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RESEARCH ARTICLE

PRIORITIZING OPTIMAL STRATEGIES FOR SUSTAINABLE WATER RESOURCE MANAGEMENT IN BUENG SI FAI, THAILAND USING THE ANALYTICAL HIERARCHY PROCESS (AHP)

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ABSTRACT

This study investigates sustainable water resource management strategies for Bueng Si Fai, an ecologically and socio-economically important freshwater wetland in Thailand. It aims to identify and prioritize strategic alternatives by assessing the relative importance of environmental, social, economic, and technological criteria using the Analytic Hierarchy Process (AHP). Data were collected via questionnaires and interviews with 20 experts in water management and sustainable development. Results show environmental factors as most influential (32%), particularly forest and wetland abundance (27%), followed by social (29%) and economic (24%) factors, with community development and local economic stability as key sub-criteria. Technological factors had the lowest weight (15%), though increasing water availability was prioritized. Biodiversity conservation emerged as the top strategic goal (41%), underscoring the need to embed ecological priorities within development plans. The findings validate AHP as an effective tool for complex decision-making and emphasize a holistic, participatory approach to sustainable water management. This framework offers a transferable model for similar wetland ecosystems.

KEYWORDS

Analytic Hierarchy Process, Sustainable Development, Water Resources Management, Environmental Factors, Social Factors, Economic Factors, Technological Factors.

1. INTRODUCTION

Water resource management is a fundamental pillar for achieving balanced and sustainable development, supporting both ecological restoration and environmental equilibrium. It is also closely linked to improvements in water governance, environmental quality, and human well-being (DWR, 2013). Many countries are facing growing challenges from the rapidly increasing demand for water driven by population growth, economic expansion, urbanization, industrial development, and mechanization (Ardakanian, 2010). Infrastructure development including road construction and tourism facilities often alters natural hydrological systems, significantly impacting water resources. Moreover, climate change induced droughts lead to rainfall variability, contributing to water scarcity (Supriyasilp et al., 2009). Reduced rainfall in catchment areas results in insufficient water stored in dams and reservoirs, especially during dry seasons. In addition, recurrent flooding, water pollution, and the degradation of aquatic ecosystems including biodiversity loss continue to worsen. Climate change, energy insecurity, and socioeconomic instability are interrelated threats that pose complex challenges to sustainable water resource management today (Ganoulis, 2009)

In the 21st century, growing global constraints on water resources have created complex challenges in managing water quality and availability (Ardakanian, 2010). Variability in supply and demand across regions calls for real-time, integrated water management. The Sustainable Development Goal on Water, established at the Rio+20 UN Conference, highlights water's vital role in economic growth, poverty reduction, and sustainable development. Water supports human needs, food and energy production, biodiversity, and climate regulation (Reid et al., 2005). Integrated planning aims to achieve water sustainability by reducing scarcity impacts over time and space (Chitradon et al., 2009; Loucks, 2000; GWP, 2012). Sustainable water management must balance the needs of current and future generations, ensuring poor communities' access while meeting growing economic demands without harming ecosystems. Key strategies include innovative production and consumption, efficient use, financial tools, and alternative water sources (Alexandratos et al., 2012; UN-Water, 2015). These integrated approaches align demand with supply, reduce risks, and support environmental, social, and economic sustainability from the start.

Water management is inherently multidisciplinary, involving trade-offs that must be addressed through participatory and transparent decision-making (Loucks, 2000). It should incorporate consistent monitoring, cost-effectiveness, and equitable stakeholder engagement. As emphasized in Our Common Future by the Brundtland Commission (UN, 1987). Sustainable water systems must meet the needs of both present and future societies while preserving ecological, environmental, and economic integrity (Loucks et al., 2000; McMahon, 1999; Water Foundation, 2020; Cypra et al., 2020). Achieving this balance is central to the SDGs (UN-Water, 2015; Cortés-Borda et al., 2024), which reflect a shift toward long-

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term strategic thinking (Gallagher et al., 2018). Without forward-looking water policies that consider basin-wide and intergenerational needs, sustainability cannot be achieved (Davis, 2007). Moreover, economic pressures have led to wetland degradation, increasing social vulnerability, especially in agriculture, a sector highly sensitive to climate change (Laeni, 2023). Holistic, interdisciplinary governance is required to enhance environmental outcomes and ensure cost-effective water management Bonacci, 2004; OCED, 1997).

