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Addressing ecosystem, sedimentation and collaborative approaches challenges in Jatibarang reservoir: A path towards sustainable water management

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Abstract: The 2024 World Water Forum in Bali highlighted urgent challenges in water resource management, particularly for developing countries grappling with climate change, urbanization, and rising demands for clean water. The Forum emphasized the need for integrated and sustainable management approaches to secure long-term water availability while protecting ecosystems. In this context, our study focuses on Jatibarang Reservoir in Semarang, a vital infrastructure for flood control and raw water supply, which is now threatened by severe sedimentation. Current data indicate that the reservoir's operational lifespan has diminished to 21.1 years, well below the projected 50 years, due to an annual sediment load of 653,977.32 tons. Exacerbating the issue is a top-down management approach that limits community engagement and prioritizes flood control over comprehensive, sustainable practices. Through a qualitative case study, we explore ecological impacts, technical catchment characteristics, and institutional collaboration among key stakeholders. Our findings reveal inadequate sediment management and poor stakeholder cooperation, underscoring the need for a shift to collaborative governance. We recommend legal frameworks for community-based management, green technologies for sediment control, and stronger partnerships. These strategies aim to extend the reservoir's lifespan and ensure sustainable water resource management, aligning with the Forum's global call for action.

Keywords: *Collaborative governance, Community-based management, Flood management, Reservoir sedimentation, Water resource management.*

1. Introduction

Water resource management remains a critical challenge for developing countries, especially in the face of climate change and increasing demand for clean water and irrigation [1]. Previous researchers have highlighted the urgency for an urgent decision making in managing the country's water resources management (Hamidi, 2020; He et al., 2020; Hinegk et al., 2022; Roncoli et al., 2009; Soekarno et al., 2024).Therefore, the World Water Forum in Bali underscored the necessity of sustainable and comprehensive water management practices, emphasizing cross-sector collaboration [7]. This paper aligns with the Forum's recommendations, focusing on case studies like the Jatibarang Reservoir to illustrate the environmental, economic, and social aspects of sustainable reservoir management.

Jatibarang Reservoir, located in Semarang, serves a dual purpose: flood control and raw water supply. However, it faces significant challenges such as rapid sedimentation and pollution, which threaten its operational lifespan and water quality. Addressing these issues requires a holistic approach involving technological interventions, effective governance, and adaptive management strategies. The sedimentation problem is particularly acute, reducing water storage capacity and impacting ecosystem balance, which calls for strategic, long-term solutions.

The study also highlights the importance of institutional collaboration among government bodies, private sectors, and local communities. Successful water management programs often depend on robust institutional frameworks that promote cooperation across various administrative levels. For Jatibarang

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Reservoir, this means fostering coordination between central, provincial, and municipal stakeholders to develop integrated and sustainable management practices. Such collaborations are essential for addressing sedimentation issues and ensuring the reservoir continues to serve its intended purposes efficiently.

Previous research has shown that sustainable reservoir management must consider environmental sustainability, economic viability, and social well-being [8], [9], [10]. The Jatibarang case study illustrates how sedimentation and pollution can be mitigated through green technology, comprehensive planning, and stakeholder partnerships. By incorporating these elements, the reservoir can remain a reliable water source while minimizing negative ecological impacts. The research presented here aims to develop a collaborative model that ensures the reservoir's benefits are long-lasting and equitable.

The objective of this research is to conduct a comprehensive analysis of various aspects that contribute to the balance and carrying capacity of the Jatibarang Reservoir ecosystem. This includes evaluating the reservoir's lifespan, technical parameters of the catchment area, and monitoring water levels to understand fluctuations. The study will also assess storage capacities, water control functions for flood prevention and supply, and hydrological conditions such as baseflow, discharge rates, and annual inflow. Additionally, it will investigate erosion and sedimentation, assess the safety and capacity of spillway structures, and review the zoning of green belt areas, including arboretum and ecotourism components. Furthermore, the research will explore institutional cooperation among stakeholders, examining integrated flood management models and coordination practices among government entities at various levels. It will highlight the roles of key agencies, evaluate collaboration mechanisms for resource management, and assess community participation in managing the reservoir. By analyzing factors such as policy frameworks, authority distribution, funding mechanisms, and operational coordination, the research aims to identify institutional strengths and challenges and provide recommendations for improving the reservoir's management and sustainability.

Furthermore, this research explores analyzing institutional cooperation among stakeholders involved in the management of the Jatibarang Reservoir. This includes examining the integrated flood management model in Semarang City and evaluating coordination and communication practices among government entities, such as the Central Government, Provincial Government of Central Java, and the Semarang City Government. The study will highlight the strategic roles of key agencies, including the Ministry of Public Works, the Directorate General of Water Resources, the Pemali-Juana River Basin Office, and the Jatibarang Reservoir Development Team. Additionally, the method will investigate the coordination mechanisms among stakeholders responsible for flood control, water supply for irrigation and drinking purposes, hydropower generation, and the development of nature tourism destinations. Community participation, particularly from local leaders and impacted regional stakeholders (villages and subdistricts), in institutional cooperation efforts will also be assessed.

2. Methodology

2.1. Object of This Study

The research object shown in the map is the Jatibarang Reservoir, located in Semarang City, Central Java, Indonesia, with a catchment area of 54 km², a flooded area of 189 hectares, a maximum water level of +155.30 meters, a minimum water level of +148.90 meters, and a total storage capacity of 20.4 million cubic meters.

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Figure 1.
Geographic overview of jatibarang reservoir, Semarang, Central Java, Indonesia.

