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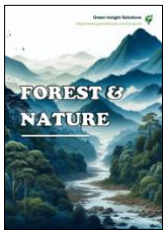

RESEARCH ARTICLE

Integration of Local Knowledge and Adaptive Practices in Small-Island Water Governance: An Ethnohydrological Study of Negeri Soya, Ambon, Indonesia

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ABSTRACT

Water resource sustainability in tropical small-island environments is increasingly challenged by ecological degradation, seasonal variability, and limited infrastructure, particularly in areas where springs serve as the primary freshwater source. In customary forest landscapes, water governance is embedded in local knowledge systems, ritual practices, and community institutions that regulate resource use while supporting ecosystem conservation. This study examines how local knowledge, customary institutions, and adaptive practices contribute to spring conservation and community-based water governance in Negeri Soya, Ambon, Indonesia. Employing a convergent mixed-method approach, the research combines ethnographic techniques—comprising in-depth interviews, participant observation, and visual documentation—with quantitative analysis using the Chi-square test. The findings reveal that water governance is structured through a culturally embedded system in which ritual practices, traditional artifacts, and hierarchical customary institutions collectively regulate access, maintain water quality, and support spring conservation. Quantitative results indicate that customary sanctions and temporary access restrictions are the most influential mechanisms in ensuring compliance under ecological and social pressures, while deliberation and knowledge transmission contribute to long-term system resilience. The study also identifies the role of simple monitoring tools, such as manual flow observation and recording, in strengthening adaptive responses to seasonal variability. Furthermore, artifacts such as *Perigi Soya*, *Tempayan Soya*, and communal storage facilities function not only as physical infrastructure but also as socio-ecological interfaces reinforcing governance legitimacy. The results demonstrate that water management in Negeri Soya operates as a multi-layered socio-ecological system integrating ecological signals with socially legitimate decision-making processes. This research contributes to the advancement of ethnohydrology by providing empirical evidence of how culturally embedded practices and low-cost technologies can support sustainable, community-based water governance in vulnerable small-island environments.

1. Introduction

Negeri Soya in Ambon, Indonesia, represents a distinctive case of a customary community in a small-island forest landscape where water management is closely linked to local knowledge, ritual practices, and traditional institutions. The community relies on spring-based water systems that are regulated by customary norms, collective decision-making, and cultural practices, including ritual activities and the use of traditional artifacts. These practices are embedded in indigenous governance systems, where resource management is shaped by local wisdom, customary law, and participatory institutional arrangements that reinforce sustainability and collective stewardship (Zulfiani et al., 2025).

This study aims to address the identified research gap by examining the ethnohydrological system in Negeri Soya through three main objectives. First, the study seeks to document the forms of local knowledge, customary institutions, and traditional artifacts associated with water governance. Second, it aims to analyze the adaptive practices through which the community regulates access, maintains water quality, and responds to ecological and social pressures. Third, the study evaluates the contribution of customary governance mechanisms to spring conservation and sustainable water distribution using a combination of qualitative and quantitative approaches.

The security and sustainability of water resources constitute an increasingly critical global challenge, particularly in tropical small-island environments that are highly vulnerable to climatic variability, ecological degradation, and demographic pressures (UN-Water, 2018; UNESCO, 2020). In many small-island contexts, freshwater availability largely depends on natural springs, which are closely linked to forested landscapes and the ecological processes that regulate infiltration, storage, and discharge. Limited infrastructure, combined with increasing environmental stress, intensifies the vulnerability of these systems, making sustainable water management a pressing concern. Therefore, approaches that integrate ecological processes, social dynamics, and cultural values are essential to ensure long-term water security and ecosystem conservation (United Nations, 2023; UN-Water, 2014).

Within customary forest landscapes, water management is not merely a technical activity but is deeply embedded in local knowledge systems, ritual practices, and community institutions. Indigenous and local knowledge has been widely recognized as a valuable source of context-specific strategies for resource management, often overlooked in technocratic governance frameworks (United Nations, 2023; UN-Water, 2014). Empirical evidence demonstrates that traditional knowledge systems contribute significantly to spring conservation, risk mitigation, and equitable distribution of water resources, particularly in regions facing environmental constraints. In this context, community-based management approaches emphasize participatory governance, in which local actors play a central role in regulating access, maintaining ecological balance, and ensuring sustainability (UNEP, 2017; United Nations, 2021).