Bueng Si Fai, a large freshwater body in lower northern Thailand, plays a vital role in regional water management as a designated wetland of international importance, fishery habitat, and water retention area. Despite its ecological significance, the area faces ongoing challenges such as land encroachment, declining water levels, pollution, and infrastructure degradation, which reflect broader water management issues in Thailand. Recent initiatives including canal dredging and lake deepening aim to increase storage capacity and improve dry-season water availability. In the Bueng Si Fai area, sustainable water and resource management must align with the Sustainable Development Goals (SDGs) by addressing four interrelated dimensions: environment, economy, society, and technology. These dimensions serve as a framework for assessing and prioritizing strategic alternatives, each supported by relevant development indicators to ensure systematic spatial planning and informed decision-making. The overarching goal is to achieve a balanced and integrated approach to water management that reflects the needs and dynamics of all sectors. In response to these challenges, the primary objectives of this study are to identify and prioritize sustainable development strategies for water resource management in Bueng Si Fai and to evaluate the relative importance of environmental, social, economic, and technological criteria, along with their sub-criteria, in order to determine the most effective and con-text-appropriate strategies that support long-term sustainability in Bueng Si Fai. To achieve these aims, the Analytical Hierarchy Process (AHP) is applied, utilizing data collected from questionnaire surveys and in-depth interviews. This structured decision-making method enables a comprehensive evaluation and ranking of strategic alternatives. The findings are intended to guide the development of an evidence-based management framework that supports future policy decisions and practical implementation tailored to the specific context of the area.

2. MATERIALS AND METHODS

2.1 Study area

Bueng Si Fai is located in Mueang District, Phichit Province, in the lower northern region of Thailand. The term "Bueng" refers to a still water body such as a freshwater wetland. The area lies within a central lowland plain and spans several sub-districts (Table 1). The climate is tropical, with an average annual temperature of 26.8°C, ranging from 23.0°C in December–January to 29.6°C in April. Annual relative humidity averages 76.2%, varying between 67.1% and 83.9%. Based on 30-year data (1990–2019) from the Royal Irrigation Department, Department of Water Resources, and Thai Meteorological Department, the Nan River basin catchment area covers about 58,663 km^2. Annual runoff ranges from 7.87 to 13,266.53 million cubic meters. Average annual rainfall is 1,281.66 mm, with 87% (1,120.03 mm) occurring in the rainy season (May–October) and only 161.63 mm during the dry season (November–April).

Table 1: Geographical coverage of Bueng Si Fai

Bueng Si Fai Area (ha)	Sub-district	Sub-district area area (ha)	Bueng Si Fai in sub-district area (ha)
862.496	Tha Luang	2,446.4064	306.16
Lat 16.421665	Rong Chang	3,141.4816	108.2608
Long 100.324294	Khlong Khachen	3,248.3808	8.2624
	Muang Kao	4,039.6768	356.656
	Muang	1,034.4704	83.2496
	Total	**13,910.416**	**862.496**

2.2 Ecological importance of Bueng Si Fai

Bueng Si Fai currently holds 12.64 million cubic meters of water at a depth of 4.40 meters, reaching its full capacity. Covering approximately 0.45 square kilometers, it plays a vital role in regional water security as part of the lower Nan River Basin (Figure 1). As a wetland ecosystem, it functions as a natural reservoir for rainwater and runoff, filters sediments and pollutants, and supports biodiversity by connecting aquatic and terrestrial systems. Although altered by infrastructure and partial excavation, the lake still retains moist lowland features and provides important habitats for wildlife. It serves local communities by supplying water and supporting fisheries, vegetation, and water birds, contributing to ecological balance and sustainable resource use.

