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## Application of PESTLE and SWOT in Conservation Planning

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### Abstract

The U Minh Thuong National Park (UMT) wetland ecosystem faces mounting pressures from climate change and anthropogenic activities, severely impacting ecosystem services and the livelihoods of vulnerable buffer zone communities. Developing a management plan that balances conservation with socio-economic development remains a complex challenge. Consequently, this study employs an integrated PESTLE and SWOT framework to formulate a sustainable management strategy. This study utilizes secondary data from reliable sources combined with field observations of the wetland ecosystem. The findings identify key strengths, including high biodiversity, a unique peatland ecosystem, and cultural heritage, alongside critical weaknesses such as fire risks associated with peat, inadequate tourism infrastructure, and shortages in specialized human resources. Leveraging these insights, we propose a comprehensive framework consisting of four priority solutions. First, implementing adaptive water management to mimic natural hydrological regimes. Second, diversifying local livelihoods and empowering communities through resource co-management models. Third, commercializing ecosystem services, such as carbon credits and Payment for Forest Environmental Services. Finally, leveraging smart technology to enhance biodiversity monitoring and forest fire prevention. By integrating these strategies, this research provides a robust, evidence-based foundation for policymakers to foster sustainable development in U Minh Thuong.

*Keywords:* Ecosystem Services; PESTLE; SWOT; Wetland Management; U Minh Thuong.

## 1. Introduction

Wetland ecosystems are significant importance to humans as they provide ecological services that include provisioning, regulating, cultural, and sustaining services [1-3]. The services provide tangible as well as intangible benefits, which are needed for the existence of human life [4]. Abundant food sources and biomass from wetlands contribute to stable livelihoods for surrounding communities, particularly vulnerable and landless groups [5-8]. Wetlands are characterized by high biodiversity and therefore a rich source of unique genetic resources [9, 10] and a repository of vital natural knowledge for the key sectors of education [4], healthcare [9], engineering, and arts. In the current context of climate change, clean water provided by wetlands is an invaluable resource. Wetlands play a critical role in regional water management as they absorb precipitation and floodwaters and help to recharge groundwaters [11]. Many insects and birds living in wetlands contribute significantly to the pollination of both wild and economically important local plants [12, 13]. Wetlands also serve as highly effective and free wastewater treatment plants, capable of processing many forms of waste from domestic, agricultural, and industrial sources [14].

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Flood and microclimate regulation are also vital functions. By storing or reducing the energy of flood currents, wetlands significantly mitigate impacts on populations and agricultural systems while curbing erosion downstream [15]. The sequestration of CO<sub>2</sub> into plant biomass and its fixation in soil and peat are critical in the current climate change context [16]. However, without proper management, the process can reverse, leading to significant emissions with 1.8–22.8 Mg CO<sub>2</sub>-eq/ha/year from soil carbon loss alone [17]. Beyond provisioning and regulating, supporting services are equally essential. Wetlands provide critical habitats for indigenous wildlife and migratory avifaunas [9, 18]. Nutrient cycling, such as photosynthesis, decomposition, and organic matter absorption, creates the unique values inherent to these ecosystems. Although providing intangible values, cultural services play a very special role. Wetlands act as living knowledge dictionaries and engaging learning models, helping learners grasp complex natural concepts. Furthermore, artistic inspiration often stems from wetland components in painting, poetry, film, and more [4, 19]. These values generated by wetlands sustain, support, and influence the distinct cultures and experiences of communities living nearby [20].

Currently, wetland habitats are undergoing serious decline from a number of anthropogenic and natural factors. The transformation of land for human use is the most important issue [21]. The conversion of natural wetlands to agricultural and aquaculture systems by humans across the globe has led to a large reduction in the size of natural ecosystems [22]. It is estimated that approximately 21% (equivalent to about 3.4 million km<sup>2</sup>) of global inland wetlands have been lost since 1700, primarily converted to agricultural land [23]. Research indicates that wetland health is declining at a rate of 0.02–3.14% per year [24], with wetlands vanishing at a pace nearly three times faster than forests [8]. In China, 73% of wetlands in the Sanjiang Plain have been lost in a period of 60 years, whereas about 64% of wetlands in India have degraded [3]. In Vietnam, U Minh Thuong National Park has lost around 84% of its major peatland wetland area since 1930 due to conversion to agricultural land [25]. Wetland habitat loss leads to a reduction in biodiversity and ecological services such as flood control, water purification, carbon sequestration, and recreation. It also increases greenhouse gas emissions due to the loss of peat and soil carbon. Furthermore, the loss of wetlands has a substantial impact on the livelihoods of communities dependent on them (agriculture, fisheries, fuel, fodder); poverty, inequality, and declining SDG, HDI, and EPI indices are often linked to areas of severe degradation [24].

Sustainable management of wetland ecosystems is a fundamental target of the globe and Vietnam. However, it is a significant challenge developing a management plan that effectively balances conservation with economic exploitation. Poor communities often rely heavily on agriculture, fisheries, and timber; thus, restricting exploitation for conservation may result in income loss and conflict [21]. Over-exploitation (agriculture, fishing, and harvesting materials) degrades wetlands but acts as a vital lifeline during poverty, creating a difficult trade-off. The major challenges are lack of an integrated management plan, weak enforcement, institutional redundancy, and the gap between policy and implementation [26, 27]. In many places, communities are only informed of decisions rather than actively involved [28], leading to poor understanding of conservation roles, resulting in illegal encroachment and resource extraction or other actions that harm the ecosystem [29]. Benefits from wetlands (such as eco-tourism or support projects) often accrue to those who already have resources rather than focusing on vulnerable groups [30]. The unpredictable and increasing consequences of climate change [31], which challenge conservation attempts, underscore the need for a flexible strategy that capitalizes on the presence of wetland ecosystems [32].

The SWOT analysis framework is a common tool used in conservation to evaluate and develop effective strategies by examining strengths, weaknesses, opportunities, and threats [5, 33, 34]. Additionally, SWOT has been applied in a large number of studies to prioritize and determine the best approaches for wetland conservation and development [35–38]. However, this framework has certain limitations when addressing the complex and intertwined factors affecting conservation initiatives [39], especially as more external factors impact management. The PESTLE study provides a thorough analysis by examining Political, Economic, Social, Technological, Legal, and Environmental elements that would impact a given situation. Amid rapid social change, making accurate decisions requires careful consideration of many complex influencing factors. Detailing each aspect can support policymakers in building effective solutions that meet practical needs. The PESTLE tool has been widely used by organizations and individuals worldwide for analysis and decision-making in various fields. A notable example is its use in analyzing coastal management in India to balance ecosystem value conservation with sustainable resource exploitation. Sridhar et al. [40] conducted an in-depth analysis identifying many strengths and difficulties to help manage coastal areas sustainably. Other applications of PESTLE include identifying risks associated with wave energy projects [41] and addressing stormwater management issues in Poland [42].

In general, studies have used the PESTLE method to facilitate in-depth management analysis and support decision-making. Although PESTLE is widely used in many industrial and economic sectors, it remains limited in the field of wetland conservation. To manage ecosystems sustainably, it is necessary to clearly understand the impacts of political, economic, social, and physiological aspects to help mitigate negative impacts and optimize the benefits provided [43]. The examination and assessment of the links between ecosystem services and the elements that influence them will lead to improvement of human well-being. This study explores the combination of these two analytical tools in the

development of a wetland ecosystem management strategy. This innovative methodology allows managers to successfully design specific biodiversity conservation plans through concrete evaluation and monitoring indicators so that more efficient investment efforts can be developed and the established conservation objectives can be achieved.

## 2. Methodology

### 2.1. Research Location

U Minh Thuong National Park was established pursuant to Decision No. 49/2002/QĐ-UBND dated July 8, 2002, by the People's Committee of Kien Giang province, based on the Prime Minister's Decision No. 11/2002/QĐ-TTg dated January 14, 2002, which upgraded the U Minh Thuong Nature Reserve to a National Park. It is located within the administrative boundaries of U Minh Thuong commune, An Giang province, with coordinates ranging from 9°31'16" to 9°39'45" latitude and 105°03'06" to 105°07'59" longitude (Figure 1). It is one of the two largest remaining peatland wetlands in the Mekong River basin and the second-to-last remnant of melaleuca forests on peat soil in the Mekong Delta, Vietnam [44]. The natural area of the National Park is 21,107 ha, comprising a core zone of 8,038 ha and a buffer zone of 13,069 ha, with six identified primary habitats: peatlands, melaleuca forests on peat, swamps, grasslands, open water, and a canal system. The park is recognized as an Important Bird Area (IBA) of Vietnam, the 8<sup>th</sup> Ramsar site in Vietnam, and is one of the ASEAN Heritage Parks.

The terrain is low-lying, with elevations ranging from 0.6 m to 1.8 m above mean sea level. Approximately 50% of the land area has an elevation below 1.0 meter; only 20% of the land lies between 1.4 m and 1.8 m [44]. During the 1993–2014 period, sea levels in nearby coastal areas rose by an average of 3.3 to 3.5 ( $\pm 0.7$ ) mm/year. Specifically, at Phu Quoc and Tho Chu islands near UMT, the rates were 3.4 ( $\pm 0.8$ ) mm/year and 5.3 ( $\pm 0.8$ ) mm/year, respectively. In peat swamps, the depth of peat layers varies from 40 to 120 cm depending on topographic elevation. According to Luom [45], the total peatland area is 3,906.6 ha, with two identified types: black peat and brown peat. Black peat, with high decomposition, is found in lower layers, while brown peat has a loose structure. Beneath the peat layers lies gray clay, and where peat is absent, thick layers of brown clay are found. Beneath the peat and clay are sulfidic horizons located at varying depths. In deeper areas, these horizons contain potential acid sulfate soils, while in shallower areas, they contain active acid sulfate soils.

UMT has a monsoon climate with a dry season from December to April and a rainy season lasting from May to November. The highest number of sunny days is recorded from January to April. Approximately 90% of annual rainfall occurs during the rainy season, particularly between August and September. Rainfall in the National Park is approximately 2,400 mm/year, with the number of rainy days ranging from 163 to 171 days. Conversely, the dry season receives very little water, accounting for only 5% (110–120 mm) of total annual rainfall, while evaporation rates during this period are very high, ranging from 587 to 614 mm [46]. The National Park lies within a sub-equatorial tropical monsoon climate zone and receives the highest rainfall in the Mekong Delta, a state that has remained quite stable for many years. The average annual humidity ranges from 82.2% to 87.5%. September and October are the most humid months (86.0–89.0%), and the driest months are February and March (75.6–83.2%). Temperatures range from 26.5 to 27.3 °C, occasionally fluctuating between 16.8 and 38.6 °C, with an average temperature of approximately 27 °C to 27.4 °C. April is typically the hottest month, and January is the coldest. UMT is primarily influenced by two wind streams: the northeast monsoon from November to April and the southwest monsoon from June to September.