The research method involves a comprehensive analysis of various aspects that support the balance and carrying capacity of the Jatibarang Reservoir ecosystem. This includes evaluating the reservoir's planned lifespan, technical data on the catchment area and water surface extent, and monitoring water levels, from maximum to low, to understand fluctuations. The study will measure gross, effective, and dead storage capacities, assess water control functions for flood prevention and drinking water supply, and analyze hydrological conditions, such as baseflow, average discharge, annual inflow, and filling duration. Furthermore, the method will investigate erosion and sedimentation patterns in the upstream and reservoir base, inspect the capacity and safety of the spillway structure, and review the spatial zoning of the reservoir's green belt area, focusing on its components like arboretum, agroforest, ecotourism, and buffer zones.

2.2. Data Collection and Interviews

The data collection and interviews are focused on examining the existence and condition of Green Belt Vegetation, the level of community involvement, and the effectiveness of institutional communication and coordination. Additionally, the interviews address organizational issues related to the current management approach, the implementation of community-based policies and regulations, institutional strategies for collaborative management, and the establishment of a legal framework that empowers community participation.

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2.3. Calculation

Followings are the formulas to determine the parameters related to total material load, reservoir storage capacity, and the remaining lifespan of the reservoir.

a. Total Material Load (ton/year) = ∑ (Qsuspended Load + Qbed Load)

where:

- Qsuspended Load = suspended sediment load per year (ton/year)
- Qbed Load = bed sediment load per year (ton/year).

b. Specific Gravity/Density of Sediment = Weight of Sediment / Volume of Sediment

c. Total Material Load (m^3/year) = Total Material Load (ton/year) / Specific Gravity (ton/m^3)

where: Specific Gravity is 2.44 ton/m^3.

Dead Storage Capacity of Jatibarang Reservoir (m^3) is given to 5,632,545.6879 m^3

d. Remaining Lifespan of Jatibarang Reservoir (Years) = Dead Storage Capacity of Jatibarang Reservoir (m^3) / Total Material Load (m^3/year)

where Total Material Load (m^3/year) is obtained from the previous formula.

3. Results

3.1. Land surrounding the Jatibarang Reservoir

Table 1 reflects the various segments and types of ecosystems designed to promote conservation and sustainability around Waduk Jatibarang. The table presents six distinct segments of land surrounding the Jatibarang Reservoir, detailing their locations, ecosystem types, and primary functions. These segments demonstrate a diverse approach to ecosystem management, balancing conservation, agriculture, tourism, and environmental protection.

Segment 1 is located in Kelurahan Jatirejo and spans 24.59 hectares, functioning as an Arboretum. It supports education and research by housing various plant collections, particularly medicinal plants. Segment 6, located in Kelurahan Jatibarang and Kedungpane, also serves as an Arboretum, with a focus on preserving tree species, including fruit and timber plants. Segment 2, situated in Kelurahan Kandri over 13.84 hectares, is classified as an Agro-Forestry area. It combines agriculture and forestry by supporting fruit plantations and eco-tourism activities. Segment 3, covering 30.27 hectares in Kelurahan Kandri, integrates Agro-Forestry and Ecotourism. This area features wildlife tourism, including long-tailed monkeys, and offers an open stage for public tourism. Segment 4, located in Kelurahan Kedungpane, also combines Agro-Forestry and Ecotourism, with buffer zones and sites for fruit and flower tourism. It includes a management office. Finally, Segment 5, located in Kelurahan Kedungpane, functions as both an Arboretum and Buffer Zone. It focuses on pollution management and maintaining water quality by planting timber and fruit trees.

Table 1.
The existing ecosystems around Waduk Jatibarang, divided into segments and types of areas.

No	Segment	Location	Ecosystem type	Description
1	Segment 1	Kelurahan Jatirejo, 24.59 ha	Arboretum	Functions as an arboretum with various plant collections, especially medicinal plants, supporting education and research.
2	Segment 6	Kelurahan Jatibarang & Kedungpane	Arboretum	Focuses on preserving various tree species, including fruit and timber plants.
3	Segment 2	Kelurahan Kandri, 13.84 ha	Agro-Forestry	Combines agriculture and forestry, with fruit plantations and eco-tourism activities.
4	Segment 3	Kelurahan Kandri, 30.27 ha	Agro-Forestry & Ecotourism	Incorporates agro-forestry, wildlife tourism (e.g., long-tailed monkeys), and an open

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				stage for public tourism.
5	Segment 4	Kelurahan Kedungpane	Agro-Forestry & Ecotourism	Serves as agro-forestry, buffer zone, fruit and flower tourism site, and includes a management office.
6	Segment 5	Kelurahan Kedungpane	Arboretum & Buffer Zone	Acts as an arboretum with various timber and fruit trees and a critical area for managing pollution to maintain water quality.

3.2. Description of Terrestrial Situations

Table 2 presents several critical issues related to the management and environmental conservation of the green belt surrounding the Jatibarang Reservoir. The first issue is the suboptimal growth of green belt vegetation from 2015 to 2020, which resulted in ineffective erosion control and increased sedimentation. The lack of a clear institutional mechanism for managing and harvesting fruit from the trees planted in the green belt has limited the economic benefits to local communities. Furthermore, the decision to plant sengon trees, a production crop, contradicts the conservation goals of the green belt, as it poses challenges related to harvesting and potential deforestation.

The second issue highlights the lack of community involvement and weak institutional communication and coordination. There is no formal cooperation between BBWS Pemali-Juana and local tourism groups, leading to unauthorized construction of semi-permanent structures within the green belt. The absence of proper communication channels between BBWS Pemali-Juana and local stakeholders has resulted in unresolved issues and ineffective environmental management.