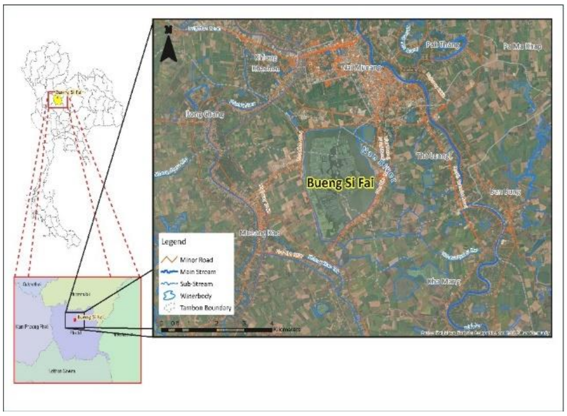

Figure 1: Map of Bueng Si Fai, located the lower northern region of Thailand

2.3 Developing main and sub-criteria for water resource management

The Analytical Hierarchy Process (AHP) is a multi-criteria decision-making method that combines qualitative and quantitative assessments via a structured decision matrix. This study evaluates 22 sub-criteria (Table 2) grouped into four main dimensions including environmental, social, economic, and technological, aligned with the Sustainable Development Goals (SDGs). These interrelated dimensions guide the assessment and prioritization of strategic alternatives for sustainable water management in Bueng Si Fai. The goal is a balanced, integrated approach that enhances local economic resilience and quality of life while ensuring ecological sustainability. The strategy promotes efficient and equitable water use within environmental limits, emphasizing long-term preservation and sustainable utilization. The framework aligns with national policies from the National Economic and Social Development Board (NESDB) and the Office of Natural Resources and Environmental Policy and Planning (ONEP).

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Table 2: Main and sub-criteria for water resource management in Bueng Si Fai

Main criteria	Sub–criteria (strategic indices)
Environment	Abundance of forest and wetland resources (A1)
	Abundance of water volume to support surface and groundwater use (A2)
	Good environmental quality (A3) Soil fertility (A4) Biodiversity (A5) Climate change (A6)
Social	Developing potential and adaptation in a knowledge-based society (B1)
	Quality of life and stability of people's livelihoods (B2) Developing strong communities (B3) Participation in preserving national identity, culture, and local cultural diversity (B4) Creating equality and participation (B5) Implementation of the water resources act, water plan (B6) Equitable access to water resources (B7)
Economic	Quality development (C1)
	Economic stability development (C2)
	Wealth distribution (C3)
	Community economy expansion and self-reliance (C4)
Technology	Increasing the amount of water resources (D1) Diverting water from neighboring areas (D2)
	Developing water network systems (D3) Diverting floodwater to store in medium-sized reservoirs (D4) Increasing drainage efficiency (D5)

2.4 Data analysis using the Analytic Hierarchy Process

In this study, the Analytic Hierarchy Process (AHP) was used to prioritize sustainable water management strategies for Bueng Si Fai. While calculations to determine weights and scores can be complex, they are manageable with tools like Excel or specialized software (Munier et al., 2021). AHP employs pairwise comparisons at each hierarchy level to assign relative importance (weights) to criteria, enabling structured analysis of complex, multi-dimensional problems. It is well-suited for integrating environmental, economic, social, and technological factors in water resource management, incorporating stakeholder input to align strategies with sustainable development. A mixed-methods approach combined questionnaires and in-depth interviews with 20 experts, each having over 15 years of experience in water resources and sustainable development. The AHP process involves several steps (Table 3).

First, problem decomposition restructures the complex decision into a hierarchy from the overall goal at the top, through primary and secondary criteria (environmental, economic, social, technological), down to strategic alternatives at the bottom. This facilitates systematic evaluation and pairwise comparisons. Next, relative importance is determined via pairwise comparisons of criteria and sub-criteria at the same level, using Saaty's 1–9 numerical scale (Saaty, 1987). This scale quantifies the priority between decision elements (Pawattana et al., 2008), enabling objective weighting within the hierarchy.

- A value of 1 implies equal importance,
- A value of 9 indicates extreme importance of one criterion over another,
- And reciprocals (e.g., 1/3, 1/5) reflect the lesser importance of one element compared to another.

These comparisons are used to construct a reciprocal square matrix A={a_{ij}}, where:

$a_{ij} = \frac{s_i}{s_j}$ and $a_{ij} = \frac{1}{a_{ij}}$

If all the comparisons are perfectly consistent, the matrix will satisfy the condition:

$a_{ik} = a_{ij} * a_{jk}$ for all i, j, k

In such a case, the matrix A is said to be consistent, and the elements $s_1, s_2, ..., s_n$ represent the exact weights of the corresponding criteria. However, in practical applications, the values a_{ij} are usually based on subjective human judgment, not exact measurements. As a result, they often deviate from the ideal ratio $\frac{s_i}{s_j}$, and the matrix may exhibit some inconsistency. Then the matrix A is consistent. In the case of a consistent matrix, the comparison is based on an exact measurement, that is, the weights $s_1, s_2 ..., s_n$. In practice, a_{ij} is not based on an exact measurement, but on a subjective judgment, where a_{ij} deviates from the ideal ratio $\frac{s_i}{s_j}$ and equation (1) is no longer true. Matrix of pairwise comparison values to find the priority vector (vector w), it must satisfy equation (2), where

$$AW = nw \quad (1)$$

$$AW = \lambda_{max} w \quad (2)$$

For numerical calculations, Saaty developed an approximation method in which the weights (also known as the priority vector) are determined by normalizing the eigenvector corresponding to the largest eigenvalue (λ_{max}) of the reciprocal pairwise comparison matrix, and the largest eigenvalue is given in Eq. 5.

