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EDITED BY
Hélder Tiago Da Silva Lopes,
University of Minho, Portugal

REVIEWED BY
Roderikus Agus Trihatmoko,
Universitas Surakarta, Indonesia
Nasfi,
Sekolah Tinggi Ekonomi Syariah Manna Wa Salwa Tanah Datar, Indonesia

*CORRESPONDENCE
Endro Suswantoro,
endrosuswantoro@apps.ipb.ac.id

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Institutional frameworks for the governance of hydropower resources in Indonesia: policy implications for sustainable rural development

Endro Suswantoro[1]*, Dodik Ridho Nurrochmat[2], Aceng Hidayat[3] and Sofyan Sjaf[4]

[1]Study Program of Natural Resources and Environmental Management, Graduate School, IPB University, Bogor, Indonesia, [2]Department of Forest Management Science, Faculty of Forestry and Environment, IPB University, Bogor, Indonesia, [3]Department of Environmental and Resource Economics, Faculty of Economics and Management, IPB University, Bogor, Indonesia, [4]Department of Communication and Community Development Sciences, Faculty of Human Ecology, IPB University, Bogor, Indonesia

Introduction: This study examines the institutional framework of economic governance for hydropower resources in Indonesia, focusing on interactions between national and subnational governance structures.
Methods: Data were drawn from national and regional policy documents on hydropower, renewable energy, and natural resource management; organizational structures and actor roles across government, private, and community stakeholders; meeting minutes, cooperation agreements, and institutional performance reports. These were complemented by in-depth interviews and focus group discussions with government officials, hydropower operators, community leaders, and civil society organizations. The Institutional Analysis and Development (IAD) framework and content analysis were used to map action arenas, actor networks, and rules-in-use.
Results: Findings reveal a multi-layered institutional configuration with overlapping mandates, fragmented coordination, and weak cross-sectoral integration. Although formal frameworks prescribe mechanisms for resource allocation, revenue distribution, and environmental safeguards, implementation is constrained by limited stakeholder engagement and weak enforcement.
Discussion: The institutional mapping provides a basis to strengthen coordination mechanisms, clarify actor mandates, and enhance participatory governance to achieve more coherent and equitable hydropower resource management in Indonesia.

KEYWORDS

economic governance, hydropower governance, institutional frameworks, renewable energy policy, rural development

Introduction

Hydroelectric power plants (PLTA) play a strategic role in supporting Indonesia's renewable energy mix. This role aligns with the national target of achieving net-zero emissions by 2060, as stated in the Enhanced Nationally Determined Contribution (ENDC) (Diyono et al., 2023; Mehrotra and Benjamin, 2022; Putri et al., 2024). With a technical potential of up to 75 GW (GW), hydropower is seen as capable of making a significant

contribution to the diversification of national energy sources. This diversification expands energy availability and reduces dependence on fossil fuels, which are vulnerable to global price fluctuations and supply risks (Mayer, 2022). Furthermore, the integration of hydropower into the national energy system is a strategic instrument for reducing greenhouse gas emissions, particularly from the energy sector, which is a major contributor. The implication of strengthening the role of hydropower is to support the achievement of the Sustainable Development Goals, especially Affordable and Clean Energy (Goal 7) and Climate Action (Goal 13) (Sjaf et al., 2021; 2024). In addition, hydropower expansion is increasingly linked to broader development goals such as Decent Work and Economic Growth (Goal 8) and Reduced Inequalities (Goal 10), positioning hydropower projects as instruments of both national decarbonisation and local sustainable development.

In the transition towards a low-carbon energy system, which is a strategic agenda of the national energy policy, hydropower occupies a key position in realizing the renewable energy mix target of 23% by 2025 as stipulated in the National Energy General Plan (RUEN) (Algarvio et al., 2020; Shahgholian, 2020). Its advantages as a stable, large-capacity, and reliable energy source make it a significant contributor to the stability of the national electricity grid (Atkinson, 2021; Aytac et al., 2023; Williams, 2020). Indonesia's geographical conditions, which are abundant in water resources, further strengthen the relevance of hydropower as the primary basis for hydropower, especially when compared with intermittent sources, such as solar or wind power (Artika et al., 2022; Somura et al., 2019). Thus, hydropower is a crucial component for the national energy transition and for the development of academic studies related to renewable energy and natural resource governance in Indonesia (Putri et al., 2024). At the same time, it opens up fundamental questions about the economic governance of water, land, and forest resources in hydropower territories and about who gains or loses from these projects.

The sustainability of hydropower operations is highly dependent on the preservation of watersheds (DAS), the primary source of water resources. This function is closely linked to forestry policies, spatial planning, and aquatic ecosystem conservation (Annys et al., 2019; Aung et al., 2021; Liu et al., 2022). Integration of energy, forestry, and water governance policies is key to maintaining a continuous water supply for hydropower plants. Failure to maintain upstream water quality and quantity can reduce power generation capacity, increase reservoir sedimentation, and shorten the lifespan of infrastructure (Bazzana et al., 2020; Rousseau and Habich-Sobiegalla, 2021). This confirms that the success of hydropower plants is shaped by a combination of technical and financial performance and effective institutional coordination across sectors and regions. In this context, hydropower management in Indonesia faces the global challenge of balancing energy needs with the protection of river ecosystems, which often hold high social, cultural, and ecological value for local communities. Changes in land use, forest cover, and river flow associated with dam construction and reservoir operation directly affect soil stability, water quality, fisheries, and farming systems, thereby reshaping the ecological foundations of local livelihoods. The way these forest–water impacts are governed therefore has immediate consequences for the long-term socio-economic sustainability of communities living around hydropower projects.

While hydropower has widely been examined from technical and economic perspectives, far less scholarly attention has been given to how institutional arrangements and spatial equity shape its implementation. Many studies continue to frame hydropower as a purely infrastructural intervention, rather than a socio-ecological system embedded in complex actor interactions (Hensengerth, 2024; McIntyre, 2023; Polanco and Inchima, 2024). In fact, cross-country studies show that the sustainability of hydropower is highly dependent on institutional design that can integrate the interests of the state, the private sector, and local communities in an inclusive coordination mechanism (Rahayu et al., 2022; Rospriandana et al., 2023). Inefficient governance is often characterized by overlapping authority between agencies, weak community participation, and low community capacity to articulate their interests (Didik et al., 2018; Qurani and Adnan, 2023). As a result, the economic benefits of hydropower tend to be concentrated on a macro scale, while the surrounding community has not yet achieved significant improvements in welfare (Ahmad et al., 2023; Alsaleh and Abdul-Rahim, 2021; Tang et al., 2019). In this sense, hydropower projects function as arenas of economic governance in which state agencies, private operators, and intermediary institutions decide how the costs and benefits of electricity generation, watershed conservation, and land-use restrictions are distributed across territories and social groups, and the extent to which local communities can participate in and influence these decisions.

Beyond hydropower, Indonesian scholarship on natural resource governance–including studies on forest co-management, social forestry schemes, and coastal or fisheries governance–highlights persistent tensions between national development objectives, ecological conservation, and local livelihood security. However, these contributions rarely examine how economic governance in upstream hydropower territories mediates rights, access, and benefit-sharing across water, forest, and land uses. This study extends that literature by analysing hydropower as a multi-level economic governance arena in which institutional arrangements shape who bears the ecological costs and who captures the economic gains in an Indonesian watershed context.

In general, solutions to these problems require reforming the institutional framework, with an emphasis on technical efficiency together with the principles of spatial equity and environmental sustainability. Such reforms must explicitly clarify the role of government at multiple levels and create meaningful spaces for community participation in decisions that shape sustainable economic development around hydropower projects. A polycentric governance approach is a relevant alternative, where authority and decision-making capacity are distributed across multiple levels of government and community groups, yet linked through mutually reinforcing coordination mechanisms. This model has been proven in several countries to improve the effectiveness of natural resource management by reducing the risk of authority conflicts and enhancing adaptive responses to local dynamics (Ahmad et al., 2023; Hensengerth, 2024; Polanco and Inchima, 2024; Wu et al., 2021).

Specifically, improving hydropower governance in Indonesia requires strengthening cross-sectoral policy, enhancing coordination mechanisms between levels of government, and improving local institutional capacity. This could include

developing fair and transparent benefit-sharing mechanisms, integrating watershed management plans into energy planning, and implementing environmental economic valuation instruments to quantify the contribution of hydropower to sustainable development comprehensively. Thus, hydropower will serve both as an instrument for the energy transition and as a driver for sustainable and equitable village development.

In Lampung Province, these governance challenges are clearly visible in the Batutegi hydropower project located in the upper Way Sekampung catchment. The dam supplies electricity to the national grid and water for downstream irrigation, while upstream villages depend on coffee-based agroforestry in protection forests, smallholder agriculture, river and reservoir fisheries, and emerging micro-tourism activities. Hydropower development has generated new income opportunities, infrastructure, and market access for some households, but it has also involved resettlement, loss of agricultural land, restrictions on access to forests and riparian zones, and changes in water allocation that directly affect local farming and fishing livelihoods. These mixed positive and negative socio-economic impacts, together with the altered forest and water regimes in the watershed, underline the need to understand how government agencies and other actors govern rights, obligations, and benefit sharing around the Batutegi hydropower system, and how local communities participate or are excluded from decisions about sustainable economic development in this upstream territory.

Previous studies in Indonesia indicate that research on hydropower which explicitly examines economic governance through institutional perspectives, spatial equity analysis, and environmental economic valuation remains limited (Didik et al., 2018; Diyono et al., 2023; Rospriandana et al., 2023; Tang et al., 2019). However, in countries like Norway and Brazil, the implementation of a polycentric institutional model involving the central government, regional governments, local communities, and the private sector has successfully created adaptive and sustainable hydropower governance (Liljenfeldt et al., 2025; Lindström and Ruud, 2017; Mayer et al., 2023; Soukhaphon et al., 2021; Wu et al., 2021). This cross-country comparison provides essential lessons for Indonesia in designing an effective and inclusive institutional framework.

