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Research Article

Integrated Water Resources Management in the Seputih Sekampung River Basin, Indonesia: Challenges Strategies and Institutional Synergy

Arlina Phelia[1,a*)]; Mirnanda Cambodia[2,b)]

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Abstract

The Seputih Sekampung River Basin in Lampung Province, Indonesia, represents a nationally strategic watershed facing multifaceted challenges, including critical land degradation, water deficits, declining water quality, and competing demands across sectors. This study aims to formulate an integrated water resources management (IWRM) strategy that addresses the complex hydrological, ecological, and institutional dynamics of the basin. A qualitative-analytical approach was adopted by synthesizing hydrometeorological data, land use analysis, stakeholder consultations, and a review of relevant water governance policies. The analysis revealed that 29.2% of the basin area is categorized as critical land, contributing significantly to erosion and reduced groundwater recharge, while 10 of the 37 water districts are experiencing seasonal water scarcity, exacerbated by uncoordinated usage and weak institutional control. The presence of overlapping responsibilities among agencies and limited stakeholder involvement further undermines effective resource management. Based on scenario planning aligned with projected economic growth, a high-growth strategy was identified as the most viable, emphasizing watershed conservation, efficient allocation of water resources, strengthened flood and drought mitigation infrastructure, and enhanced stakeholder collaboration. This research offers valuable insight into the design of adaptive and participatory water governance models, contributing to the broader discourse on sustainable watershed management in rapidly developing tropical regions under environmental stress.

Keywords: *IWRM; Land Degradation; Stakeholder Involvement; Watershed Planning; Water Scarcity*

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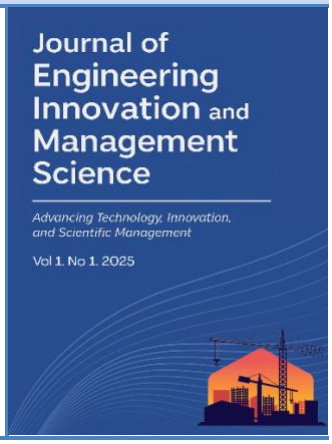

INTRODUCTION

Effective water resource management has emerged as a central concern in global development discourse, particularly in regions where rapid land-use changes, urban expansion, and climate variability are altering hydrological cycles. As water becomes increasingly contested among agricultural, domestic, and industrial users, integrated approaches are required to balance competing interests while preserving ecosystem integrity (Mishra et al., 2022; Stringer et al., 2021). Integrated Water Resources Management (IWRM) provides a structured framework to harmonize water governance by aligning institutional roles, ecological realities, and socio-economic objectives (Cook & Bakker, 2012; Meinzen-Dick et al., 2002; Nesheim et al., 2010). While widely adopted in theory, many developing countries face significant obstacles in translating IWRM principles into practice (Dirwai et al., 2021; Nagata et al., 2022). Fragmented institutions, lack of stakeholder coordination, and limited access to reliable data often inhibit progress (Ji et al., 2024; M. Rahman et al., 2024). In Southeast Asia, Indonesia presents a unique case due to its archipelagic geography and the diverse socio-ecological conditions of its watersheds (Maruf, 2019; Turnip et al., 2022). With pressures mounting from population growth and economic development, there is a growing need to reform how water is planned, allocated, and conserved. Addressing these challenges requires both strategic vision and context-sensitive solutions grounded in local realities.