$$w_i = \sum_{j=1}^{n} a_{ij} / n \quad (3)$$

$$a_{ij} = a_{ij} / \sum_{i=1}^{n} a_{ij} \quad (4)$$

$$\lambda_{max} = \frac{\sum_{i=1}^{n} \left(\sum_{j=1}^{n} (a_{ij} w_j) \right) / w_i}{n} \quad (5)$$

The degree of inconsistency in a pairwise comparison matrix was assessed using the Consistency Index (CI), calculated as:

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (6)$$

where λ_{max} is the maximum eigenvalue of the comparison matrix, and n is the number of criteria.

To determine whether the level of inconsistency is acceptable, the CI is compared with the Random Consistency Index (RI), which is derived from randomly generated matrices of the same size. The ratio of CI to RI, known as the Consistency Ratio (CR), is then computed as:

$$CR = \frac{CI}{RI} \quad (7)$$

A CR value of less than 0.10 is considered acceptable, indicating that the judgments are reasonably consistent. The steps involved in the Analytic Hierarchy Process (AHP) are summarized in simplified form in Table 3. After confirming consistency, the next step involves ranking the decision alternatives based on their relative importance derived from the calculated priority vectors.

Table 3: Steps associated with AHP (Kumar et al., 2023)

Step – 1 Formation of PCM $A = [aij]$	**Step – 2** Evaluation of Normalized PCM $\bar{A} = [\bar{a}_{ij}]$	**Step – 3** Evaluation of normalized Eigen vector $W = [w_1, w_2, w_3]^T$	**Step – 4** Evaluation of Principal Eigen value	**Step – 5** Consistency Ratio (CR)
$A = \begin{bmatrix} 1 & a_{12} & a_{13} \\ \frac{1}{a_{12}} & 1 & a_{23} \\ \frac{1}{a_{13}} & \frac{1}{a_{23}} & 1 \end{bmatrix}$	$A = \begin{bmatrix} \bar{a}_{11} & \bar{a}_{12} & \bar{a}_{13} \\ \bar{a}_{21} & \bar{a}_{22} & \bar{a}_{23} \\ \bar{a}_{31} & \bar{a}_{32} & \bar{a}_{33} \end{bmatrix}$	$w_i = \frac{\sum_{k=1}^{3} \bar{a}_{ik}}{3}$	$\lambda_{max} = \sum_{j=1}^{3} (\sum_{i=1}^{3} \bar{a}_{ij}) w_j$	$CR = \frac{CI}{RI}$ Where, $CI = \frac{(\lambda_{max} - n)}{n-1}$ and RI is random index
Where, $a_{12}, a_{13}, a_{23} \in S$	$\bar{a}_{ij} = \frac{a_{ij}}{\sum_{k=1}^{3} a_{kj}}$			

After analyzing each main criterion and its corresponding sub-criteria using the AHP process, the final step is synthesis, which involves integrating the results to identify the most appropriate strategic alternative. This is done by calculating the global priority of each alternative, taking into account the relative importance of each criterion and sub-criterion in relation to the overall goal.

$$goal = W_1 + W_2 + W_3 \ldots + W_n \quad (8)$$

$$W_i = S_1 + S_2 + S_3 \ldots + S_n$$

where goal is the weight of the main goal

W is the weight of the sub-criteria in the first level

S is the weight of the sub-criteria in the second level

$$W_g = S_{ij} \times W_i \quad (9)$$

where, Wg is the sub-weight that affects the main goal, as shown in Figure 2

The Analytical Hierarchy Process (AHP) addresses both subjective and objective aspects of decision-making by simplifying complex problems into pairwise comparisons and synthesizing the results. This approach is valuable for tasks such as resource allocation, selecting the best option, and strategic planning. AHP organizes the problem hierarchically, beginning with the overall goal, followed by main criteria and sub-criteria, and culminating in the optimal choice, through analyzing the relationships among these elements.