Based on this literature gap, this study proposes an institutional approach that combines Institutional Analysis and Development (IAD) with the concepts of a bundle of rights, access theory, and spatial justice to analyze the inequality of rights and benefits in the economic governance of the Batutegi hydropower plant in Lampung Province and to link these institutional configurations to the differentiated socio-economic outcomes experienced by surrounding communities. This approach enables a multi-level analysis of how formal rules and local practices interact in the context of resource management actions, as well as how institutional configurations influence the access, recognition, and distribution of economic benefits among actors. Thus, the article makes three main contributions: empirically, it provides a grounded account of how hydropower development in an upstream watershed reconfigures access to land, forests, and water and produces differentiated socio-economic impacts; conceptually, it advances the application of the IAD framework by integrating bundle of rights, access theory, and spatial justice to analyse economic governance in hydropower territories; and practically, it offers policy-relevant insights for improving institutional coordination, benefit-sharing mechanisms, and community participation in Indonesia's sustainable energy system.

Literature review and analytical framework

Institutional analysis and development framework

Since its introduction by Elinor Ostrom and colleagues, IAD has become one of the most influential approaches in the study of commons resource governance and institutional design (McGinnis, 2011; Ostrom, 2009). IAD seeks to explain how actors, rules, and resources interact within a social-ecological system and how these interactions produce specific outcomes. This framework focuses on key conceptual elements: actors, rules, action arenas (or action situations), interactions, and outcomes, which are influenced by external variables such as biophysical conditions, community attributes, and resource characteristics (McGinnis, 2011; Ostrom, 2009; Ostrom, 2014; Ostrom, 2015).

From an IAD perspective, actors include individuals, groups, institutions, and organizations that make decisions within an action arena; rules consist of formal rules (e.g., regulations, permits, laws) and operational rules (e.g., social norms, local practices) that govern the behavior of actors; the action arena is the social space where these interactions occur; and outcomes are the concrete results of these dynamics, whether in the form of benefit distribution, resource allocation, or institutional feedback. Recent critiques of IAD highlight the importance of paying attention to the relationship between rules-in-form and rules-in-use Cole (2017), as not all formal rules are actually implemented as working rules on the ground. Local norms can modify, negotiate, and even challenge formal rules established by the state (Ostrom, 2014).

Recent developments in the institutional literature emphasize the integration of IAD with the Social-Ecological Systems (SES) framework, which positions the interactions between institutions and ecosystems as a unified analysis (Cole et al., 2019; Fleischmann and Burgmer, 2020). This approach enables a more comprehensive examination of the relationships between policies, institutions, and resource sustainability. In the context of the Batutegi hydropower plant, IAD is used to explore how formal regulations (e.g., policies of the Ministry of Environment and Forestry, the Ministry of Public Works and Housing, and the State Electricity Company) interact with local practices (e.g., agroforestry and intercropping management) within a single action arena. This framework helps identify gaps in cross-sectoral coordination, overlapping authorities, and their effects on the distribution of economic and ecological benefits from the hydropower system.

Bundle of rights and access theory

The concept of resource rights is articulated through the idea of a bundle of rights, which emphasizes that resource ownership is layered and comprises several distinct rights: access rights, withdrawal/use rights, management rights, exclusion rights, and

alienation rights. This concept offers an analytical tool for examining the distribution of rights among various actors and understanding how these rights are formally and informally regulated. In an institutional context, these rights are operationalized through rules-in-form and rules-in-use.

However, formal ownership of rights does not necessarily guarantee the ability to obtain tangible benefits from those resources. This is where the access theory, proposed by Ribot and Peluso (2003), provides an essential extension of the concept of bundles of rights. They define access as "the ability to benefit from something," encompassing legal rights as well as the social, economic, and political power that enables or hinders actors from accessing resources. Within this framework, access is understood as a bundle of powers—a combination of social capital, networks, knowledge, authority, and legitimacy that determines who can actually control the benefits of a resource (Hall et al., 2011; Ribot and Peluso, 2003). Sikor and Lund (2009) reinforce this view by highlighting the gray area between rights and access, where individuals or groups may possess formal rights but lack actual access, or conversely, gain access without legal rights. This tension often arises in relations between the state and local communities, where power is a primary source of legitimacy for controlling resources.

In the context of the Batutegi hydropower plant, the bundle of rights framework is used to map formal rights, such as operating permits, protected forest area designations, and water management regulations. Meanwhile, access theory helps analyze how local communities actually gain or lose benefits from these resources.

Spatial justice and institutional power

The concept of spatial justice broadens institutional studies by emphasizing that justice is social and economic, and at the same time inherently spatial. Soja (2015) Asserts that space is an arena for the production of power and injustice, not simply a neutral platform in which policies are implemented. In this context, spatial justice consists of three dimensions: redistributive justice (the geographical distribution of resources and benefits), procedural justice (participation and transparency in decision-making processes), and recognitional justice (recognition of the values, identities, and rights of local communities) (Fraser, 2020; Harvey, 2009; Soja, 2015).

Sikor and Lund (2009) demonstrate that the dimension of spatial justice is closely related to institutional power, in the form of the state's or certain institutions' ability to determine the legitimacy of space and limit community access to resources. When the state establishes protected areas or conservation zones without involving the community, these spaces become political products of exclusion. Thus, spatial justice highlights the relationship between power structures, institutional rights, and the social position of actors within a landscape.

In the context of the Batutegi hydropower plant, a spatial justice approach is crucial for understanding how specific spaces (e.g., protected forest areas, green belts, and water catchment areas) become arenas for unequal rights and benefits. This analysis assesses the extent to which communities have access to land, water, and economic compensation and how they are recognized in decision-making processes and within the institutional structures governing these resources.

By combining the framework of a bundle of rights and access theory with the concept of spatial justice, this study examines how inequality in rights and power is articulated in the distribution of spatial benefits in the Batutegi hydropower plant area. The fundamental question that needs to be answered is "who gets what, where, and how"—an approach that positions spatial justice as an analytical lens for evaluating equitable energy economic governance.

Methods

This study employed a qualitative case study design within a constructivist institutional paradigm to analyse the economic governance of the Batutegi hydropower plant and its upstream watershed. The research object is the multi-level governance system that links hydropower operations, forest and water management, and village development in the Way Sekampung River Basin, with a particular focus on how institutional arrangements shape the distribution of rights and economic benefits among actors.

The research was conducted in the Way Sekampung River Basin (DAS) of Tanggamus and Pringsewu Regencies, Lampung Province, Indonesia. The study area comprises a heterogeneous landscape ranging from lowlands to hilly terrain with protected forest cover, plantations, and rural settlements (Figure 1). The watershed supplies water to the Batutegi hydropower plant, which is connected to the national energy grid. This hydrological and institutional setting provides a suitable case for examining the interlinkages between water resource governance, energy management, and rural development in an upstream hydropower territory.

The participants of the study includes stakeholders involved in hydropower, forest, and water governance at different levels, namely: national and regional government agencies, the hydropower operator, district and village governments, community-based organisations, and civil society actors. From these participants, the study selected a purposive sample of key informants who possess relevant knowledge and experience regarding hydropower governance, watershed management, and the socio-economic impacts of the Batutegi project on surrounding communities. In total, the research conducted in-depth interviews with 29 informants from eight villages in Tanggamus and Pringsewu Regencies. These informants included officials from the Ministry of Environment and Forestry (KLHK), the Ministry of Public Works and Housing (PUPR) and the River Basin Agency (BBWS), the Watershed Management Agency (BPDAS), the Forest Management Unit (KPHL), the State Electricity Company (PLN), district and village governments, community leaders, and representatives of farmer and forest-farmer groups. The distribution of village-level informants is summarised in Table 1.

In addition, the study organised four semi-structured focus group discussions (FGDs) with a total of 17 participants drawn from affected villages, river fishing groups, irrigation managers, and local NGOs. Each FGD combined participants from two

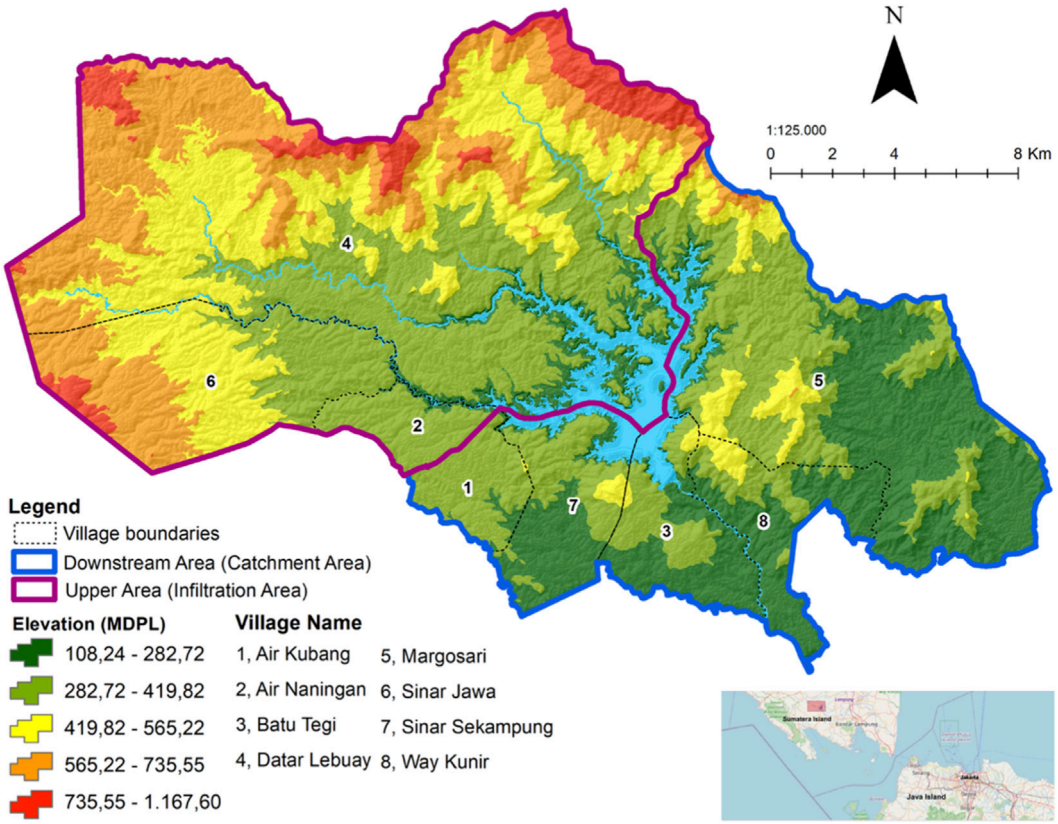

FIGURE 1
Map of research location.

