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Qualitative Landscape Analysis on the Pansipit River in Batangas, Philippines: A Social-Ecological Systems (SES) Perspective

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Abstract

Freshwater ecosystems, despite being extremely vital to human life and societal well-being, are often neglected as compared to their counterpart terrestrial and marine ecosystems. The Pansipit River in Batangas province is one of the approximately 420 rivers in the Philippines where water-related issues persist due to various socio-economic and environmental factors. It is a critical freshwater resource connecting Taal Lake to Balayan Bay. To provide insights for improved management and conservation, this study aimed to analyze the Pansipit River landscape as a social-ecological system (SES) to understand the complex interactions between its social (actors and governance systems) and ecological dimensions (resource units and resource system). Using a qualitative approach in landscape analysis, the research involved semi-structured interviews with key informants from local government agencies and collecting secondary data from government reports and academic sources. The findings reveal that the river, vital for biodiversity and community livelihoods, faces significant challenges from anthropogenic pressures such as siltation, unregulated fishing practices, and pollution. Despite its historical and cultural significance, management efforts are fragmented and insufficient. The study underscores the need for a holistic approach to river management, advocating for better coordination among local government units, enhanced conservation strategies, and community engagement. Recommendations include developing an inter-agency task force, investing in pollution control measures, and utilizing GIS technology for monitoring. These actions are essential for ensuring the Pansipit River's ecological health and sustaining its role in the local community.

Keywords— river landscape, landscape analysis, social-ecological system

1 Introduction

Rivers are natural landscapes that serve a vital role in sustaining ecological balance. These ecosystems are considered lifelines for contributing to the well-being of human communities [1] as they utilize fresh water for consumption, irrigation, and transportation. Rivers also serve as central elements in human societies' cultural and social fabric. As cultural landscapes, they have evolved through a long history of human-nature interactions. These bodies of water have been pivotal in shaping civilizations, serving as connectors and dividers of people and places [2]. Rivers have facilitated trade, cultural exchange, and the movement of people, marking boundaries and defining territories. Such complex interplay between natural processes and human activities has shaped river landscapes into what they are today.

Understanding the relationship between rivers and human societies highlights the need to understand rivers as physical entities and as integral components of a broader social and ecological context. Recognizing that past, present, and future developments in river landscapes result from these intricate interactions between society and nature has led to the conceptualization of rivers as social-ecological systems (SESs) [2]. This perspective acknowledges that rivers are influenced by many factors, including environmental changes, technological advancements, economic activities, and social practices, all of which contribute to their ongoing transformation. Such an approach is particularly crucial in addressing the challenges of urbanization, climate change, and other global processes that increasingly impact riverine environments.

With its approximately 420 rivers, the Philippines is a country where water-related issues persist due to geographic disparities, increasing population, and growing demand for resources [3]. Located in the highly populated and rapidly growing agro-industrial region of Southern Luzon, the Pansipit River has not been immune to these pressures. While a few studies have examined the river's fish community dynamics [4, 5], the human dimensions and socio-cultural values concerning the Pansipit River remain underexplored. This gap in research highlights the need for a more comprehensive understanding of the river as an SES.

Thus, this study sought to characterize a river landscape in the Philippines, the Pansipit River, as an SES. We specifically aimed to provide an overview of the river's social (actors and governance systems) and ecological dimensions (resource units and resource system) and examine how their interactions result in outcomes. Through this, the study can provide valuable baseline information to guide future research, policy-making, and community engagement efforts related to the Pansipit River, contributing to the broader discourse on river management in the Philippines and similar contexts.

2 Analyzing Landscapes Within a Planning Context

As defined in the European Landscape Convention [6], landscape is "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors." Moreover, they are inherently dynamic and constantly evolving. According to Stahlschmidt et al. [7], landscape change occurs incrementally and in dramatic steps, driven by diverse factors. These drivers include biophysical processes, technological advancements, economic shifts, urbanization, public policy interventions, and the actions of local landscape agents whose daily activities continuously reshape the environment. Analyzing landscapes within a planning context, thus, requires a systematic approach that considers both its social and ecological dimensions.

Stahlschmidt et al. [7] further highlights how landscape analysis can be done using quantitative and qualitative approaches. Quantitative analysis can be done based on measurable dimensions of a landscape and its components. In contrast, qualitative analysis involves assessing the properties of a landscape and its components directly, without using instruments, standard measures, or calculations. However, despite the potential of qualitative approaches to provide context-specific insights, they are often overshadowed by the dominance of quantitative methodologies in land-

scape analysis. Many current methods, such as GIS and spatial modeling, involve complex technical processes requiring specialized knowledge and advanced tools.

Similarly, while central to the social sciences, qualitative methodologies remain underutilized in SES research. Integrating descriptive and analytical approaches is crucial for improving our understanding of the human and social factors that influence the functioning and sustainability of Earth systems [8]. For instance, pinto-Correia and Kristensen [9] illustrated how various factors – both natural and structural, as well as socio-economic and cultural – interact to shape the local landscape. It is emphasized that these factors must be collectively considered to fully understand the current reality of landscapes, particularly in everyday decisions made by landscape managers and users. Moreover, Rojas-Caldelas et al. [10] utilized qualitative assessments through interviews and visual representations to capture the perceptions of residents and non-residents, which has provided insights into the cultural and emotional connections people have with the Mexicali Valley landscape.