The Seputih Sekampung River Basin, located in Lampung Province, is one of Indonesia's nationally strategic watersheds (Nurlia et al., 2024). The basin supports a range of vital functions, including agricultural irrigation, domestic water supply, aquaculture, and hydrological services that benefit both upstream and downstream communities (Atapattu & Kodituwakku, 2009; Dile et al., 2016; Molle et al., 2010; Rockström et al., 2004). However, the sustainability of these functions is threatened by land degradation, sedimentation, and increasingly erratic rainfall patterns (AbdelRahman, 2023; Borrelli et al., 2020; Hossain et al., 2020). Approximately 29.2% of the basin area has been identified as degraded land, leading to accelerated erosion and reduced infiltration. In addition, ten out of thirty-seven sub-watersheds in the region are currently facing water deficits, particularly during the dry season (Jaung et al., 2018; Leksono et al., 2021; S. A. Rahman et al., 2019). The uneven spatial distribution of water, combined with growing demand from multiple sectors, is contributing to rising tensions over allocation priorities. Moreover, extreme weather events, such as floods and droughts, are becoming more frequent, exposing the fragility of existing infrastructure and institutional preparedness. These dynamics underscore the urgency of implementing integrated strategies that account for both physical and institutional complexities particularly by incorporating local ecological knowledge and community-based resource management as demonstrated in previous research (Ali et al., 2020; Ardianti et al., 2023; He et al., 2022).

Previous research on Indonesian river basins has primarily addressed hydrological modeling, flood control, and infrastructure development. While such studies offer valuable insights, many fail to

incorporate the broader governance dimensions that influence water management outcomes. For instance, limited attention is given to how institutional fragmentation, overlapping jurisdiction, and lack of participatory mechanisms affect implementation (Asdak et al., 2023; Shah & Nabeel, 2023; Yanto & Maryati, 2023). In the case of the Seputih Sekampung Basin, technical studies often emphasize physical interventions without engaging with the social or political context in which decisions are made. Furthermore, few studies have employed scenario-based planning methods that incorporate economic, demographic, and environmental trends to guide adaptive responses (Gu et al., 2022; Koorts et al., 2022). International experiences suggest that integrated and forward-looking planning can enhance resilience and support more equitable resource distribution. Despite this, comprehensive planning models that merge spatial, institutional, and hydrological data remain underutilized in the Indonesian context. This gap presents a key opportunity for developing a more robust and applicable IWRM framework (Chidammodzi & Muhandiki, 2017).

Institutional coordination remains a persistent challenge in watershed governance across Indonesia. In the Seputih Sekampung Basin, responsibilities are distributed among national ministries, provincial authorities, and local governments, often with overlapping mandates and limited coordination (Fitri et al., 2023; Sulistyaningsih et al., 2021). Stakeholder engagement platforms such as river basin councils have been established, but their authority is frequently constrained to advisory roles. At the community level, water user groups exist but often lack formal recognition and technical capacity to meaningfully participate in planning or monitoring (Lindsay et al., 2019; Pacheco-Vega, 2020). The absence of integrated decision-making processes leads to duplication of efforts and inconsistent implementation across sectors. These institutional limitations hinder the ability to manage the basin holistically and to respond effectively to emerging pressures. Strengthening the role of multi-stakeholder coordination bodies and embedding participatory governance within formal planning mechanisms are essential. Such approaches are not only aligned with IWRM principles but also improve the legitimacy and sustainability of policy interventions (Dewata, 2019; Garau et al., 2020).

Another critical barrier to integrated planning is the limited availability and accessibility of high-quality data. Hydrological and meteorological information is collected by multiple agencies using varying standards, making integration and analysis difficult. Although technological tools such as remote sensing and geographic information systems (GIS) offer potential, their use in basin-scale planning remains limited due to technical and financial constraints (Indrawati & Simarmata, 2023; Zhou et al., 2021). Moreover, real-time monitoring of water quality and pollution sources is often lacking, undermining the ability to enforce regulations or design targeted interventions. The development of a comprehensive water information system is essential to support evidence-based decision-making. Such a system must include data harmonization protocols, open-access platforms, and training for local institutions. Experiences from other Indonesian basins, such as Brantas and Ciliwung, show that data gaps not only affect technical planning but also erode public

trust in water management institutions. To move toward a more responsive and accountable governance model, data infrastructure must be strengthened alongside institutional reforms.