TABLE 1 Number of informants by village.

No.	District	Village name	Number of informants
1	Tanggamus	Batutegi	9
2	Tanggamus	Sinar sekampung	3
3	Tanggamus	Air kubang	2
4	Tanggamus	Air naningan	2
5	Tanggamus	Sinar jawa	5
6	Tanggamus	Datar lebuay	5
7	Pringsewu	Way kunir	1
8	Pringsewu	Margosari	2
Total			29

neighbouring villages in the upstream catchment to capture shared and divergent perceptions of hydropower, watershed conservation, and local economic development. The composition of FGD participants by village is presented in Table 2. Informants and FGD participants were selected using purposive and snowball sampling, allowing the study to trace institutional linkages and inter-organisational relations across governance levels (macro, meso, and micro).

Data collection consisted of four complementary components.

1. A policy and document review of laws and regulations on hydropower development, water resources, spatial planning, social forestry, and village development (including statutory regulations, watershed management plans, and provincial/district planning documents);
2. Audio-recorded in-depth interviews with key stakeholders at macro, meso, and micro levels;
3. Semi-structured FGDs with community and intermediary actors to explore collective perceptions of rights, access, and benefit-sharing; and
4. Field observations of hydropower infrastructure, water and land access patterns, local economic activities (e.g. agroforestry, fisheries, micro-tourism), and environmental conditions such as vegetation cover and erosion control structures.

All interviews and FGDs were conducted using an interview guide aligned with the study objectives. With the consent of participants, the conversations were audio-recorded and transcribed verbatim. Field notes were compiled to document contextual information and informal interactions that took place outside formal interview settings.

Triangulation was conducted across data sources (interviews, FGDs, field observations, and policy documents) and across stakeholder groups to enhance credibility. FGDs and field observations functioned as confirmability checks by validating or challenging narratives emerging from individual interviews.

TABLE 2 Number of FGD participants.

No.	FGD activity	Village(s)	Number of participants
1	FGD 1	Air kubang and sinar sekampung	4
2	FGD 2	Sinar jawa and air naningan	4
3	FGD 3	Datar lebuay and batutegi	5
4	FGD 4	Way kunir and margosari	4
Total			17

Dependability was reinforced by presenting preliminary research findings in a public seminar, allowing external stakeholders to assess interpretive coherence and provide feedback. Together, these steps constitute the study's confirmability, credibility, and dependability procedures within a qualitative validation framework.

Data analysis was conducted using ATLAS.ti 21. Transcripts and field notes were subjected to an iterative process of open coding, categorisation, and theme development. First, segments of text were coded inductively to capture recurrent issues related to actor roles, rules-in-use, access to resources, benefit-sharing, and local governance practices. Second, related codes were grouped into higher-order categories that reflect key governance dimensions, such as boundary and position rules, decision-making and information rules, and payoff structures. Third, these categories were interpreted through the Institutional Analysis and Development (IAD) framework, which was used to map action arenas, multi-level actor networks, and rules-in-use across macro, meso, and micro levels. In parallel, a bundle of rights and access analysis was applied to examine how rights to access, withdrawal, management, exclusion, and transfer are distributed among actors, and how this distribution is translated into unequal economic benefits.

The results of this analytical process are presented in subsequent tables and figures, which synthesise patterns from the coded interview and FGD data, triangulated with policy and planning documents and field observations. These tables and figures therefore represent empirically derived governance configurations rather than purely theoretical illustrations. Together, they provide the basis for assessing spatial justice and institutional coherence in the economic governance of the Batutegi hydropower system.

Results

This study presents findings on how the sustainability of the Batutegi hydropower plant is determined by the configuration of cross-level governance in the upstream Way Sekampung watershed. Based on policy review, interviews, FGDs, and observations, the analysis focuses on four main aspects: (1) institutional mapping of macro, meso, and micro actors and their functional relationships; (2) rules-in-use (formal rules that do not work, and informal rules that do work), as well as coordination flows and points of overlapping authority; (3) bundle of rights that maps rights of access, withdrawal, management, exclusion, and final authority in protected forests, water catchment areas, and generation assets; and (4) local governance that explains the translation of mandates by village governments, farmer groups/*Gapoktan*, and forest farmer groups into conservation and rehabilitation practices, riparian protection, and coffee agroforestry and their impacts on discharge and sediment. The analysis focuses on determining how these empirical findings align with the IAD perspective, the bundle of rights/access theory, and the concept of spatial justice.

Action arena

The action arena is a space for interaction between actors, rules, and resources in the Batutegi hydropower plant management system. The action arena is understood as the intersection of formal rules, local practices, and resource systems that shape actual governance patterns in the field. In the Batutegi region, the action arena comprises the relationship between protected forest areas, reservoirs, and mixed agricultural land, which serve as sources of community livelihoods and support the hydropower plant ecosystem. The distribution of resource systems, resource use practices, and local governance arrangements illustrates how actors at various levels interact to maintain a balance between conservation, energy, and community welfare interests, as shown in Figure 2. In IAD terminology, this action arena refers to an action situation where actors, rules, and physical conditions intersect, such that outcomes (e.g., discharge stability, sediment levels, and distribution of economic benefits) must be viewed as products of interactions between these elements.

From the perspective of surrounding communities, the governance configuration of the Batutegi hydropower system produces mixed socio-economic outcomes. On the positive side, the dam and reservoir create new income opportunities through polyculture farming in the buffer zone, reservoir fisheries, small-scale tourism and trading activities at the docks, as well as more reliable water supply for irrigation in certain areas. As one woman who now runs a small stall near the dock recalled, "*This used to be our garden land before; it was taken as compensation for the project*" (MRA, Batutegi, interview), indicating both the loss of former farmland and the shift toward reservoir-based livelihoods.

At the same time, the project has generated significant negative consequences: several families were relocated and lost productive land and long-term asset-building opportunities—one villager explained that "*in 1982 we started to be relocated from the village below the dam up to Batutegi*" (LL, Batutegi, interview). After relocation, many upstream households still rely on their own

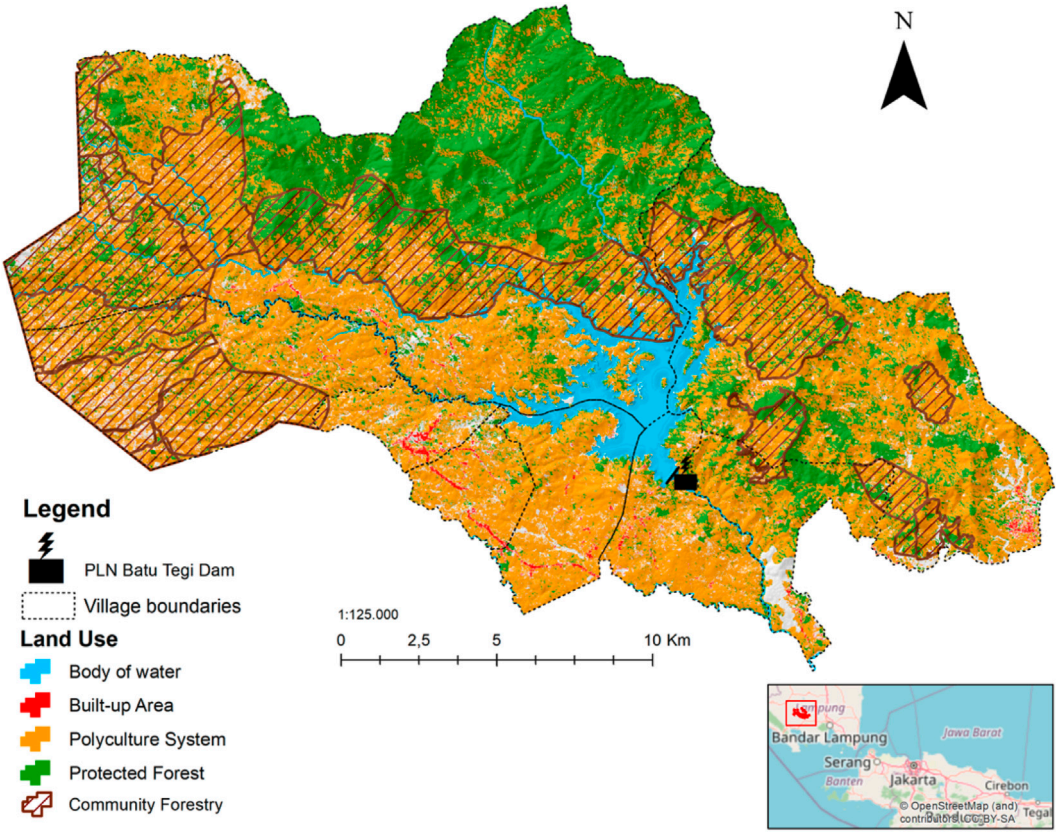

FIGURE 2
Map of action arena.

efforts to secure basic services; regarding drinking water, another interviewee noted that "*we have to carry it ourselves from the arboretum, using jerry cans*" (MRA, Batutegi, interview). Access to forests, the green belt and riparian zones is increasingly regulated through a mix of informal and formal rules. In Air Kubang, a hamlet head emphasized that "*there are no written rules, only verbal instructions. People can fish, but they are not allowed to use electric shock*" (HH, Air Kubang, interview), showing how local norms fill gaps in written regulation. Meanwhile, benefits from the hydropower operator are perceived as limited and uneven: a village leader observed that "*every year the hydropower company does provide some assistance, but it is for orphans and the very poor,*" and when asked about free electricity he stressed that "*we do not receive any free electricity from the hydropower plant; there are no free cables at all*" (BTR, Batutegi, interview). These contrasting impacts form the empirical basis for analysing how economic governance, rights and access are distributed among actors in the Batutegi hydropower territory.