3. Results

The results of the AHP analysis revealed that environmental factors were considered the most critical in influencing the sustainable water resource management of Bueng Si Fai, receiving the highest priority weight of 0.32 (Table 4). This was followed by social factors with a weight of 0.29, economic factors at 0.24, and technological factors at 0.15. The prominence of environmental issues reflects the central role of Bueng Si Fai as a natural wetland ecosystem, which contributes significantly to hydrological functions such as water retention, sediment filtration, and ecological balance.

Table 4: Priority and decision matrix of main criteria

Criteria	E	E	S	T	W_i
E	0.300	0.563	0.300	0.125	0.32
E	0.100	0.188	0.300	0.375	0.24
S	0.300	0.188	0.300	0.375	0.29
T	0.300	0.063	0.100	0.125	0.15

Note; $\lambda_{max} = 4.018$, CI = 0.0059, CR = 0.007

Note; E is Environment, E is Economic, S is Social and T is technology.

Within the environmental dimension as shown in Table 5, the integrity of forests and wetlands (A1) emerged as the most influential sub-criterion in determining appropriate water resource management strategies, with a weight of 0.27. This was followed by good environmental quality (A3) at 0.25, and abundance of water volume to support surface and groundwater use (A2) at 0.19. Other factors such as soil fertility (A4) and biodiversity (A5) held moderate importance with weights of 0.11 and 0.10, respectively. The least influential sub-criterion was identified as climate change (A6), with a weight of 0.08. The prioritization reflects the crucial role of wetland–forest ecosystems in supporting hydrological and ecological stability.

Table 5: Priority and decision matrix of environmental sub-criteria

Criteria	A1	A2	A3	A4	A5	A6	W_i
A1	0.267	0.567	0.250	0.111	0.300	0.250	0.27
A2	0.083	0.150	0.250	0.300	0.100	0.250	0.19
A3	0.250	0.150	0.250	0.300	0.300	0.250	0.25
A4	0.250	0.050	0.083	0.100	0.100	0.083	0.11
A5	0.083	0.150	0.083	0.100	0.100	0.083	0.10
A6	0.083	0.050	0.083	0.100	0.100	0.083	0.08

Note; $\lambda_{max} = 6.431$, CI = 0.086, CR = 0.069

Note; A1 is abundance of forest and wetland resources, A2 is abundance of water volume to support surface and groundwater use, A3 is good environmental quality, A4 is soil fertility, A5 is biodiversity and A6 is climate change.

In the social dimension (Table 6), the most influential sub-criterion was strong community development (B3), with a relative weight of 0.25, indicating its central role in sustainable water resource management in the Bueng Si Fai area. This was followed by quality of life and stability of people's livelihood (B2) at 0.17, and joint efforts to preserve national identity, culture, and local cultural diversity (B4) at 0.15. Sub-criteria such as developing potential and adaptation in a knowledge-based society (B1) and quality of life and stability (B2) were weighted at 0.11, while creating equality and participation (B5) was ranked lowest at 0.07.

Table 6: Priority and decision matrix of social sub-criteria

Criteria	B1	B2	B3	B4	B5	B6	B7	W_i
B1	0.081	0.059	0.231	0.043	0.200	0.111	0.040	0.11
B2	0.243	0.176	0.231	0.130	0.200	0.111	0.120	0.17
B3	0.081	0.176	0.231	0.391	0.200	0.333	0.360	0.25
B4	0.243	0.176	0.077	0.130	0.200	0.111	0.120	0.15

Table 6 (Cont.): Priority and decision matrix of social sub-criteria								
B5	0.027	0.059	0.077	0.043	0.067	0.111	0.120	0.07
B6	0.081	0.176	0.077	0.130	0.067	0.111	0.120	0.11
B7	0.243	0.176	0.077	0.130	0.067	0.111	0.120	0.13

Note; λ_{max} = 7.7378, CI = 0.1230, CR = 0.0911

Note; B1 is developing potential and adaptation in a knowledge-based society, B2 is quality of life and stability of people's livelihood, B3 is developing strong communities, B4 is participation in preserving national identity, culture, and local cultural diversity, B5 is creating equality and participation, B6 is implementation of the water resources act, water plan and B7 is equitable access to water resources.

Economic sub-criteria in water resource management revealed that stable economic development (C2) and self-reliant community economy (C4) were the most influential sub-criteria in selecting strategies for sustainable water resource management in the Bueng Si Fai area, with both criteria having an equal relative weight of 0.31 (Table 7). These were followed by quality development (C1) with a weight of 0.24, while wealth distribution (C3) was the least important, with a weight of 0.14. These findings indicate that promoting economic stability and self-reliance at the community level are critical to the success of sustainable water management strategies.