On the other hand, Santiago and Buot [11] conducted focus group discussions to identify strategies for maintaining the social-ecological resilience of the Chaya Rice Terraces through the perspectives of the local community. Ferriss et al. [12] applied qualitative network analysis to bivalve aquaculture in the USA, revealing the interconnectedness of social and ecological components and the value of different stakeholders' perspectives. Finally, Corpuz and Espaldon [13] employed a participatory socio-ecological assessment in Bataan, Philippines to gather local perceptions of riverine and mangrove fisheries for ecosystem management and conservation. These studies highlight how qualitative data can complement technical approaches by revealing the human dimensions of environmental issues, offering a more holistic view essential for effective management and resilience building in socio-ecological systems. Therefore, it is important to develop methodologies empowering local governments and communities to manage and adapt their landscapes effectively towards bridging the gap between advanced technical tools and practical, community-driven applications.

3 River Landscapes as Social-Ecological Systems (SES)

The SES framework offers a comprehensive understanding of river landscapes as integrated entities where ecological and social dynamics are intricately connected. SES emphasizes that rivers are not isolated from human activities but deeply embedded within broader social and ecological contexts, influenced by natural processes and human practices [14]. As pointed out by Berkes [15], "social-ecological" is a more fitting term rather than "socio-ecological" because the former emphasizes the equal importance of both subsystems, whereas "socio-" functions as a modifier, which suggests a lesser status of the social subsystem. This perspective is crucial for addressing the multifaceted challenges of river management and conservation, as it acknowledges that rivers are shaped by a complex interplay of biophysical factors, such as hydrology, geology, and climate, alongside human activities like agriculture, urbanization, and resource extraction [16].

Several studies have effectively applied the SES framework to conceptualize river landscapes, providing valuable insights into their management and sustainability. Firstly, Carpenter et al. [17] explored the resilience of SESs in lake and river ecosystems, emphasizing the need to consider ecological processes and human dimensions in managing freshwater resources. On the other hand, Folke et al. [18] examined the adaptive capacity of SESs in managing complex ecosystems, such as rivers. It is argued that understanding the interactions between ecological dynamics and social structures is essential for developing adaptive management strategies that can respond to environmental changes and uncertainties.

Moreover, Zhang et al. [19] highlighted how various social and ecological factors like land use, social economy, and climate influence the balance of ecosystem services in the Yangtze River Economic Belt, providing insights into balancing economic development with environmental pro-

tection. Kattel [20] further enriches the SES framework by highlighting the crucial role of response diversity in enhancing the resilience of freshwater systems in the lower Mekong basin amidst severe environmental stress and by developing a framework to understand the dynamics of regime shifts and their impacts on social-ecological resilience. These studies collectively demonstrate the value of the SES framework in understanding and managing river landscapes. By integrating ecological and social perspectives, researchers and practitioners can develop more holistic and adaptive strategies that address the diverse challenges facing SESs.

It is worth noting, however, that in analyzing river landscapes through the SES framework, incorporating qualitative case studies is essential for capturing the complex interactions between social and ecological dimensions that quantitative methods alone may miss. While quantitative data on variables such as water quality and governance structures are crucial for building theoretical models, qualitative insights are necessary to understand the heterogeneous costs and benefits experienced by various stakeholders, including governments, communities, and individuals [14]. Qualitative approaches provide a deeper understanding of local perceptions, social dynamics, and the lived experiences of those interacting with the river, which enriches the analysis and supports the development of more effective and adaptive management strategies.

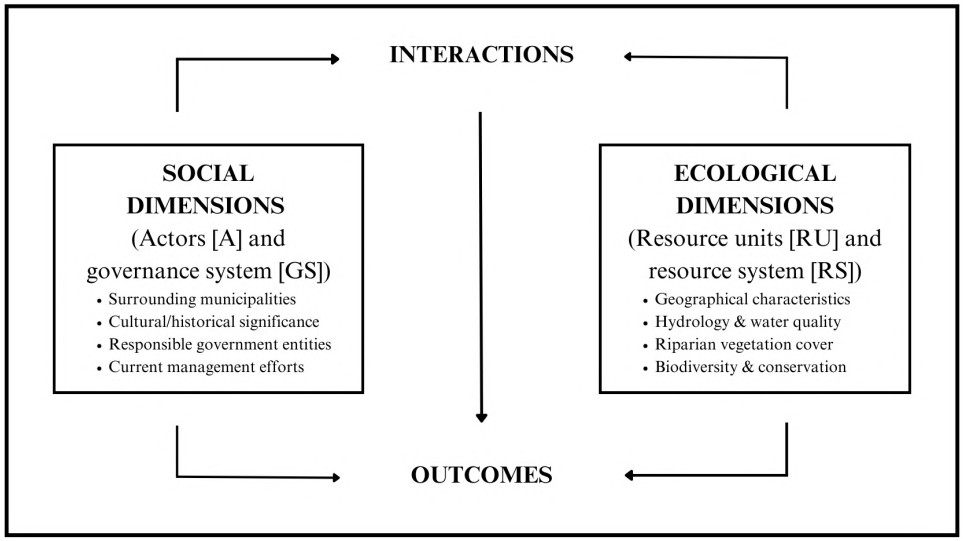

Figure 1.
Simplified social-ecological systems (SES) framework for landscape analysis with specific elements identified

4 Conceptual Framework

The study's conceptual framework (Figure 1), which integrates both the social and ecological dimensions of SES, was then developed, largely based on the elements of the revised general framework for analyzing SES [21]. The ecological aspects include geographical characteristics, hydrology and water quality, riparian vegetation cover, and biodiversity and conservation, capturing the physical and biological features of the river system. From a social perspective, the framework considers surrounding municipalities, cultural and historical significance, responsible government entities, and current management efforts, emphasizing human interactions and governance. The interactions between these social and ecological components are central to the framework. Meanwhile, the outcomes of these interactions reflect the current reality of the SES.