Table 2.
The key problems related to the terrestrial ecosystem of Waduk Jatibarang:

No	Key issue	Description
1	Suboptimal Growth of Green Belt Vegetation, Unclear Institutional Mechanism for Fruit Trees. Contradictory Decision to Plant Sengon Trees	During the initial five years (2015–2020), the planted vegetation was still developing, which resulted in ineffective erosion control and increased sedimentation. No clear framework has been established by BBWS Pemali-Juana regarding who can access and harvest fruit from trees planted in the green belt, limiting economic benefits.. The planting of sengon trees, a production crop, contradicts the conservation goals of the green belt, leading to issues of harvesting and the potential for deforestation.
2	Lack of Community Involvement. Weak Institutional Communication and Coordination	There is no formal cooperation between BBWS Pemali-Juana and local tourism groups, leading to the unauthorized construction of semi-permanent structures in the green belt. The lack of proper communication and coordination between BBWS Pemali-Juana and local stakeholders has resulted in unresolved issues and poor environmental management.
3	Illegal Logging of Sengon Trees	In 2022, illegal logging occurred, causing infrastructure damage and raising concerns about landslides and sedimentation in the reservoir.

The final issue addresses the illegal logging of sengon trees, which occurred in 2022. This logging activity caused significant infrastructure damage and raised concerns about landslides and further sedimentation in the reservoir. These findings underscore the need for stronger collaboration, clearer management policies, and stricter enforcement to protect the reservoir's ecosystem and surrounding green belt.

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3.3. The Problems of Water Ecosystem

Table 3 presents various water quality parameters measured in different studies conducted on Jatibarang Reservoir. These parameters are essential to assess the level of water pollution and overall ecosystem health. The 2015 study focuses on pollutants such as Nitrogen Total (2.27 kg/day), Nitrate (0.69 kg/day), and Nitrite (0.3 kg/day). The Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are measured at 30.78 kg/day and 43.72 kg/day, respectively, indicating organic matter levels in the water. Total Dissolved Solids (TDS) are shown to exceed capacity at -168.65 kg/day, reflecting water quality concerns, while Total Suspended Solids (TSS) and Ammonia levels are relatively low, at 0.52 kg/day and -0.42 kg/day.

A 2017 study on phytoplankton abundance (236–865 ind/l) includes diversity, evenness, and dominance indices, with values ranging between 1.02–1.77 for diversity, 0.58–0.85 for evenness, and 0.14–0.96 for dominance. The Water Quality Index (IKA) suggests moderate pollution, while the Saprobiotic Index and Trophic Saprobiotic Index indicate mesotrophic to oligosaprobic conditions, which are characteristic of moderately polluted water.

The 2019 study shows water temperature around 30–31°C, with Total Suspended Solids (TSS) between 20–80 mg/l and Dissolved Oxygen (DO) at 6.8–8.6 mg/l. BOD and COD levels range from 1.46–3.95 mg/l and 9.7–15.69 mg/l, respectively, indicating the presence of organic waste. Ammonia and Total Coliform are also measured, with Total Coliform reaching up to 4,600 cells/100 ml, suggesting microbial contamination.

Lastly, the pollution levels in different zones of the reservoir show that the Dock Area and Inlet experience moderate pollution, while the Outlet shows light pollution, according to the Pollution Index (IP) values. This comprehensive water quality analysis is crucial for understanding the environmental health and the effectiveness of pollution control measures in Jatibarang Reservoir.

Table 3.
The quantitative findings related to the water ecosystem problems.

Relevant problems	Parameter	Measurement/Value
Water pollution levels (2015 study):	Nitrogen Total	2.27 kg/day
	Nitrate	0.69 kg/day
	Nitrite	0.03 kg/day
	Biochemical oxygen demand (BOD)	30.78 kg/day
	Chemical oxygen demand (COD)	43.72 kg/day
	Total dissolved solids (TDS)	-168.65 kg/day (Exceeded capacity)
	Total suspended solids (TSS)	0.52 kg/day
	Ammonia	-0.42 kg/day
Phytoplankton abundance and water quality (2017 study)	Phytoplankton abundance	236–865 ind/l
	Diversity index	1.02–1.77
	Evenness index	0.58–0.85
	Dominance index	0.14–0.96
	Water quality index (IKA)	51.74–55.06 (Moderate pollution)
	Saprobitic index	0.60–2.75 (β-mesosaprobic/oligosaprobic)
	Trophic saprobitic Index	2.02–4.06 (moderate pollution)
Water quality parameters (2019 study):	Temperature	30–31°C
	Total suspended solids (TSS)	20–80 mg/l
	pH	Neutral
	Dissolved oxygen (DO)	6.8–8.6 mg/l
	Biochemical oxygen demand (BOD)	1.46–3.95 mg/l

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	Chemical oxygen demand (COD)	9.7–15.69 mg/l
	Ammonia	0.110–0.566 mg/l
	Total coliform	15–4,600 cells/100 ml
Pollution levels at different reservoir Zones (2019 study):	Dock area pollution index (IP)	3.62–5.49 (light to moderate pollution)
	Inlet pollution index (IP)	2.88–5.93 (light to moderate pollution)
	Outlet pollution index (IP)	1.43–1.84 (light pollution)

3.4. Sedimentation Trends

Based on the table, the following parameters can be calculated:

- Total Material Load (tons/year): 653,977.32 tons/year
- Specific Gravity/Density of Sediment (tons/m^3): 2.44 tons/m^3
- Total Material Load (m^3/year): 268,006.63 m^3/year
- Dead Storage Capacity of Jatibarang Reservoir (m^3): 5,632,545.6879 m^3
- Remaining Lifespan of Jatibarang Reservoir's Storage (Years): 21.1 years

Thus, based on the sediment load calculation (268,006.63 m^3/year) and the reservoir's dead storage capacity (5,632,545.69 m^3), it can be predicted that the remaining lifespan of Jatibarang Reservoir's storage is 21.1 years out of the originally expected 50 years.

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Tabel 4.
Sediment load and sedimentation parameters for jatibarang reservoir.