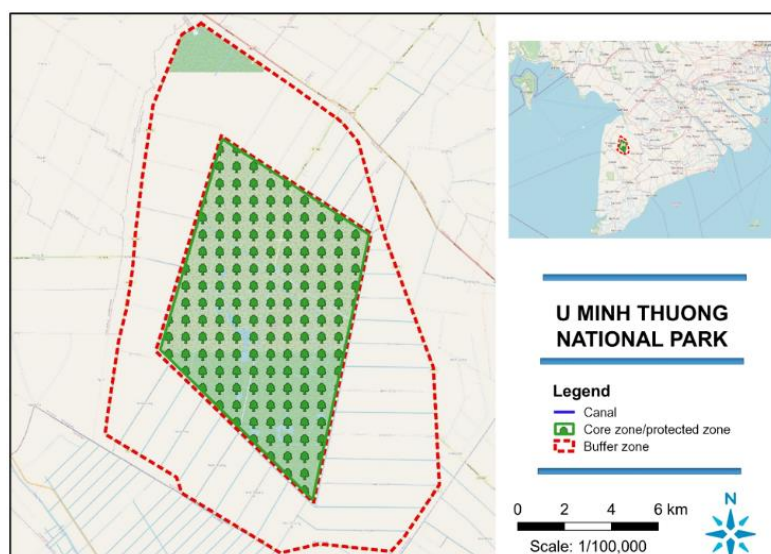


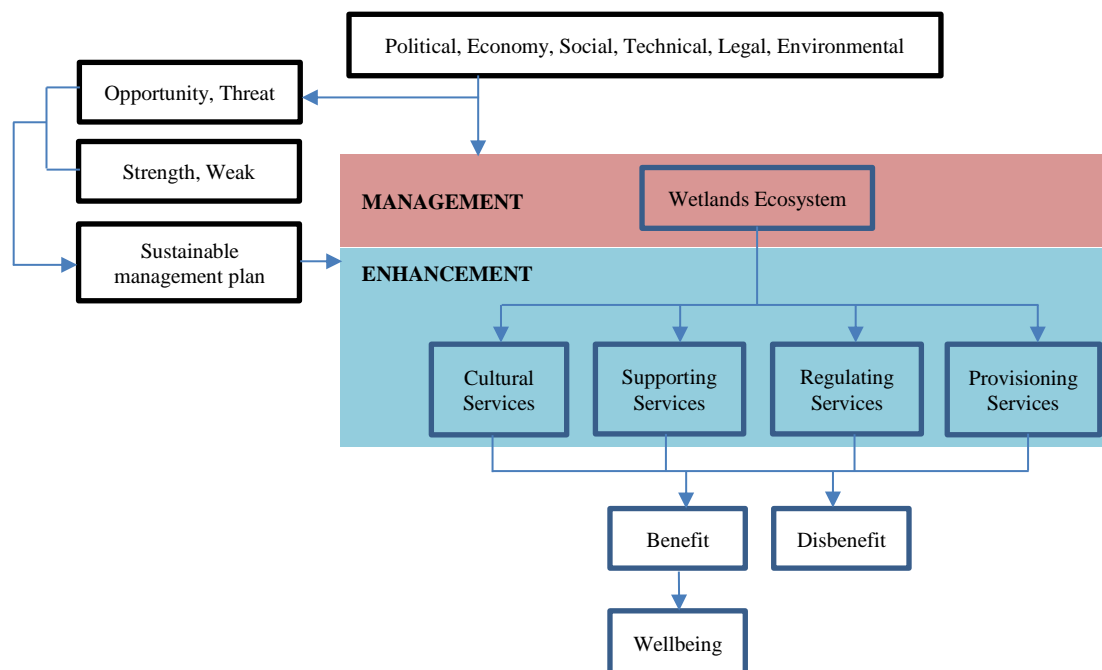
Figure 1. Research location, U Minh Thuong National Park, Kiên Giang, Vietnam

UMT is influenced by the semi-diurnal tidal regime of the Gulf of Thailand from various directions, primarily via the Cai Lon-Cai Be river system to the north and the Ong Doc River to the south. The convergence point of these two major river systems is located on the border between An Giang and Ca Mau provinces. Consequently, there are two primary factors influencing the water regime of UMT, tides and rainfall. However, the latter has a significantly greater impact on the park’s water regime, maintaining a freshwater wetland ecosystem despite the park’s proximity to the sea. Water levels are highest from July to February and reach their lowest point between March and June each year. Heavy rainfall, combined with poor drainage capacity through the canal network, results in prolonged flooding in the area, which facilitates the process of peat accumulation. Much like sponges, the peat layers absorb rainwater during the wet season and gradually release it throughout the dry season.

**2.2. Analytical Framework**

The evaluation framework developed by Rendón et al. [43] clearly illustrates the relationship between ecosystem services and human well-being through a detailed analysis of biophysical, social, economic, and political factors. On this basis, it contributes directly to ecosystem management by enabling more comprehensive and informed decision-making, while accounting for impacts on human welfare. This theoretical framework is useful for researchers in identifying the interdependence between services and benefits (or dis-benefits), as well as determining trade-offs that specifically impact human well-being across different scales and for various stakeholders. Without fully considering the domains of human well-being, policy and management risk overlooking a range of impacts, potentially leading to inefficient trade-offs. However, this evaluation framework has certain limitations when placed within the complex context of wetland ecosystem management, which requires a more holistic assessment of numerous internal and external influencing factors. Clearly, to enhance ecosystem services in a way that benefits the community while minimizing detrimental services, necessary adjustments to wetland management practices are required.

Currently, wetland ecosystems are effectively managed by conservation agencies through the national special-use forest system as a management mechanism. However, these activities are significantly influenced by a variety of interconnected and complex factors. In the context of wetland conservation, UMT faces numerous complex challenges that impact management efforts [47]. To comprehensively analyze the factors affecting wetland management at UMT, this study proposes an analytical framework based on the work of Rendón et al. [43], integrating both the PESTLE and SWOT analysis frameworks (see Figure 2).



**Figure 2. Framework for analyzing the impact of the management plan on ecosystem services**

The PESTLE analysis examines six external factors: Political, Economic, Social, Technological, Legal, and Environmental. Then, the SWOT analysis identifies the opportunities and threats using the findings from PESTLE. The last two elements of the SWOT analysis relate to assessing strengths and weaknesses of the internal operation of the wetland ecosystem (see Table 1).

**Table 1. PESTLE-Based Analysis of Strengths and Weaknesses**

	Strengths	Weaknesses
Political		
Economic		
Social		
Technological		
Legal		
Environment		

The data used in both analytical frameworks were collected from reliable secondary sources and field observations. By integrating these two analytical methods, this study aims to provide a comprehensive assessment of the diverse factors influencing wetland management at UMT. Ultimately, this holistic approach will facilitate the enhancement of community ecosystem services and contribute to more effective wetland conservation efforts.

Within this analytical framework, the research team examines how PESTLE factors impact the existing weaknesses of UMT while leveraging its internal strengths to maximize the beneficial effects derived from these PESTLE factors. Consequently, this approach enables the proposal of effective management solutions for UMT. Table 2 illustrates how to analyze each aspect of these two analytical frameworks.

**Table 2. Instructions of analyzing SWOT and PESTLE aspects**

Aspect	Indicator	Description
<b>Strengths</b>	Biodiversity	The current diversity of flora and fauna species at UMT
	Unique wetland ecosystem	Characteristic landscapes with high ecological and conservation value
	Infrastructure	Infrastructure (including digital infrastructure) has been invested in, upgraded, and remains in good working condition
	Human resources	Quantity and quality of staff supporting UMT
	Existing legal documents	Legal recognition from Vietnam and international organizations
<b>Weaknesses (Excluding any points already appearing in "Strengths")</b>	Biodiversity	Analysis of the current diversity of flora and fauna species at UMT is at a low level.
	Unique wetland ecosystem	Existing landscapes lack uniqueness, have no ecological or high conservation value, and may even cause adverse impacts on the community.
	Human resources	A shortage in both the quantity and quality of staff supporting UMT management work.
	Infrastructure	Infrastructure (including digital infrastructure) has been invested in but is degraded, no longer serving well, or there is a lack of necessary infrastructure to operate the UMT management plan.
<b>Political</b>	Stability of the political system	Political stability is reflected by the absence of armed or non-armed conflicts since national reunification.
	Government interest through investment policies	Direct investment activities for UMT or surrounding areas, including investments in infrastructure and local socio-economic development programs.
	Budget allocation for UMT	Annual funding for conservation depends heavily on state allocation. Depending on political goals, funding may vary, which significantly affects the management and development of the Park
<b>Economic</b>	Livelihood status of buffer zone communities	Economic models applied by residents and their connection to the conservation area. Detailed analysis of livelihood processes and labor requirements is needed to assess the level of dependency on UMT. Livelihoods less dependent on the conservation area will limit resource extraction, while models closely linked to the area. Stable income for residents will reduce behaviors that damage the conservation area.
	Conservation area revenue sources	Regular revenue for conservation management from the state budget. Revenue generated from off-budget investment projects such as tourism activities, projects from non-governmental organizations, or private companies.
	National and global economic trends	Domestic and global economic development partially influence biodiversity conservation. Economic growth can increase human consumption demands, thereby increasing the number of tourists visiting conservation areas, bringing income to the Park and surrounding communities. Additionally, economic development also attracts investment capital for conservation.
<b>Social</b>	Professional qualifications of the management team	Analysis of the management team's expertise, specifically knowledge regarding the four groups of ecosystem services at UMT. By correctly understanding the functions and ecosystem services, the management team can ensure these values are promoted.
	Education level of local communities	Many aspects are closely related to literacy and awareness regarding the role and importance of the UMT wetland ecosystem and the implementation of local conservation programs.
	Gender and age	Examination of the male/female ratio; age groups
	Crime trends related to UMT	Offenses related to illegal wildlife hunting or illegal land encroachment.
	Health awareness trends	Community demand for areas that maintain fresh air, a clean environment, and safe food sources for tourism, recreation, and stress relief.

<b>Technological</b>	GIS technology	Application of mapping and remote sensing technology in wetland ecosystem management, conservation area planning, as well as forest fire prevention.
	Information technology	Internet and mobile networks with comprehensive coverage and sufficient strength to support better management, such as patrols to prevent illegal hunting. Additionally, internet connectivity facilitates the promotion of information about UMT to attract tourists. Includes simulation models for economic, social, and environmental resources.
	Other conservation technologies	Water resource control technology, artificial breeding/propagation technology.
<b>Legal</b>	UMT management mechanism	Analysis of the Park's management system from central to local levels, focusing on critical issues such as finance, human resources, etc. The impact of the current management status on the conservation management work of UMT.
	Legal documents related to UMT management	Central-level legal documents such as Law on Biodiversity; Law on Forestry; Land Law.
	International conventions	Convention on Biological Diversity, CITES, Ramsar Convention, ASEAN Heritage Parks.
<b>Environment</b>	Soil and water environmental quality	Surrounding water environment issues such as saltwater intrusion and water source pollution.
	Extreme events	Droughts, heavy rainfall, storms.
	Climate change	Changes in rainfall patterns, changes in precipitation levels, and sea-level rise.
	Invasive alien species	Dangerous alien species, species at risk of becoming invasive.

### 2.3. Data Collection

This paper utilizes a diverse range of data sources, combining field observations with secondary data collected from multiple reliable sources, as follows:

- First, field surveys were conducted at UMT to observe the current state of habitats, biodiversity, and the park's hydrological regime, as well as to examine how the park is managed and the connectivity between the National Park and surrounding communities.
- Second, data were gathered from UMT's periodic biodiversity monitoring program, which tracks changes in flora and fauna as well as wetland ecosystems. Additionally, data from the monitoring and measurement of hydrological parameters (used to calculate water balance for fire prevention and fighting at UMT) were utilized. These are official data, collected using clear scientific methods by specialized units. Subsequently, the data were analyzed and synthesized into scientific reports, which were transparently and publicly appraised by a scientific council, ensuring the scientific integrity of the data and reports. These scientific products are officially used in legal documents related to the conservation management of UMT, and serve as a scientific basis for local authorities to propose legal documents or management policies. More broadly, these data are also used by the Government of Vietnam to issue policies on national biodiversity.
- Third, scientific studies from prestigious domestic and international journals; data and information from research topics and projects conducted within the Park; and data sources from local agencies, such as databases of legal documents and annual statistics, were utilized.

These sources were carefully verified for accuracy before use. The accuracy verification method involved evaluating the scientific methodologies employed, the approval and appraisal process of the results, and the extent of the reports' application or their intended audience.