Data collection methods included semi-structured key informant interviews (KIIs) with the Municipal Environment and Natural Resources Officers (MENRO) from Taal and Lemery, as well as a representative from the Community Environment and Natural Resources Office (CENRO) in

Calaca City. These interviews aimed to gather in-depth insights into local management practices and institutional knowledge. Ethical procedures were rigorously followed, with all participants providing informed consent. In addition to interviews, secondary data were also collected from various sources, including government reports, plans, and existing research related to the Pansipit River as summarized in Table 1. These data were sourced from local government units (LGUs) and academic databases such as Scopus and Google Scholar as of May 2024. Data analysis then involved thematic analysis for the interview data to identify and interpret key themes. Qualitative content analysis, on the other hand, was applied to secondary data to synthesize and integrate existing information. Figure 2 illustrates the integration of thematic and content analyses.

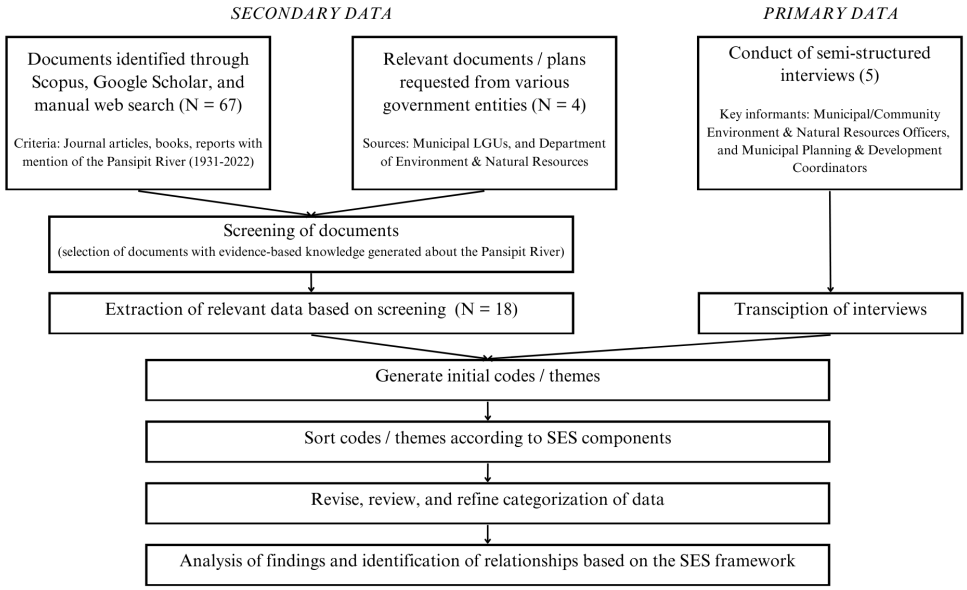

Figure 2.
Workflow of the research methodology

5 Methodology

In the context of the study, landscape analysis is used as a qualitative tool for environmental planning and management. As defined by Stahlschmidt [7], it is "an examination of a landscape to understand its character, structure, and function, to make policy, planning or design decisions concerning its future condition and management". Moreover, there are two broad applications of landscape analysis – situational analysis and action-oriented analysis. The former aims to gain knowledge and understanding of a landscape before any specific proposals, plans, or actions, which the study sought to achieve. For the Pansipit River, this means examining its physical characteristics, such as water quality, flow patterns, and biodiversity, alongside the social actors and governance systems that influence its management.

6 Case Study: Pansipit River

The Pansipit River (Figure 3) in Batangas, Philippines, spans 9.9 kilometers and serves as the sole drainage outlet for Taal Lake, the third-largest lake in the country. It connects Taal Lake to Balayan Bay, part of the ecologically significant Verde Island Passage. The river has historically been regarded as an essential freshwater resource for its surrounding communities [4]. However, like many other rivers in the Philippines, it faces significant challenges due to natural and human pressures.