Given these interrelated challenges, this study aims to develop an integrated water resources management strategy for the Seputih Sekampung River Basin that is both adaptive and grounded in the basin's socio-hydrological realities. The study applies a qualitative-analytical approach, combining spatial data interpretation, hydrometeorological analysis, stakeholder mapping, and scenario development. By integrating these components, the research seeks to formulate a comprehensive framework that supports long-term water security, ecosystem protection, and institutional coordination. This study not only fills a gap in current literature but also offers practical insights for policymakers and planners working in similar watershed contexts. The resulting framework is expected to inform the design of more resilient and inclusive water governance strategies across Indonesia. Furthermore, the research contributes to global discourse on localized IWRM applications in the Global South. It emphasizes the importance of context, collaboration, and capacity in achieving sustainable water outcomes. Ultimately, the findings aim to strengthen the integration of ecological and institutional perspectives in watershed-scale planning.

METHODS

This study employed a qualitative-descriptive approach supported by spatial, hydrological, and institutional analysis to develop an integrated water resources management (IWRM) framework for the Seputih Sekampung River Basin. The methodology was designed to synthesize technical data, policy frameworks, and stakeholder perspectives to reflect the multi-dimensional nature of basin-level water management. Data collection was primarily based on secondary sources, including hydrometeorological data, land use and land cover (LULC) maps, institutional reports, and government planning documents. Key sources included datasets from the Ministry of Public Works and Housing, BBWS Mesuji Sekampung, and the Central Statistics Agency, covering the period of 2010–2016.

Hydrological data were used to assess surface and groundwater availability, seasonal water deficits, and trends in rainfall and discharge patterns across the 37 identified water service units (WSUs) within the basin. Land degradation levels were evaluated using classified critical land maps, which informed the analysis of erosion-prone zones and infiltration capacities. Institutional mapping was conducted to identify the roles and mandates of relevant government agencies, community water user groups, and coordination forums operating within the basin. Stakeholder analysis was integrated to examine the structure and influence of decision-making entities, including their level of participation in planning and implementation.

To support decision-making, a scenario-based planning approach was applied, incorporating three economic growth projections (low, moderate, and high). Each scenario was assessed based on its implications for water demand, conservation priorities, infrastructure needs, and institutional

coordination. Triangulation was conducted by cross-verifying spatial data, technical reports, and stakeholder consultations to enhance the reliability of the findings. The methodological framework allowed for the development of strategic alternatives aimed at improving water allocation, reducing environmental risk, and strengthening institutional collaboration in the basin.

RESULT AND DISCUSSIONS

Land Degradation and Watershed Vulnerability

Land degradation in the Seputih Sekampung Basin poses a serious threat to watershed sustainability. Approximately 118,725 hectares, or 29.2% of the basin area, are classified as critical or very critical land, based on data from land cover assessments and critical land classifications. These areas are heavily concentrated in the upstream regions where land clearing, monoculture plantations, and minimal conservation practices have led to accelerated erosion and reduced infiltration. The decline in vegetative cover has also intensified surface runoff, which increases sedimentation in downstream reservoirs and channels. The critical zones contribute to the sediment load in key rivers such as Seputih and Way Sekampung, reducing reservoir capacity and raising flood risk.

Table 1. Land Degradation Status in Seputih Sekampung River Basin

Land Status	Area (ha)	Percentage (%)
Critical	76.516	18,8
Very Critical	42.209	10,4
Not Critical	287.014	70,8
Total	405.739	100

The high percentage of degraded land indicates the urgent need for upstream watershed rehabilitation, reforestation programs, and sustainable land-use zoning to restore hydrological balance.