No	Lebar (m)	H (m)	Qw (m3/dt)	Qsuspended Load (ton/tahun)	Qbed Load (ton/tahun)	Qs+Qb (ton/tahun)
1.00	2.79	0.01	0.01	3,024.77	566.79	3,591.56
2.00	2.79	0.02	0.02	5,780.92	412.58	6,193.50
3.00	2.79	0.03	0.04	8,157.13	540.22	8,697.35
4.00	2.79	0.04	0.07	10,301.37	516.55	10,817.92
5.00	2.79	0.05	0.10	12,282.46	513.18	12,795.64
6.00	2.79	0.06	0.13	14,139.92	521.61	14,655.97
7.00	2.79	0.07	0.18	15,897.97	521.64	16,419.48
8.00	2.79	0.08	0.23	17,584.84	528.22	18,052.84
9.00	2.79	0.09	0.27	19,182.80	535.58	19,596.38
10.00	2.79	0.10	0.32	22,228.03	543.29	21,001.27
11.00	2.79	0.11	0.37	22,834.70	551.17	22,277.19
12.00	2.79	0.12	0.43	23,678.63	559.12	23,459.67
13.00	2.79	0.13	0.49	24,508.88	567.09	24,552.10
14.00	2.79	0.14	0.55	25,460.35	575.04	25,565.73
15.00	2.79	0.15	0.62	26,481.04	582.93	26,481.04
16.00	2.79	0.16	0.69	27,303.57	590.75	27,303.57
17.00	2.79	0.17	0.76	28,061.49	598.49	28,061.49
18.00	2.79	0.18	0.83	28,741.71	606.15	28,741.71
19.00	2.79	0.19	0.91	29,351.23	613.71	29,351.23
20.00	2.79	0.20	0.98	31,842.96	598.45	32,444.64
21.00	2.79	0.21	1.05	33,266.69	606.15	33,432.90
22.00	2.79	0.22	1.13	34,072.29	613.71	34,369.43
23.00	2.79	0.23	1.21	35,045.83	621.18	35,260.56
24.00	2.79	0.24	1.29	36,181.42	628.53	36,113.07
25.00	2.79	0.25	1.36	37,407.29	621.18	40,999.94

Source: Jatibarang Reservoir Final Report (2020)(Proyek Kerjasama Pemerintah dan Badan Usaha (KPBU), 2020)

3.5. Organisation Issues

Table 5 summarizes the key issues identified in the management of Waduk Jatibarang. The table outlines key issues in the management of Jatibarang Reservoir, which has been managed by Balai Besar Wilayah Sungai Pemali-Juana (BBWS/ Pemali-Juana River Basin Authority) using a top-down approach. This approach involves minimal participation from local communities and stakeholders. Policies and regulations were designed without considering local needs, making it difficult for these communities to gain any legal authority or influence in the management processes. Furthermore, there is little collaboration between BBWS Pemali-Jua, local governments, and community stakeholders, effectively excluding the local populace from decision-making.

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Table 5.
The key findings from the research on the management of Waduk Jatibarang.

No	Key issue	Description
1	Top-down management approach	Waduk Jatibarang was managed by BBWS Pemali-Juana using a top-down approach, with little involvement from local communities and stakeholders.
2	Lack of community-based Policy and regulation	Policies and regulations were designed without considering the needs of local communities, making it difficult for them to gain legal authority to participate.
3	Institutional weakness in collaborative management	There was minimal collaboration between BBWS Pemali-Juana, local governments, and stakeholders, excluding local communities from decision-making processes.
4	Failure to establish community-based legal framework	Initiatives like the Forum Komunitas Peduli Waduk (FKPW) were not supported, leaving local communities without a legal framework for involvement in management.
5	Limited authority of local governments	The Central Java Provincial Government and the City of Semarang had limited authority, with BBWS Pemali-Juana holding exclusive control over flood control.
6	Community exclusion from water management and tourism development	Local groups like Pokdarwis and farmers' groups were excluded from participating in water management and tourism development around the reservoir.
7	Excessive focus on flood control	BBWS Pemali-Juana focused primarily on flood control, neglecting other important functions such as water resource management and tourism development.

One of the major challenges is the failure to establish a community-based legal framework. Initiatives like the Forum Komunitas Peduli Waduk (FKPW) were not supported adequately, leaving local communities without a legal avenue for involvement in reservoir management. Additionally, the Central Java Provincial Government and the City of Semarang hold limited authority in water management and flood control, which is largely monopolized by BBWS Pemali-Juana.

Moreover, community groups such as Kelompok Sadar Wisarta (Pokdarwis/ Tourism Awareness Group) and farmers' associations were excluded from water management discussions and tourism development projects around the reservoir, despite these being crucial areas for local benefit. Lastly, BBWS Pemali-Juana has placed excessive focus on flood control, often neglecting other vital functions such as water resource management and the development of tourism, which are essential for the broader sustainability of the region.

This top-down management approach has led to limited engagement with local stakeholders, preventing a more collaborative and sustainable method of managing the Jatibarang Reservoir.

4. Discussions

4.1. Overview

The findings on Waduk Jatibarang reflect global trends in flood control, water resource management, environmental and social impacts, and economic contributions. These themes are common across dam projects worldwide, underscoring the multi-functional role of dams in infrastructure systems.

Flood control is a crucial function of Waduk Jatibarang, protecting Semarang from heavy rainfall, similar to other dams globally. Dams in densely populated areas are essential for mitigating natural disasters, with flood control being a primary purpose both locally and internationally.

Waduk Jatibarang significantly contributes to local water supply during dry seasons, aligning with global trends where dams are central to water management. Studies in China and the USA emphasize the need for integrated management to ensure long-term water availability, balancing environmental and developmental needs [2].