Figure 2 illustrates the action arena, which explains the spatial relationship between resource systems, utilization practices, and local institutional rules in the upstream (catchment) area of the Batutegi reservoir. This area encompasses protected forest landscapes, water catchment areas, and mixed agricultural areas, all of which are managed by various actors at local to national levels. Land use patterns reveal the dominance of protected forests in the north and west, serving as the primary conservation zone that supports the ecological function of the reservoir. In contrast, the area surrounding the reservoir features agricultural land use, mixed gardens, and village settlements that directly interact with the reservoir system and hydropower plant.

Table 3 summarizes the three main action arenas (Community Forestry, Polyculture, and Protected Forest) and demonstrates the functional linkages between governance arrangements, practices, and resource systems within the IAD context. The HKm scheme serves as a formal channel for the legal community to access forest areas, where they are required to reforest and are prohibited from cutting large trees. This arena represents a form of co-management between the community and the state, linking formal regulations of the Ministry of Environment and Forestry (MoEF/KLHK) and the Protected Forest Management Unit (KPHL) with local practices. Meanwhile, the polyculture practice reflects community innovation in utilizing agricultural land around the reservoir to maintain productivity while supporting soil and water conservation. This practice demonstrates how informal community rules directly contribute to the sustainability of the reservoir's ecological system. However, formal institutional recognition and support are still limited, making this practice vulnerable to changes in policy and funding.

Furthermore, protected forests serve as an arena for action at the resource system level, providing ecosystem services essential for the sustainability of hydropower, such as water availability,

TABLE 3 Action arena in batutegi dam source governance.

Action arena	Function	Findings	IAD
Community forestry (HKm)	Community forestry is a legal framework that provides community access to forests, mandates reforestation areas, prohibits large-scale logging, and establishes local co-management mechanisms	To become a formal channel for legal access for communities in forest management	Governance arrangement (local GS)
Polyculture system (practice)	Implemented by farmer groups to increase productivity and promote soil conservation, it helps reduce erosion and water runoff	Polyculture practices help reduce erosion and water runoff	Practice (RU management)
Protected forest	A prime location for community forestry practices and community conservation activities, and provides ecosystem services for reservoirs and hydropower plants	Provider of ecosystem services (water flow, water quality, sedimentation) for reservoirs/hydropower plants	Resource system (RS)

erosion control, and environmental quality. This situation creates a policy trade-off between ecological protection and local economic needs; thus, forest management issues must be analyzed as a bundle of rights distribution that directly impacts socio-ecological outcomes. These three arenas demonstrate that the governance of the Batutegi hydropower plant is multi-level and hybrid, where the interaction between formal rules, local institutions, and collective community action shapes management decisions and practices. Therefore, spatial justice in the context of the Batutegi hydropower plant is primarily determined by the extent to which the integration of the resource system, resource use, and governance arrangements can create a balance between ecological conservation and the socio-economic sustainability of the surrounding community.

Qualitative findings in the action arena indicate that polyculture and conservation practices, as ecological indicators, result in reduced sedimentation or stable water discharge, which are strongly influenced by resource management practices in Batutegi, involving interactions between actors at various governance levels. To understand how these dynamics are regulated, mediated, and controlled by formal structures, mapping the multi-level institutional configuration that underpins the governance of the Batutegi hydropower plant becomes essential. This mapping illustrates the functional relationships between actors at national and village levels, demonstrating how policy mandates are translated into practice on the ground and how cross-sectoral coordination influences ecosystem performance and the distribution of economic benefits. The mapping process also reveals points of overlapping authority, differentiated access power, and incentive pathways that determine who benefits from, and who bears the burden of, conservation efforts.

Institutional mapping

The sustainability of the Batutegi hydropower plant is crucially determined by forest governance, as it serves as an ecological infrastructure that maintains flow regimes, water quality, and sediment control. Institutional mapping reveals that the supply of ecosystem services supporting the dam is influenced by hydropower operations and the complex interactions among actors that shape the rules, incentives, and field practices depicted in Appendix Figure A1.

Appendix Figure A1 illustrates the logic of multilevel governance: strategic policies are formulated at the macro level, institutionalized and coordinated at the meso level, and then implemented in practice at the micro level. The integrity of these relationships determines hydrological stability, environmental quality, and generation performance, so that the sustainability of the Batutegi Hydroelectric Power Plant is ultimately a function of the integration between these levels. The governance of the Batutegi Dam rests on the orchestration of complementary, cross-level actors. At the macro level, technical ministries, particularly the Ministry of Forestry, play a role in forest area management, water resource allocation, and dam supervision. The Ministry of Energy and Mineral Resources, together with the State Electricity Company, establishes policy direction, operational standards, and a licensing framework that serve as a reference for all hydroelectric power plant subsystems. The Ministry of Transportation, meanwhile, plays a role in directing the synchronization of hydroelectric power plant supporting infrastructure within the central government's domain. The macro level provides a regulatory horizon that determines incentives, constraints, and management priorities in the dam area.

At the meso level, policy translation and coordination functions are realized through the Forest Management Unit (KPH), the River Basin Agency (BBWS), the Watershed Management Agency (BPDAS), district governments, as well as multi-stakeholder forums and NGOs. These actors translate macro mandates into relevant operational plans and procedures on the ground, harmonizing watershed conservation, rehabilitation, and hydropower reservoir operational needs, and facilitating partnerships with local actors. Their role is both intermediary and policy cohesion, as it is through this synchronization of forestry, water resources, and energy sectors that consistent and sustainable programs can be realized. At the micro level, village governments, farmer groups, and farmer group associations (gapoktan) implement daily practices that directly impact the sustainability of dam buffer ecosystems, including riparian protection, rehabilitation, coffee agroforestry, and other cultivation systems that regulate erosion and surface runoff.

Overlapping authority arises primarily at the boundaries of space and function. First, the overlap between the management areas of protected forest areas (KPHL) and the domain of river basin offices creates uncertainty over who leads rehabilitation or erosion control in specific sub-watersheds. Second, regional licensing and spatial planning often conflict with forestry regimes, particularly

regarding access to infrastructure and the use of riparian areas. Third, the rehabilitation authority of the Regional Water Resources Management Agency (BPDAS) has the potential to overlap with KPHL and district programs, leading to duplication of activities. Fourth, reservoir operations and power generation, which fall under the authority of electricity operators, must be aligned with water allocation across needs, making daily coordination with river basin offices crucial. Misalignment of data and program schedules increases the risk of fragmentation.

Decision-making mechanisms operate through a combination of formal instruments and collaborative arenas. At the policy level, sectoral regulations and zoning provide a binding framework. At the meso-level, forest management plans (RPHJP/RKPHL), watershed management plans, and watershed forum decisions serve as vehicles for cross-actor synchronization. At the same time, local governments integrate these into planning documents. At the micro-level, Musrenbang and RKPDes translate priorities into village budgets and work agreements on the ground. Co-management practices, such as those in community forests and forest farmer groups, are supported by memoranda of understanding and operational guidelines. In contrast, reservoir and hydropower operations follow standard operating procedures (SOPs) that have been negotiated with river authorities.

Table 4 shows a cross-level institutional map (macro, meso, micro) that reconstructs the roles, functional relationships, field findings, and positions of each actor within the IAD framework. These findings confirm that the macro domain (Ministries: KLHK, ESDM, PUPR) provides the regulatory framework and technical mandate that determines access boundaries, water allocation priorities, and operational standards; the meso-domain (BPDAS, BBWS, KPHL, PLN, reservoir forum, NGOs) serves to translate the macro mandate into operational procedures, rehabilitation programs, and cross-sector coordination mechanisms; while the micro domain (pekon, gapoktan, KTH, HKm, agroforestry practices) is the arena for implementing conservation and resource management practices that directly affect flow regimes, erosion, and electricity generation performance.

The critical points of the research findings indicate that: (1) overlapping authority patterns, especially at the management boundaries between KPHL and river basin offices; (2) weakness of operational coordination channels (synchronization of water release schedules between BBWS-PLN); and (3) dependence of programs and compensation on sporadic interventions (CSR) so that economic benefits for local communities are unsustainable. From the IAD perspective, these three critical points represent failures at the regulatory level, collective arena, and reward mechanisms that together weaken collective management capacity and produce spatial injustice in the priority action arena (water allocation, rehabilitation, compensation/relocation), and the determination of policy recommendations that close the gap between formal mandates and local practices to improve spatial justice and the sustainability of hydropower operations.

The mapped institutional structure reveals the pattern of authority and coordination among actors; however, the effectiveness of Batutegi hydropower management is primarily determined by how these rules are implemented in practice. Therefore, the following section examines rules-in-use—the actual regulations that actually operate in the field, both formal and informal, and their implications for the clarity of authority boundaries, collective decision-making mechanisms, and the distribution of benefits between actors.

Rules-in-use and governance practices

The regulation of water and forest resource utilization that supports the operation of the Batutegi hydropower plant, including both formal written rules and local practices in place, as well as the governance consequences that arise from the interaction between these regulations. The focus is on key themes: clarity of boundaries and positions of authority, collective decision-making mechanisms, operational information flows, and incentive/compensation schemes. The analysis focuses on how the gap between rules-in-form and rules-in-use affects the adaptive capacity of upstream communities, the coherence of rehabilitation programs, and the distribution of economic benefits from the power plant's operations, as described in Table 5.

Table 5 presents the regulations governing the use of water and forest resources for the operation of the Batutegi Hydroelectric Power Plant. The use of these resources as an arena for action demonstrates overlapping authority patterns, such as issues with boundary and position rules: administrative and functional boundaries between units (KPHL vs. river basin offices) are not operationally defined, making it unclear who has the authority to make technical decisions and allocate resources for sub-watershed rehabilitation. This ambiguity is also felt at the village level. One village head underlined that "*this is not our asset, it belongs to the water resources office; the village has no authority even to legalise people's plots*" (RHT, Batutegi, interview). The consequences are program redundancies, budget leaks, and institutional conflicts that hamper preventive measures against erosion and sedimentation. Similar patterns of fragmented mandates and weakly coordinated river-basin management have been documented in comparative water governance studies, which show that unclear boundary and position rules reduce coordination and adaptive capacity in multi-level regimes.