Recent developments in socio-hydrology and social-ecological systems research highlight the importance of integrating human behavior, institutional arrangements, and ecological dynamics in water management (Jackson, 2019; Somerville, 2014). These approaches recognize that water systems are shaped not only by physical processes but also by social interactions, cultural values, and governance structures. However, despite growing attention to the role of local knowledge, significant gaps remain in understanding how ritual practices, traditional artifacts, and customary institutions function as integrated mechanisms for conservation and adaptive management, particularly in small-island environments in Southeast Asia (Balasooriya et al., 2023; Ncube, 2018). Most existing studies focus on large-scale indigenous knowledge systems or their incorporation into formal policy frameworks. At the same time, relatively few examine how everyday practices in local communities contribute to resource conservation and resilience. In particular, the role of ritualized practices in regulating access to water resources, reinforcing social norms, and supporting ecological sustainability remains underexplored. This gap is especially relevant in ethnohydrology, which seeks to understand the interactions between water systems and cultural practices within a holistic socio-ecological framework (Borthakur and Singh, 2020; Utami and Oue, 2022).

The urgency of this research is further underscored by the limitations of top-down approaches and high-cost technological interventions, which often fail to address the contextual realities of marginal and remote communities (UNESCO, 2023; Prober et al., 2011). In contrast, local knowledge systems offer adaptive, low-cost, and socially legitimate solutions that have evolved through long-term interaction with the environment. Studies from Africa and other regions have shown that integrating traditional practices with simple technological tools can enhance water distribution, improve community resilience, and support sustainable resource use. Nevertheless, such integrative approaches remain insufficiently documented in small-island contexts in Indonesia and the broader Southeast Asian region (Karki and Adhikari, 2015).

Within Indonesia, research on water governance has largely focused on legal frameworks, policy instruments, and large-scale infrastructure development (Latuamury, 2025c; Latuamury et al., 2021). While these studies provide important insights, they often overlook the role of customary institutions, ritual practices, and locally embedded knowledge systems in managing water resources. This limitation results in an incomplete understanding of how community-based governance operates in practice, particularly in areas where formal institutions are less dominant and customary systems continue to play

a central role. Consequently, there is a need for empirical studies that document and analyze the integration of ecological, social, and cultural dimensions in local water management systems (Latuamury, 2025a; 2025b).

Negeri Soya in Ambon, Indonesia, represents a distinctive case of a customary community in a small-island forest landscape where water management is closely linked to local knowledge, ritual practices, and traditional institutions. The community relies on spring-based water systems that are regulated by customary norms, collective decision-making, and cultural practices, including ritual activities and the use of traditional artifacts. These elements form a complex system that not only governs water use but also contributes to the conservation of spring ecosystems and surrounding forest areas. This study aims to address the identified research gap by examining the ethnohydrological system in Negeri Soya through three main objectives. First, the study seeks to document the forms of local knowledge, customary institutions, and traditional artifacts associated with water governance. Second, it aims to analyze the adaptive practices through which the community regulates access, maintains water quality, and responds to ecological and social pressures. Third, the study evaluates the contribution of customary governance mechanisms to spring conservation and sustainable water distribution using a combination of qualitative and quantitative approaches.

By integrating ethnographic analysis with quantitative assessment, this research provides a comprehensive understanding of how culturally embedded practices function as adaptive mechanisms in water governance. The findings are expected to advance ethnohydrology as an interdisciplinary field and to provide empirical evidence supporting the roles of community-based and ecosystem-based approaches in sustainable resource management. Furthermore, this study offers practical insights for developing conservation strategies that recognize and incorporate local knowledge systems, particularly in tropical small-island environments where ecological vulnerability and socio-cultural complexity are closely intertwined.

2. Materials and Methods

2.1. Study Area

The study was conducted in Negeri Soya, a customary village located in Ambon City, Maluku Province, Indonesia. Geographically, Negeri Soya is situated in the upland area of Ambon Island at approximately 3°41′–3°43′ South Latitude and 128°10′–128°12′ East Longitude, at an elevation ranging from 150 to 400 meters above sea level. The village lies approximately 7–10 km from the administrative center of Ambon City, making it both accessible and representative of peri-urban small-island communities where traditional and modern systems intersect.

Negeri Soya comprises two primary kinship groups, namely *Soa Pera* and *Soa Erang*, each playing a central role in local water governance. Site selection criteria included: (1) The presence of the primary water source, *Wae Soya*, which supplies domestic, agricultural, and ritual needs; (2) The existence of traditional water artefacts serving as management focal points and socio-spiritual symbols, including *Perigi Soya*, *Tempayan Soya*, and *Bak Air Minum*; (3) The ongoing practice of customary water rituals, such as the *Cuci Negeri*, representing socio-ecological control mechanisms and intergenerational transmission of cultural values; and (4) A hierarchical local institutional structure, ranging from the Council of Elders to household water user groups, farmers, and ritual practitioners, enabling observation across social strata. The purposive selection aimed to capture representative data on ethnohydrological water management while enabling analysis of the integration of local knowledge with simple adaptive technologies (Back, 1981; Gartin et al., 2010a).