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Environmental and social changes, such as habitat loss and increased sedimentation, are common consequences of dam construction, as seen in Waduk Jatibarang. Globally, dam projects often lead to environmental degradation and displacement of local communities, reflecting similar patterns in regions like the Middle East and Asia [4], [9]. Waduk Jatibarang also contributes to the local economy through hydropower, tourism, and water supply, similar to global dam projects that provide energy and economic benefits. In China and the USA, dams are viewed as critical infrastructure for economic development, supporting reliable water resources and energy production.

In terms of flood control, Waduk Jatibarang's construction aligns with global findings that large dams protect downstream areas but can cause long-term environmental changes. Similarly, agro-pastoral dams in Benin are noted for flood control but lead to conflicts over water use. Managing sedimentation and water quality at Waduk Jatibarang reflects broader challenges in sustainable water management globally, where multiple users and conflicting needs complicate resource management. Studies in Benin also highlight the difficulties in balancing water use across stakeholders [12], [13].

While dams like Waduk Jatibarang provide economic benefits, such as hydropower and water supply, they also face challenges in equity and sustainability, as seen in global comparisons. Conflicts and management issues often undermine the economic potential of dams in various regions [14], [15].

4.2. The Ecosystems Surrounding Waduk Jatibarang

Table 1 provides a comprehensive overview of ecosystem types and management strategies at Waduk Jatibarang, focusing on arboretum, agro-forestry, ecotourism, and buffer zones. This approach reflects efforts to manage biodiversity, agriculture, and tourism in an integrated manner, drawing insights from global practices. In arboretum management, segments such as 1 and 6 emphasize preserving medicinal and timber plants, aligning with international research that stresses biodiversity conservation. These arboreta serve as hubs for ecological preservation and scientific study, although ensuring community involvement through eco-friendly tourism remains a challenge [16].

Agro-forestry in Segments 2, 3, and 4 integrates agriculture with forest conservation, supporting environmental sustainability and local livelihoods. This system mirrors practices seen in Benin, where agro-forestry enhances soil conservation and biodiversity. However, integrating tourism into these systems poses risks of ecological degradation if not carefully managed [17].

Ecotourism in Segment 3, focusing on wildlife like long-tailed monkeys, aligns with global models promoting conservation alongside economic opportunities. Successful ecotourism, however, depends on managing human-wildlife interactions to prevent habitat disruption, a common challenge in similar projects worldwide [3].

The buffer zone in Segment 5, designed to manage pollution and preserve water quality, reflects international practices in sediment control and runoff prevention. Combining buffer zones with arboretum efforts supports both biodiversity and water management, though balancing conservation, community needs, and tourism remains a key challenge [18].

4.3. Problems of Terrestrial Ecosystems

The issues at Waduk Jatibarang regarding terrestrial ecosystem management, such as unclear institutional roles, lack of community involvement, and illegal logging, reflect global challenges in dam management. Addressing these requires inclusive governance, stronger community engagement, and improved institutional coordination, as emphasized in international studies [19]. One key issue is the suboptimal growth of green belt vegetation, particularly from 2015–2020, which led to ineffective erosion control and increased sedimentation. This mirrors global research where newly constructed dams often face difficulties with vegetation regrowth and soil stabilization, resulting in similar sedimentation problems that reduce reservoir capacity [20].

Unclear institutional mechanisms for managing fruit trees in the green belt further compound ecosystem management challenges. Without a clear framework, local communities are unable to benefit economically. This lack of clarity in governance is common in dam projects worldwide, where ineffective stakeholder inclusion limits resource management and social benefits [18].

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The lack of community involvement in tourism has led to unauthorized construction and poor management of tourism resources. This issue is seen globally, where insufficient local engagement in dam-related tourism often leads to unsustainable practices and missed economic opportunities. Stronger cooperation between local groups and authorities is needed for sustainable tourism development [21].

Lastly, the decision to plant sengon trees, a production crop, contradicts the conservation goals of the green belt and has led to issues like illegal logging. Similar conflicts between conservation and economic utility are observed globally, where monoculture plantations near reservoirs undermine ecological goals, leading to environmental degradation. Weak institutional coordination exacerbates these problems, resulting in greater environmental risks [22], [23], [24].

4.4. Water Ecosystems Problems

The table highlights water ecosystem problems at Waduk Jatibarang, including issues related to water pollution, phytoplankton abundance, and water quality. Elevated nutrient levels and suspended solids indicate moderate pollution, reflecting common water management challenges in dam reservoirs worldwide. The biochemical oxygen demand (BOD) and chemical oxygen demand (COD) values are notably high, indicating significant organic and chemical pollution, similar to findings in international dam studies. Excessive nutrient loads contribute to eutrophication, which degrades water quality.

High total dissolved solids (TDS) levels further indicate water quality degradation, consistent with findings from regions like the Mekong River Basin. Excessive TDS levels harm aquatic ecosystems and reduce the suitability of water for human consumption and agriculture [25], [26]. Phytoplankton abundance and the Water Quality Index (IKA) show moderate pollution in Waduk Jatibarang, largely due to nutrient loads. These findings are similar to global trends where increased nutrients lead to phytoplankton blooms that disrupt ecosystems, as documented in dam studies from China and the USA [2].

Localized pollution, particularly in high-use areas like docks and inlets, highlights the need for targeted management to prevent further water quality degradation. This pattern is commonly observed in reservoirs where human activities concentrate pollutants in specific zones [9]. Addressing these issues requires a comprehensive approach that includes reforestation, soil conservation, advanced water quality monitoring, sediment management, and stronger community engagement. Integrating these measures, as seen in successful dam projects globally, will help improve water management and ecosystem health at Waduk Jatibarang.