Table 1. List of secondary data sources used for analysis

Author (Year)	Title of Document	Data Extracted
P. G. Orlina (1976) [22]	Taal	Historical and cultural significance of the Pansipit River
P. Delmelle et al. (1998) [23]	Geochemical and isotopic evidence for seawater contamination of the hydrothermal system of Taal Volcano, Luzon, the Philippines	Geological history of the Pansipit River as influenced by its proximity to Taal Volcano
I. E. Samonte (2000) [24]	Molecular phylogeny of Philippine freshwater sardines based on mitochondrial DNA analysis	Biological history of the Pansipit River
T. R. Perez et al. (2008) [25]	Catchment characteristics, hydrology, limnology and socio-economic features of Lake Taal, Philippines	Hydrologic flow of the Pansipit River
Conservation International Philippines, DENR - Protected Areas and Wildlife Bureau & Haribon Foundation (2006) [26]	Priority Sites for Conservation in the Philippines: Key Biodiversity Areas	Status of the Pansipit River as a candidate key biodiversity area
Municipal Government of Lemery (2012) [27]	Comprehensive Land Use Plan of Lemery, Batangas 2012-2021	Fluvial geomorphology and hydraulics and pollution status
D. B. Magcale-Macandog et al. (2014) [28]	Eliciting Local Ecological Knowledge and Community Perception on Fishkill in Taal Lake through Participatory Approaches	Ecological implications of anthropogenic activities in the Pansipit River
M. U. Mendoza et al. (2015) [4]	Dietary habits and distribution of some fish species in the Pansipit River-Lake Taal Connection, Luzon Island, Philippines	Historical and ecological significance of the Pansipit River
M. N. C. Corpuz et al. (2016) [5]	Diversity and distribution of freshwater fish assemblages in Lake Taal River systems in Batangas, Philippines	Riparian ecology and human activities driving pollution of the Pansipit River
DENR – CENRO of Calaca (2016) [29]	Pansipit River Management Plan	Biodiversity, characteristics of nearby communities, and management efforts in the Pansipit River
U.P. Training Center for Applied Geodesy and Photogrammetry (2017) [30]	Light detection and ranging (LiDAR) surveys and flood mapping of Pansipit River	Geographical characteristics of the Pansipit River
International Union for Conservation of Nature (2018) [31]	Sardinella tawilis (Bombon sardine)	Critically endangered status of Sardinella tawilis
M. V. G. Aguilar & R. M. Mujal (2018) [32]	The Locals and Their Use of Oral History in Tourism: The Case of the Candle Vendors of Taal, Batangas	Historical and cultural significance of the Pansipit River
A. S. Recto (2019) [33]	Sacred spaces and fluvial processions	Religious significance of the Pansipit River
J. C. Peracullo et al. (2020) [34]	The Virgin of the Vulnerable Lake: Catholic Engagement with Climate Change in the Philippines	Religious and ecological significance of the Pansipit River

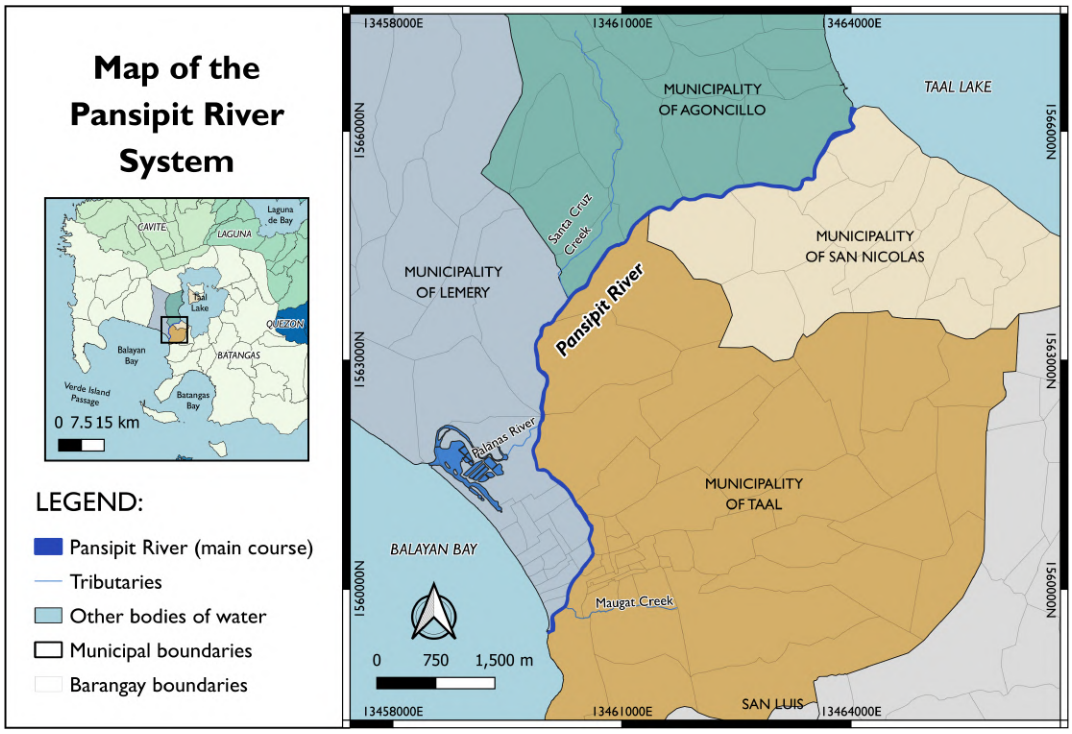

Figure 3.
Location Map of Pansipit River

7 Results and Discussion

7.1 Ecological Dimension 1: Resource System (RS)

The resource system (RS) describes the environmental conditions where the resources are located or produced [35]. Pansipit River is a freshwater resource used for irrigation, navigation, and aquaculture by the communities adjacent to it [36]. It is a 9.90 km long channel of water [30] traversing the municipalities of Agoncillo, Lemery, San Nicolas, and Taal in the province of Batangas. The river serves as Taal Lake's sole drainage outlet (the country's third largest lake), flowing into the Balayan Bay, which is connected to the Verde Island Passage (the center of the marine biodiversity) in the West Philippine Sea (Figure 4). As such, it forms part of the Taal Lake - Pansipit River Basin or Watershed that encompasses the provinces of Batangas and Cavite.