The geographical and ecological characteristics of Negeri Soya further underscore its relevance. The area features hilly topography, intact customary forest vegetation, and spring networks sensitive to climatic variations, particularly during prolonged dry seasons. These factors render Negeri Soya a natural social-ecological laboratory for evaluating the resilience of community-based water systems and customary practices under external pressures. Moreover, the community's cultural homogeneity allows for an in-depth study of knowledge transmission and compliance with customary norms.

2.2. Data Collection Techniques

Data were collected from both primary and secondary sources, using a triangulated research design to strengthen the study's validity, reliability, and contextual depth. Given the socio-ecological and culturally embedded nature of water governance in Negeri Soya, the study employed three principal ethnographic techniques for primary data collection: in-depth interviews, participant observation, and visual documentation. These methods were selected to capture not only the technical and institutional dimensions of water management but also the symbolic, ritual, and conservation-related meanings associated with springs and the surrounding forest landscapes.

In-depth interviews were conducted with 12 key informants, purposively selected based on their social roles, customary authority, practical involvement in water management, and knowledge of local ecological change. The respondents included customary elders, heads of *soa*, female community leaders, youth representatives, ritual practitioners, and operational customary officers directly involved in managing water access, spring-related practices, and collective decision-making. The interviews explored four principal themes: (1) Ritual practices and symbolic meanings associated with water sources; (2) Customary regulatory mechanisms, including temporary collective restrictions and sanctions; (3) Adaptive responses to ecological and social pressures affecting spring sustainability; and (4) The integration of local knowledge with simple monitoring and management practices. Semi-structured interviews were used to allow analytical consistency while maintaining sufficient flexibility to accommodate local narratives, cultural sensitivities, and contextual elaboration.

To clarify the composition of respondents and their relevance to the study, **Table 1** presents a brief profile of the key informants and their positions within the community-based water governance system.

Table 1. Characteristics of key informants and their positions in the study

No.	Respondent Category	Position / Social Role	Number	Relevance to the Study
1	Customary elders	Senior customary authorities/ members of the council of elders	3	Provided information on customary rules, ritual legitimacy, spring protection norms, and traditional governance
2	Heads of *soa*	Leaders of customary kinship groups	2	Explained collective decision-making, water allocation, and inter-group coordination
3	Female community leaders	Women are responsible for household and communal water-related activities	2	Contributed perspectives on domestic water use, conservation practices, and intergenerational transmission
4	Youth representatives	Young community members involved in socio-ecological activities	2	Provided information on participation in monitoring, maintenance, and local adaptation practices
5	Ritual practitioners	Persons directly involved in customary ritual implementation	1	Explained ritual procedures, symbolic meanings, and the connection between ritual and water conservation
6	Operational customary officers	Local actors involved in the day-to-day supervision of water distribution	2	Described practical governance, compliance monitoring, and management of water artifacts
	Total		**12**	

Participant observation was undertaken through direct involvement in community activities related to water use and spring conservation, including the *Cuci Negeri* ritual, water collection at *Perigi Soya*, and the maintenance of communal water artifacts. Observation focused on patterns of social interaction, collective deliberation, role distribution across generations, and informal mechanisms of ecological monitoring. Particular attention was paid to how customary practices helped maintain spring cleanliness, regulate access, and reinforce collective responsibility for water conservation. This method enabled the researcher to document water management as an everyday social practice embedded in both ecological realities and cultural values.

Visual documentation included photographs of traditional water artifacts, ritual activities, spring sites, and institutional arrangements associated with local water governance. These visual materials served multiple analytical purposes: they provided documentary evidence of the water system's physical

infrastructure, supported spatial interpretation of spring-related management networks, and helped identify the relationships among material artifacts, ritual practice, and governance structure. In this study, visual documentation also contributed to understanding how conservation is materially and symbolically expressed within the customary forest landscape.

Secondary data were used to complement and verify primary findings. These data included academic literature on ethnohydrology, community-based water governance, customary institutions, and environmental adaptation in small-island settings; local documents such as records of customary meetings and rules governing temporary access restrictions; and archival photographs and topographic materials used to support spatial and ecological interpretation. The integration of primary and secondary sources allowed the study to develop a more comprehensive understanding of the interactions among cultural institutions, forest-supported spring ecosystems, and adaptive water management practices (Chiblow, 2020; Mackenzie et al., 2012).

2.3. Research Procedures

The research followed a systematic protocol to ensure scientific integrity while respecting social and cultural norms. The initial stage involved field preparation, including a literature review on ethnohydrology and community-based water governance, and the identification of key informants via recommendations from the Council of Elders and local community leaders. Ethical and social approvals were obtained from indigenous governance structures and local authorities to guarantee legitimate participation, respect for local norms, and minimization of social risk. This process adhered to social research ethics, including voluntariness, informed consent, and respect for indigenous knowledge.