4.5. Sedimentation Trend

The table presents important data on the sediment loads and material flows in Waduk Jatibarang, particularly focusing on the suspended and bed loads of sediment. Based on this data, we observe the cumulative impact of sediment deposition in the reservoir, which totals to 653,977.32 tons per year. This figure is alarming as it suggests that sedimentation is a significant issue affecting the reservoir's storage capacity and its long-term sustainability. The total material load volume of 268,006.63 m^3 per year emphasizes the substantial amount of sediment that accumulates annually, reducing the effective storage capacity of the reservoir.

Comparing these findings with international research on sediment management in reservoirs, the challenges faced at Waduk Jatibarang are not unique. Globally, sedimentation has been a major issue for many reservoirs, as documented in various studies. For instance, research on dams in Southeast Asia, such as those in the Mekong Basin, shows similar patterns where high sediment loads drastically reduce the reservoir's lifespan by filling in the storage space with sediment rather than water. This leads to reduced water availability, especially during dry seasons when reservoirs play a crucial role in providing water for agriculture and domestic use [27], [28].

The specific gravity of the sediment, recorded as 2.44 ton/m^3, indicates that the material contributing to the sedimentation is quite dense, which would imply that it settles quickly and has the potential to block channels and reduce water flow efficiency. This matches findings in dam studies from China, where similar sedimentation patterns have been observed, leading to operational challenges in managing water flow and maintaining hydropower efficiency(Kumpulan paper 3). In many cases, such

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dense sediments exacerbate the need for dredging operations, which are both costly and disruptive to local ecosystems [29].

The dead storage capacity of Waduk Jatibarang is calculated to be 5,632,545.6879 m^3, which signifies the volume designated to accommodate sediment accumulation over time. However, given the annual material load and the rate of sedimentation, the remaining lifespan of the reservoir is estimated to be only 21.1 years. This lifespan is considerably short for a major reservoir, and it calls for immediate intervention to extend its functionality. Studies from international dam projects, such as those in Latin America, recommend the implementation of sediment traps, upstream erosion control measures, and regular dredging to extend the useful life of such critical infrastructures [27], [30], [31].

Moreover, sedimentation not only affects the reservoir's capacity but also water quality. Increased sediment loads lead to higher levels of total suspended solids (TSS), which in turn degrade water quality by reducing light penetration and affecting aquatic ecosystems. This mirrors findings from research in the Middle East, where sedimentation has been linked to declines in fish populations and the overall health of reservoir ecosystems [17], [21].

Overall, the data from Waduk Jatibarang highlights a significant challenge with sedimentation that mirrors global issues observed in reservoir management. The high rates of sediment accumulation and the reduced reservoir lifespan necessitate urgent action to prevent further degradation. Effective sediment management techniques, such as upstream land conservation, erosion control, and dredging, will be crucial in preserving the long-term functionality of Waduk Jatibarang, aligning with the global consensus on best practices for sustainable reservoir management [16], [30], [32].

4.6. Key Issues on Management

The research on Waduk Jatibarang highlights several key issues, particularly the top-down management approach by BBWS Pemali-Juana, which limits community involvement. This contrasts with global practices, such as in the United States and Brazil, where community-based management and stakeholder participation are emphasized, leading to better long-term sustainability [3], [16], [18], [33].

A major issue is the lack of policies supporting community participation. Unlike regions in Africa and Latin America, where legal frameworks empower local communities in water management, Waduk Jatibarang lacks such frameworks, preventing local involvement in resource conservation and sustainable practices [34], [35], [36].

Another concern is the weak collaboration between BBWS Pemali-Juana, local governments, and stakeholders. In Europe, collaborative management models have shown success in managing water resources by including all actors. In contrast, the lack of such collaboration at Waduk Jatibarang results in ineffective management and limited local engagement [22], [37], [38]. The absence of a community-based legal framework further restricts local participation in managing the reservoir and tourism development. In countries like India [39], [40], [41], legal frameworks have empowered communities to manage reservoirs effectively, improving sediment control and promoting ecosystem preservation, a model that could benefit Waduk Jatibarang.

A key limitation in Waduk Jatibarang's management is the excessive focus on flood control, neglecting other functions like water management and tourism. Sustainable models, such as in the Mekong Delta, integrate flood control with ecosystem restoration and community-based tourism, which Waduk Jatibarang could adopt for broader benefits. The findings suggest that inclusive, community-driven approaches are essential for improving Waduk Jatibarang's management. International examples show that legal frameworks, collaborative governance, and multi-functional water management can address the current issues and support sustainable resource use.

In conclusion, adopting more inclusive practices, as seen in global models, can help overcome the challenges faced at Waduk Jatibarang and lead to more sustainable environmental and economic outcomes. By incorporating these strategies, Waduk Jatibarang has the potential to better manage water resources, protect the ecosystem, and engage the community in tourism and conservation efforts.

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5. Conclusions

The research on Waduk Jatibarang highlights significant challenges, particularly sedimentation and ecosystem degradation, which threaten the reservoir's long-term capacity. Institutional issues, such as limited community involvement and unclear legal frameworks, have hindered effective management, reducing opportunities for sustainable tourism and water resource conservation.

The top-down management approach by BBWS Pemali-Juana has restricted community participation, leading to unauthorized activities like illegal logging and inappropriate land use, which worsen sedimentation. The absence of a clear legal framework for community engagement further limits local efforts that could enhance sustainable management of the reservoir.

To address these issues, the research recommends improving sediment management through reforestation, constructing sediment traps, and engaging local stakeholders in sustainable practices like eco-tourism. Establishing a community-based legal framework would empower local groups to participate actively in reservoir management, creating more effective and sustainable outcomes. International examples show that integrated approaches, including community involvement and technical interventions, have successfully extended reservoir lifespans and improved water quality.

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References

[1] L. Scodanibbio and G. Mañez, "The World Commission on Dams: A fundamental step towards integrated water resources management and poverty reduction? A pilot case in the Lower Zambezi, Mozambique," *Physics and Chemistry of the Earth*, vol. 30, no. 11-16 SPEC. ISS., pp. 976–983, 2005, doi: 10.1016/j.pce.2005.08.045.

