https://doi.org/10.1007/978-3-319-70069-4_6

Hajkowicz, S., & Collins, K. A. (2007). A Review of Multiple Criteria Analysis for Water Resource Planning and Management. *WaterResour. Management*, *21*, 1553–1556. https://ideas.repec.org/a/spr/waterr/v21y2007i9p1553-1566.html

Harris, R., & Shahriyani S. R. (2024). Investment Incentives in Environmental Projects in Indonesia: An Analysis of Legal Potentials & Challenges. *Nurlaily*, *17*(1), 17–32. https://doi.org/10.37253/jjr.v2

He, H., Zumitzavan, V., & Yang, W. (2025). Integrating Local Communities into Sustainable Tourism Development: Strategic Policy Perspectives along the China-Laos High-Speed Railway. In *International Journal of Environmental Sciences*, *11*(14). https://www.theaspd.com/ijes.php

Ho, L. T., & Goethals, P. L. M. (2019). Opportunities and challenges for the sustainability of lakes and reservoirs in relation to the Sustainable Development Goals (SDGs). *Water (Switzerland)*, *11*(7). https://doi.org/10.3390/w11071462

Ho, W. (2008). Integrated analytic hierarchy process and its applications–A literature review. *European Journal of Operational Research*, *186*(1), 211–228. https://doi.org/10.1016/j.ejor.2007.01.004

Ishizaka, A., & Labib, A. (2009). Analytic Hierarchy Process and Expert Choice: Benefits and limitations. *OR Insight*, *22*(4), 201–220. https://doi.org/10.1057/ori.2009.10

Jeppesen, E., Sørensen, P. B., Johansson, L. S., Søndergaard, M., Lauridsen, T. L., Nielsen, A., & Mejlhede, P. (2025). Recovery of lakes from eutrophication: changes in nitrogen retention capacity and the role of nitrogen legacy in 10 Danish lakes studied over 30 years. *Hydrobiologia*, *852*(2), 377–387. https://doi.org/10.1007/s10750-024-05478-6

Jiang, M., & Nakano, S. (2022). The crucial influence of trophic status on the relative requirement of nitrogen to phosphorus for phytoplankton growth. *Water Research*, *222*, 118868. https://doi.org/10.1016/j.watres.2022.118868

Kalmah, K., Larasati, E., Purnaweni, H., & Kismartini, K. (2022). Policy Content Analysis of Rawapening Lake Management Team. *Technium Social Sciences Journal*, *38*, 768–778. https://doi.org/10.47577/tssj.v38i1.7894

Kumar, G. P., & Osuri, M. (2014). *Evaluation of Multi Criteria Decision Making Methods for Potential Use in Application Security*. Diva Portal.

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

Lee, B. K., Kang, K. H., & Lee, Y. H. (2008). Decomposition heuristic to minimize total cost in a multi-level supply chain network. *Computers & Industrial Engineering*, *54*(4), 945–959. https://doi.org/10.1016/j.cie.2007.11.005

Leigh, D. (2009). *Handbook of Improving Performance in the Workplace: Selecting and Implementing Performance Interventions* (R. Watkins & D. Leigh, Eds.). Wiley. https://doi.org/10.1002/9780470587102

Lynch, A. J., Cooke, S. J., Arthington, A. H., Baigun, C., Bossenbroek, L., Dickens, C., Harrison, I., Kimirei, I., Langhans, S. D., Murchie, K. J., Olden, J. D., Ormerod, S. J., Owuor, M., Raghavan, R., Samways, M. J., Schinegger, R., Sharma, S., Tachamo-Shah, R., Tickner, D., … Jähnig, S. C. (2023). People need freshwater biodiversity. *WIREs Water*, *10*(3). https://doi.org/10.1002/wat2.1633

Makanda, K., Nzama, S., & Kanyerere, T. (2022). Assessing the Role of Water Resources Protection Practice for Sustainable Water Resources Management: A Review. *Water*, *14*(19), 3153. https://doi.org/10.3390/w14193153

Mandari, D. Z., Thamrin, T., & Putra, R. M. (2024). Research Article Open Access Strategi Pengelolaan Danau Sepunjung Desa Rantau Baru Kecamatan Pangkalan Kerinci Kabupaten Pelalawan. *Jurnal Zona*, *7*(2), 150–159. https://doi.org/10.52364/zona.v7i2.101

Mladenovi´c-Ranisavljevi´c, I. I., Taki´c, L., & Nikoli´c, Đ. (2018). Water Quality Assessment Based on Combined Multi-Criteria Decision Making Method with Index Method. *Water*

Resour. Manag, *32*, 2261–2276. https://ideas.repec.org/a/spr/waterr/v32y2018i7d10.1007_s11269-018-1927-3.html