Weaknesses in operational coordination channels, such as the failure to synchronize water release schedules between the BBWS and hydropower operators, indicate weaknesses in choice and aggregation rules, as well as in information rules. Daily technical decisions remain in the technical realm without a regular collective arena that integrates irrigation needs, generation, and domestic water availability. At the local level, information about the hydropower plant is channelled through a long chain from the dam operator to the village, then to hamlet heads and neighbourhood leaders. A hamlet head explained that the information he receives and passes on is "*usually only about assistance; apart from that, there is no other information*" (BTR, Batutegi, interview). Unpublished operational information (release schedules, discharge predictions) diminishes the ability of local users to plan economic activities, thereby reducing positive payoffs for local conservationists and weakening compliance with environmental regulations. Global reviews of hydropower governance similarly highlight how technocratic decision-making and limited disclosure of operational information undermine local preparedness and social legitimacy in dam-affected communities.

TABLE 4 Institutional mapping of multi-level actors in batutegi dam governance.

Level	Actor	Function and relationship	Key findings	IAD
Macro (national)	Ministry of environment and forestry (KLHK)	• Grants mandates to BPDAS and KPHL • KPHL regulates protected forest areas • BPDAS coordinates cross-sectoral efforts in watershed rehabilitation	• Provide a legal framework and conservation norms • Establish key guidelines for prohibiting high-crop logging; and • Establish guidelines for watershed rehabilitation	Governance system (policy)
	Ministry of energy and mineral resources (ESDM)	• Regulate and grant operating permits to PLN • Establish RUPTL policies; and • Coordinate the synchronization of water discharge and power plant operations with BBWS and PLN	• The issuance of licenses and the RUPTL policy serve as the main operational reference for the hydropower plant • The synchronization between electricity generation and irrigation demands remains weak	Governance system (policy)
	Ministry of public works and housing (PUPR)	• Granting the BBWS a mandate to regulate water operations and allocation by establishing operational and water allocation regulations • Establishing reservoir infrastructure regulations and becoming the institutionally authoritative owner of the dam	• The public perceives BBWS as the dam owner • Its policies favor irrigation	Governance system (policy/ Infrastructure owner)
Meso (technical/ Regional Institution)	BPDAS (watershed agency)	• Coordinating cross-sectoral efforts in watershed rehabilitation • Supporting villages and community groups through seedling and reforestation programs; and • Monitoring the implementation of conservation activities	• Rehabilitation programs are recorded, but follow-up monitoring varies between regions	Governance system (operational)
	BBWS mesuji–Sekampung (river basin agency)	• Regulate water release from dams • Coordinate reservoir operations with PLN, districts, and reservoir forums; and c Control cross-sectoral water governance	• Dam management decisions were made unilaterally • Daily coordination with the hydroelectric power plant operator and the village was not routine	Governance system (operational)
	KPH/KPHL batutegi	• Regulating protected forest areas • Enforcing regulations on spatial use and non-permanent access in the green belt; and • Facilitating forest farmer groups (KTH) and farmer associationsg(Gapoktan) in conservation activities	• Acting as a regulatory enforcer in the field • Limited human resource capacity within the KPHL • Needs intersectoral coordination support	Governance system (operational)
	State electricity company batutegi	• Operating the power plant • Coordinating with the BBWS, KPHL, and local governments; and • distributing CSR assistance to villages and community groups surrounding the reservoir	• CSR distribution and use are sporadic • Residents believe the direct electricity benefits to the village are limited	Public enterprise (operator)
	Reservoir community forum (FDTA/FDR)	• Serve as a multi-stakeholder collaboration platform connecting BBWS, PLN, and village communities • Mediate on reservoir environmental issues such as flood control and dock maintenance	Once active (handling kiambang/ pier) but now inactive	Collaborative/Intermediary arena
	LSM/NGO	• Facilitating conservation activities and group mentoring • Advocating for community rights to forest access (HKm); and bridging coordination between KPHL, village governments, and farmer groups	Involved in conservation outreach and group mentoring	Intermediary/Support

(Continued on following page)

TABLE 4 (*Continued*) Institutional mapping of multi-level actors in batutegi dam governance.

Level	Actor	Function and relationship	Key findings	IAD
Micro (local/Village)	Village government (pekon)	• Managing village administrative channels (village budget, village deliberations) • Channeling community proposals and aspirations to the meso-level; and • Mediating resource conflicts and managing village water	• Acting as a mediator • Regulating clean water management between villages • Submitting proposals and channeling community aspirations	Local governance
	Farmers' group union (gapoktan)	• Coordinating farmer groups at the village level • Aggregating needs and access to conservation programs; and • Implementing rehabilitation, check dam, and CSR activities	Serves as the main entry point for rehabilitation projects and conservation work	Users/Producers (collective)
	Agricultural farmers group (kelompok tani)	• Implementing polyculture practices and soil-water conservation activities • Coordinating with pekon and KPHL for the implementation of project-based programs	• Engage in land-based conservation projects • Practices are dependent on program support	Users (appropriators)
	Forest farmer groups (KTH)	• Managing community forests (HKm) in protected areas • Practicing coffee agroforestry and maintaining reservoir boundaries; and • Enforcing local anti-logging regulations	Key conservation actors in green belts and protected forest areas	Users/Co-producers

TABLE 5 Key findings of rules-in-use and governance practices.

Aspect	Core rules/practices	Governance practices
Formal rules (statutory and plans)	• Determination of protection forest by the ministry of environment and forestry • RPHJP/RKPHL documents; reservoir operating regulations by the ministry of public works and Housing/BBWS • Permits and RUPTL (energy and mineral resources)	• Formal regulations provide a legal and technical framework, but implementation on the ground is limited • Coordination between sectors is still lacking
Informal rules (practice and norms)	• "Mutual knowledge" practices in green belt access • Non-permanent fish and rice cultivation • Prohibition on electrocuting fish	• Community norms serve to maintain orderly access and conservation, but are not consistently recognized by formal institutions
Boundary rules (who may use what)	• Green belt access is non-permanent • HKm permits for KTH; exclusion by KPHL in the core zone of protected forests	• The boundaries of authority between agencies (KPHL–BBWS) and between the community and the state are often blurred, giving rise to access conflicts and overlapping programs
Position and authority rules	• Public works/Water resources management agency (PU/BBWS) as reservoir authorities • Ministry of environment and forestry/Forest management agency (KPHL) as forest managers • PLN as water users; and pekon as local implementers	• Authority is dispersed without a fixed coordination mechanism; the authority structure has not yet formed an integrated decision-making system across sectors
Choice and aggregation rules (decision-making)	• Decisions are made technically by the BBWS • The DAS/FDTA forum is not routine • Musrenbang is a channel for ad hoc proposals	• The collective decision-making arena is vacuumed • Decisions are top-down and do not accommodate operational needs at the grassroots level
Information rules (communication and reporting)	• Information on reservoir operations and CSR is not published regularly • The flow of information is predominantly one-way, from the pekon to the rukun tetangga (neighborhood association)	• Communication is not transparent, resulting in low community preparedness for changes in water discharge and program allocation
Payoff rules (incentives and sanctions)	• CSR and compensation programs are sporadic • There is no structured benefit-sharing mechanism	• Environmental incentives are not tied to conservation outcomes • Economic benefits are temporary and unsustainable
Participation and accountability assessment	• Community participation through Gapoktan and KTH is stronger in the implementation stage than in the planning stage	• Public accountability mechanisms are weak • Participatory forums are irregular and lack formal enforcement power

Reliance on CSR and sporadic interventions cuts to the heart of payoff rules: incentives are temporary, not tied to measurable conservation outcomes, and do not create long-term rights or compensation for upstream communities. These dynamics are experienced unevenly across villages. *In Batutegi, the village head recalled that CSR support from the hydropower company used to be relatively routine, ranging from assistance for public facilities and religious infrastructure to annual donations for orphans—but has become more limited after changes in corporate management* (RHT, Batutegi, interview). In contrast, the head of Air Kubang reported that "*for our village there has never been any direct program or assistance from the hydropower company; until now there is no cooperation at all*" (KD of Air Kubang, interview). Village leaders in Batutegi also noted that limited quotas for CSR recipients "*often create social tensions"* when only a few households are selected from a larger pool of eligible poor families (BTR, Batutegi, interview). Without precise and conditional benefit-sharing mechanisms, collective behaviors that support ecosystem services (such as planting and maintaining boundaries) are less economically viable, fostering a fragile equilibrium in which communities bear the costs of conservation. In contrast, structural benefits—such as electricity and a steady income stream—accrue primarily to other actors. Comparative research on hydropower benefit-sharing shows that similar ad hoc compensation and CSR schemes frequently generate perceptions of unfairness and conflict rather than long-term legitimacy.

Alongside statutory regulations, communities rely on informal rules and norms to govern everyday resource use. In Air Kubang, the hamlet head explained that people are allowed to fish in the reservoir "*as long as they do not use electric shock or poison*," and that "*there are no written rules, only verbal instructions*" relayed by extension officers and the village government (KD, Air Kubang, interview). These rules-in-use help maintain order and basic conservation in the green belt, but they are seldom acknowledged in formal documents or integrated into official watershed plans. This resonates with broader water governance literature indicating that informal institutions can effectively regulate access and cooperation in the short term, yet remain vulnerable when they are not supported or recognized by formal authorities.