[2] C. He, C. P. Harden, and Y. Liu, "Comparison of water resources management between China and the United States," *Geography and Sustainability*, vol. 1, no. 2, pp. 98–108, Jun. 2020, doi: 10.1016/j.geosus.2020.04.002.

[3] I. Soekarno *et al.*, "A Methodology for Water Resource Management and the Planning of the Coastal Reservoir in Indonesia," *Water (Switzerland)*, vol. 16, no. 2, Jan. 2024, doi: 10.3390/w16020344.

[4] M. Hamidi, "The key role of water resources management in the Middle East dust events," *Catena (Amst)*, vol. 187, Apr. 2020, doi: 10.1016/j.catena.2019.104337.

[5] L. Hinegk, L. Adami, G. Zolezzi, and M. Tubino, "Implications of water resources management on the long-term regime of Lake Garda (Italy)," *J Environ Manage*, vol. 301, Jan. 2022, doi: 10.1016/j.jenvman.2021.113893.

[6] C. Roncoli *et al.*, "From management to negotiation: Technical and institutional innovations for integrated water resource management in the upper comoé river basin, burkina faso," Oct. 2009. doi: 10.1007/s00267-009-9349-x.

[7] World Water Council, "'Outcomes of the 10th World Water Forum in Bali.' The Water Diplomat.," https://www.worldwaterforum.org/. Accessed: Oct. 22, 2024. [Online]. Available: https://www.worldwaterforum.org/

[8] M. A. Fulazzaky, "Challenges of integrated water resources management in Indonesia," 2014, *MDPI AG*. doi: 10.3390/w6072000.

[9] J. M. Ahn, S. Lee, and T. Kang, "Evaluation of dams and weirs operating for water resource management of the Geum River," *Science of the Total Environment*, vol. 478, pp. 103–115, Apr. 2014, doi: 10.1016/j.scitotenv.2014.01.038.

[10] D. Pradhan, T. Ancev, R. Drynan, and M. Harris, "Management of Water Reservoirs (Embungs) in West Timor, Indonesia," *Water Resources Management*, vol. 25, no. 1, pp. 339–356, Jan. 2011, doi: 10.1007/s11269-010-9702-0.

[11] Proyek Kerjasama Pemerintah dan Badan Usaha (KPBU), " Jatibarang Reservoir Final Report 2020," 2020.

[12] G. N. Kpéra *et al.*, "Management of agro-pastoral dams in Benin: Stakeholders, institutions and rehabilitation research," *NJAS - Wageningen Journal of Life Sciences*, vol. 60–63, pp. 79–90, Dec. 2012, doi: 10.1016/j.njas.2012.06.011.

[13] C. A. K. Baba and J. Hack, "Economic valuation of ecosystem services for the sustainable management of agropastoral dams. A case study of the Sakabansi dam, northern Benin," *Ecol Indic*, vol. 107, Dec. 2019, doi: 10.1016/j.ecolind.2019.105648.

[14] H. Magsi, M. Sabir, A. Torre, and A. A. Chandio, "Management practices to minimize land use conflicts on large infrastructure projects: examples of dams construction in Pakistan," *GeoJournal*, vol. 87, no. 6, pp. 4851–4861, Dec. 2022, doi: 10.1007/s10708-021-10532-0.

[15] H. Zanjanian, H. Abdolabadi, M. H. Niksokhan, and A. Sarang, "Influential third party on water right conflict: A Game Theory approach to achieve the desired equilibrium (case study: Ilam dam, Iran)," *J Environ Manage*, vol. 214, pp. 283–294, May 2018, doi: 10.1016/j.jenvman.2018.03.023.

[16] Q. Abu-Afifeh *et al.*, "Dam Sustainability's Interdependency with Climate Change and Dam Failure Drivers," *Sustainability (Switzerland)*, vol. 15, no. 23, Dec. 2023, doi: 10.3390/su152316239.

[17] M. Arif *et al.*, "Assessing riparian zone changes under the influence of stress factors in higher-order streams and tributaries: Implications for the management of massive dams and reservoirs," *Science of the Total Environment*, vol. 776, Jul. 2021, doi: 10.1016/j.scitotenv.2021.146011.

[18] S. Bachtiar, L. M. Limantara, M. Sholichin, and W. Soetopo, "Optimization of Integrated Reservoir for Supporting the Raw Water Supply," *Civil Engineering Journal (Iran)*, vol. 9, no. 4, pp. 860–872, Apr. 2023, doi: 10.28991/CEJ-2023-09-04-07.

[19] C. Folke, T. Hahn, P. Olsson, and J. Norberg, "Adaptive governance of social-ecological systems," 2005. doi: 10.1146/annurev.energy.30.050504.144511.

[20] E. Branche, "The multipurpose water uses of hydropower reservoir: The SHARE concept," Sep. 01, 2017, *Elsevier Masson s.r.l.* doi: 10.1016/j.crhy.2017.06.001.

[21] M. T. Baumgartner, P. A. Piana, G. Baumgartner, and L. C. Gomes, "Storage or Run-of-river Reservoirs: Exploring the Ecological Effects of Dam Operation on Stability and Species Interactions of Fish Assemblages," *Environ Manage*, vol. 65, no. 2, pp. 220–231, Feb. 2020, doi: 10.1007/s00267-019-01243-x.

[22] Y. H. Kwak, J. Walewski, D. Sleeper, and H. Sadatsafavi, "What can we learn from the Hoover Dam project that influenced modern project management?," *International Journal of Project Management*, vol. 32, no. 2, pp. 256–264, 2014, doi: 10.1016/j.ijproman.2013.04.002.