Ni, Z., Zhao, W., Yin, C., Meadows, M. E., & Pereira, P. (2025). Mapping geography's engagement with the Sustainable Development Goals: Research foci, contributions, and future directions. *Geography and Sustainability*, 100376. https://doi.org/10.1016/j.geosus.2025.100376

Ntislidou, C., Lazaridou, M., Tsiaoussi, V., & Bobori, D. C. (2018). A new multimetric macroinvertebrate index for the ecological assessment of Mediterranean lakes. *Ecological Indicators*, *93*, 1020–1033. https://doi.org/10.1016/j.ecolind.2018.05.071

Petriki, O., & Bobori, D. C. (2025). Ecological Assessment and SWOT–AHP Integration for Sustainable Management of a Mediterranean Freshwater Lake. *Sustainability (Switzerland)*, *17*(11). https://doi.org/10.3390/su17114950

Prentice, M. J. (2021). *Phosphorus sources contributing to phytoplankton blooms in a subtropical reservoir*. https://doi.org/10.25904/1912/4353

Reid, A. J., Carlson, A. K., Creed, I. F., Eliason, E. J., Gell, P. A., Johnson, P. T. J., Kidd, K. A., MacCormack, T. J., Olden, J. D., Ormerod, S. J., Smol, J. P., Taylor, W. W., Tockner, K., Vermaire, J. C., Dudgeon, D., & Cooke, S. J. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*, *94*(3), 849–873. https://doi.org/10.1111/brv.12480

Rosyada, S. (2023). *Kajian Status Trofik Sebagai Upaya Pengelolaan Kualitas Perairan di Telaga Cebong, Kabupaten Wonosobo, Jawa Tengah*. Universitas Gadjah Mada.

Saaty, T. L. (1980). *The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation*. Mcgraw-Hill.

Saaty, T. L. (2008). Decision making with the analytic hierarchy process. *International Journal of Services Sciences, 1,* 83. https://doi.org/10.1504/IJSSCI.2008.017590

Sancak, A. Ş., Kesgin, E., Tan, R. I., Agaccioglu, H., Demir, İ., & Sinan, İ. (2022). Effect of lake-water budget management preferences on optimum operating conditions and neighboring basins interacting: case of Lake Beyşehir (Turkey). *Sustainable Water Resources Management*, *8*(1), 12. https://doi.org/10.1007/s40899-021-00599-5

Sarkar, K., & Majumder, M. (2021). Application of AHP-based water quality index for quality monitoring of peri-urban watershed. *Environment, Development and Sustainability* , *23*, 1780–1798. https://doi.org/10.1007/s10668-020-00651-y

Scolozzi, R., Schirpke, U., Morri, E., D'Amato, D., & Santolini, R. (2014). Ecosystem services-based SWOT analysis of protected areas for conservation strategies. *Journal of Environmental Management*, *146*, 543–551. https://doi.org/10.1016/j.jenvman.2014.05.040

Setiawan, M. A., Stoetter, J., Sartohadi, J., & Christanto, N. (2009). The Integrated Soil Erosion Risk Management Model of Central Java, Indonesia. *Geophysical Research Abstracts*, *11*. http://meetingorganizer.copernicus.org/EGU2009/EGU2009-6802.pdf

Sinulingga, S., Marpaung, J. L., Sibarani, H. S., Amalia, A., & Kumalasari, F. (2024). Sustainable Tourism Development in Lake Toba: A Comprehensive Analysis of Economic, Environmental, and Cultural Impacts. *International Journal of Sustainable Development and Planning*, *19*(8), 2907–2917. https://doi.org/10.18280/ijsdp.190809

Soares, L. M. V., Thouillot, M., Frossard, V., Desgué-Itier, O., Barouillet, C., Baulaz, Y., Clément, J.-C., Domaizon, I., Dorioz, J.-M., Goulon, C., Guillard, J., Jacquet, S., Réalis, E., Tran Khac, V., & Jenny, J.-P. (2025). Expanding the European water Framework Directive indicators to address long-term climate change impacts on lakes using mechanistic lake models. *Ecological Indicators*, *172*, 113220. https://doi.org/10.1016/j.ecolind.2025.113220

Soeprobowati, T. R., Agung Suedy, S. W., & Hadiyanto. (2017). Diatoms and Water Quality of Telaga Warna Dieng, Java Indonesia. *IOP Conference Series: Earth and Environmental Science*, *55*(1). https://doi.org/10.1088/1755-1315/55/1/012051

Søndergaard, M., Lauridsen, T. L., Johansson, L. S., & Jeppesen, E. (2017). Nitrogen or phosphorus limitation in lakes and its impact on phytoplankton biomass and submerged macrophyte cover. *Hydrobiologia*, *795*(1), 35–48. https://doi.org/10.1007/s10750-017-3110-x