Meanwhile, local participatory forums that once mediated relations between communities and the dam operator have weakened over time. A hamlet head in Air Kubang recounted that around 2015–2016 a "*reservoir community forum" involving six villages was formed to protect catchment and recharge areas and to develop activities such as using aquatic weeds (kiambang) for organic fertilizer; this forum later became inactive ("mati suri") after leadership changes in the water resources agency* (KaD, Air Kubang, interview). Similarly, residents in Batutegi reported that they have "*never received training or extension activities from the dam or hydropower company*" and that there is "no cooperation for joint management" of the reservoir (RT, Batutegi, interview). These accounts illustrate how the erosion of collective arenas for decision-making and learning further weakens the implementation of choice and aggregation rules on the ground.

The findings reveal a gap between formal rules and actual practice, with formal institutions retaining structural benefits, while local communities receive temporary or unsustainable benefits. This pattern parallels evidence from other hydropower and river-basin cases in the Global South, where misaligned rules-in-form and rules-in-use contribute to institutional fragmentation, weak accountability, and limited adaptive capacity. To improve governance coherence and support the sustainability of hydropower, the findings emphasize the urgent need to: clarify boundary and position rules (operational clarification is needed); strengthen routine and inclusive operational decision-making arenas (the function of collective forums is weakened/inconsistent); ensure transparent operational information flows (schedule publication practices are inconsistent); and design payoff rules that link compensation to measurable conservation indicators (a shift from formal schemes to ad hoc CSR is evident).

The gap between formal rules and actual practices, as outlined in the previous section, raises fundamental questions about how resource rights are distributed and who benefits from the hydropower system. To address these questions, the following section examines the structure of the bundle of rights as a basis for analyzing spatial justice in Batutegi's resource governance. This approach enables a more nuanced understanding of the relationships of power, access, and benefits among actors within a multi-level institutional system.

Bundle of rights as a basis for spatial justice

The analysis of the bundle of rights in this draws on the concept of resource ownership rights as formulated by Ostrom (2015) and integrates the access theory of Ribot and Peluso (2003), which emphasizes that the ability of actors to obtain benefits from resources is determined by a combination of formal rights, power relations, social networks, and institutional legitimacy. This perspective is further expanded by Sikor and Lund (2009), who demonstrate that access and rights are continually negotiated within the context of state power and local practices. In relation to spatial justice, this framework is linked to the views of Soja (2015) and Sjaf et al. (2025) that the distribution of rights and benefits over space is a key dimension of social justice, thus, the bundle of rights serves as an analytical bridge to assess the extent to which the governance of the Batutegi hydropower plant reflects spatial justice between actors and between institutional levels.

The research findings show that formal rights (rules-in-form) regulated by the Ministry of Environment and Forestry (KLHK), the Ministry of Public Works and Housing (PUPR), and the State Electricity Company (PLN)/Ministry of Energy and Mineral Resources (ESDM) place greater emphasis on institutional control, technical regulations, and strategic infrastructure interests. In contrast, local communities hold only limited operational rights, such as restricted access and utilization, without guarantees of ownership, management, or the sustainable transfer of rights. This gap highlights the asymmetry of power and economics: upstream communities play a crucial role in maintaining ecosystem sustainability through agroforestry, reforestation, and soil-water conservation practices, yet receive only small-scale, temporary economic benefits, dependent on sporadic project or CSR programs.

In contrast, formal institutions gain structural benefits in the form of control over electricity, institutional revenues, and infrastructure projects. In other words, "who gets what," "where,"

TABLE 6 Bundle of rights and distribution of economic benefits of the batutegi hydroelectric power plant.

Bundle of rights	Findings	Distribution of economic benefits
Right of access	• Access to the reservoir and green belt areas is limited and transient • Many residents still rely on traditional access methods without formal permits	• Economic benefits are local and small-scale (fisheries, micro-tourism) • Downstream villages and relocated communities lose direct access to resources
Right of withdrawal	• Residents harvest fish, intercrop, and produce biomass, but are restricted by PU/KPHL regulations • Organized groups have easier access to programs	• Farmers with access to polyculture earn significant income, but the distribution is uneven • Relocated families lose physical assets and use rights
Right of management	• Gapoktan and KTH initiated conservation management (cek-dam, reforestation), but without formal authority	• Active groups benefit from projects and capacity building, while remote areas are rarely involved • Multistakeholder forums are weakened
Right of exclusion	• KPHL/PU establishes logging bans and protected zones • Communities also enforce local bans (e.g., electrocuting fish)	• Formal authorities wield exclusionary control and institutional benefits • Residents lose out on economic opportunities (e.g., tourism development) due to rigid registration boundaries
Right of alienation	• There are no formal ownership rights to registered/green belt land • Only informal use rights and crop transactions	• The lack of ownership transfer rights hinders asset accumulation and access to capital • Relocated families do not receive adequate compensation, leading to intergenerational economic disadvantage

and "how" are heavily influenced by the actors' positions within these rights structures. Differences in the levels of rights and economic benefits between actors in the Batutegi hydropower project governance are presented in Table 6.

Table 6 illustrates how the distribution of resource rights (a bundle of rights) underlies spatial inequality around the Batutegi Hydroelectric Power Plant. The analysis reveals that the formal rules governing area boundaries, access permits, and the authority of state institutions are not fully aligned with the rules-in-use (actual practices) of the community. Residents' rights to access and utilize water resources and forest land are informal and non-permanent. In contrast, management and decision-making rights remain monopolized by formal institutions such as the BBWS, KPHL, and PLN. This situation results in the distribution of economic benefits from the hydroelectric power plant, such as electricity, projects, and compensation, being enjoyed primarily by institutional actors. At the same time, local communities only receive temporary benefits through intercropping, reforestation projects, or unsustainable CSR activities. This imbalance between formal rights and local practices suggests that spatial equity has not been achieved, as the contribution of upstream communities to ecosystem services is not adequately compensated for with economic rights and institutional recognition, as illustrated in Figure 3.

Figure 3 illustrates the configuration of relationships between actors within the bundle of rights structure that shapes the distribution of rights and benefits in the Batutegi hydropower system. The color scheme indicates the connections between institutions (PLN/ESDM, BBWS/PUPR, KPHL/KLHK, Gapoktan/KTH, Village Government, and Local Residents) and the five main rights categories (access, utilization, management, exclusion, and transfer). The thickness of the scheme indicates the intensity and dominance of actors over each type of right.

The multilevel actor analysis results show that three state institutions (PLN/ESDM, BBWS/PUPR, and KPHL/KLHK) dominate management, exclusion, and partial withdrawal rights, indicating that formal control over water resources and protected areas rests with technocratic institutions operating within a national regulatory framework. In contrast, local community groups, Gapoktan/KTH, and village governments have more limited access rights and a smaller portion of withdrawal rights, indicating their indirect role as users without strong institutional rights.

The limited pathway to alienation signifies the absence of ownership and transfer rights throughout the hydropower system, for both local actors and formal institutions. This emphasizes that all parties operate within the context of a public resource (state property regime), but with an unequal distribution of power. This relationship demonstrates overlapping authority between agencies, particularly between BBWS/PUPR and KPHL/KLHK, in terms of management and exclusion. This overlap weakens governance effectiveness and creates an institutional gray zone often filled with informal community rules. In this context, spatial justice depends on both the distribution of economic benefits and the recognition of local practices and operational rights exercised by communities.

Spatial justice in the Batutegi hydropower plant is relational and multi-level: (1) the state dominates structural rights and economic benefits; (2) local communities play a role in maintaining ecological functions without adequate institutional recognition; and (3) intermediary institutions such as Gapoktan and village governments act as fragile bridges between formal rules and local practices. This situation reflects that control and benefits are shaped by formal ownership and by the ability of actors to utilize networks, capital, and social legitimacy to access resources. Thus, the unequal bundle of rights is not simply a legal or formal issue, but rather the result of power relations inherent in the multi-level governance system. Taken together, these results form the basis of the conceptual framework presented in the Appendix, which integrates the IAD framework, bundle of rights, and spatial justice to explain how hydropower governance in Batutegi generates unequal, yet potentially transformable, socio-economic outcomes.

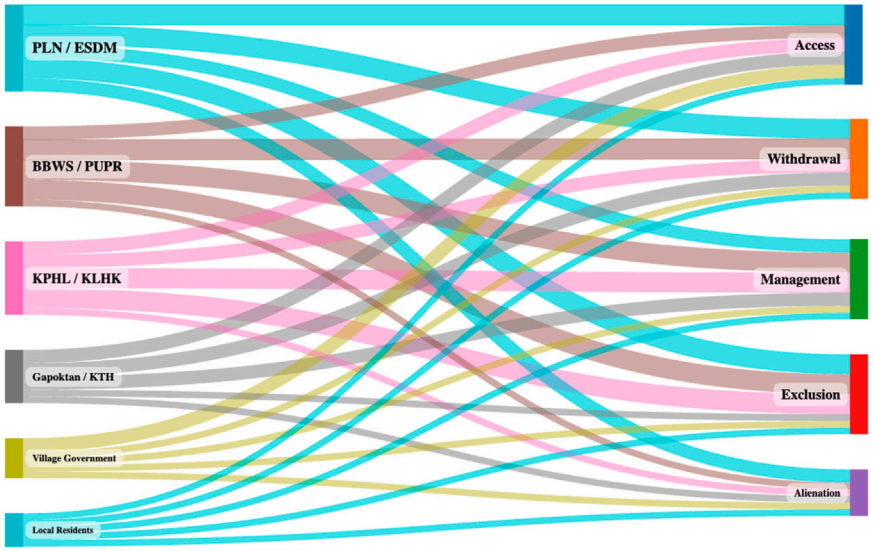

FIGURE 3
Bundle of rights and distribution of economic benefits in batutegi hydropower governance.

Local capacity and self-governance

Local Capacity and Self-Governance focuses on village-level actors who effectively carry out ecological and economic management functions in the Batutegi upstream, including the village government as an administrative and mediating actor; Gapoktan/KTH as implementers of conservation practices; and PDAM/PAMSIMAS, NGOs, MSMEs, and cooperation volunteer networks as supporting institutions. Table 5 summarizes the resource capacities (organizational, technical, and social capital) and the emerging self-governance practices (such as gotong royong, border patrols, check dams, and dock management), supported by field evidence that illustrates how these arrangements operate in practice. While local capacity is strong at the implementation level, formal legitimacy, access to sustainable funding, and representation in strategic decision-making arenas remain limited, which influences the extent to which local contributions can be translated into economic benefits and ecosystem resilience. The functional roles outlined in Table 7 provide the basis for designing policy interventions that better connect micro-level community practices with meso- and macro-level governance structures.