The second stage encompassed in-depth interviews and participant observation, which formed the core of qualitative data collection. Interviews were conducted face-to-face, with verbatim notes and audio recordings, enabling in-depth analysis of adaptive practices, rituals, and social-ecological monitoring mechanisms. Participant observation took place during *Cuci Negeri* and water distribution activities, focusing on individual and group roles, social interactions, and control over water artifacts and resources. This enabled the researcher to capture contextual human–water interactions, identify adaptation patterns, and reveal symbolic and structural dimensions of ethnohydrological practices.

The third stage involved visual documentation and data processing. Traditional artifacts, spring locations, and community institutional structures were visualized through photography, mapping, and field notes to support symbolic, spatial, and structural analysis. All interview data were fully transcribed and analyzed thematically to extract adaptive practices, symbolic meanings, and socio-ecological mechanisms. Field observations and visual documentation were examined to identify inter-element relationships, intergenerational interactions, and adaptive strategies informed by local knowledge. This methodology produced comprehensive, valid empirical data suitable for constructing an adaptive, inclusive, and sustainable community-based water governance model.

2.4. Data Analysis

Data analysis in this study employed a convergent mixed-method approach that integrated qualitative ethnohydrological interpretation with quantitative statistical assessment. This analytical framework was designed to capture the complex and multidimensional nature of water governance in Negeri Soya, where ecological processes, indigenous governance structures, ritual practices, and social responses interact within a customary forest landscape. By combining qualitative and quantitative methods, the study provided a comprehensive evaluation of the contributions of local knowledge and governance mechanisms to spring conservation and sustainable water management.

The qualitative analysis focused on the systematic interpretation of interview transcripts, field observations, and visual documentation. All data were transcribed verbatim and organized for analysis using a thematic coding matrix in Microsoft Excel. The coding process followed three sequential stages. First, open coding was conducted to identify initial concepts emerging directly from the data, including ritual practices, spring protection, customary restrictions, water distribution, knowledge transmission, and ecological change. Second, axial coding was applied to establish relationships among these concepts and to group them into broader analytical categories, such as customary governance, the conservation functions of traditional artifacts, adaptive monitoring, collective deliberation, and intergenerational learning. Third, selective coding was conducted to integrate these categories into a coherent

interpretation of the ethnohydrological system, particularly its role in regulating access to water, sustaining spring ecosystems, and strengthening community resilience.

Three complementary theoretical perspectives guided the qualitative analysis. Ethnohydrology served as the primary analytical lens, enabling the exploration of interactions between water systems and cultural practices. The social-ecological systems framework was employed to interpret how community-based institutions and practices contribute to adaptation, resilience, and conservation within a spring-dependent environment. Additionally, the hydrosocial governance perspective was used to explain how water access, authority, social legitimacy, and symbolic meanings are co-produced through institutional and cultural processes. The integration of these frameworks ensured that the analysis extended beyond descriptive ethnography to a more robust conceptual interpretation relevant to conservation and governance studies.

The quantitative component utilized the Chi-square test to assess the relative contribution of selected governance mechanisms to community responses under ecological and social pressures. The variables analyzed included customary sanctions, temporary collective restrictions, customary deliberation, water redistribution, and local knowledge transmission. These variables were derived from qualitative findings and translated into comparable analytical categories. Structured compliance-related data from end users were classified according to whether specific mechanisms were associated with responses to ecological or social pressures. The Chi-square test was then applied to compare observed and expected frequencies, thereby identifying the governance mechanisms that most strongly contributed to the stability and effectiveness of the local water management system.

The analytical procedure was conducted in several stages. Initially, qualitative data were coded and organized into thematic categories. Subsequently, these categories were interpreted using the selected theoretical frameworks to identify their conservation, governance, and adaptive functions. Quantitative tabulation was then performed to structure community responses into measurable variables, followed by the Chi-square test to determine statistical significance. Finally, the qualitative and quantitative findings were integrated to produce a holistic interpretation of the ethnohydrological governance system in Negeri Soya. To ensure research rigor, validity was strengthened through methodological triangulation across multiple data sources, including interviews, observations, visual records, and documentary materials. Interpretive validity was further enhanced through cross-verification with key informants, particularly those holding customary authority or operational roles in water management. Reliability was maintained by applying consistent coding procedures, re-examining and refining thematic categories, and verifying quantitative tabulations before statistical analysis. Through this integrated approach, the study generated empirically grounded and theoretically informed insights into the role of customary institutions, local knowledge, and adaptive practices in supporting spring conservation and sustainable water governance in tropical small-island forest landscapes (Sihombing, 2019; Ben-Daoud et al., 2021).