Water Balance and Sectoral Demand

Water resource distribution across the 37 water districts (WDs) in the basin is uneven, with 10 WDs already experiencing seasonal shortages and 2 classified as water-deficit zones. The mismatch between available supply and rising demand is driven by expanding agriculture, increasing population, and industrial development. Urban centers such as Bandar Lampung, Metro, and surrounding municipalities require more than 8.56 m^3/s of raw water, while projected availability without new infrastructure is significantly lower in dry periods. Hydrological analysis projects that under a high-growth economic scenario, water demand could exceed 250 m^3/s in peak periods by 2034.

Table 2. Water Supply and Demand in Selected Water Districts

Water District	Supply (m3/s)	Demand (m3/s)	Status
Way Sekampung Hilir	7,20	6,40	Surplus
Metro	2,80	3,65	Deficit

Way Pengubuan	3,50	2,10	Surplus
Way Buah	1,20	1,90	Deficit
Bandar Lampung	2,30	3,90	Deficit

Deficits during the dry season are expected to increase unless supported by enhanced infrastructure and allocation efficiency, especially for irrigation and urban water supply.

Institutional and Stakeholder Coordination

Despite the presence of river basin coordination institutions such as TKPSDA, institutional arrangements in the basin remain fragmented. Jurisdictional overlaps between central, provincial, and district-level agencies result in inconsistent implementation of water management programs. Stakeholder involvement, particularly from community-based water user groups, remains limited to project-based engagement without clear mandates or support mechanisms. This fragmentation reduces the efficiency of planning, causes duplication of effort, and weakens accountability. Effective IWRM implementation requires restructuring institutional mandates, improving inter-agency collaboration, and legally empowering participatory platforms. Best practices from other Indonesian basins suggest that establishing integrated watershed authorities with clear legal mandates may improve operational effectiveness and reduce conflict among sectors.

Strategic Infrastructure and Scenario Development

The basin planning process incorporated three economic growth scenarios: low (<3% growth), moderate (3–6%), and high (>6%). The high-growth scenario was selected as the basis for infrastructure prioritization, given the recent trend of 4.9% annual growth in Lampung Province. Major infrastructure proposed includes the Segalamider, Pengubuan, and Harapan Jaya multipurpose dams, designed to increase irrigation coverage, control flooding, and supply domestic water.

Table 3. Proposed Strategic Infrastructure Projects

Infrastructure Project	Function	Estimated Benefit
Segalamider Dam	Irrigation + Flood Control	3.000 ha irrigation; 30% flood risk
Harapan Jaya Dam	Raw Water Supply	2,5 m3/s water supply to urban areas
Way Pengubuan Dam	Irrigation	Additional 2.000 ha dry season supply

Scenario planning allows flexible prioritization of investments and guides trade-off analysis among sectors. It is particularly relevant given the basin's exposure to climatic extremes and development pressures.

Surface Water Quality and Pollution Trends

Water quality in the basin shows deterioration in urban and agricultural zones. Biological oxygen demand (BOD) values have increased in rivers adjacent to densely populated areas, often exceeding recommended thresholds. The primary pollution sources include domestic wastewater, livestock waste, and agricultural runoff containing fertilizers and pesticides. The absence of

centralized wastewater treatment in rural areas further worsens downstream water quality. Mitigation strategies proposed include development of communal wastewater treatment facilities (IPAL Komunal), implementation of effluent standards, and promotion of integrated pest and nutrient management (IPM). These interventions are essential to maintaining ecosystem health and ensuring water usability across sectors.

Toward Integrated Water Governance

The results of this study affirm that technical solutions alone are insufficient without institutional reform and stakeholder inclusion. The integrated strategy proposed emphasizes cross-sector collaboration, watershed conservation, infrastructure development, and improved governance. It also highlights the value of scenario-based planning in anticipating future risks and informing infrastructure investment. Long-term success will depend on transparent monitoring, sustained funding, and community engagement at all levels. By aligning spatial, institutional, and hydrological data, the proposed IWRM framework offers a practical roadmap for basin-scale water management in complex, resource-constrained settings. The Seputih Sekampung case serves as a model for other regions in Indonesia facing similar sustainability challenges.