Table 7 illustrates the central and diverse roles of local institutions within the Batutegi Dam catchment action arena, where the village government serves as the formal channel—managing proposals, mediation, and implementation of village projects, while Gapoktan and KTH act as technical drivers of conservation (check dams, gabions, reforestation) and intermediaries for program access and CSR; village water units (PDAM/PAMSIMAS) provide operational water supply capabilities crucial for local resilience; the reservoir community forum was once a collective arena but has since weakened; NGOs supply technical expertise and participatory facilitation; microeconomic actors (dock traders) and mutual assistance volunteers provide livelihood mechanisms and labor for implementing conservation activities. Evidence from transcripts, FGDs, and field notes confirms that local capacity is strong for implementation and collective solidarity. Still, it often lacks formal legitimacy, access to sustainable funding, and representation in decision-making arenas. This combination makes local contributions crucial yet vulnerable to being translated into long-term economic benefits.

Discussion

The research findings show that the Batutegi hydropower plant in Lampung Province reflects the complexity of relationships between cross-level actors operating within overlapping institutional frameworks. Although formal rules (rules-in-form)—such as the designation of protected forest areas, RPHJP/RKPHL, BBWS SOPs, and the ESDM licensing framework—are normatively available, their implementation in the field is adaptive, selective, and not always aligned with the formal regulatory framework (Williams, 2020; Wu et al., 2021). This lack of synchronicity appears most clearly in three mutually reinforcing areas: (1) unclear boundaries and position rules between technical institutions such as KPHL and river basin offices; (2) weak collective decision-making mechanisms and operational information flows (choice/aggregation and information rules), especially regarding the publication of water release schedules; and (3) incentives that are more ad hoc (CSR) than binding and results-based payoff mechanisms (Bazzana et al., 2020; Polanco et al., 2023).

These institutional challenges reduce collective capacity to manage erosion, sedimentation, and the fair distribution of benefits. This reinforces Ostrom's (2011) argument that institutional effectiveness depends on both regulatory strength and the congruence between formal rules and social practices in the action arena (Mayer et al., 2021; 2023; McIntyre, 2023). In Batutegi, this incongruity results in institutional dualism: informal

TABLE 7 The role of local institutions in the action arena.

Local institutions	Action arena		Analytical justification
	Local capacity	Self-governance practices	
Village government	• Having administrative access through the village budget (APBDes) and program proposal space; basic organizational capacity; and local communication media such as meetings and bulletin boards	• Mediating community requests at the meso/macro level • Initiating well drilling, community dredging projects, and submitting program proposals • Occasionally establishing village regulations regarding resource management	• The role of villages tends to be reactive to programs from above • There is no permanent institution for integrating conservation into village planning • Spontaneous initiatives demonstrate the adaptive capacity of communities
Gapoktan/Farmers' group union	• Having a collective organizational structure, access to training and project tools, and substantial social capital among members	• Aggregating equipment and seed requirements; implementing conservation activities (chelistack dams, gabions); and acting as an intermediary for the company's CSR implementation	• Gapoktan serves as a bridge between technical institutions and farmers, but remains dependent on external projects. Its continued role depends on continued support
Kelompok tani/KTH (forest farmer groups)	Have technical knowledge in agroforestry practices, HKm (social forestry) based legitimacy, and reforestation implementation capabilities	• Implementing co-management in border areas • Implementing polyculture system practices	• KTH demonstrates the strongest collective capacity for forest protection • Weak economic incentives and uncertain access rights hinder long-term institutional strengthening
PDAM/PAMSIMAS/ Village water unit	• Have basic technical expertise in the provision and distribution of clean water	• Managing community water resources • Regulating supply rotations; improving basic water infrastructure	• Village water units demonstrate successful self-provisioning; however, they lack connectivity to macro hydropower water governance
Reservoir community forum (FDTA/FDR)	• Potential to become a multi-actor coordination arena • Has a cross-institutional network, but it is currently weakened	• They have been active in the kiambang and pier issues • They have a historical collaborative MoU	• The FDTA/FDR has become a symbol of a collaborative arena that has failed to sustain itself; the lack of institutional support has led to the forum's stagnation
Civil society organizations/NGOs	• Have technical capacity for conservation, advocacy, and access to external grants	• Facilitate training, participatory research, and environmental compensation advocacy • Serve as a mediator between residents and formal institutions	• NGOs play a catalytic role, but their presence is sporadic and dependent on donor projects; long-term structural collaboration has not yet been established
MSME group/Dock traders	• Micro-enterprise capital and dependence on reservoir activity for the local economy	• Providing transportation, fishing, and small-scale tourism services • Managing community dock facilities	• Their economic activities are vulnerable to regional regulations and fluctuations in access; there are no policies yet that integrate microeconomics into hydropower management
Volunteers/Community mutual cooperation	• Collective work capacity based on local solidarity • Mobilization of volunteer labor for environmental activities	• Carrying out riverbank cleaning, building gabions, and simple reforestation	• It is the moral and social foundation of local self-governance, but is less formally recognized in conservation policy

social norms, such as mutual recognition arrangements practiced in the green belt, function as coordination mechanisms that compensate for limited formal oversight (Soukhaphon et al., 2021).

At the macro level, central institutions such as KLHK, PUPR, and PLN maintain authority over policy direction, licensing, and water resource allocation (Rospriandana et al., 2023). However, at the implementation level, most ecological management responsibilities fall on village governments, forest farmer groups (KTH), and farmer group associations (Gapoktan). Although these local institutions play a critical role in sustaining reservoir buffer ecosystems, their contributions are rarely acknowledged in formal decision-making, and they have limited access to sustained funding (Qurani and Adnan, 2023; Rahayu et al., 2022). This situation illustrates a governance paradox: while hydropower development is normatively based on cross-sector coordination and community participation, it remains empirically dominated by central institutions with limited space for community involvement (Aung et al., 2021; Didik et al., 2018; Hidayat, 2006). As a result, the institutional effectiveness of the Batutegi hydropower plant is shaped more by power relations among actors than by formal regulatory design (Schulz and Skinner, 2022; Wu et al., 2021).

These findings can be further interpreted through the IAD approach, which provides a systematic lens to examine how decision-making authority is distributed across governance levels (Ostrom, 2009; Ostrom, 2014; Ostrom, 2015). The analysis shows that the macro-level action arena (ministries and national institutions) focuses primarily on regulatory arrangements and licensing frameworks. At the meso-level (BPDAS, KPHL, BBWS, and PLN), operational negotiations take place to translate these mandates into practical applications on the ground. Meanwhile, the micro-level action arena reflects an adaptive dynamic between formal compliance and community autonomy, where self-governance practices are grounded in social solidarity and ecological knowledge. This dynamic is evident, for example, in the green belt area, where community monitoring of land clearing and mutual agreements on planting patterns are

maintained informally, even though these activities are not explicitly integrated into official watershed management protocols. Such practices illustrate what Ostrom (2014) refers to as institutional layering, in which formal and informal governance systems coexist but do not directly reinforce one another.

The integration of bundle of rights analysis broadens the understanding of this gap by highlighting how the distribution of rights determines the structure of economic benefits and spatial equity. In the Batutegi context, rights to natural resources are distributed hierarchically: state institutions and corporations hold management, exclusion, and alienation rights, while local communities only have temporary and informal access and withdrawal rights. This situation demonstrates the difference between "having rights" and "having access," as explained by Ribot and Peluso (2003), where the ability to obtain benefits is primarily determined by social capital, networks, and institutional legitimacy, not simply legal claims.

This situation exemplifies a form of spatial injustice, specifically the inequality in access to and benefits from resources that is determined by institutional positions and power structures. As stated by Soja (2015) and expanded by Sjaf et al. (2025), space is not simply a vehicle for economic activity, but also a political arena that determines who has the right to access development benefits. In the Batutegi context, spatial justice is reflected in the subordination of upstream communities to formal authorities that control resources and economic distribution across regions.

A significant contribution of this research is its emphasis on the bundle of rights as a tool for analyzing spatial justice in energy governance. By using the perspective of Ostrom (2014), This research demonstrates how the distribution of institutional rights creates an asymmetric economic structure, where formal actors obtain structural benefits, such as institutional income and policy legitimacy.

The consequences of this unequal rights structure include social injustice and a loss of collective incentives to maintain ecosystem sustainability. Without a conservation-based benefit-sharing mechanism, local community behavior will shift toward short-term survival strategies, such as expanding intercropping into protected areas or increasing water resource exploitation. Thus, spatial equity represents both an ethical value and a functional prerequisite for the technical sustainability of hydropower.

From the perspective of energy policy legitimacy, spatial justice emerges as both a normative and instrumental component of energy policy. Normative, because the recognition of rights and the fair distribution of benefits are ethical demands for projects that utilize community living spaces and resources; instrumental, because the legitimacy built through spatial justice strengthens compliance, reduces conflict, and increases the operational sustainability of hydropower plants. In other words, without precise benefit-sharing mechanisms and participatory access to decision-making, energy policies oriented toward energy source substitution or technical efficiency risk socio-political failure. These findings strengthen the argument that energy policy design should incorporate redistributive and participatory elements as early as possible, rather than as add-ons after the construction or commercialization of the power plant.

The legitimacy of spatial justice-based energy policies is essential because it has two dimensions: normatively, through the recognition of the rights and contributions of local communities as an ethical requirement for public projects; and instrumentally, through increased institutional effectiveness, trust, and social participation. Spatial justice-based policy legitimacy can align with the relatively strong local institutional capacity around the Batutegi hydropower plant in terms of technical conservation implementation, but is weak in terms of formal legitimacy and political representation. The village government, Gapoktan (Farmer Group), and KTH (Farmers Group) have the adaptive capacity to manage natural resources through co-management practices that rely on social norms and cooperation. However, the absence of formal recognition prevents their contributions from being integrated into the national energy policy or watershed management framework.