## 3. Results and Discussion

### 3.1. Strengths of U Minh Thuong National Park

UMT possesses high biodiversity, featuring 254 plant species, 32 mammal species, 184 bird species, 8 amphibian species, 42 reptile species, 64 fish species, and 209 insect species. UMT serves as a vital habitat for numerous rare and precious species. During the breeding season (from April to October), the bird population concentrated in UMT can reach up to 23,402 individuals [48]. Inventory results at UMT have identified 43 rare flora and fauna species listed in the Vietnam Red Data Book and the IUCN Red List. Some typical species include the Hairy-nosed Otter (*Lutra sumatrana*), Fishing Cat (*Prionailurus viverrinus*), Sunda Pangolin (*Manis javanica*), Lyle's Flying Fox (*Pteropus lylei*), Lesser Adjutant (*Leptoptilos javanicus*), Painted Stork (*Mycteria leucocephala*), Spot-billed Pelican (*Pelecanus philippensis*), Malayan Box Turtle (*Cuora amboinensis*), Yellow-headed Temple Turtle (*Heosemys annandalii*), and Malayan Snail-eating Turtle (*Malayemys subtrijuga*). These species represent valuable and rare genetic resources, not only for Vietnam but for the world. In addition, many species with economic and aesthetic value are also found in UMT. Specifically, there are up to 128 species of non-timber forest products that can be harvested, including 98 medicinal plant species, 39 food species, 23 ornamental plant species, and 01 fiber-producing plant species. The local

fauna also offers significant potential for the exploitation of non-timber forest products. UMT's assessment results indicate that the total fish biomass in the park's canals reaches approximately 297.9 tons, with an annual fish harvest of 108.26 tons. Honey production at UMT has the potential to reach 4,686.4 kg per year, equivalent to 3,445.9 liters per year.

Beyond its high biodiversity, UMT is one of the two most precious remaining peatland resources in the Mekong Delta. Currently, the peatland area covers approximately 3,906.6 hectares with a thickness ranging from 30 to 130 cm [45]. The dense melaleuca forest ecosystem on the thick peat swamps of UMT serves to filter freshwater, preventing surface water acidification, filtering groundwater, and storing freshwater for the dry season.

UMT's headquarters are built to be relatively solid, with all necessary facilities to ensure the operational management of the Park. Facilities dedicated to forest protection and fire prevention have also been prioritized for investment, including forest protection stations, water pumps, and boats. Internal road systems have been upgraded to a length of 42.56 km and a width of 2.5 m, facilitating the movement of motorcycles and specialized vehicles. These internal roads are also directly connected to major inter-provincial routes, aiding traffic and connectivity. The hydrological regime of UMT is strictly managed by a closed dyke system and sluice gates, consisting of a 38 km dyke with 01 drainage sluice surrounding the entire core zone, along with auxiliary dykes and 10 internal sluice gates that divide the core zone into 05 distinct hydrological control sub-zones.

The staff serving at UMT have, on average, over 15 years of experience in the park's operational management. The majority of the Park's personnel possess postgraduate or undergraduate degrees, accounting for approximately 86.77% which significantly facilitates the implementation of professional activities. The park's direct forest protection force is well-staffed, proactive, and distributed throughout the entire area. There are 10 specialized forest protection teams in total, in which 09 teams are evenly distributed along the dyke line bordering the core and buffer zones, performing management duties in their respective areas, and 01 mobile team functions to address hotspots across the entire territory managed by the National Park. Beyond the quantity and quality of personnel, passion and dedication to conservation are considered the primary drivers for why staff remain committed to UMT over the long term.

Due to these invaluable assets, UMT is recognized as a National Park of Vietnam, Vietnam's 8<sup>th</sup> Ramsar site, and an ASEAN Heritage Park. Furthermore, UMT served as a crucial revolutionary base for Region IX and the Viet Minh during both the resistance wars against the French and the Americans [49]. In addition to its political history, the area is home to the Oc Eo civilization. Consequently, the Minister of Culture and Information issued Decision No. 1768 QD/VH on June 28, 1997, designating the UMT Resistance Base Cultural Heritage Site, comprising 19 historical sites within the area.

### 3.2. Weaknesses of U Minh Thuong National Park

Although the peatland ecosystem is a unique and highly valuable feature of UMT, it is also one of the park's key weaknesses due to the high fire risk associated with peat. This was tragically demonstrated in 2002, when approximately 2,500 hectares of melaleuca forest on peat soil were incinerated [50], with many areas in this region losing their capacity for regeneration. Furthermore, peat soil is susceptible to oxidation when exposed to air; the resulting shrinkage during water shortages leads to the subsidence of many roads and dykes, severely impacting forest protection and fire prevention efforts. To cope with this, the National Park has implemented measures to build dykes and close sluice gates to keep the area flooded year-round. However, prolonged and deep flooding has altered the peat structure, creating an anaerobic environment that stunts melaleuca root development and slows growth, leading to mass death and trees falling over. This artificial measure also destroys the habitats of certain bird and wildlife species, posing a risk to the integrity of the ecosystem. There is a vast accumulation of organic matter on the ground (ranging from 0.42 to 34.52 tons/ha, with a thickness of 20–60 cm). During the dry season, when the groundwater level drops deeply (100 cm), the moisture of this layer falls to only about 12%, creating an extremely high risk of ignition and forest fires. Additionally, the native ecosystem is being threatened by invasive alien species, most dangerously the giant sensitive plant (*Mimosa pigra*), followed by water hyacinth and golden apple snails.

Tourism infrastructure remains underdeveloped and has not been invested in a manner commensurate with the region's immense potential for eco-tourism. The restroom facilities for tourism activities do not meet standards; overnight accommodation rooms are degraded, aged, and odorous; and there is a lack of overnight services such as recreation and entertainment. UMT has yet to develop the technological infrastructure necessary to enhance eco-tourism experiences.

Despite the high academic qualifications of the staff, there is a reality where professional expertise does not always align with job requirements, particularly regarding conservation expertise for wetland ecosystems, and the number of officials with formal, specialized training remains low. Due to difficult working conditions, low income, and irregular working and rest hours coupled with compensation that is not competitive compared to the broader societal standard, the National Park faces significant challenges in retaining staff for stable, long-term employment, especially within the

forest management and protection force. Consequently, even though staff may be academically qualified, the competence of certain departments is limited due to high turnover. New recruits require a certain period to become accustomed to the work before they can perform their duties effectively.

### 3.3. Political Aspect

The conservation of biodiversity in Vietnam is closely associated with the nation's political stability. Since reunification in 1975, Vietnam has maintained a stable one-party socialist state, becoming one of the most politically stable countries in Southeast Asia [51]. This stability has created a favorable environment for both economic growth and social stability. Forest conservation, especially the UMT area, holds a significant place on the Vietnamese Government. UMT served as a revolutionary base during critical historical periods, such as the Viet Minh era (1941–1954) and the South-western region campaigns (1960–1975) during the French colonial and American imperial invasions [49]. Consequently, the Government aims to preserve these sites as historical monuments to maintain awareness of their importance and pass on knowledge to future generations. The 2001 Law on Cultural Heritage emphasizes the allocation of funding for the construction and maintenance of memorial sites associated with revolutionary movements. Multiple agencies have been established to protect forests designated for these specific purposes. The state management apparatus in Vietnam demonstrates a high degree of flexibility, with leaders who are open and receptive to new concepts and proposals. This adaptability was evidenced by the Party's adoption of the "Doi Moi" (Renovation) strategy in 1986, aimed at transforming Vietnam's socio-economic structure. In the UMT buffer zone, the implementation of the Doi Moi policy led to livelihood growth through the provision of infrastructure, financial capital, and various forms of support. In summary, political stability and the Vietnamese Government's commitment to conserving forests like UMT play an essential role in biodiversity conservation [52]. The Government's focus on historical sites and its adaptable management strategy have significantly aided sustainable development and biodiversity conservation nationwide.

Nonetheless, several political constraints, historical disputes, and governance inefficiencies are hindering conservation efforts at UMT. Conservation strategies have traditionally concentrated on the management and protection of the *Melaleuca* tree, frequently neglecting the wider aquatic and wetland ecosystems. The existing special-use forest management system includes all forest types, leading to an absence of specific strategies for managing *Melaleuca* forests in wetland ecosystems. Consequently, the *Melaleuca* tree is always prioritized for protection rather than the conservation of the entire ecosystem. Wetland governance is fragmented due to its overlap with multiple administrative sectors, including agriculture, planning, water resources, and environmental protection. These agencies often function independently resulting in inadequate coordination, overlapping duties, policy loopholes, and dispersed funding. Despite Vietnam's established legal framework for conservation, law enforcement is decentralized to local authorities that frequently lack the requisite capacity, personnel, and expertise for effective law enforcement. Forest rangers and field conservation personnel encounter substantial difficulties due to these enforcement constraints, notwithstanding the existence of legal provisions.

### 3.4. Economic Aspect

The financial resources for maintaining UMT's operations depend entirely on state budget allocations approved by the People's Council and the People's Committee of An Giang Province. Depending on conservation needs, the Park's management board must submit a management plan with a detailed budget for the following year for review and approval. In general, the budget allocated to the Park depends heavily on Vietnam's economic growth as well as the country's commitments regarding greenhouse gas emission reductions and biodiversity conservation.

It can be observed that, in the period prior to 2022, the annual funding allocated to UMT remained quite similar, with no significant discrepancies. Conversely, this funding recorded a sharp increase in the 2024–2025 period. On one hand, this increase reflects the adjustment of the state apparatus's base salary fund, but more importantly, it demonstrates the Vietnamese Government's interest and revaluation of resources for biodiversity conservation. This is entirely consistent with the roadmap for implementing Vietnam's strong international commitments, such as the Kunming-Montreal Global Biodiversity Framework (COP15), the objectives of the Ramsar Convention on Wetlands, and especially the goal of achieving "Net-Zero" emissions by 2050, as pledged by the Prime Minister at COP26.

This increase in budget allocation also accurately reflects the state of Vietnam's economic growth, as nominal GDP reached approximately 310 billion USD in 2018, rising to over 510 billion USD in just the first 9 months of 2025. This highlights the close link between the economic development of Vietnam and the world, and the funding for conservation activities at UMT.

In addition to the annual funding for UMT's operations (Figure 3), An Giang province has also allocated a substantial budget to UMT for the implementation of key conservation projects. Specifically, over 23.4 billion VND was invested in the UMT Silviculture Project during the 2012–2015 period, aimed at maintaining ecological balance

and increasing forest cover [53]. The project for investment, restoration, protection, and development of the National Park was launched with the goal of maintaining and developing the melaleuca forest ecosystem on peatlands in the U Minh region. The project for the conservation and development of the National Park was funded to plan operational programs and synchronized solutions for management, protection, fire prevention and fighting, and forest ecological restoration, with a total investment of over 226.7 billion VND, sourced from the central budget and a portion of the local budget.

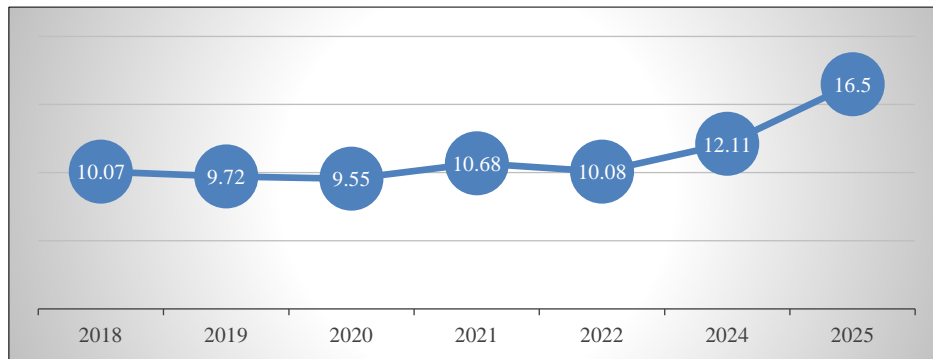


Figure 3. Budget allocated to UMT for annual operation

The salaries of UMT staff are influenced by economic expansion, with the determination of base salaries depending on factors such as the Consumer Price Index and the country’s economic growth rate. The salaries paid to the Park’s management staff are relatively low (averaging approximately 5.6 million VND/month, equivalent to 215 USD/month) [53], which fails to meet their families’ living expenses. This hinders their commitment to conservation efforts, leading some conservation staff to seek part-time jobs or resign to find new employment with better income. To improve staff income and generate additional funding for conservation activities, UMT has been approved to develop eco-tourism activities.

Figure 4 shows an increasing trend in tourist arrivals to UMT between 2010 and 2018, followed by a sharp decline between 2019 and 2021 due to the significant impact of the Covid-19 pandemic. The majority of tourists participated in eco-tourism activities, accounting for 355,154 visitors (65.38%). This was followed by recreational fishing, which attracted 121,890 visitors (22.41%), while approximately 0.6% of visitors took part in scientific research activities. On average, UMT receives around 45,317 visitors annually, generating an estimated revenue of approximately 2.7 billion VND (around 122,000 USD) for the Park. This revenue represents about 17% to 28% of the total annual budget allocated to the Park. This is a significant source of income that helps increase the salaries of the Park’s management staff as well as supports infrastructure reinvestment and conservation activities for UMT.