Discussion

The results of this study reflect the complex interplay between ecological degradation, hydrological stress, and institutional fragmentation in managing water resources at the basin level. The significant proportion of degraded land in the Seputih Sekampung Basin not only threatens the ecological balance of upstream areas but also disrupts downstream water availability due to increased runoff and sedimentation. These conditions impair the recharge of groundwater systems and diminish the capacity of rivers and reservoirs to regulate flow. The spatial mismatch between areas of high water demand and zones of surplus further illustrates the need for more responsive allocation frameworks and investment in conveyance infrastructure. In particular, urban and peri-urban regions continue to face growing water deficits due to population expansion and economic activity, outpacing the development of supporting facilities. The application of scenario-based planning in this context enables the projection of future pressures and helps prioritize interventions under varying assumptions of economic growth. Through this approach, it becomes possible to anticipate shifts in demand and assess the implications for resource allocation, infrastructure needs, and conservation targets. Thus, an integrated strategy that links land rehabilitation, water infrastructure development, and demand management is essential for enhancing the resilience of the basin. Beyond technical considerations, the governance structure of water resource management in the basin emerges as a central issue influencing implementation effectiveness. Fragmented institutional roles, unclear jurisdictional boundaries, and limited stakeholder engagement weaken coordination and reduce accountability across planning and operational levels. While multi-stakeholder forums exist, their advisory function often limits their authority in guiding strategic decisions. Local water user groups remain underutilized, lacking institutional support and integration into formal governance mechanisms. These findings reinforce the argument that successful integrated water resources management is contingent upon governance reform, particularly the alignment of planning mandates, decision-making power, and stakeholder

capacities. Moreover, the deterioration of water quality due to diffuse pollution sources highlights the urgent need for decentralized wastewater management and the adoption of environmentally sustainable land practices. Addressing water quality concerns should be integrated into broader watershed planning rather than treated as an isolated technical issue. The case of Seputih Sekampung demonstrates that achieving water security requires a systemic approach—one that simultaneously improves institutional performance, strengthens ecological foundations, and anticipates future socio-economic transformations.

Implication

The findings from the Seputih Sekampung River Basin planning study offer practical implications for improving the effectiveness of integrated water resources management in complex watershed systems. First, the high proportion of degraded land and spatial water imbalances reinforce the urgency of linking land-use planning with hydrological management at the basin scale. This calls for a coordinated policy approach that unites environmental conservation with economic development goals, especially in regions experiencing rapid agricultural expansion and urban growth. Restoration of upstream catchment areas, combined with demand-side water efficiency, can serve as a foundation for long-term water availability and disaster risk reduction. The application of scenario-based planning in this study also demonstrates the value of using future-oriented tools to guide infrastructure investment and prioritize adaptive strategies under conditions of uncertainty. Therefore, the planning model used in the Seputih Sekampung case could be replicated or adapted for other basins across Indonesia and similar developing contexts, especially where water demand is expected to rise due to economic transformation and population growth. From a governance perspective, the study highlights the importance of strengthening institutional alignment and enabling stakeholder participation to improve policy implementation and accountability. The current fragmentation among agencies with overlapping responsibilities not only reduces planning efficiency but also weakens the legitimacy of water-related decisions. Establishing clearer institutional mandates, enhancing inter-agency coordination, and formalizing the role of community-based organizations are essential steps toward more inclusive and responsive water governance. Moreover, the degradation of water quality linked to agricultural and domestic activities suggests that environmental regulation must be integrated into local planning instruments, supported by both infrastructure investment and behavioral change campaigns. These insights carry implications not only for regional planners and water authorities, but also for national policymakers seeking to operationalize the principles of IWRM in practice. The Seputih Sekampung case thus serves as a reference for designing context-sensitive, scalable, and governance-driven models for sustainable watershed management.