Figure 4.
Mouth of the Pansipit River towards Balayan Bay (April 2024) [left] and the Entrance of the Pansipit River from Taal Lake (May 2024) [right]

Its current form is a remnant of a previously wide navigable channel rearranged and narrowed off by a series of powerful eruptions of the Taal Volcano in the 18th century [23, 24]. The Pansipit River also feeds various tributaries, the largest of which is the 1-km-long Palanas River that branches in the southwestern part. Many small creeks are connected to the Pansipit River, including the Santa Cruz Creek in Agoncillo and the Maugat Creek in Taal. However, many others have already been built over or dried up.

According to the nationwide identification process of key biodiversity areas (KBAs) in the Philippines [26], Pansipit River was declared as one of the 51 candidate KBAs in the country. Candidate KBAs are areas suspected to be biologically important but do not yet have conclusive data to satisfy the KBA criteria set by the International Union for Conservation of Nature (IUCN). Moreover, about half of the entire length of the river is covered by the Taal Volcano Protected Landscape (formerly the Taal Volcano Island National Park), which is a protected area established by the National Integrated Protected Areas System (NIPAS) Act of 1992 [37]. Thus, an "ecological gap" exists, as this protected area does not fully encompass the entire river system [38].

Pansipit River has a gentle bed gradient and shallow river banks, with a center stream depth range of 0.3-4.7 m (mean: 2.6 m). It has a laminar flow (slow and almost smooth), and travels generally in the South-West direction towards the sea [27]. Based on a time series of 12 years, its average outflow rate is 15 m^3/s. The outflow rate fluctuates seasonally, with the lowest rates of 7.0-7.5 m^3/s occurring from April to May and the highest rates of 20-23 m^3/s from September to November [25]. Riverside plains in the upstream and midstream part of the river include grasslands, crop and coconut plantations, and a few residential areas. Some areas in the riverbanks are generally lined by mosses, ferns, and other riparian vegetation structures, with some steep areas that are surrounded by secondary forests, bryophytes, and perennial weeds [5].

Table 2. Flora and fauna species found in the Pansipit River [29]

Flora species	Fauna species
Tambo (*Phragmites vulgaris*)	
Coconut (*Cocos nucifera*)	
Aroma (*Acacia farnesiana Linn*)	Maliputo (*Caranx ignobilis*)
Water hyacinth (*Eichhornia crassipes*)	Tawilis (*Sardinella tawilis*)
Caballero (*Caesalpinia pulcherrima*)	Bia (*Glossogobius giuris*)
Hauili (*Ficus septica*)	Dalag (*Channa striata*)
Banana (*Musa sapientum*)	Martiniko (*Anabas testudineus*)
Rain tree (*Samanea saman*)	Tilapia (*Oreochromis niloticus*)
Kakawate (*Gliciridia sepium*)	Tilapiang arroyo (*Sarotherodon melanotheron*)
Narra (*Pterocarpus indicus*)	Dugong (*Parachromis managuensis*)
Balangot (*Typha capensis*)	Pangasius (*Pangasianodon hypophthalmus*)
As-is (*Ficus coronata*)	Muslo (*Caranx sexfasciatus*)
Kamatsile (*Pithecellobhium dulce*)	Bangus (*Chanos chanos*)
Bamboo (*Bambuseae*)	Igat (*Anguilla marmorata*)
Neem (*Azadirachta indica*)	Also (*Lutjanus argentimaculatus*)
Mahogany (*Swietenia macrophylla*)	Banak (*Mugil cephalus*)
Nipa/Sasa (*Nypha fruticans*)	Siliw (*Zenarchopterus buffonis*)
Pagatpat (*Sonneratia alba*)	Kitang (*Scatopagus argus*)
Saging-saging (*Aegicerus corniculatum*)	Hito (*Clarias batrachus*)
Holly-leaved acanthus (*Acanthus ilicifolius*)	Ayungin (*Leiopotherapon plumbeus*)
Lagolo (*Acrostichum aureum*)	Dangat (*Apogon thermalis*)
Bakawan babae (*Rhizophora mucronata*)	
Bakawan bato (*Rhizophora stylosa*)	
Bungalon (*Aviccenia marina*)	

7.2 Ecological Dimension 2: Resource Units (RU)

Resource units (RU) describe the natural resource units the RS generates [35]. Based on its current use, the river belongs to Class C [39] in the fresh surface water usage and classification of the DENR. Class C encompasses fishery waters used to propagate and grow fish and other aquatic resources [40]. According to Corpuz et al. [5], the estimated vegetation cover of the river ranged from 25–60%. Pansipit River is ultimately known for being the breeding ground for *maliputo* (Caranx ignobilis) and *tawilis* (Sardinella tawilis), along with different species of fish, which are either permanent inhabitants of the freshwater or use it as a migratory channel [29]. Tawilis, endemic to Taal Lake and its rivers, holds economic and cultural importance as a traditional food in the province. However, in 2019, it was listed by the International Union for Conservation of Nature (IUCN) as critically endangered due to habitat loss, overfishing, and environmental degradation [31]. Table 2 shows an extensive list of plant and animal species historically found in the Pansipit River.