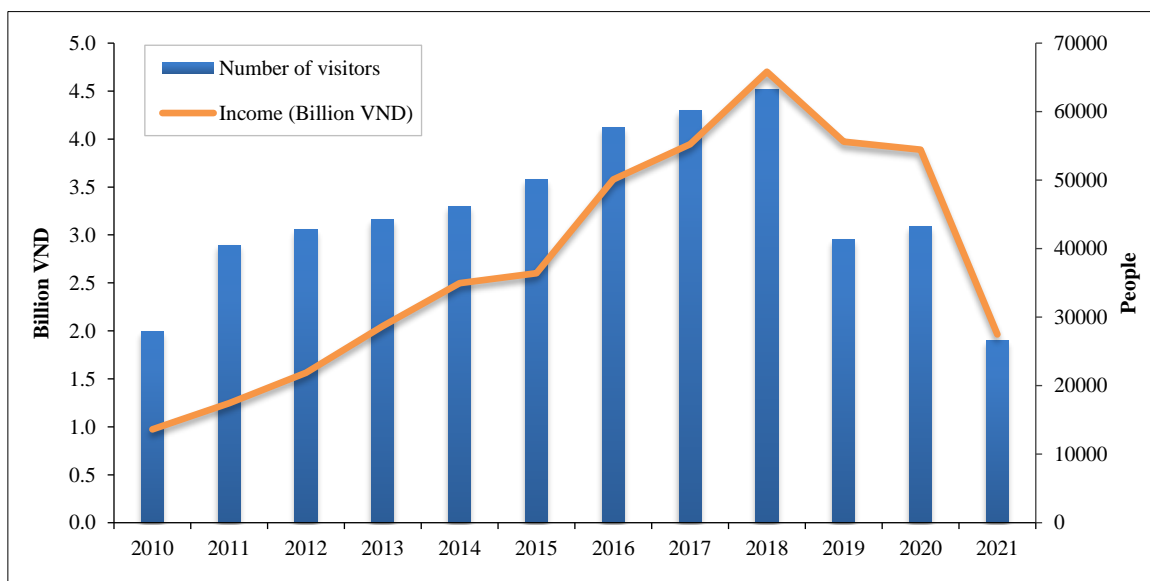


Figure 4. Number of visitors to UMT and income from 2010 to 2021

Biodiversity conservation is inextricably linked to local economic development [54]. Between 1970 and 2015, more than 35% of global wetlands disappeared or degraded due to human prioritization of economic value [55]. Economic development and market demand accelerate wetland loss through the conversion and illegal exploitation of natural

resources [56]. Market demand fuels illegal poaching due to the high value of the products. In the buffer zone, livelihood activities and illegal hunting cause severe damage to the core zone [57].

Figure 5 demonstrates that to mitigate illegal hunting, it is essential to increase income sources for the community. A report by WCS [58] indicates that individuals who participate in illegal hunting often have limited financial resources, unstable employment prospects, and lack land ownership rights. By providing these individuals with a stable income through participation in sustainable livelihood activities, illegal hunting in the core zone of UMT can be reduced. The welfare and economic activities of the community in the buffer zone have an indirect impact on the core zone of UMT. Local communities are increasingly diversifying their farming models toward intensification, multi-cropping, and spontaneous development. For instance, the adoption of saltwater shrimp farming by local communities during the dry season could increase rapidly in the future [44]. Although shrimp farming may provide economic benefits, it also poses a threat to UMT.

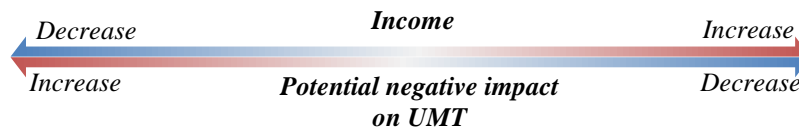


Figure 5. Relation between income and negative impact on UMTNP

Climate change has been observed to impact on the livelihoods of communities in the buffer zone (Table 3), resulting in economic losses [59]. The system of dykes and saltwater prevention sluice gates has significantly hindered waterborne transportation. Many large boats belonging to traders purchasing agricultural products cannot reach cultivation areas, forcing residents to transport products by two-wheeled vehicles (due to narrow roads) from the fields to areas where boats are anchored at the sluice gates. This small-scale transport has increased transportation costs and placed immense pressure on labor, especially in a context where local labor is becoming increasingly scarce as the young workforce migrates to large industrial zones. Additionally, several road sections have suffered severe landslides, further affecting the transportation of goods by land. The cause of these landslides is the prolonged hot and dry season, which lowers water levels inside the dykes, leading to the oxidation of the peat layer beneath the roads, which in turn causes subsidence. This economic pressure has the potential to drive some individuals toward poaching in the National Park as a means of generating additional income.

Table 3. Changes in local community livelihoods over time

Time	1990 - 1999	2000 - 2009	2010 - 2012	2014 - 2020	Presently
Livelihood	Rice cultivation (1crop/year), vegetable farming	Development of melaleuca-fish, rice-fish, and industrial crop models	Rice cultivation (1-3 crops/year). Integrated models: Rice-shrimp. Diversified crops: banana, coconut, vegetables, and melaleuca	Sugarcane development and cultivation of integrated models: Seasonal rice + sugarcane + pineapple + ginger	Expansion of integrated models: Rice-shrimp; Seasonal rice + fish; Fish + vegetables; Vegetables + fruit trees; Farming (following VietGAP, GlobalGAP standards) across the entire buffer zone

In general, it is clear that economic factors play a key role in influencing conservation efforts and illegal activities at UMT. Sustainable livelihood opportunities and appropriate compensation for staff are essential aspects that must be considered to effectively manage the Park’s resources and conserve its ecological integrity. However, this also underscores the importance of being prepared for unexpected risks, such as the COVID-19 pandemic, which halted tourism operations and caused major financial consequences. Nevertheless, unexpected events can significantly impact the finances and conservation efforts of UMT, so the management board must always remain vigilant and adaptable. The National Park management must develop strategies to mitigate future crises and protect both staff and buffer zone communities. Diversifying income sources, contingency planning, and sustainable management can help conserve the biodiversity of UMT.

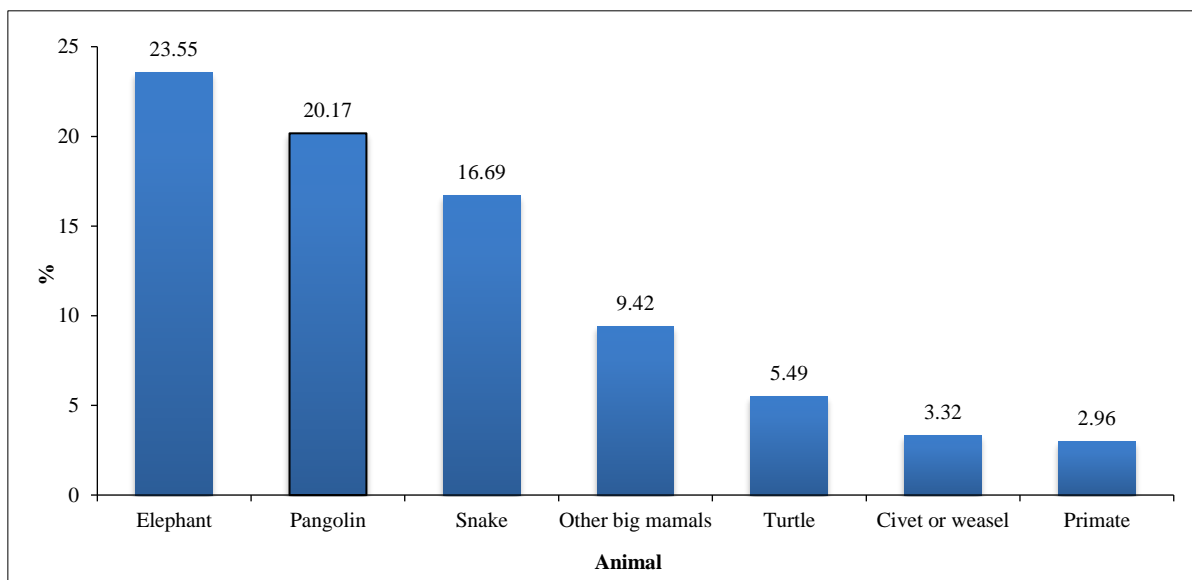
### 3.5. Social Aspect

The effectiveness of biodiversity conservation is significantly impacted by the level of community awareness regarding the importance of wetland ecosystems [60]. A lack of awareness within the community about the critical role of the wetland environment at UMT has led to an increased demand for wildlife products. Based on the findings of Loi & Hanh [25], it is observed that 46% of individuals residing in the buffer zone have a primary school education, while 44% have an even lower level of education.

Biodiversity protection is influenced by age and gender in distinct ways. Approximately 81.52% of illegal hunting activities can be attributed to males, and the highest rate of violations is observed in the 30–41 age group, accounting for 46.48% of the total. This demographic has the highest rate of interaction with and reporting of illegal hunting

activities, and it is also the group that frequently experiences direct conflicts with wildlife (particularly otters catching fish in aquaculture ponds). This is followed by the 24–29 age group, which accounts for 15.81% of violations. In contrast, relatively few violations are observed in age groups under 18 or over 41 [58]. While these groups are less involved in hunting, they also possess a lower level of understanding regarding wildlife-related issues.

Wildlife exploitation has long been a traditional practice among residents of the Mekong Delta and the U Minh Thuong region [61]. Historically, agricultural conditions in this area were extremely arduous, resulting in low population density [62]. Consequently, people relied heavily on the abundant natural resources available in the region. Despite the increasing degradation of wetland ecosystems and the resulting loss of biodiversity, this prolonged downward trend has persisted for decades. The demand for wild species is driven by the belief in the valuable medicinal properties of rare species [61]. For example, the pangolin is believed to possess medicinal properties in traditional Chinese medicine, making it the most trafficked species in the illegal wildlife market, accounting for over 20% of all illegal wildlife trade cases [63]. Pangolin trafficking ranks second in Vietnam, accounting for 20.17% of total trade, following ivory, which accounts for 23.55% of transactions (see Figure 6).



**Figure 6. Percentage of illegal trade in some wildlife species**

Unrestricted access via transportation facilitates individuals entering and exiting the core zone of UMT, both from within and outside the Park. This lack of restrictions increases the vulnerability of wildlife to illegal hunting activities and poses significant challenges for UMT in its efforts to prevent criminal behavior.

### 3.6. Technological Aspect

Current social development requires continuous adaptation in conservation strategies applied to wetland ecosystems to keep pace with the speed of societal transformation. According to Pimm et al. [64], the deployment of supporting technologies has been proven to enhance management efficiency and reduce the financial burden associated with biodiversity conservation efforts. Unmanned Aerial Vehicles (UAVs), remote sensing, the Internet of Things (IoT), large-scale data analysis, computational models, and various other technological platforms play a crucial role in strengthening conservation initiatives. In particular, the rapid development of artificial intelligence (AI) has opened up new opportunities to enhance conservation effectiveness, though it also carries inherent risks.

Some potential applications for UMT include integrating multispectral satellite imagery through cloud computing platforms like Google Earth Engine or Geographic Information System software, which provide the capability to monitor the status of wetlands over vast areas, rather than relying on manual, on the ground measurements, thereby supporting rapid, high precision decision making. The deployment of automatic hydrological monitoring stations using sensors and IoT platforms placed deep beneath the peat layer facilitates the continuous, real time recording of humidity, temperature, and groundwater levels. This data is transmitted to the operations center, allowing the Management Board to adjust sluice gates flexibly based on actual conditions rather than fixed schedules tied to the rainy/dry seasons. This helps solve the difficult problem of balancing fire prevention with protecting the melaleuca forest ecosystem from waterlogging. Using high-quality, AI-integrated cameras to monitor unauthorized intrusions into the core zone helps provide timely, accurate, and clearly documented warnings.