3. Results and Discussion

3.1. Chi-Square Analysis Results

The results of the Chi-square analysis indicate variation in the contribution of different ethnohydrological governance mechanisms to community responses under ecological and social pressures. **Table 2** presents the observed frequencies of responses classified into compliant and non-compliant categories, alongside the expected frequencies and Chi-square values for each mechanism. The analysis indicates that customary sanctions and temporary collective restrictions exhibit the highest Chi-square values, indicating their strong influence on maintaining compliance and regulating water use within the community-based system.

The results demonstrate that customary sanctions ($\chi^2 = 4.38$) and temporary collective restrictions ($\chi^2 = 3.49$) make the greatest contributions to compliance under both ecological and social pressure conditions. These mechanisms are particularly effective during periods of reduced spring discharge, when the risk of over-extraction and conflict increases. In contrast, customary deliberation, water redistribution, and local knowledge transmission show relatively lower Chi-square values, indicating a more indirect or long-term contribution to system stability. Further results indicate that simple monitoring practices also play a measurable role in strengthening compliance. The use of basic flow

observation and recording reduces distribution conflicts ($\chi^2 = 3.21$, $p < 0.05$), particularly during prolonged dry periods. These observations allow the community to anticipate water scarcity and implement access regulations promptly (Persada et al., 2018; Putri, 2020).

Table 2. Chi-square results for ethnohydrological governance mechanisms under ecological and social pressure

Governance Mechanism	Observed Response to Ecological Pressure (O)	Observed Response to Social Pressure (O)	Expected Ecological Response (E)	Expected Social Response (E)	χ^2 Ecological	χ^2 Social	χ^2 Row Total
Temporary collective restriction	35	18	28.20	24.80	1.63	1.86	3.49
Customary deliberation	28	26	28.70	25.30	0.02	0.02	0.04
Customary sanctions	22	34	29.80	26.20	2.05	2.33	4.38
Water redistribution	30	24	28.70	25.30	0.05	0.06	0.11
Local knowledge transmission	25	21	24.50	21.50	0.01	0.01	0.02
Total	140	123	139.90	123.10	3.76	4.28	8.04

The **Fig. 1** illustrates the expected frequency distribution for each governance mechanism across ecological and social pressure responses. Higher expected values for customary sanctions and temporary restrictions confirm their dominant role in maintaining system stability.

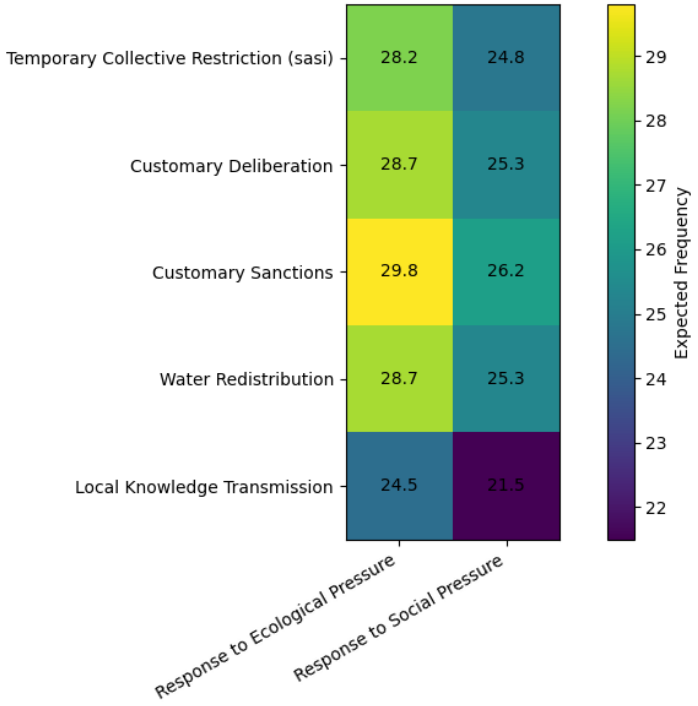

Fig. 1. Expected frequency matrix of ethnohydrological governance mechanisms in response to ecological and social pressures.

The findings suggest that governance mechanisms based on direct social control, particularly customary sanctions and temporary restrictions, function as the primary regulatory instruments in managing water resources in Negeri Soya. These mechanisms operate effectively because they are embedded within socially legitimate customary institutions, ensuring compliance even in the absence of

formal enforcement systems (Jiao et al., 2012; O'Donnell, 2023). Their effectiveness increases under ecological stress, indicating that they act as adaptive buffers against environmental variability. In contrast, mechanisms such as customary deliberation and local knowledge transmission play a foundational role in sustaining long-term system resilience. Although their immediate quantitative contribution is lower, they are essential for maintaining social cohesion, reinforcing shared norms, and facilitating intergenerational knowledge transfer. These processes ensure that adaptive practices are continuously reproduced within the community (Getahun, 2016; Nasrin et al., 2023).