Table 3. Latest population census data on the local government units (LGUs) around the Pansipit River [41]

Municipality	Classification	Riverside Barangay	Population (2020)
Agoncillo	Fourth-class	Bangin	2,506
		Pansipit	1,789
		Pook	2,798
		Santa Cruz	1,130
	Total Municipal Population		**39,101**
Lemery	First-class	Ayao-iyao	3,182
		Bagong Sikat	1,315
		Dayapan	2,831
		District I	1,325
		District II	606
		District IV	1,789
		Palanas	2,580
		Wawa Ibaba	2,692
		Wawa Ilaya	1,456
	Total Municipal Population		**93,186**
San Nicolas	Fifth-class	Bangin	2,356
		Calangay	2,139
		Pansipit	443
		Poblacion	3,178
	Total Municipal Population		**23,908**
Taal	First-class	Apacay	2,300
		Butong	5,335
		Cawit	2,489
		Laguile	3,224
		Poblacion 4	301
		Poblacion 5	2,038
		Seiran	3,015
		Tatlong Maria	1,217
	Total Municipal Population		**61,640**
Total Provincial Population			**2,908,494**

7.3 Social Dimension 1: Actors (A)

Actors (A) describe the actors affecting or affected by the RS [35]. Batangas Province is a first-class province located in the Southern Tagalog (southwestern Luzon) region of the Philippines and is the country's second-richest and eighth-most populous province. Pansipit River, along with Calumpang River (16 km) and Lobo River (26 km), is among the significant rivers in the province. It passes through 25 barangays across four municipalities, home to around 200,000 people (see Table 3).

According to the Pansipit River Management Plan (2016-2021) [29], local communities in these municipalities have agricultural-based economies with varying involvement in fisheries, local commerce, and crafts. Agriculture is the dominant activity in Agoncillo and San Nicolas, with much of the land used for farming. They also engage in fish culture, given their access to the Taal Lake. Similarly, Lemery's residents also focus on growing rice, corn, and vegetables, though the municipality also promotes local tourism and industry. Taal, known for its historical agricultural and commercial activities, produces crops like cotton, cacao, and sugar and is famous for its local embroidery industry, particularly piña cloth products.

For Catholics, the Pansipit River is a profoundly significant religious landmark, where the small wooden image of the Virgin Mary, known as Our Lady of Caysasay, was miraculously caught by a fisherfolk in 1603. This event is highly revered, as it preceded Marian apparitions and numerous miraculous cures, leading to the widespread veneration of Our Lady of Caysasay in the region [33, 34]. Beyond its cultural importance, the river also boasts historical significance. Archaeological excavations near the river, dating back to the Paleolithic period, suggest that the area may have been one of the earliest Filipino settlements, potentially the origin of the Tagalog people [22, 32].

7.4 Social Dimension 2: Governance Systems (GS)

Finally, the governance system (GS) looks into the processes through which decisions on SES management are made, implemented, reformed, and reinforced [35]. The aforementioned LGUs encompassing the Pansipit River serve as the primary entities responsible for areas of the river within their territorial limits. Still, they also work hand in hand with various national government agencies (NGAs) to ensure effective management in addressing specific concerns beyond local capabilities. In view of the Pansipit River as an SES, two NGAs are most relevant: the Department of Environment and Natural Resources (DENR) and the Department of Human Settlements and Urban Development (DHSUD).

Section 16, Article II of the 1987 Philippine Constitution states that the State is committed to protecting and advancing people's right to a balanced and healthful ecology [42]. DENR is the primary NGA responsible for upholding this constitutional mandate. It leads efforts to mobilize the citizenry in protecting, conserving, and managing the country's environment and natural resources for current and future generations [43]. On the other hand, DHSUD is the sole and main planning and policy-making, regulatory, program coordination, and performance monitoring entity for all housing, human settlement, and urban development concerns. This mandate is particularly relevant in the context of broader land and water use policy concerning social dimensions, given that riverside settlements play a crucial role in the overall health of the river. Both agencies engage with LGUs in their respective domains – DENR through Provincial Government/Municipal Environment and Natural Resources Offices (PG/MENROs) and DHSUD through Provincial/Municipal Planning and Development Offices (P/MPDOs).

The Community Environment and Natural Resources Office (CENRO) in Calaca City is particularly significant as one of DENR's sub-provincial offices, covering 13 municipalities in Batangas. Since the river harbors four different municipalities, CENRO-Calaca is primarily responsible for managing the entire Pansipit River. This includes the crucial task of formulating the Pansipit River Management Plan, which requires close coordination with the respective MENROs of the involved LGUs.

Interviews revealed that the management of the river is further complicated by the fact that the upstream portion of the Pansipit River also falls within the jurisdiction of the Taal Volcano Protected Landscape - Protected Area Management Office (TVPL-PAMO), which is also under the purview of DENR. Therefore, before making any proposed plans for the improvement of the Pansipit River and its tributary, the Palanas River, it must be ensured that any plans would not create major conflict with the management plans of TVPL.