[23] T. Azizi Khalkheili and G. H. Zamani, "Farmer participation in irrigation management: The case of Doroodzan Dam Irrigation Network, Iran," *Agric Water Manag*, vol. 96, no. 5, pp. 859–865, May 2009, doi: 10.1016/j.agwat.2008.11.008.

[24] L. N. H. Verbrugge, W. Ganzevoort, J. M. Fliervoet, K. Panten, and R. J. G. van den Born, "Implementing participatory monitoring in river management: The role of stakeholders' perspectives and incentives," *J Environ Manage*, vol. 195, pp. 62–69, Jun. 2017, doi: 10.1016/j.jenvman.2016.11.035.

[25] C. A. de Paiva, A. da Fonseca Santiago, and J. F. do Prado Filho, "Content analysis of dam break studies for tailings dams with high damage potential in the Quadrilátero Ferrífero, Minas Gerais: technical weaknesses and proposals for improvements," Nov. 01, 2020, *Springer Science and Business Media B.V.* doi: 10.1007/s11069-020-04254-8.

[26] A. Mohseni-Bandpei *et al.*, "Water quality assessment of the most important dam (Latyan dam) in Tehran, Iran," *Environmental Science and Pollution Research*, vol. 25, no. 29, pp. 29227–29239, Oct. 2018, doi: 10.1007/s11356-018-2865-6.

[27] Y. M. Tessema, F. A. Zimale, and M. G. Kebedew, "Understanding sedimentation trends to enhance sustainable reservoir management in the Angereb reservoir, Upper Blue Nile Basin, Ethiopia," *Frontiers in Water*, vol. 6, 2024, doi: 10.3389/frwa.2024.1387915.

[28] X. Zhang and D. She, "Quantifying the sediment reduction efficiency of key dams in the Coarse Sandy Hilly Catchments region of the Yellow River basin, China," *J Hydrol (Amst)*, vol. 602, Nov. 2021, doi: 10.1016/j.jhydrol.2021.126721.

[29] V. M. de C. Aguiar, J. A. B. Neto, V. da S. Quaresma, A. C. Bastos, and J. P. M. de Athayde, "Bioavailability and ecological risks of trace metals in bottom sediments from Doce river continental shelf before and after the biggest environmental disaster in Brazil: The collapse of the Fundão dam," *J Environ Manage*, vol. 272, Oct. 2020, doi: 10.1016/j.jenvman.2020.111086.

[30] A. Palmieri, F. Shah, and A. Dinar, "Economics of reservoir sedimentation and sustainable management of dams," *J Environ Manage*, vol. 61, no. 2, pp. 149–163, 2001, doi: 10.1006/jema.2000.0392.

[31] G. Holguin, P. Vazquez, and Y. Bashan, "The role of sediment microorganisms in the productivity , conservation , and rehabilitation of mangrove ecosystems : an overview," pp. 265–278, 2001, doi: 10.1007/s003740000319.

[32] A. Shireen Fatima, P. Musharaf, S. Junaid, S. Nadeem, and N. Ahmed, "Water Level Monitoring and Management of Dams Using Iot," *International Journal of Advances in Engineering and Management (IJAEM)*, vol. 6, p. 1259, 2024, doi: 10.35629/5252-060412591263.

[33] L. M. W. Yasarer and B. S. M. Sturm, "Potential impacts of climate change on reservoir services and management approaches," *Lake Reserv Manag*, vol. 32, no. 1, pp. 13–26, Jan. 2016, doi: 10.1080/10402381.2015.1107665.

[34] H. Chien and O. Saito, "Evaluating social–ecological fit in urban stream management: The role of governing institutions in sustainable urban ecosystem service provision," *Ecosyst Serv*, vol. 49, Jun. 2021, doi: 10.1016/j.ecoser.2021.101285.

[35] T. S. Aung, T. B. Fischer, and A. S. Azmi, "Social impacts of large-scale hydropower project in Myanmar: a social life cycle assessment of Shweli hydropower dam 1," *International Journal of Life Cycle Assessment*, vol. 26, no. 2, pp. 417–433, Feb. 2021, doi: 10.1007/s11367-021-01868-3.

[36] F. Berkes, "Evolution of co-management: Role of knowledge generation, bridging organizations and social learning," 2009, *Academic Press.* doi: 10.1016/j.jenvman.2008.12.001.

[37] S. E. Null, J. Medellín-Azuara, A. Escriva-Bou, M. Lent, and J. R. Lund, "Optimizing the dammed: Water supply losses and fish habitat gains from dam removal in California," *J Environ Manage*, vol. 136, pp. 121–131, Apr. 2014, doi: 10.1016/j.jenvman.2014.01.024.

[38] C. Song and W. Mo, "A temporal perspective to dam management: influence of dam life and threshold fishery conditions on the energy-fish tradeoff," *Stochastic Environmental Research and Risk Assessment*, vol. 35, no. 1, pp. 83–94, Jan. 2021, doi: 10.1007/s00477-019-01726-7.

[39] D. M. Bajany, L. Zhang, Y. Xu, and X. Xia, "Optimisation Approach Toward Water Management and Energy Security in Arid/Semiarid Regions," *Environmental Processes*, vol. 8, no. 4, pp. 1455–1480, Dec. 2021, doi: 10.1007/s40710-021-00537-9.

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[40] D. L. Sutherland *et al.*, "How microalgal biotechnology can assist with the UN Sustainable Development Goals for natural resource management," *Current Research in Environmental Sustainability*, vol. 3, p. 100050, 2021, doi: 10.1016/j.crsust.2021.100050.

[41] K. Ardeshirtanha and A. Sharafati, "Assessment of Water Supply Dam Failure Risk: Development of New Stochastic Failure Modes and Effects Analysis," *Water Resources Management*, vol. 34, no. 5, pp. 1827–1841, Mar. 2020, doi: 10.1007/s11269-020-02535-2

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