However, integrating technology into conservation efforts requires the coordination of many factors, including infrastructure, financial resources, and human capital [64]. Currently, UMT's telecommunications infrastructure has

received significant investment, leading to widespread coverage of mobile phone services and high-speed internet. This enables managers to access and utilize global conservation databases and knowledge. Furthermore, the availability of online training courses and events has facilitated the Park's staff in enhancing their professional expertise and accessing modern conservation technologies. UMT has the potential to enhance its reputation by leveraging diverse media platforms, thereby attracting attention from both domestic and international audiences. This strategic approach can facilitate the expansion of eco-tourism initiatives and promote investor interest. Moreover, technological infrastructure helps improve the effectiveness of communication efforts aimed at raising the awareness of buffer zone communities regarding the importance of wetland ecosystems.

Additionally, modern smart mobile devices are now affordable and diverse, making them common among the majority of UMT staff. These devices provide a convenient means to collect images, videos, and geographic data related to species, facilitating the monitoring of population fluctuations [65]. PlantSnap, iNaturalist, and CyberTracker are among the many free online applications that can be used for biodiversity research purposes. These applications support activities such as plant identification, species recording, and data analysis. Currently, conservation units lack technical uniformity, and the use of disparate technologies leads to challenges in data sharing and analysis. Information technology also poses potential threats to UMT, facilitating illegal wildlife trade and providing easier access to poaching equipment via online platforms.

### 3.7. Legal Aspect

The rapidly evolving domestic and international socio-economic environment poses significant challenges to conservation efforts, while the static nature of the management structure at UMT hinders the park's development. To adjust action plans, the Park must obtain feedback and consent from various departments for activities that deviate from past precedents or differ significantly from existing plans, which is anticipated to be very time-consuming.

Since joining the Ramsar Convention in 1989, Vietnam has issued over 10 legal documents related to wetlands. Decree No. 109/2003/NĐ-CP, regarding the protection and sustainable development of wetlands, was subsequently replaced by Decree 66/2019/NĐ-CP in 2019. The Government has developed a 10-year National Action Plan on the conservation and sustainable development of wetlands to effectively manage the conservation of wetland ecosystems. Vietnam has implemented measures to address conservation violations, including the enforcement of Decree 45/2022/NĐ-CP and the updated Penal Code. These regulations have been in effect since July 7, 2022. List of detail regulations that UMT can apply to its management (see Table 4).

**Table 4. Key regulations related to wetland management**

Regulation title	Core relevant content
Forestry Law 2017	<ul style="list-style-type: none"> <li>Require forest owners to develop Sustainable Forest Management Plans.</li> <li>Establish strict regulations for opening/closing natural forests and controls land-use conversion.</li> <li>Affirm the benefits and obligations of the National Park Management Board in protecting ecosystems.</li> </ul>
Biodiversity Law 2008	<ul style="list-style-type: none"> <li>Define criteria for establishing protected areas, including National Parks.</li> <li>Require distinct functional zoning: strict protection, ecological restoration, and service-administration zones.</li> <li>Mandate periodic biodiversity status reports.</li> </ul>
Law on Environmental Protection 2020	<ul style="list-style-type: none"> <li>Classify important wetlands as environmentally sensitive areas in environmental impact assessments.</li> <li>Establish a payment mechanism for natural ecosystem services for tourism, recreation, and aquaculture activities in these areas.</li> </ul>
Decree 66/2019/NĐ-CP on preservation and sustainable use of wetlands	<ul style="list-style-type: none"> <li>Provide detailed regulations on the conservation and sustainable use of wetlands.</li> <li>Establish quantitative criteria for nationally important wetlands.</li> <li>Institutionalize Ramsar Convention governance principles and shapes investment incentive policies for Ramsar sites.</li> </ul>
Decree 156/2018/NĐ-CP on enforcement of a number of articles of the law on forestry	<ul style="list-style-type: none"> <li>Detail guidance on implementing the Forestry Law.</li> <li>Specify management regulations for National Parks and establish the Forest Environmental Service Payment policy.</li> <li>Designate clearly categories for state budget expenditure on protection and development of special-use forests.</li> </ul>
Decree 91/2024/NĐ-CP amending some articles of decree 156/2018/NĐ-CP dated november 16, 2018 of the government elaborating law on forestry	<ul style="list-style-type: none"> <li>Decentralize the entire authority for deciding forest land-use conversion to the Provincial People's Council.</li> <li>Shorten administrative procedure processing time from 50 days to 35 days.</li> <li>Specify regulations for leasing forest environments for eco-tourism services.</li> </ul>
Decree 42/2026/NĐ-CP amending and supplementing some articles of decrees in the field of forestry and forestry inspection	<ul style="list-style-type: none"> <li>Increase financial support for special-use forest protection to 1,000,000 VND/ha/year (coefficient 1.5 for coastal areas).</li> <li>Increase support for natural regeneration to 2,500,000 VND/ha/year.</li> <li>Double livelihood support for buffer zone communities to 100,000,000 VND/community/year.</li> </ul>

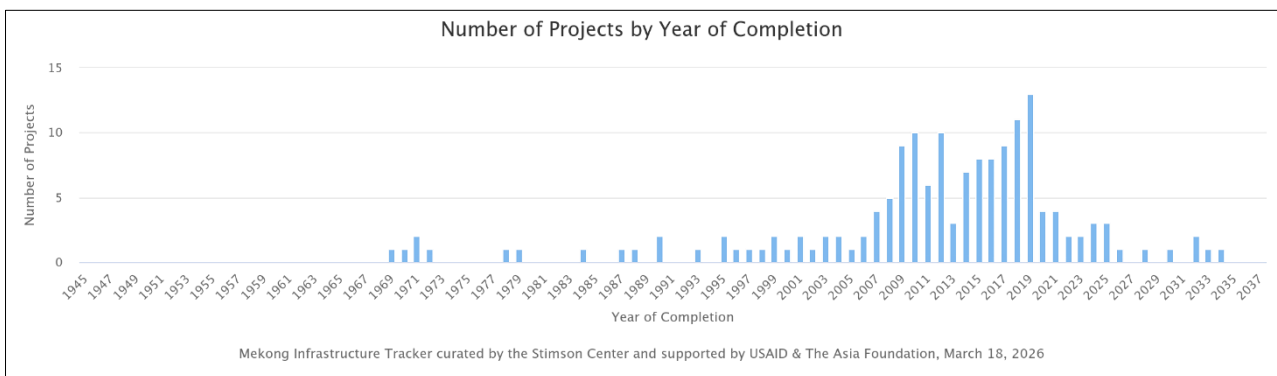
Although Vietnam’s legal framework for biodiversity conservation is comprehensive, challenges continue to arise in the effective enforcement of these regulations at the local level. Many managers frequently face difficulties due to limited understanding of legal issues and their reliance on past precedents. Consequently, protected area management boards face limitations in their direct law enforcement capacity, necessitating the support of local law enforcement forces when apprehending individuals engaged in poaching. The time required to apprehend poachers places significant pressure on law enforcement agencies due to their limited authority and resources.

**3.8. Environmental Aspect**

The hydrological regime of UMT plays a pivotal role in promoting conservation efforts and facilitating sustainable development. Maintaining adequate water resources is essential for fire prevention within this unique peatland ecosystem. According to Cuong et al. [46], annual rainfall during the wet season generates an estimated volume of approximately 2.64 billion cubic meters of water. In the dry season, water scarcity is common, as rainfall reaches only 196.1 mm, accounting for a mere 9% of the total annual precipitation. Consequently, in the event of prolonged heat, especially during El Niño years and the subsequent saltwater intrusion in surrounding areas, the Park’s water storage capacity may become inadequate.

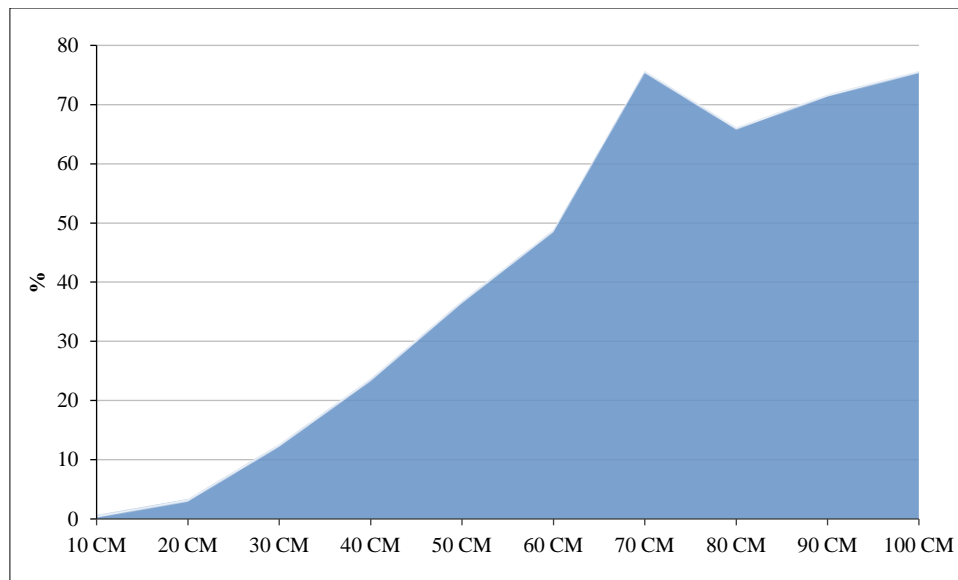
Water pollution is currently a cause of significant concern. The direct discharge of agricultural pesticides into rivers has led to severe water contamination. In a study conducted by Giao et al. [66], it was observed that surface water in Kien Giang province showed concentrations of various pollutants exceeding the regulatory limits set by Vietnamese authorities. Farmers in Kien Giang province use fertilizers at levels 20–30% higher than the prescribed amount per hectare per crop. Similar to fertilizers, pesticides are also overused, with quantities exceeding 3.5 tons per 1,000 hectares [67]. Furthermore, the use of toxic and banned substances, such as endosulfan and methyl parathion, is prevalent. Toan et al. [68] reported the presence of the chemical isoprothiolane in water at a concentration of 11.24 µg/L, while the compound buprofezin was detected in sediment at a concentration of 521 µg/kg. These chemicals pose significant risks to human health [67].

The Mekong Delta is located in the lower reaches of the Mekong River, facing the sea with a low, flat topography. Therefore, water sources here are highly sensitive to the impacts of upstream, coastal, and local economic activities, as well as climate change. Water-intensive development and large-scale deforestation in upstream Mekong countries have profoundly altered the flow patterns and sediment layers of the Mekong Delta. The construction of hydropower dams on the Mekong mainstream is a key investment focus for upstream nations. These hydropower works are considered the primary cause of major disturbances to the hydrological regime of the Mekong River. According to statistics from the Stimson Center [69], there are currently 194 hydropower projects in operation in the Mekong basin, accounting for 37.6%; approximately 15 projects are under construction, accounting for 2.9%; and up to 289 projects are planned, accounting for 56% (see Figure 7).



**Figure 7. Number of hydropower dams completion by years**

The number of hydropower dams being invested in and constructed is increasing, with projects of various scales. In particular, dams spanning the main stem of the Mekong River are concentrated heavily in Yunnan Province, China, and in Laos. Furthermore, these hydropower dams obstruct the flow of sediment, nutrients, and other aquatic resources, leading to numerous impacts on downstream areas. Not only that, rising sea levels and declining upstream discharge have caused saltwater intrusion in the Mekong Delta to become increasingly severe, as seen during the historic saltwater intrusion events in the 2016–2019 dry seasons. According to Ministry of Natural Resources and Environment [70], the risk of inundation for U Minh Thuong District is projected to range from 0.66% to 75.68% of its total area, corresponding to sea-level rises of 10 cm to 100 cm (see Figure 8).