Based on the TVPL Management Plan 2021-2030, the Pansipit River is zoned as a Restoration

under the Multiple Use Zone to ensure that it continues to support migration and serve its proper function in the Taal Lake ecosystem [44]. Priority activities include comprehensive water quality monitoring across the various lake and river tributary stations across the TVPL to ensure the water quality and health of the freshwater resources. The implementation of such initiatives of CENRO Calaca and TVPL-PAMO for river management is supported by the four municipal LGUs, as well as the 25 barangays that are directly adjacent to the river.

In 2013, Agoncillo and San Nicolas initiated activities on ecotourism and conservation of the Pansipit River, along with the development of the Pansipit River and Volcano Island Bird Sanctuary as an ecotourism site. They also continued rehabilitation efforts on the riverbanks of Pansipit. Meanwhile, Lemery and Taal have concentrated on conducting information, education, and communication (IEC) campaigns focused on proper waste disposal at the barangay level to address the pollution from the residential areas [29]. They also collaborated with the Department of Public Works and Highways (DPWH) - Batangas 1st District Engineering Office (DEO) to undertake dredging activities, as they are situated in the lower reaches of the river where heavy siltation occurs, especially during the rainy season.

In one of the interviews, the MENRO of Taal shared the vision of their local government for the Pansipit River: "Right now, we're constructing a multi-purpose building and a covered court near the river. We hope this will encourage the start of economic activities in the area, helping improve the local community. The idea is to use the river positively to contribute to the community's economic development and help them become more resilient. Maintaining cleanliness and having LGU support for infrastructure development are key to this. With discipline in keeping the river clean and making use of the river in a good way, the community can be more resilient. They can benefit economically and improve their overall situation, turning the river into a resource that supports their resilience."

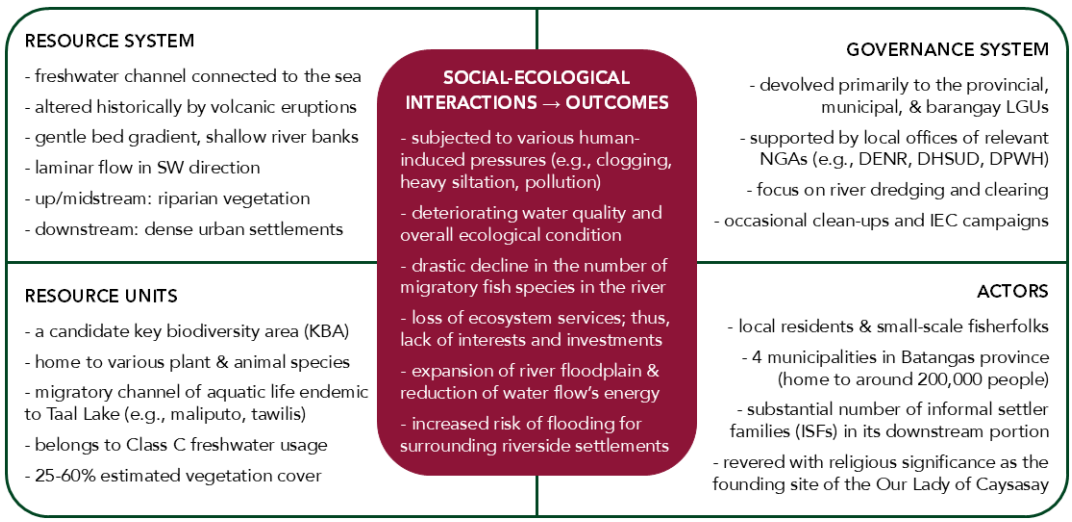

Figure 5.
Analysis of the SES components, their interactions, and resulting outcomes

7.5 Social-Ecological Interactions (I) and Outcomes (O)

Interactions are the dynamic relationships between the sub-systems above, while the outcomes describe the results of these interaction processes and how they influence the SES [35]. Figure 5 summarizes these interactions showing the dynamic relationships between the resource system, resource units, governance system, actors, and the social-ecological interactions and outcomes. As the lone conduit for water and migratory fish species to flow and swim from Taal Lake to Balayan

Bay and back, the Pansipit River is crucial in maintaining the ecosystem balance of Taal Lake [34]. However, the river has been subjected to different anthropogenic pressures, such as siltation, unregulated installation of fish pens/corrals, illegal construction of structures, and uncontrolled settlements along its riverbanks [5, 27]. To date, the river remains heavily silted as an aftermath of the 2020 eruption of Taal Volcano and because water from Taal Lake had either receded, dried out or raised to the adjacent land/road [44].

With the clogging and narrowing of the river, the natural exchange of fresh water from the lake and saltwater from the bay, as well as the movement of migratory fish species, is critically affected [28]. There has been a drastic decline in the number of migratory fish species in the Lake Taal – Pansipit River system, with a drop of 84% from 31 in 1927 to only 5 in 1996, due to overfishing and the obstruction posed by fishing and fisheries structures (i.e., corrals, cages, and pens) that impede the migration of diadromous fish [25].