Limitation and Suggestion for Further Research

This study, while offering a structured approach to integrated water resources planning in the Seputih Sekampung River Basin, is subject to several limitations that merit reflection and guide future research. The analysis relied predominantly on secondary data from planning documents and government reports, which, although useful, may lack consistency in temporal resolution and

spatial accuracy, particularly regarding real-time water availability, land degradation dynamics, and pollution load trends. Furthermore, the absence of direct stakeholder engagement through field interviews or participatory mapping limits the depth of understanding regarding local knowledge systems, governance behaviors, and community priorities in water management. The scenario-based approach used to estimate future water demand was built on broad economic assumptions without integrating real-time modeling of land use, population growth, or climate variability, potentially reducing its predictive precision. Therefore, future research should focus on incorporating primary data collection, participatory assessment tools, and hydrological modeling that reflects the complexity of socio-environmental interactions in the basin. Investigating institutional effectiveness through stakeholder analysis and exploring the adaptive capacities of local governance structures would also enrich understanding of implementation barriers. Comparative studies across other watersheds in Indonesia using standardized IWRM indicators would enable benchmarking and cross-learning to improve national policy coherence. Ultimately, bridging empirical gaps with interdisciplinary methods and inclusive stakeholder engagement will be critical to refining and operationalizing sustainable watershed governance in dynamic and vulnerable regions like Seputih Sekampung.

CONCLUSION

The integrated assessment of the Seputih Sekampung River Basin demonstrates the urgent need for a systemic approach to water resources management that accounts for ecological degradation, spatial water imbalance, and fragmented institutional governance. With nearly one-third of the basin classified as critically degraded land, watershed health is under severe threat, affecting runoff regulation, sediment transport, and water storage capacity. Simultaneously, rising sectoral demands and uneven water distribution reveal structural weaknesses in infrastructure and allocation systems, particularly in urban and agriculturally intensive zones. The scenario-based planning approach applied in this study provides a forward-looking tool to anticipate future pressures and guide investment priorities, while also emphasizing the necessity of aligning infrastructure development with conservation and risk reduction goals. However, technical planning alone is insufficient without parallel reforms in institutional arrangements, stakeholder empowerment, and data integration. Strengthening inter-agency coordination, formalizing participatory mechanisms, and improving environmental monitoring are essential to ensure that integrated water governance becomes operational and impactful. Ultimately, the experience of Seputih Sekampung offers a transferable model for managing river basins in similar socio-ecological contexts, underscoring that sustainable water management is not only a technical endeavor, but also a political, institutional, and social challenge that requires adaptive, inclusive, and evidence-based strategies.

AUTHORS INFORMATION

Corresponding Authors

Arlina Phelia – Land and Enviromental Resource Engineering Program, Politeknik Negeri Lampung (Indonesia)
Email: arlinaphelia@polinela.ac.id

Authors

Mirnanda Cambodia – Land and Enviromental Resource Engineering Program, Politeknik Negeri Lampung (Indonesia)
Email : mirnandacambodia@polinela.ac.id

AUTHORS CONTIBUTIONS STATEMENT

Arlina Phelia led the overall conceptualization and design of the study, including the development of the research framework and integration of the IWRM theoretical model. She was primarily responsible for collecting, synthesizing, and interpreting hydrological and land degradation data, and contributed substantially to drafting the introduction, methods, and conclusion sections. Mirnanda Cambodia contributed to the institutional and stakeholder analysis, carried out the scenario-based planning assessment, and led the formulation of strategic recommendations. She also critically reviewed the relevant policy frameworks and coordinated the preparation of the results and discussion sections. Both authors participated in manuscript revisions, provided input on the structure and academic clarity of the article, and approved the final version. They jointly take full responsibility for the integrity and originality of the work and confirm that all data interpretations and conclusions were reached independently.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article. All research activities, analyses, and interpretations were conducted independently, without any financial, professional, or personal relationships that could have influenced the results or their presentation in this manuscript.

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