The integration of simple monitoring tools with customary governance further strengthens the system's adaptive capacity. By providing observable and shared information on spring conditions, these tools enhance transparency and support evidence-informed decision-making without undermining customary authority. This combination of empirical observation and social regulation reflects a hybrid governance model in which ecological signals are translated into collective action through culturally embedded institutions (McDonald and Figueiredo, 2022; Sze et al., 2022).

From a broader perspective, the results demonstrate that water governance in Negeri Soya operates as a multi-layered socio-ecological system. Direct control mechanisms ensure short-term compliance, while deliberative and knowledge-based processes sustain long-term resilience. This configuration is consistent with ecosystem-based and community-centered approaches to water management, in which local institutions play a central role in regulating resource use and maintaining environmental sustainability (Latuamury, 2025b; Latuamury et al., 2021). Overall, the Chi-square analysis provides quantitative evidence that customary governance mechanisms are effective in supporting spring conservation and adaptive water management in a small-island forest landscape. The findings highlight the importance of integrating social legitimacy, local knowledge, and simple monitoring practices in developing sustainable water governance models.

3.2. Artifacts and Ritual Practices

Field observations and interviews show that water management in Negeri Soya is materially and symbolically organized around three principal artifacts, namely *Perigi Soya*, *Tempayan Soya*, and *Bak Air Minum*, as well as the continuing performance of the *Cuci Negeri* ritual (**Fig. 2**). Informants consistently identified these elements as central to the regulation of water access, the maintenance of spring-related practices, and the transmission of customary values across generations. The results indicate that each artifact performs a distinct but interconnected function within the local water management system. *Perigi Soya* serves as the primary point of access to spring water and the ritual center for community interaction with the water source. *Tempayan Soya* serves as a symbolic marker of customary legitimacy and regulated access. *Bak Air Minum* operates as a communal storage structure that stabilizes short-term domestic supply, particularly during periods of fluctuating discharge. Together, these artifacts form the material basis for a community-based spring management system embedded in customary authority and supported by forest hydrological processes.

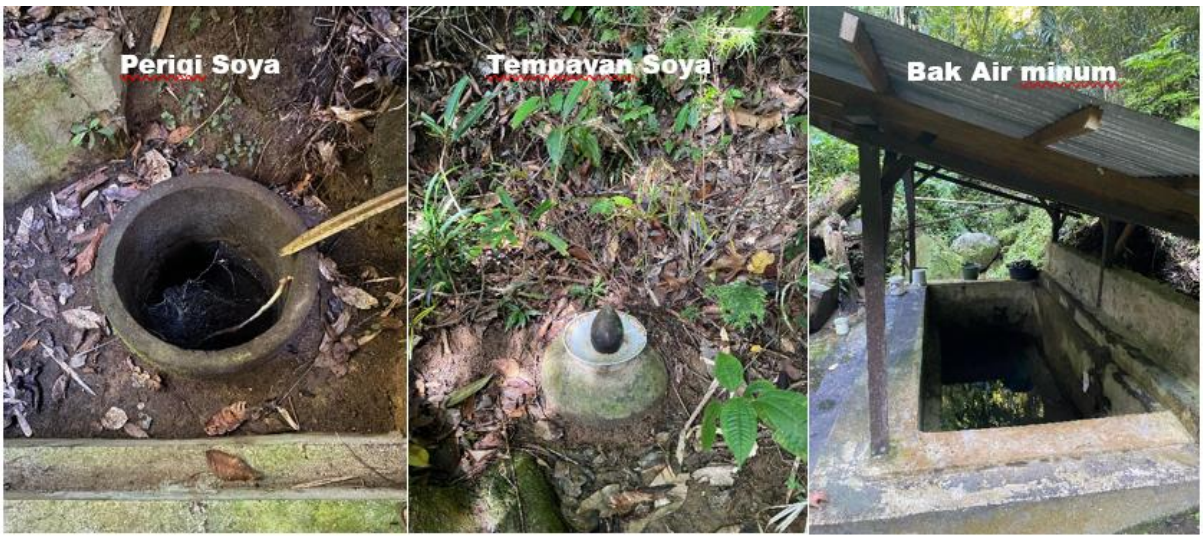

Fig. 2. Traditional water-related artifacts in Negeri Soya.

The results further show that the use of these artifacts is inseparable from ritual practice. Community members reported that the *Cuci Negeri* ritual, including the cleaning of the spring environment and the renewal of customary commitments, remains an important collective mechanism for maintaining both the physical condition and the cultural legitimacy of the water source. During field observation, this ritual involved removing sediment, decaying organic matter, moss, and foreign materials from the spring surroundings, followed by collective prayers and ceremonial actions led by customary authorities. Participation included elders, women, youth, and children, indicating that the ritual serves not only as a spiritual event but also as a practical, intergenerational activity related to spring care and environmental stewardship.