Table 7: Priority and decision matrix of economic sub-criteria

Criteria	C1	C2	C3	C4	W_i
C1	0.250	0.300	0.125	0.300	0.24
C2	0.250	0.300	0.375	0.300	0.31
C3	0.250	0.100	0.125	0.100	0.14
C4	0.250	0.300	0.375	0.300	0.31

Note; λ_{max}= 4.157, CI = 0.052, CR = 0.059

Note; C1 is quality development, C2 is economic stability development, C3 is wealth distribution and C4 is community economy expansion and self-reliance.

Technological sub-criteria indicate that the most important factor was increasing the amount of water resources (D1), with a relative weight of 0.25 (Table 8). This was followed by developing a water network system (D3) at 0.23, diverting water from neighboring areas (D2) at 0.20, increasing the efficiency of water drainage (D5) at 0.19, and diverting floodwater for storage in a medium-sized reservoir (D4) at 0.13. The prioritization of increasing available water resources reflects the importance of ensuring water accessibility for consumption, agriculture, and general utilization in the Bueng Si Fai area.

Table 8: Priority and decision matrix of technology sub-criteria

Criteria	D1	D2	D3	D4	D5	W_i
D1	0.231	0.474	0.231	0.111	0.200	0.25
D2	0.077	0.158	0.231	0.333	0.200	0.20
D3	0.231	0.158	0.231	0.333	0.200	0.23
D4	0.231	0.053	0.077	0.111	0.200	0.13
D5	0.231	0.158	0.231	0.111	0.200	0.19

Note; λ_{max}= 5.293 CI = 0.073 CR = 0.066

Note; D1 is increasing the amount of water resources, D2 is diverting water from neighboring areas, D3 is developing water network systems, D4 is diverting floodwater to store in medium-sized reservoirs and D5 is increasing drainage efficiency.

From this study, the data summarized in Figure 2 presents the best strategy for sustainable management of water resources in Bueng Si Fai. The analysis was based on four key dimensions: environmenta (W*1*), social (W*2*), economic (W*3*), and technical (W*4*). Among these, the environmental dimension (W*1*) was given the highest importance (*32%*), highlighting the need to conserve forest and wetland resources (*27%*), maintain good environmental quality (*25%*), and ensure the abundance of water for surface and groundwater use (*19%*). The social dimension (W*2*) followed closely with *29%*, emphasizing the development of strong communities and improving the quality of life and cultural preservation. The economic dimension (W*3*) accounted for *24%*, focusing on economic stability, community self-reliance, and quality development. Lastly, the technical dimension (W*4*) received *15%*, with priority placed on increasing water volume, developing water systems, and improving drainage efficiency. These findings indicate that a balanced, multi-dimensional approach, led by environmental and social considerations, is key to achieving sustainable water resource management in the area.

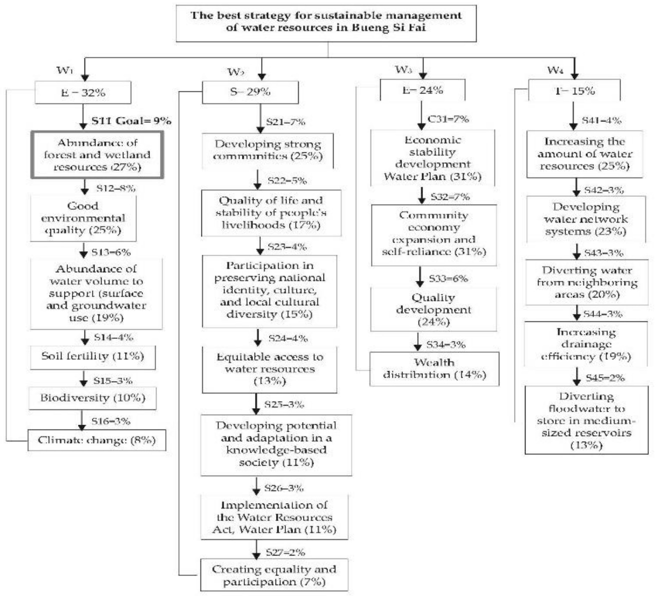

Figure 2: Hierarchical structure of key criteria for sustainable water resource management in Bueng Si Fai

The most appropriate strategy can be further analyzed by applying the AHP process specifically to the indicators identified as the most critical, thereby reducing the complexity of analysis by not including an excessive number of indicators. Using the development indicator criteria outlined (OEPP, 2021) the five selected indicators were used (Table 9). Among these, biodiversity (D2) was found to have the highest relative importance, with a weight of 0.42. This highlights the critical role of biodiversity in influencing the formulation of policies and strategies for water resource-related initiatives in Bueng Si Fai.