**Figure 8. Percentage of area inundated by sea level rise**

Forecast results indicate that if sea levels rise by 100 cm, only the core area of UMT would remain free from saltwater intrusion. However, due to the characteristics of peat soil, the potential for saltwater to seep through the National Park's embankments is very high, threatening the freshwater ecosystem within the Park. It is forecasted that by 2030, the study area will experience flooding levels ranging from 0.5 to 1.5 meters. The area projected to be flooded most deeply is located in the northern part of the UMT buffer zone. The impacts of climate change become even more severe when compounded by other contributing factors. One such impact is land subsidence in the delta. The Mekong Delta was formed on alluvial deposits over approximately 6,000 years, making it a young delta. The lack of fresh alluvial deposits leads to processes of erosion and subsidence. Furthermore, the excessive use of groundwater by residents has accelerated the rate of land subsidence. According to data from the Ministry of Natural Resources and Environment [56], during the 25-year period from 1991 to 2016, the study area experienced approximately 20 cm of subsidence. In 2015 alone, this region recorded a subsidence rate of 1 cm per year; and the rate of subsidence from 2011 to 2020 fluctuated between 2–3 cm per year.

### 3.9. Integration of SWOT and PESTLE

The results of the analysis of UMT's strengths and weaknesses indicate that the National Park possesses many significant strengths, particularly its biodiversity and the unique wetland ecosystem on peat soil. Alongside these strengths, the Park also reveals many concerning weaknesses. Numerous opportunities and challenges from external factors have been strongly impacting UMT. Therefore, it is necessary to propose management strategies to leverage UMT's strengths to enhance beneficial impacts, as well as to improve upon its weaknesses to mitigate adverse effects on the National Park.

Based on the analysis in Table 5, priority management strategies can be drawn to leverage UMT's existing strengths, creating beneficial impacts for both the Park and the buffer zone communities:

- **Political factor:** Capitalize on the interest from the Vietnamese government and international bodies regarding National Parks and Ramsar sites to attract investment funding for UMT, integrating it into key national programs and prioritizing it for grants and payments for forest environmental services.
- **Economic factor:** UMT possesses a unique melaleuca forest ecosystem on peatlands and historical revolutionary sites with high eco-tourism potential, alongside an emerging carbon credit market. It is essential to assess and commercialize the massive carbon stocks accumulated in the melaleuca forest biomass and peat layers; this represents a breakthrough and sustainable economic revenue source. Combine natural resources (bird sanctuaries, freshwater fish, melaleuca forests) with historical narratives (revolutionary bases) to design unique eco-tourism and experiential education tours. Reinvest tourism revenue back into conservation.
- **Social factor:** UMT has abundant aquatic and non-timber forest resources that can provide livelihoods for buffer zone communities currently under pressure due to their dependence on agriculture and forest resources. Build co-management and benefit-sharing models for the community. Utilize the abundance of resources (fish, wild honey) to establish cooperatives or collaborative groups for buffer zone residents to harvest legally under controlled quotas. Leverage local cultural beliefs (worship, water-region customs) combined with biodiversity values to foster local pride, thereby transforming residents from forest encroachers into forest guardians.

- Technological factor: UMT’s system of canals, enclosed dykes, and vast forest area requires modern management via rapidly developing technologies such as GIS, remote sensing, AI, and IoT. Deploy automated sensor technology to continuously monitor groundwater levels and peat moisture. Use drones and satellites for biodiversity monitoring and early detection of fire risk hotspots. Utilize virtual reality or biological identification apps to allow visitors to explore UMT online or look up information on rare bird/animal species while on boat tours.
- Legal factor: Clear geographical boundaries help define the Park’s strict protection zones. Supported by an increasingly robust legal framework including the Law on Forestry and the Law on Biodiversity, it becomes easier to enforce laws regarding wetland ecosystem conservation, using a solid legal foundation to strictly prevent illegal hunting and exploitation. Additionally, it is necessary to utilize provisions such as forest environmental leasing to attract private enterprises to legally invest in eco-tourism infrastructure without disrupting the landscape.
- Environmental factor: UMT acts as a giant water reservoir, regulating water and microclimates for the entire region at a time when the surrounding environment faces alarming climate change, drought, saltwater intrusion, and surface water pollution. It is crucial to promote the core zone’s role in climate change resilience, practicing flexible water management (avoiding water levels high enough to waterlog melaleuca, but not so low as to risk peat fires). UMT should be positioned and promoted as a natural freshwater reservoir and a core ecological filtration system that helps buffer zone communities combat drought and salinity.

**Table 5. Strengths and PESTLE analysis matrix**

PESTLE Factor	Strengths				
	Biodiversity	Unique wetland ecosystem	Infrastructure	Human resources	Policy & Legal
P	-	Leverage government interest in this unique area as a driver to secure funding from the central government.	-	-	-
E	High bird populations during breeding season (matching Vietnamese holidays) and 43 Red Book species can attract tourists. Enhance sustainable harvesting of economic, medicinal, and landscape-valued species.	Develop experiential learning and scientific research programs for this unique ecosystem. Plan for carbon credit sales in domestic and international markets.	Attract domestic and foreign investment. Vietnam has established a network of Ramsar sites with prioritized conservation budgets.	-	Leverage preferential policies and legal documents to attract investment; develop business projects/activities at the park to secure domestic and foreign financial resources.
S	Clarify mutual benefits between UMT and buffer zone communities to reduce livelihood-conservation conflicts; encourage local community contribution to biodiversity conservation. Highlight Red Book species to capture community interest.	Enhance the role of unique peatland ecosystems in adapting to and mitigating climate change impacts to develop projects that attract investment from diverse organizations/communities.	Utilize existing infrastructure to attract social investment in UMT development, such as eco-tourism (using existing boats for tours, encouraging community homestays and services).	Use forest management teams from the community or build community-liaison forest management teams to bridge UMT and buffer zone communities, enhancing management.	Promote forest land-allocation policies to the community to attract the contribution and cooperation of buffer zone residents.
T	Apply modern technology in biodiversity and peatland ecosystem monitoring, carbon sequestration calculation, and disseminating biodiversity values to the public.	Use high-speed internet for biodiversity monitoring, promotion, and connecting relevant values.	-	Digital transformation policies and high-tech applications; develop digital transformation programs in conservation and wetland ecosystem management.	-
L	Leverage legal documents (e.g., Biodiversity Law 2018, Forestry Law 2017, Decree 06/2019/NĐ-CP) to elevate UMT’s status as a biodiversity hotspot.	Decree 06/2022/NĐ-CP on opening the carbon credit market by 2028 creates opportunities for UMT to exploit wetland ecosystem service values.	State prioritized investment under the Cultural Heritage Law 2013. Kien Giang province has invested 34.115 billion VND in transport and upgrades; total relic investment is 151.293 billion VND.	Decision 1975/QĐ-TTg: Seize opportunities from investment priorities regulated by law.	-
E	Use species capable of treating wastewater; research wetland species to develop wastewater treatment processes and Nature-based Solutions.	Enhance the value of wetland ecosystem services, helping buffer zone communities cope with climate change (e.g., rainwater absorption, carbon sequestration [71], and limiting water pollution.	Efficient water management and regulation to prevent saltwater intrusion and land subsidence.	-	-

Based on the analysis in Table 6, the following solutions are proposed to help mitigate UMT’s weaknesses against adverse impacts, contributing to positive outcomes for both the Park and the buffer zone communities:

- **Economic factor:** Strengthen forest fire control and prevention solutions to reasonably expand the time and space available for controlled eco-tourism, thereby increasing revenue. Support the community in diversifying livelihood models that are linked to UMT’s tourism activities. Address budgetary shortfalls by commercializing ecological values (such as carbon sequestration by peatlands and freshwater supply) to create a reinvestment fund for forest protection and micro-credit support for local residents.
- **Social factor:** Implement short-term vocational training courses aligned with practical needs. Transform residents from forest encroachers into forest beneficiaries by giving them opportunities to participate in eco-tourism activities, such as providing homestays, rowing boat services, or selling local specialties, helping them realize that protecting the forest is synonymous with protecting their livelihoods. Diversify communication products to raise community awareness.
- **Technological factor:** Infrastructure for conservation and tourism remains weak (difficult access, lack of standardized accommodations). The biodiversity monitoring and fire warning systems still rely primarily on human labor and manual patrols. In the digital age, without technology, UMT will lag in attracting tourists and fail to respond promptly to environmental emergencies. Installing a network of IoT sensors to measure peat moisture and groundwater levels in real-time; use drones and remote sensing imagery for thermal scanning to detect fire risks early from above. Developing virtual reality experiences or interactive information apps to overcome the difficulty of traversing the terrain, allowing visitors to gain a deep understanding of the Ramsar site’s values without deep physical intrusion, thus reducing pressure on the core zone.
- **Legal factor:** There is a historical conflict of interest between the State’s strict forest closure policy and the long-standing survival needs of local residents. Absolute prohibitions can sometimes become rigid, leading to clandestine opposition from the community and keeping law enforcement forces in a state of constant tension and overload. Transition from absolute prohibition to shared responsibility and benefits. It is necessary to complete the legal framework to license the sustainable exploitation of non-timber forest products (such as traditional bee-hive placement or seasonal fishing) for self-managing community organizations under strict quotas.
- **Environmental factor:** Shift from the mindset of keeping dykes closed to retain water year-round toward an adaptive hydrological management approach tailored to specific habitat conditions. It is necessary to establish flexible water regulation regimes that simulate natural hydrological rhythms (with alternating flood and dry seasons) to allow melaleuca roots to breathe and to flush out alum, while still ensuring the peat layer does not dry out to the point of ignition. Develop scenarios for surface water pollution, saltwater intrusion, and landslides to implement evidence-based preventive solutions effectively.

**Table 6. Weaknesses and PESTLE analysis matrix**

PESTLE Factor	Weaknesses		
	Unique wetland ecosystem	Infrastructure	Human resources
<b>E</b>	Research optimal water levels for each specific area; develop diverse fire prevention scenarios to remain ready for expanded tourism activities even during the dry season, increasing UMT’s revenue.	Apply socialization models to improve infrastructure for eco-tourism expansion. Build an official park website. Integrate tourism products from the buffer zone or nearby attractions. Connect with travel agencies to promote tourism products.	Train staff and the community in technology application, management, and eco-tourism operations. Diversify community-based products and models, integrating them into UMT eco-tourism to increase income and raise awareness.
<b>S</b>	Develop diverse communication products to raise local community awareness and reduce illegal wildlife exploitation. Protecting peatland habitats also helps prevent future pandemics like COVID-19 [72].	Use diverse media channels to disseminate information about the value of wetland ecosystems.	Strengthen relationships between local communities and staff; share benefits fairly with buffer zone communities to collectively combat poachers.
<b>T</b>	Apply high-tech and remote sensing imagery for fire monitoring and control [73]. Develop water resource scenarios for the dry season to ensure sufficient water storage for fire prevention.	Build a website using advanced technology that is accessible and easily scalable. Develop virtual reality programs for more intuitive exploration of the park.	Enhance UMT staff capacity in applying GIS, modeling, and promoting images on media platforms. Train the community on technology application in production and business.
<b>L</b>	Lobby and provide sufficient evidence to obtain a specific wetland management mechanism, reducing fire prevention pressure and allowing more flexibility in UMT management.	Upgrade infrastructure for law enforcement, such as temporary detention rooms for poachers.	Provide training for staff and residents on Vietnamese conservation-related laws. Simplify legal terminology in official documents.
<b>E</b>	Frequently update climate information to calculate adequate water supply for the Park. Assess risks of saltwater intrusion and water resource pollution.	Upgrade water control systems, especially dyke systems on peatlands at high risk of landslides and saltwater intrusion.	Support the community in adopting appropriate, eco-friendly farming models. Apply new cultivation and processing technologies to increase income. Avoid transitioning to saltwater aquaculture.

## 4. Conclusions

The management and conservation of wetland ecosystems, particularly the melaleuca forests on peatlands at UMT, cannot rely solely on traditional silvicultural measures. The integrated application of the PESTLE and SWOT models in strategic planning has provided a multidimensional lens, facilitating a comprehensive diagnosis of both the internal health of the National Park and the complex fluctuations of the external macro-environment.