A further result concerns the mechanism of *Bak Air Minum* utilization. Interviews and direct observation indicate that *Bak Air Minum* serves as a communal storage and distribution facility for everyday domestic needs, particularly drinking water and basic household use. Water is channeled or transferred from the spring source into the tank when discharge is sufficient, and its use is subsequently regulated through customary agreement and social monitoring. During periods of reduced flow, access to the tank is prioritized for essential needs, thereby reducing direct extraction pressure on the spring. Maintenance activities, including cleaning, inspection of water quality, and regulation of withdrawal orders, are carried out collectively under the supervision of local customary actors. In this sense, *Bak Air Minum* functions not merely as a passive storage facility but as an adaptive buffer within the community's water governance system (Damonte and Boelens, 2019; Mills-Novoa et al., 2020).

These findings provide several important interpretations. First, the term *sasi* should be used with caution in this context unless local informants explicitly confirm that it is the term used in Negeri Soya. To avoid conceptual overgeneralization across Maluku, the more precise formulation of "customary temporary access restriction" or "customary temporary prohibition" is preferable, unless the local terminology has been directly verified. Such caution is methodologically important because the study aims to represent the specific customary vocabulary and governance logic of Negeri Soya rather than impose a broader regional term that may not fully correspond to local practice (Sangkhamanee, 2007; West et al., 2016). Second, the relationship between ritual practice and water conservation is direct and substantive rather than merely symbolic. The *Cuci Negeri* ritual contributes to spring conservation through at least three mechanisms. At the ecological level, it facilitates the physical cleaning of the spring environment, thereby helping maintain water quality and reducing obstruction around the source. At the institutional level, it renews collective adherence to rules governing access, use, and protection of the water source. At the social level, it strengthens environmental responsibility through intergenerational participation and moral reinforcement. The ritual, therefore, operates as a culturally embedded conservation practice in which ecological maintenance, customary authority, and social cohesion are mutually reinforcing (Gartin et al., 2010b; Ruth et al., 2019). Third, the combined presence of *Perigi Soya*, *Tempayan Soya*, *Bak Air Minum*, and *Cuci Negeri* demonstrates that water-related artifacts in Negeri Soya should not be understood merely as technical infrastructure or relics of tradition. Rather, they function simultaneously as hydrological interfaces, social regulators, and conservation instruments. This interpretation is consistent with scholarship emphasizing that water governance in customary settings is shaped not only by material access to water but also by symbolic legitimacy, institutional authority, and community-based ecological practices.

In this respect, the findings align with perspectives on hydrosocial territory and community-based socio-ecological resilience, in which access to water is co-produced by environmental processes, cultural values, and local institutions (Ruth et al., 2016; Sriskandarajah and Sivapalan, 2023). More broadly, the results indicate that the artifacts and rituals of Negeri Soya operate across three analytical dimensions. The first is a functional dimension, through which water is accessed, stored, and distributed for domestic use. The second is a normative and symbolic dimension, through which customary authority regulates legitimacy, access order, and collective obligation. The third is an adaptive and conservation-oriented dimension, through which local knowledge, communal participation, and simple monitoring practices help maintain spring ecosystems within a customary forest landscape. This multi-layered structure explains why the water governance system in Negeri Soya remains socially legitimate and ecologically responsive despite environmental variability and limited formal infrastructure. The evidence demonstrates that artifacts and ritual practices form a core component of adaptive spring governance in Negeri Soya. *Perigi Soya* regulates direct access to the source, *Tempayan Soya* reinforces customary legitimacy, *Bak Air Minum* provides a practical buffer for community supply, and *Cuci*

Negeri links ritual continuity with environmental maintenance. Taken together, these findings show that customary water management in Negeri Soya constitutes a culturally embedded and ecologically relevant model of community-based conservation, with particular significance for forest-dependent and spring-reliant small-island environments.

3.3. Institutional Structure and Water Governance

The analysis indicates that water governance in Negeri Soya is organized through a customary institutional structure that is both hierarchical and functionally differentiated. As illustrated in **Fig. 3**, authority over water resources is distributed across several social levels, extending from senior customary authorities to end-user groups. This structure governs access to spring water, regulates collective responsibilities, and maintains the social legitimacy of water-related decision-making. Rather than operating as an informal or fragmented arrangement, the institutional system demonstrates a relatively stable governance framework that integrates social authority, ecological responsibility, and cultural values within everyday water management practices (McDonald and Figueiredo 2022; Vogel et al., 2022).