Table 9: Priority and weighting of alternative indicators for policy formulation to manage water resources in Bueng Si Fai

Criteria	D1	D2	D3	D4	D5	W_i
D1	0.048	0.091	0.032	0.036	0.024	0.05
D2	0.238	0.455	0.484	0.542	0.366	0.42
D3	0.238	0.152	0.161	0.181	0.122	0.17
D4	0.238	0.152	0.161	0.181	0.366	0.22
D5	0.238	0.152	0.161	0.060	0.122	0.15

Note; λ_{max}= 5.302 CI = 0.076 CR = 0.068

Note; D1 is forest area required to maintain ecological balance, D2 is biodiversity, D3 is status as a watershed area, D4 is expansion of wetlands and their relevance to well-being, society, culture, tourism, and recreation, and D5 is urban wetlands, including their conservation, maintenance, and sustainable use.

4. Discussion

4.1 Application of AHP for water resource management

This study clearly demonstrates the effectiveness of the Analytic Hierarchy Process (AHP) in planning sustainable water resource management for Bueng Si Fai. By comparing the relative importance of main criteria, sub-criteria, and key factors, AHP helps decision-makers identify optimal strategies. Using pairwise comparisons and weighted scoring based on input from 20 water resource experts, the approach ensured reliable prioritization with Consistency Ratios below 0.1. The findings align with, emphasizing participatory decision-making, and, who highlights the need to balance water sustainability with social, economic, and environmental dimensions (Feng, 2015; Faust et al., 2013). AHP's structured framework facilitates stakeholder engagement and clarifies complex criteria tailored to local conditions. Widely applied in water management, AHP supports selection, assessment, and prioritization tasks (Thungngern et al., 2015). It has proven effective in flood risk assessment, hazard forecasting, vulnerability evaluation, groundwater management, and urban planning for environmental sustainability (Adenle et al., 2021; Lee et al., 2008; Erhan et al., 2013; Abdullahi et al., 2023; Bharath et al., 2023). Overall, AHP simplifies multi-criteria decision-making, enabling systematic comparison and supporting informed choices for sustainable water governance.

4.2 The dominance of environmental factors in water resource management

The results indicate that environmental criteria are the most influential dimension (32%) in sustainable water resource management in Bueng Si Fai. Among sub-criteria, forest and wetland integrity ranked highest, followed by environmental quality and water availability. These findings align with global perspectives on wetland management, emphasizing the role of ecological balance and hydrological function in long-term sustainability. As a designated wetland of international importance since 1989 under the Asian Wetland Registry and a critical site for migratory birds under the Ramsar Convention, Bueng Si Fai also supports inland fisheries and freshwater biodiversity. Functionally, it serves as a natural retention basin similar to the "monkey cheek" model, mitigating floods during the rainy season (Åhlén et al., 2022). The high priority on forest and wetland integrity stems from their role in soil and water conservation. Forested wetlands stabilize soil, enhance infiltration, reduce erosion, and maintain water quality, factors essential for ecosystem resilience and biodiversity. Thus, conserving these areas is not only ecologically vital but also supports livelihoods and disaster risk reduction. These insights underscore the importance of ecosystem-based approaches, including protection, restoration, and sustainable use of forest-wetland systems, alongside integrated land-use planning and environmental monitoring.

This study also supports previous research that emphasized multi-criteria approaches to natural resource management (Shabbir et al., 2016; Calizaya et al., 2010). In the Poopó Lake basin, MCDA revealed environmental criteria as more critical than economic or social ones (Calizaya et al., 2010). Similarly, the AHP-based risk assessment framework developed highlighted environmental stability and system capacity by (Shabbir et al., 2016). These consistent findings reinforce the centrality of environmental considerations in sustainable resource governance.

4.3 The role of social capital and community empowerment

The social dimension (29%) highlights the critical role of community-based management in sustainable water governance. The highest-ranking social sub-criterion, strong community development, underscores the need for participatory governance, capacity-building, and inclusive decision-making. This aligns with previous studies that found empowered communities to be more effective in natural resource management. The integration of cultural identity, local knowledge, and equitable water access reflects the importance of socio-cultural values in water planning. To strengthen resilience and adaptive capacity, future initiatives should promote education, local leadership, and conflict resolution mechanisms. A key strategy is to foster environmental stewardship and a shared sense of ownership among residents, which supports Bueng Si Fai's potential as a center for environmental education, ecotourism, and sustainable local livelihoods. Community participation is essential for reducing conflicts, enhancing unity, and developing equitable water management plans.