Sudarmadji, Supriyono, H., & Lestari, S. (2015). Danau-Danau Volkanik Di Dataran Tinggi Dieng: Pemanfaatan dan Masalah Lingkungan yang Dihadapi. *Jurnal Tekno Sains*, *5*(1). https://doi.org/10.22146/teknosains.26856

Sudarmadji, S., Suprayogi, S., Lestari, S., & Malawani, M. N. (2019). Water quality and sustainability of Merdada Lake, Dieng, Indonesia. *E3S Web of Conferences*, *76*. https://doi.org/10.1051/e3sconf/20197602003

Sutadian, A. D., Muttil, N., Yilmaz, A. G., & Perera, B. J. C. (2017). Using the Analytic Hierarchy Process to identify parameter weights for developing a water quality index. *Ecological Indicators*, *75*, 220–233. https://doi.org/10.1016/j.ecolind.2016.12.043

Tallar, R., & Suen, J.-P. (2017). Measuring the Aesthetic Value of Multifunctional Lakes Using an Enhanced Visual Quality Method. *Water*, *9*(4), 233. https://doi.org/10.3390/w9040233

Thungngern, J., Wijitkosum, S., Sriburi, T., & Sukhsri, C. (2015). A Review of the Analytical Hierarchy Process (AHP): An Approach to Water Resource Management in Thailand. *Applied Environmental Research*, 13–32. https://doi.org/10.35762/AER.2015.37.3.2

Thuyen, N. T. T. (2023). AHP-SWOT Analysis of Strengths, Weaknesses, Opportunities, and Threats of Implementing Green Innovation. *Thailand and The World Economy*, *41*(3). https://so05.tci-thaijo.org/index.php/TER/article/view/267624

Tibebe, D., Kassa, Y., Melaku, A., & Lakew, S. (2019). Investigation of spatio-temporal variations of selected water quality parameters and trophic status of Lake Tana for sustainable management, Ethiopia. *Microchemical Journal*, *148*, 374–384. https://doi.org/10.1016/j.microc.2019.04.085

Tolonen, K. T., Hämäläinen, H., Lensu, A., Meriläinen, J. J., Palomäki, A., & Karjalainen, J. (2014). The relevance of ecological status to ecosystem functions and services in a large boreal lake. *Journal of Applied Ecology*, *51*(3), 560–571. https://doi.org/10.1111/1365-2664.12245

Tsiaoussi V., Mavromati, I. E., & Kemitzoglou, D. (2017). *Report on the development of the national method for the assessment of the ecological status of natural lakes in Greece, using the biological quality element "phytoplankton".* The Goulandris Natural History Museum: Greek Biotope/Wetland Centre.

Ustaoglu, E., & Williams, B. (2017). Determinants of Urban Expansion and Agricultural Land Conversion in 25 EU Countries. *Environmental Management*, *60*(4), 717–746. https://doi.org/10.1007/s00267-017-0908-2

Lai, V. S., Trueblood, R. P., & Wong, B. K. (1999). Software selection: a case study of the application of the analytical hierarchical process to the selection of a multimedia authoring system. *Information & Management*, *36*(4), 221–232. https://doi.org/10.1016/S0378-7206(99)00021-X

Walangitan, H. D., Rotinsulu, W. C., & Paat, F. J. (2024). Analysis Of Management Strategies For Lake Tondano Ecosystem In North Sulawesi, Indonesia Using Swot And Ahp Methods. *Revista de Gestao Social e Ambiental*, *18*(2). https://doi.org/10.24857/RGSA.V18N2-087

Wheelen, T. L, & Hunger, D. J. (1984.). *Strategic Management Model Gathering Information Societal Environment: General forces*. Addison-Wesley.

Yang, Q., & Rahim, A. B. A. (2025). Challenges and prospects of sustainable tourism development in Jiuzhaigou, China. *International Journal of Asian Social Science*, *15*(9), 302–314. https://doi.org/10.55493/5007.v15i9.5542

Yavuz, F., & Baycan, T. (2014). Stakeholder-Based Decision Making In Integrated Watershed Management Using Swot And Analytic Hierarchy Process Combination. *International Journal of the Analytic Hierarchy Process*, *6*(1). https://doi.org/10.13033/ijahp.v6i1.194

Zayim, M. (2024). The relationship between culture, geography, and tourism: Interconnected and influential factors. In *Cases on Innovation and Sustainability in*

Tourism (pp. 267–283). IGI Global. https://doi.org/10.4018/979-8-3693-4151-3.ch015

Biography of Author

Safira Rosyada, Department of Environmental Science, Faculty of Postgraduate Studies, Universitas Gadjah Mada, Yogyakarta, DI Yogyakarta 55284, Indonesia.

- Email: safirarosyada@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A