This phenomenon emphasizes the importance of self-governance as a basis for ecological sustainability. As explained by Ostrom (2015), local communities that have control over resources tend to be more compliant with conservation regulations due to their sense of ownership. In Batutegi, forms of self-governance are evident in cooperation mechanisms for riverbank maintenance, village water management, and informal oversight of illegal practices such as logging and electrofishing. However, without financial support and legal recognition, these mechanisms are fragile and not integrated into the national energy governance system.

The scientific novelty of this research lies in the integration of formal institutional analysis and local self-governance capacity in the context of the energy transition. Previous studies in Indonesia tend to separate energy issues from village social dynamics. This research, however, emphasizes that the sustainability of renewable energy sources such as hydropower cannot be separated from the ability of local communities to manage their ecological space. In other words, the success of hydropower is not only a matter of "green technology," but also of institutional equity and village empowerment.

Cross-country evidence further supports these observations. In Norway, the polycentric governance system encourages energy–environment coordination through equitable revenue sharing between central and regional governments, where water, environmental, and energy authorities operate across multiple administrative levels under strong intergovernmental coordination (Lindström and Ruud, 2017). This approach enables better alignment between energy policy and upstream ecosystem conservation, while creating a fair revenue-sharing mechanism among central and regional governments, as well as local communities.

In Brazil, particularly in the Amazon region, Mayer et al. (2023) demonstrate that large-scale hydropower projects often trigger social tensions due to ineffective compensation schemes and the limited participation of affected communities. However, post-2015 institutional reforms introduced a territorial governance model that includes indigenous communities and smallholder farmers within the decision-making structure. This inclusion has strengthened the social legitimacy of hydropower projects and contributed to reducing land-related conflicts.

Meanwhile, in Colombia, Polanco and Inchima (2024) describes the successful management of post-conflict hydropower through the establishment of water governance regimes that facilitate

collaboration between the government, energy operators, and local communities. This mechanism mitigates resource conflicts and expands expands community access to economic benefits through payment for ecosystem services programs.

These three cases offer essential lessons for Indonesia. First, polycentric governance can be an ideal model for addressing institutional fragmentation in the hydropower sector. Second, spatial equity requires transparent and measurable benefit-sharing mechanisms. Third, the social legitimacy of energy projects depends heavily on the active involvement of local communities in planning, monitoring, and decision-making. Therefore, Indonesia can adapt good practices from other countries to strengthen its national institutional framework, without neglecting the local social and ecological context.

Comparative lessons from countries that have already integrated spatial equity into energy governance demonstrate that success is not simply a matter of PES technical design or multi-actor forums, but of long-term institutional integration between accountability, transparency and participation mechanisms. In the case of the Batutegi hydropower plant, these insights indicate that any future reform package will need to align benefit-sharing, authority clarification, operational coordination and local institutional recognition; the detailed operational steps for such a package are elaborated in the Conclusions and Recommendations section. However, the underlying principle remains that economic incentives must balance the burden of conservation so that upstream communities receive long-term benefits, not just wage labour or short-term assistance.

Finally, it is essential to note that partial interventions risk ineffectiveness: improving information flows without clarifying authority will raise expectations without providing mechanisms for redress; introducing PES schemes without strengthening local capacity and legal legitimacy can trigger a scramble for benefits that undermines solidarity (Izquierdo-Tort et al., 2024; Le et al., 2024). Therefore, the proposed recommendations should be treated as a coordinated policy package, clarifying authority, establishing operational coordination platforms, establishing information systems, establishing benefit-sharing mechanisms, and recognizing and enhancing local institutional capacity. This will enable the Batutegi hydropower plant to function as both an energy source and an instrument of equitable and sustainable development for upstream communities. Implementing this package will enhance the legitimacy of energy policy, reduce institutional conflict, and strengthen the reciprocal relationship between the plant's technical performance and the health of its supporting ecosystem.

Conclusion

This research confirms that the economic and socio-ecological sustainability of hydropower in Indonesia, as demonstrated through the Batutegi case, is determined by a combination of technical efficiency, the effectiveness of institutional coordination, and spatial equity in the distribution of rights and benefits. By integrating the Institutional Analysis and Development (IAD) approach and the bundle of rights–access theory framework, this research provides new conceptual and empirical contributions in explaining the relationship between energy governance, institutional power structures, and the adaptive capacity of local communities.

Key findings suggest that the gap between formal rules and actual use is a significant source of institutional fragmentation and weak coordination among actors. Meanwhile, the unequal distribution of rights—where formal institutions control management and transfer rights, while local communities only have limited access and utilization rights—reinforces forms of spatial injustice around hydropower plants. In this context, local communities play a crucial role in maintaining ecosystem sustainability through forest conservation, reforestation, and agroforestry management, yet they are denied proportional economic rights and institutional recognition. The results of this study reinforce the argument that the sustainability of hydropower plants cannot be separated from the principle of institutional justice, specifically the extent to which the distribution of rights, access, and authority is equitable among resource management actors. The Batutegi case thus illustrates that energy transition projects can reproduce existing inequalities if institutional arrangements are not explicitly designed to recognise local contributions and redistribute benefits.

Practically, the study points to several priority directions for policy reform. First, central and regional agencies (KLHK, PUPR/BBWS, ESDM/PLN, BPDAS and KPHL) should jointly clarify and remap their mandates in each sub-watershed, for example through a co-signed authority map that specifies who is responsible for rehabilitation, erosion control and reservoir operation; this will reduce duplication and close grey areas of responsibility. Second, these agencies together with district governments need to institutionalise a regular operational coordination forum in which hydropower operation, water allocation and rehabilitation priorities are discussed with village governments, Gapoktan and KTH as represented stakeholders; such a forum should have clear agendas, documented minutes and publicly accessible summaries. Third, PLN, BBWS and local governments should develop a simple ecosystem performance-based benefit-sharing scheme—such as payments or conditional grants linked to reforestation, sediment reduction or riparian protection—that channels predictable rewards to upstream communities that maintain ecosystem services. Fourth, formal instruments (MoUs, inclusion of local groups in RPHJP/RKPHL and village regulations) are required to legally recognise the role of village institutions, Gapoktan and KTH, and to open their access to long-term funding for conservation and local economic initiatives. These recommendations assign clear responsibilities to state agencies and outline how more accountable, transparent and participatory hydropower governance can be implemented in practice.

Further research can be directed toward developing adaptive institutional models that integrate ecological big data (e.g., watershed, sedimentation, and vegetation data) with village-based social monitoring systems. Integrating precision data technology and local institutional capacity will open up opportunities for more responsive, participatory, and socially just hydropower governance. Comparative studies across different hydropower basins and energy projects in Indonesia and the Global South would also help to refine and test the analytical framework proposed in this article. Thus, hydropower will become both a symbol of the green energy transition and a tangible instrument for sustainable and inclusive village development.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical approval was not required for the studies involving humans because This study did not require formal Ethics Committee approval according to the national regulations, as it involved minimal risk and no personal sensitive data. Nevertheless, informed consent was obtained from all participants, confidentiality was assured, and the study adhered to ethical standards for research involving human participants. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

ES: Conceptualization, Formal Analysis, Investigation, Writing – original draft, Writing – review and editing. DN: Data curation, Formal Analysis, Supervision, Validation, Writing – review and editing. AH: Data curation, Formal Analysis, Supervision, Writing – review and editing. SS: Conceptualization, Data curation, Formal Analysis, Methodology, Supervision, Writing – review and editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. Generative AI tools were used only for language editing and clarity improvements. No AI-generated content, data, analysis, or interpretations were included. The authors take full responsibility for the scientific accuracy and integrity of this manuscript.

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Appendix A

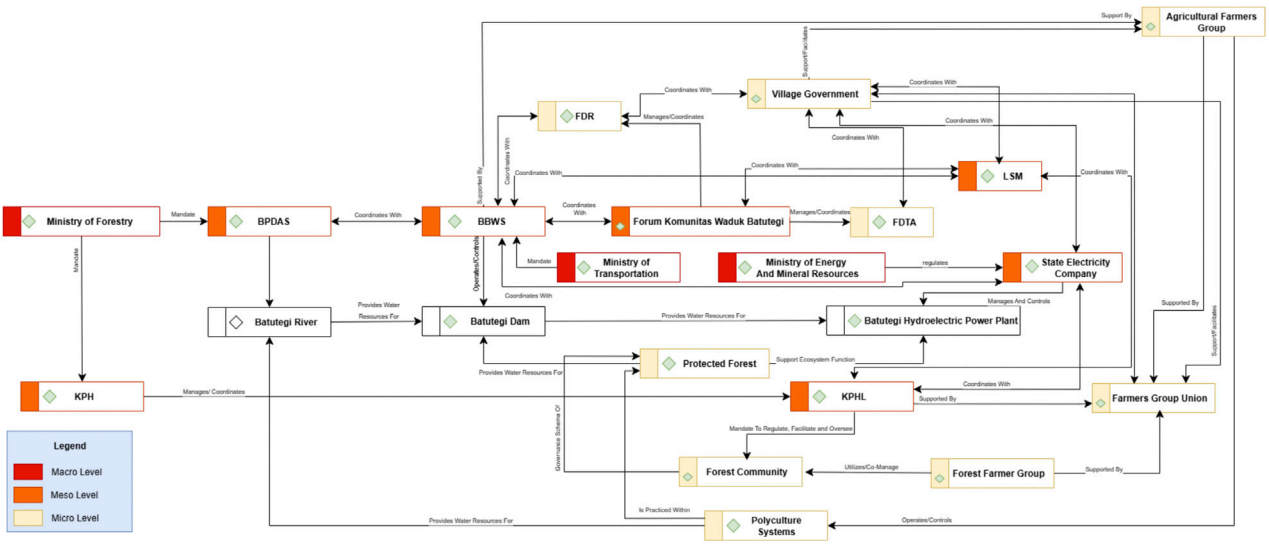

FIGURE A1
Multi-level network of actors in batutegi dam governance.