Based on these strategic analyses, the study has drawn the following core conclusions and action orientations:

- Environmental and ecological aspect: The survival of UMT depends on changing the mindset of hydrological management. There must be a transition from a mechanism of keeping dykes closed to retain water year-round to an adaptive water management regime, aimed at restoring the functionality of the peat layer and reducing the risk of forest fires during the dry season, while still ensuring growing space for endemic species.
- Socio-Economic aspect: The conflict between conservation and livelihoods is the root cause of forest encroachment. Therefore, empowering buffer zone communities through co-management mechanisms, developing eco-tourism, and transferring integrated agro-forestry-fishery techniques is the most effective prevention strategy. Forest preservation will only succeed when local people see direct economic benefits from the forest.
- Institutional and technological aspect: It is necessary to leverage opportunities from macro-policies, such as the Government's climate change commitments, to attract international capital. At the same time, unlocking new financial revenue sources (Payment for Forest Environmental Services, carbon credit markets) combined with smart monitoring technology (IoT, GIS, remote sensing) will fundamentally resolve weaknesses in budget shortages and forest protection human resources.

In summary, the integration of PESTLE and SWOT confirms that wetland conservation in the modern context is a dynamic interactive process. For UMT to maximize its status as a Ramsar site and an ASEAN Heritage Park, managers need to transform strengths and opportunities into ecological economic assets, while using these very resources to overcome weaknesses and build resilience against the challenges of climate change. The framework of this study can be fully replicated and applied as a standard model for other nature reserves nationwide.

## 5. Declarations

### 5.1. Author Contributions

Conceptualization, L.V.L. and P.T.; methodology, P.T. and P.K.; validation, P.T. and P.K.; formal analysis, L.V.L.; investigation, L.V.L.; resources, L.V.L.; data curation, L.V.L.; writing—original draft preparation, P.T.; writing—review and editing, P.T. All authors have read and agreed to the published version of the manuscript.

### 5.2. Data Availability Statement

The data presented in this study are available in the article.

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### 5.5. Institutional Review Board Statement

Not applicable.

### 5.6. Informed Consent Statement

Not applicable.

### 5.7. Declaration of Competing Interest

The authors declare that there are no conflicts of interest concerning the publication of this manuscript. Furthermore, all ethical considerations, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

## 6. References

- [1] Fentaw, G., Beneberu, G., Wondie, A., & Eneyew, B. G. (2025). Ecosystem services of wetlands in the upper Abbay River basin, Ethiopia. *Ecological Indicators*, 171. doi:10.1016/j.ecolind.2025.113142.
- [2] Sarmah, B., & Mahanta, R. (2025). Assessing the inter-linkage between ecosystem services and livelihood assets: case study of Deepor Beel Ramsar site in Assam, India. *Society Register*, 9(2), 35-50. doi:10.14746/sr.2025.9.2.02.
- [3] Yan, F., & Zhang, S. (2019). Ecosystem service decline in response to wetland loss in the Sanjiang Plain, Northeast China. *Ecological Engineering*, 130, 117–121. doi:10.1016/j.ecoleng.2019.02.009.
- [4] Balwan, Wahied Khawar, & Kour, S. (2021). Wetland- An Ecological Boon for the Environment. *East African Scholars Journal of Agriculture and Life Sciences*, 4(3), 38–48. doi:10.36349/easjals.2021.v04i03.001.
- [5] Bhardwaj, P. P. (2025). Wetland Conservation for Biodiversity and Ecosystem. *International Journal of Humanities and Social Science Invention*, 14(5), 193–198. doi:10.35629/7722-1405193198.
- [6] Kingsford, R. T., Basset, A., & Jackson, L. (2016). Wetlands: conservation's poor cousins. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 26(5), 892–916. doi:10.1002/aqc.2709.
- [7] Li, X., Bellerby, R., Craft, C., & Widney, S. E. (2018). Coastal wetland loss, consequences, and challenges for restoration. *Anthropocene Coasts*, 1(1), 1–15. doi:10.1139/anc-2017-0001.
- [8] Nyandwi, O., & Ndikubwimana, I. (2024). The Effects of Wetland Degradation on Ecological Species. *International Journal of Innovative Science and Research Technology*, 9(4), 2160–2169. doi:10.38124/ijisrt/ijisrt24apr1244.
- [9] Sonia, Kumari Sita, & Vaneet Kumar. (2025). Wetlands: crucial ecosystem service providers: A contemporary review. *International Journal of Science and Research Archive*, 14(2), 064–067. doi:10.30574/ijisra.2025.14.2.0222.
- [10] Yousaf, A., Khalid, N., Aqeel, M., Noman, A., Naeem, N., Sarfraz, W., Ejaz, U., Qaiser, Z., & Khalid, A. (2021). Nitrogen Dynamics in Wetland Systems and Its Impact on Biodiversity. *Nitrogen (Switzerland)*, 2(2), 196–217. doi:10.3390/nitrogen2020013.
- [11] Ramachandra, T. V., Asulabha, K. S., Sincy, V., & Jaishanker, R. (2024). Wetlands for human well-being. *Journal of Environmental Biology*, 45(2), 1-5. doi:10.22438/jeb/45/2/Editorial.
- [12] Hinson, A. L., McCarty, G., Du, L., Sichko, C., & Maguire, K. (2024). Native bee Pollination Ecosystem Services in Agricultural Wetlands and Riparian Protected Lands. *Wetlands*, 44(8), 116. doi:10.1007/s13157-024-01872-x.
- [13] Jacobson, M. M., Schummer, M. L., Fierke, M. K., Chesshire, P. R., & Leopold, D. J. (2025). Wild bee assemblages and pollination networks of managed emergent wetlands in central New York, USA. *Ecology and evolution*, 15(2), e70847. doi:10.1002/ece3.70847.
- [14] Agaton, C. B., & Guila, P. M. C. (2023). Ecosystem Services Valuation of Constructed Wetland as a Nature-Based Solution to Wastewater Treatment. *Earth (Switzerland)*, 4(1), 78–92. doi:10.3390/earth4010006.
- [15] Wu, Y., Sun, J., Hu, B., Zhang, G., & Rousseau, A. N. (2023). Wetland-based solutions against extreme flood and severe drought: Efficiency evaluation of risk mitigation. *Climate Risk Management*, 40. doi:10.1016/j.crm.2023.100505.
- [16] Song, A., Liang, S., Li, H., & Yan, B. (2024). Effects of biodiversity on functional stability of freshwater wetlands: a systematic review. *Frontiers in Microbiology*, 15. doi:10.3389/fmicb.2024.1397683.
- [17] Tan, L., Ge, Z., Ji, Y., Lai, D. Y. F., Temmerman, S., Li, S., Li, X., & Tang, J. (2022). Land use and land cover changes in coastal and inland wetlands cause soil carbon and nitrogen loss. *Global Ecology and Biogeography*, 31(12), 2541–2563. doi:10.1111/geb.13597.
- [18] Qiu, J., Zhang, Y., & Ma, J. (2024). Wetland habitats supporting waterbird diversity: Conservation perspective on biodiversity-ecosystem functioning relationship. *Journal of Environmental Management*, 357, 120663. doi:10.1016/j.jenvman.2024.120663.
- [19] Zhao, Q., Chen, Y., Gone, K. P., Wells, E., Margeson, K., & Sherren, K. (2023). Modelling cultural ecosystem services in agricultural Dykelands and tidal wetlands to inform coastal infrastructure decisions: A social media data approach. *Marine Policy*, 150. doi:10.1016/j.marpol.2023.105533.
- [20] MEA. (2005). *Ecosystems and human well-being: Wetlands and water synthesis*. Millennium Ecosystem Assessment (MEA), World Resources Institute, Washington, D.C., United States.
- [21] Ballut-Dajud, G. A., Herazo, L. C. S., Fernández-Lambert, G., Marín-Muñiz, J. L., Méndez, M. C. L., & Betanzo-Torres, E. A. (2022). Factors Affecting Wetland Loss: A Review. *Land*, 11(3), 434. doi:10.3390/land11030434.
- [22] Huu Nguyen, H., Dargusch, P., Moss, P., & Tran, D. B. (2016). A review of the drivers of 200 years of wetland degradation in the Mekong Delta of Vietnam. *Regional Environmental Change*, 16(8), 2303–2315. doi:10.1007/s10113-016-0941-3.

- [23] Fluet-Chouinard, E., Stocker, B. D., Zhang, Z., Malhotra, A., Melton, J. R., Poulter, B., Kaplan, J. O., Goldewijk, K. K., Siebert, S., Minayeva, T., Hugelius, G., Joosten, H., Barthelmes, A., Prigent, C., Aires, F., Hoyt, A. M., Davidson, N., Finlayson, C. M., Lehner, B., ... McIntyre, P. B. (2023). Extensive global wetland loss over the past three centuries. *Nature*, 614(7947), 281–286. doi:10.1038/s41586-022-05572-6.
- [24] Kundu, S., Kundu, B., Rana, N. K., & Mahato, S. (2024). Wetland degradation and its impacts on livelihoods and sustainable development goals: An overview. *Sustainable Production and Consumption*, 48, 419–434. doi:10.1016/j.spc.2024.05.024.
- [25] Loi, L. V., & Hanh, H. L. M. (2023). Current status of freshwater resources used in the buffer zone community of U Minh Thuong National Park. *Science Journal of Dong Thap University*, 12(2), 97–106. doi:10.52714/dthu.12.2.2023.1037.
- [26] Tung, N. S., & Dap, N. D. (2020). Analysis of the Biodiversity and Socio-Economic Values of the Wetlands in Vietnam. *Technology Audit and Production Reserves*, 3(3), 25–31. doi:10.15587/2706-5448.2020.205046.
- [27] Yadav, P. K., Jha, P., Joy, M. S., Bansal, T., Rawat, P., Begam, S., & Singh, A. K. (2025). Investigating the role of policies in the sustainable management of East Kolkata wetlands. *Discover Global Society*, 3(1), 79. doi:10.1007/s44282-025-00212-6.
- [28] Douglas, O. O., & Victor, A. O. O. (2022). Optimizing community participation in the management of Yala Wetland Ecosystem, Lake Victoria Basin, Kenya: The Yala Hub Framework. *African Journal of Environmental Science and Technology*, 16(1), 10–36. doi:10.5897/ajest2020.2940.
- [29] Kiumbuku, S. K. (2022). Challenges of Community-Based Management of Protected Areas: Contested Trade-offs Between Livelihood and Conservation Interests in Chyulu Hills National Park, Kenya. *Environment and Natural Resources Research*, 12(2), 1. doi:10.5539/enrr.v12n2p1.
- [30] Daileg, M. J. Y., Gatdula, J. R., Garalde, M. J. B., Ladao III, R. R., Magan, A. S., Martinez, C. R., Menil, L. V. C., Satorre, K. D., Tenerife, D. P., Tulod, J. P. V., Mamitag, K. R., & Pudan, J. C. (2025). Conservation at a Crossroads: Evaluating the Socio-Economic Impact of the Las Piñas-Parañaque Wetland Park on Adjacent Communities. *DIT ADS International Multidisciplinary Research Journal*, 1(3), 132–143. doi:10.63941/dit.adsimrj.2025.1.3.1.31.
- [31] Masson-Delmotte, V., Zhai, P., & Pirani, A. (2021). Climate change 2021: The physical science basis: Summary for policymakers. Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland. Available online: [https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC\\_AR6\\_WGI\\_SPM.pdf](https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf) (accessed on May 2026).
- [32] Farooqi, T. J. A., Irfan, M., Portela, R., Zhou, X., Shulin, P., & Ali, A. (2022). Global progress in climate change and biodiversity conservation research. *Global Ecology and Conservation*, 38, 2272. doi:10.1016/j.gecco.2022.e02272.
- [33] Adeeyo, A. O., Ndlovu, S. S., Ngwagwe, L. M., Mudau, M., Alabi, M. A., & Edokpayi, J. N. (2022). Wetland Resources in South Africa: Threats and Metadata Study. *Resources*, 11(6), 54. doi:10.3390/resources11060054.
- [34] Adesina, J. A., Tang, X., & Uduma-Olugu, N. (2025). Exploring the biodiversity conservation potentials and eco-benefits of wetland corridors through sustainable ecotourism and landscape design approach. *Ensaios de Geografia*, 12(25), e122510. doi:10.22409/eg.v12i25.65955.
- [35] Ghorbani, A., Raufirad, V., Rafiaani, P., & Azadi, H. (2015). Ecotourism sustainable development strategies using SWOT and QSPM model: A case study of Kaji Namakzar Wetland, South Khorasan Province, Iran. *Tourism Management Perspectives*, 16, 290–297. doi:10.1016/j.tmp.2015.09.005.
- [36] 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. doi:10.1016/j.jenvman.2014.05.040.
- [37] Srđević, B., Srđević, Z., Ilić Paunić, M., & Ždero, S. (2025). Enhancing SWOT Analysis with DEMATEL and AHP for NbS and ES in Wetland Restoration: The Landscape of Outstanding Features—Vlasina, Serbia. *HAICTA*, 20. doi:10.3390/proceedings2025117020.
- [38] Yap, C. K., & Al-Mutairi, K. A. (2025). Mangrove ecosystems in Western Asia: a literature review of trends, conservation gaps, and sustainable management strategies. *Frontiers in Forests and Global Change*, 8. doi:10.3389/ffgc.2025.1556158.
- [39] Christodoulou, A., & Cullinane, K. (2019). Identifying the main opportunities and challenges from the implementation of a port energy management system: A SWOT/PESTLE analysis. *Sustainability (Switzerland)*, 11(21), 6046. doi:10.3390/su11216046.
- [40] Sridhar, R., Sachithanandam, V., Mageswaran, T., Purvaja, R., Ramesh, R., Senthil Vel, A., & Thirunavukkarasu, E. (2016). A Political, Economic, Social, Technological, Legal and Environmental (PESTLE) approach for assessment of coastal zone management practice in India. *International Review of Public Administration*, 21(3), 216–232. doi:10.1080/12294659.2016.1237091.
- [41] Kolios, A., & Read, G. (2013). A Political, economic, social, technology, legal and environmental (PESTLE) approach for risk identification of the tidal industry in the United Kingdom. *Energies*, 6(10), 5023–5045. doi:10.3390/en6105023.