These findings are consistent with previous research. As used the Analytic Hierarchy Process (AHP) to support decision-making in irrigation planning in Iran, demonstrating the value of stakeholder-driven models (Montazar et al., 2010). Similarly, applied AHP in river basin planning to incorporate both physical and socio-economic factors, highlighting stakeholder participation as key to effective and accepted water governance (Merwe et al., 1997). AHP thus offers a transparent framework that helps identify stakeholder priorities early in the process, promoting consensus and reducing future conflict.

4.4 Balancing economic growth with ecosystem resilience

Although ranked third (24%), the economic dimension underscores the close link between sustainable livelihoods and effective water governance. Sub-criteria such as economic stability and community self-reliance highlight the importance of balancing development with ecosystem preservation. In Bueng Si Fai, where water supports agriculture, fisheries, and tourism, equitable economic policies are essential. The relatively low score for wealth distribution suggests the need for policies that ensure fair benefit sharing. Incentives such as payment for ecosystem services (PES) and eco-tourism can enhance both conservation and income generation. Currently, Bueng Si Fai sustains local livelihoods through fisheries and the harvesting of natural resources. The surrounding wetland areas including rice paddies, lotus fields, and floodplains, support agricultural activities that reduce rural migration and stimulate the local economy. Water is thus a core driver of economic value, supporting both natural systems and human well-being.

Local communities value water in its natural state for subsistence and income. However, development projects, such as land expropriation, can degrade ecosystems by reducing vegetation cover and disturbing migratory species. Therefore, sustainability assessments should include both resource suitability and value-based analyses that integrate environmental, economic, and social dimensions. Environmental impacts should be assessed using clear indicators such as ecosystem stability and pollution levels, guided by measurable criteria like water quality, species abundance, and vegetation density (Tian et al., 2013).

4.5 The supporting role of technological solutions in water resource management

Although technological factors received the lowest weight (15%), they play a vital role in supporting ecological and community-based strategies. The top-ranking sub-criterion (increasing water availability) highlights the need for engineered solutions to address dry-season shortages and rainfall variability. The prioritization of water network development and improved drainage efficiency further emphasizes the importance of infrastructure for reliable water distribution and flood mitigation. However, technological interventions must align with ecological constraints and community priorities. Projects such as water diversion or reservoir construction should avoid disrupting natural hydrology or degrading wetland ecosystems. Sustainable water management in Bueng Si Fai requires integrated approaches that combine appropriate technologies with environmental protection and local engagement. Tools like smart water systems, real-time monitoring, and low-impact infrastructure can enhance system resilience when implemented within this holistic framework. Ongoing efforts, including canal dredging and deepening of Bueng Si Fai, demonstrate how technology can address immediate water scarcity while supporting long-term sustainability. In parallel, the development of risk indices that incorporate climatic and socio-economic variables offers a robust basis for vulnerability assessment. These findings affirm that both climatic and anthropogenic stressors—such as over-pumping, pollution, and climate change—can destabilize water systems, even through minor disturbances. Thus, rational planning and targeted technological applications are essential to strengthen system resilience and ensure long-term water security (Shabbir et al., 2016).

5. Conclusion

This study demonstrates the value of a structured, multi-criteria approach in developing sustainable water resource management strategies for Bueng Si Fai. Using expert input through the Analytical Hierarchy Process (AHP), the research systematically prioritized key criteria reflecting ecological, social, economic, and technological dimensions. Environmental factors, particularly forest and wetland integrity, emerged as the most critical, underscoring the central role of ecosystem health in long-term water management. Social and economic aspects highlighted the importance of community engagement and local resilience, while technological solutions were recognized as supportive tools to enhance water availability and system efficiency. The findings affirm that sustainable water management extends beyond technical fixes, requiring integrative, participatory planning that respects ecological limits and community needs. Emphasizing nature-based solutions, efficient infrastructure, and cross-sector coordination, this approach offers a practical model for Bueng Si Fai and other freshwater ecosystems facing similar challenges. Ultimately, the study contributes to understanding how context-sensitive, expert-informed strategies can foster resilient and sustainable water governance.

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