Figure 6.
Pansipit Bridge connecting the Poblacion areas of Lemery and Taal, Batangas (April 2024)

Despite its historical, ecological, cultural, and religious significance, the Pansipit River remains underprioritized. Records of siltation brought by gravel diggings, land excavations, livestock, and domestic run-offs have been pointed out as the main contributors to the river's pollution [5]. The total coliform count in the Pansipit Bridge area (Figure 6), which ranges from 17,000 to 22,000 MPN/100mL, far exceeds the acceptable level of less than 400 MPN/100mL [27]. Improper waste disposal, especially from the dense settlements downstream of the Pansipit River, contributes to the expansion of the floodplain, which reduces the water flow's energy over time and leads to substantial deposition of sediments in the river [27]. This starkly contrasts with the community's professed reverence for the Virgen de Caysasay [34], highlighting a disconnect between the river's symbolic value and the lack of streamlined efforts to protect and conserve the freshwater resource.

This disconnect is further compounded by fragmented and reactive governance efforts, which hinder the river's effective management and long-term sustainability. While various stakeholders have undertaken clean-up drives and waste management programs, these efforts often lack continuity and targeted focus. Dependence on higher-level funding and decision-making also creates a misalignment between local needs and broader governmental agendas. Reliance on short-term solutions underscores the need for integrated, proactive governance to bridge the gap between the river's cultural importance and ecological degradation.

This gap in governance and management highlights the broader challenges faced in the Philippines, where geographic disparities and increasing resource demands further complicate effective water management. To address these challenges, there is a critical need to integrate science, technology, and innovation (STIs) into water management, particularly in such cases of mismanaged river landscapes. However, challenges such as lack of education for decision-makers, insufficient incentives, and limited adoption of adaptive management frameworks hinder the effective incorporation of these advances into water policy [45]. Bridging these gaps will ultimately require a concerted effort to align local needs with science-driven policies that empower communities toward resilience and sustainability.

8 Conclusion and Recommendations

Overall, this study revealed that the Pansipit River is a critical ecological resource and a focal point for economic, cultural, and religious activities. Its role in supporting biodiversity and providing essential services to surrounding communities and ecosystems underscores the need to integrate social-ecological dynamics as a basis for decision-making. Conducting a landscape analysis based on the elements of SESs offers a holistic approach to understanding the complex interactions between the ecological and social components within a given environment, which can be particularly valuable for planning and management. Analyzing landscapes through this method reduces the complexity of SESs. It can potentially enhance the local understanding and management capabilities of local government and communities by leveraging diverse data sources. It is also aimed at producing practical and context-specific management strategies, thereby aligning with the needs and capacities of local actors.

The analysis highlighted key aspects of Pansipit River's current ecological condition and its challenges. The river links Taal Lake and Balayan Bay, facilitating freshwater exchange and fish migration. However, the river landscape has undergone significant changes, including siltation due to human activities such as gravel extraction, land excavation, and unregulated waste disposal. These pressures, combined with the impact of the 2020 Taal Volcano Eruption, have exacerbated the river's sedimentation, affecting its water quality and ecological health. The riverbed's shallowing and clogging disrupts the natural water flow and hinders fish migration, which is critical for maintaining biodiversity in both Taal Lake and the river itself. These findings suggest that while valuable, existing planning and management efforts require better coordination and a more unified strategy.

Despite recognizing the need for an integrated approach, current management practices remain fragmentary and often rely on piecemeal approaches regarding the programs, projects, and activities (PPAs) being implemented by the different stakeholders. Given its role within the broader Taal Lake - Pansipit River basin, the river landscape would greatly benefit from an integrated watershed management approach. This approach would help address pollution control, habitat conservation, and sustainable land use while promoting socio-economic development. Such an ambitious undertaking, however, also demands strong political commitment and financial support. Therefore, establishing a dedicated task force composed of representatives from DENR, CENRO, TVPL-PAMO, and provincial, municipal, and barangay LGUs is essential to streamline decision-making and enhance inter-agency collaboration.

Results of this study provide crucial baseline information that can inform future research on the Pansipit River and its surrounding communities and serve as the foundation for developing and prioritizing necessary PPAs. It also offers a promising opportunity to advance STIs for future river landscape planning and management efforts, such as (1) the use of remote sensing and Geographic Information Systems (GIS) to monitor land use changes and water quality, (2) investing in wastewater treatment facilities or bioremediation techniques to clean up pollutants of the river, (3) construction of robust flood-control infrastructure to mitigate the impacts of siltation and

flooding, as well as (4) implementing citizen science programs or initiatives to raise awareness and foster environmental stewardship among the local community. Additionally, there is critical to prioritize ecological research initiatives to gather sufficient data and meet the criteria necessary for recognizing the Pansipit River as a Key Biodiversity Area (KBA). Achieving KBA status would be a significant step towards securing full protection for the river to ensure its ecological integrity and sustain its vital role in supporting local biodiversity and community well-being.

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Conflicts of Interest

The authors declare no competing interests.

Ethical Considerations

The study was conducted following the Declaration of Helsinki. Free, prior, and informed consent (FPIC) was sought from the participants, which included explaining to them the purpose of the study, their voluntary participation in the study, and how the collected data would be used.

Data Availability

The data of this study is available upon request from the author.

Author Contributions

F.G.I.: conceptualization, data collection, formal analysis, writing – original draft preparation, writing – review and editing, visualization. **J.P.P.T.**: conceptualization, supervision, writing – original draft preparation, writing – review and editing. **A.G.L.D.**: conceptualization, writing – original draft preparation, writing – review and editing. **J.C.L.E.**: conceptualization, writing – original draft preparation, writing – review and editing.

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