- [42] Kordana, S., & Słyś, D. (2020). An analysis of important issues impacting the development of stormwater management systems in Poland. *Science of the Total Environment*, 727, 138711. doi:10.1016/j.scitotenv.2020.138711.
- [43] Rendón, O. R., Garbutt, A., Skov, M., Möller, I., Alexander, M., Ballinger, R., Wyles, K., Smith, G., McKinley, E., Griffin, J., Thomas, M., Davidson, K., Pagès, J. F., Read, S., & Beaumont, N. (2019). A framework linking ecosystem services and human well-being: Saltmarsh as a case study. *People and Nature*, 1(4), 486–496. doi:10.1002/pan3.10050.
- [44] Pandey, V. P., Manandhar, S., & Kazama, F. (2014). Climate change vulnerability assessment. *Climate Change and Water Resources*. Minh Thuong National Park, Viet Nam (IUCN Report), CRC Press, Florida, United States. doi:10.1201/b16969.
- [45] Thai, T. L. (2020). Effect of flooding on peatland in U Minh Thuong National Park, Vietnam. *Journal of Soil Science and Environmental Management*, 11(2), 57–64. doi:10.5897/jssem2019.0776.
- [46] Van Cuong, C., Dart, P., Brown, S., Van Thang, T., & Le, V. T. M. (2019). Enhancing bird biodiversity through improved water management in a Vietnam wetland national park. *Parks*, 25(1), 55–68. doi:10.2305/IUCN.CH.2019.PARKS-25-1CVC.en.
- [47] Khai, H. V., & Yabe, M. (2014). The demand of urban residents for the biodiversity conservation in U Minh Thuong National Park, Vietnam. *Agricultural and Food Economics*, 2(1), 10. doi:10.1186/s40100-014-0010-5.
- [48] RIS. (2015). Ramsar information sheet of U Minh Thuong, Vietnam. Ramsar Information Sheet (RIS), Kien Giang, Vietnam. Available online: [https://rsis.ramsar.org/RISapp/files/RISrep/VN2228RIS\\_1505\\_en.pdf](https://rsis.ramsar.org/RISapp/files/RISrep/VN2228RIS_1505_en.pdf) (accessed on May 2026).
- [49] Biggs, D. (2005). Managing a rebel landscape: Conservation, pioneers, and the revolutionary past in the U Minh forest, Vietnam. *Environmental History*, 10(3), 448–476. doi:10.1093/envhis/10.3.448.
- [50] Tran, D. B. (2017). Restoration of Melaleuca Swamp Ecosystem for Bird Diversity in the Mekong Delta of Vietnam. *MOJ Ecology & Environmental Sciences*, 2(6), 234–241. doi:10.15406/mojes.2017.02.00040.
- [51] DIT. (2021). Overseas business risk: Vietnam. UK's Department for International Trade (DIT), London, United Kingdom. Available online: <https://www.gov.uk/government/publications/overseas-business-risk-vietnam/overseas-business-risk-vietnam> (accessed on May 2026).
- [52] World Bank, & Ministry of Planning & Investment of Vietnam. (2016). Vietnam 2035: Toward prosperity, creativity, equity, and democracy. The World Bank Group, Washington, D.C., United States. Available online: <http://documents.worldbank.org/curated/en/996421479825859721> (accessed on May 2026).
- [53] U Minh Thuong National Park. (2023). Explanation of the Sustainable Forest Management Plan for the Period 2021-2030 of U Minh Thuong National Park. People's Committee of Kien Giang Province, U Minh Thuong National Park, Ho Chi Minh City, Vietnam.
- [54] Ibisch, P. L., Vega, E., & Herrmann, T. M. (2010). Interdependence of biodiversity and development under global change (second corrected edition). Secretariat of the Convention on Biological Diversity, Technical Series No. 54.
- [55] Gardner, R. C., Finlayson, M., Davidson, N., Fennessy, S., Coates, D., Darwall, W., Dema, M., Everard, M., McRae, L., Perennou, C., Stroud, D., van Dam, A., Bambaradeniya, C., Davies, P., Fang, W.-T., Hilomen, V., Kulindwa, K., Martinez, L., Ricaurte, L., et al. (2018). *Global Wetland Outlook: State of the World's Wetlands and their Services to People*. Ramsar Convention on Wetlands, Ramsar, Iran. doi:10.69556/GWO-2018-eng.
- [56] Ministry of Natural Resources and Environment. (2019). The sixth national report to the United Nations Convention on Biological Diversity. The Socialist Republic of Vietnam, Hanoi, Vietnam. Available online: <https://www.cbd.int/doc/nr/nr-06/vn-nr-06-en.pdf> (accessed on May 2026).
- [57] Nuwer, R., & Bell, D. (2014). Identifying and quantifying the threats to biodiversity in the U Minh peat swamp forests of the Mekong Delta, Vietnam. *Oryx*, 48(1), 88–94. doi:10.1017/S0030605312000865.
- [58] WCS. (2018). Summary report on wildlife law violations and enforcement in Vietnam, period 2013-2017. Wildlife Conservation Society, Vietnam Program, Hanoi, Vietnam.
- [59] Thang, N. V., Nga, P. T. T., Huong, H. T. L., Thang, V. V., Phong, D. H., Huy, L. Q., Khiem, M. V., & Hien, N. X. (2020). Climate change scenario updated to 2020. *Environmental Resources and Maps*, Hanoi, Vietnam.
- [60] Truong, D. D. (2022). Community awareness and participation in biodiversity conservation at Phong Nha-Ke Bang National Park, Vietnam. *Biodiversitas*, 23(1), 581–592. doi:10.13057/biodiv/d230163.
- [61] Stuart, B. L. (2004). The Harvest and Trade of Reptiles At U Minh Thuong National Park, Southern Viet Nam. *TRAFFIC Bulletin*, 20(1), 25–34.
- [62] Binh, N. A., Nhut, H. S., An, N. N., Phuong, T. A., Hanh, N. C., Thao, G. T. P., Pham, T. T., Hong, P. V., Ha, L. T. T., Bui, D. T., & Hoa, P. V. (2021). Thirty-year dynamics of LULC at the dong Thap Muoi area, Southern Vietnam, using google earth engine. *ISPRS International Journal of Geo-Information*, 10(4), 226. doi:10.3390/ijgi10040226.

- [63] UNODC. (2018). Pangolin scale. United Nations Office on Drugs and Crime (UNODC), Vienna, Austria. Available online: [https://www.unodc.org/documents/data-and-analysis/wildlife/2020/WWLC20\\_Chapter\\_4\\_Pangolin.pdf](https://www.unodc.org/documents/data-and-analysis/wildlife/2020/WWLC20_Chapter_4_Pangolin.pdf) (accessed on May 2026).
- [64] Pimm, S. L., Alibhai, S., Bergl, R., Dehgan, A., Giri, C., Jewell, Z., Joppa, L., Kays, R., & Loarie, S. (2015). Emerging Technologies to Conserve Biodiversity. *Trends in Ecology and Evolution*, 30(11), 685–696. doi:10.1016/j.tree.2015.08.008.
- [65] Vu, T. T., Nguyen, T. C., Doherty, P. F., Nguyen, H. T., Clink, D. J., Nguyen, M. D., Dong, H. T., & Giang, T. T. (2023). Using mobile smartphones and bioacoustics to monitor endangered bird species. *Ibis*, 165(4), 1368–1377. doi:10.1111/ibi.13215.
- [66] Nguyen, T. G., Phan, K. A., & Huynh, T. H. N. (2022). Major concerns of surface water quality in south-west coastal regions of Vietnamese Mekong Delta. *Sustainable Environment Research*, 32(1), 46. doi:10.1186/s42834-022-00156-5.
- [67] Nguyễn, T. H. (2017). Overview of agricultural pollution in Vietnam: The cultivation sector. World Bank Group, Washington, D.C., United States. Available online: <https://documents1.worldbank.org/curated/en/681201516788003445/pdf/122934-WP-PUBLIC-Vietnam-crops-VNM.pdf> (accessed on May 2026).
- [68] Toan, P. Van, Sebesvari, Z., Bläsing, M., Rosendahl, I., & Renaud, F. G. (2013). Pesticide management and their residues in sediments and surface and drinking water in the Mekong Delta, Vietnam. *Science of the Total Environment*, 452–453, 28–39. doi:10.1016/j.scitotenv.2013.02.026.
- [69] Stimson Center. (2026). Mekong infrastructure tracker [Interactive map]. Mekong Dam Monitor. Stimson Center, Washington, D.C., United States. Available online: <https://www.stimson.org/project/mekong-dam-monitor/> (accessed on May 2026).
- [70] MONRE. (2020). Climate change scenario for Vietnam, 2020 update. Ministry of Natural Resources and Environment (MONRE), Hanoi, Vietnam. Available online: <https://imh.ac.vn/files/doc/2020/KB%20BDKH%202912.pdf> (accessed on May 2026).
- [71] Joosten, H. (2015). Peatlands, climate change mitigation and biodiversity conservation: An issue brief on the importance of peatlands for carbon and biodiversity conservation and the role of drained peatlands as greenhouse gas emission hotspots. The Nordic Co-operation, Copenhagen K, Denmark. doi:10.6027/ANP2015-727
- [72] Harrison, M. E., Wijedasa, L. S., Cole, L. E. S., Cheyne, S. M., Choiruzzad, S. A. B., Chua, L., Dargie, G. C., Ewango, C. E. N., Honorio Coronado, E. N., Ifo, S. A., Imron, M. A., Kopansky, D., Lestaris, T., O'Reilly, P. J., van Offelen, J., Refisch, J., Roucoux, K., Sugardjito, J., Thornton, S. A., ... Page, S. (2020). Tropical peatlands and their conservation are important in the context of COVID-19 and potential future (zoonotic) disease pandemics. *PeerJ*, 8, 10283. doi:10.7717/peerj.10283.
- [73] Tian, Y., Wu, Z., Li, M., Wang, B., & Zhang, X. (2022). Forest Fire Spread Monitoring and Vegetation Dynamics Detection Based on Multi-Source Remote Sensing Images. *Remote Sensing*, 14(18), 4431. doi:10.3390/rs14184431.