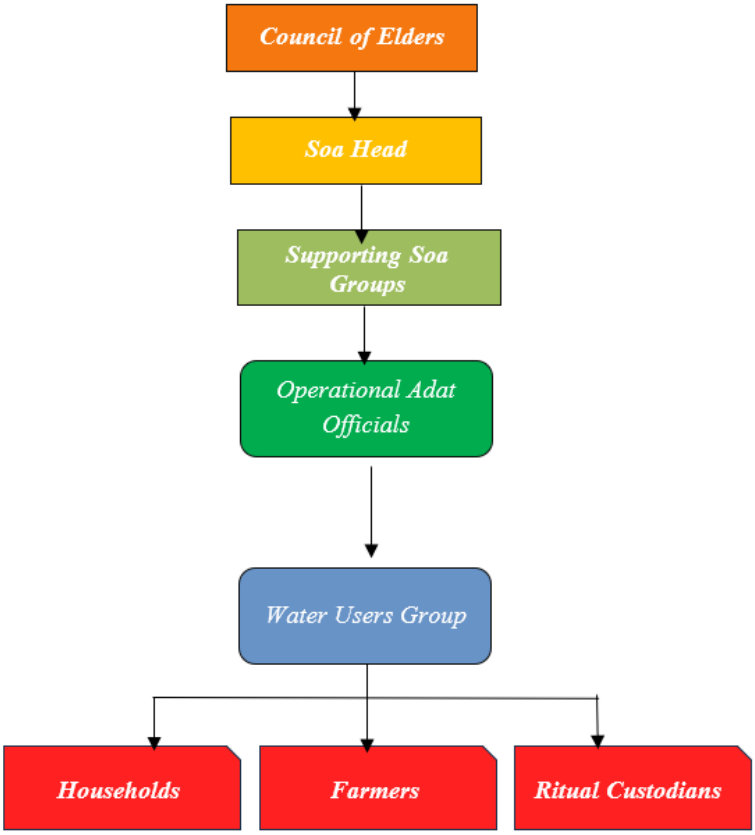

Fig. 3. Hierarchical structure of customary institutions in water governance in Negeri Soya.

At the apex of this structure is the Council of Elders ( ), serving as the principal authority and custodian of customary values in natural resource management, including water sources. From an ethnological perspective, the Council occupies a central position in symbolic and representative power structures. Their functions extend beyond strategic decision-making to safeguarding the continuity of tradition through the intergenerational transmission of local knowledge. Subsequently, the *Soa* Heads ( ) act as primary coordinators among kinship groups (*soa*) within the community. The *Soa* Heads bridge the Council of Elders' policies with technical implementation at lower levels, mediating between customary norms and the community's dynamic needs while ensuring that decision-making processes remain collective and consistent with social values.

At the intermediate level, Supporting *Soa* ( ) represents broader kinship units, holding rights and responsibilities in water management according to customary agreements, participating in deliberations, and monitoring the implementation of rules. The presence of Supporting *Soa* reinforces a strong

horizontal structure within participatory decision-making. Furthermore, the Operational Customary Officers (🟢) constitute the operational unit tasked with executing decisions from customary deliberations and overseeing water distribution in the field, from scheduling allocations to resolving minor conflicts among users. This group serves as a link between normative rules and daily practices, strengthening social oversight through direct engagement with the community.

At the base of the hierarchy are the Water User Groups (🔵), the beneficiary entities directly dependent on water distribution, encompassing three categories: Households, Farmers, and Ritual Practitioners (🔴). In contrast to the previous formulation, field evidence indicates that no formal irrigation system exists in Negeri Soya. Therefore, water use by community members should not be described as irrigation-based in the technical sense. Instead, water is used primarily for domestic purposes, limited household-scale livelihood needs, and ritual activities. This distinction is important because it more accurately reflects the local water system's actual function, centered on spring-dependent household supply and customary use rather than on agricultural irrigation infrastructure.

The institutional structure also reveals a close relationship between social organization and ecological governance. Each level of authority contributes to maintaining spring sustainability by regulating access, reinforcing compliance, and promoting collective responsibility for source protection. This demonstrates that water governance in Negeri Soya is not merely administrative, but socio-ecological in character. The institutional system is oriented towards maintaining water availability, preventing overuse, and preserving the cultural legitimacy of protection measures within a forest-supported spring environment (Mugambiwa and Makhubele, 2021). From an analytical perspective, these findings indicate that the interaction among the three dimensions shapes water governance in Negeri Soya. The first is an institutional dimension, through which authority, responsibility, and decision-making are structured across customary levels. The second is a social dimension, expressed through collective deliberation, compliance, and shared norms governing access and use. The third is an ecological dimension through which governance practices contribute to protecting spring sources and sustaining water supply within the customary forest landscape. This configuration is consistent with broader understandings of community-based environmental governance in which local institutions function as mechanisms of both social regulation and conservation (Sze et al., 2022; Westoby et al., 2020).

The results further suggest that the customary structure in Negeri Soya operates as a locally grounded form of adaptive governance. Because authority is distributed yet socially coordinated, the system can respond to fluctuations in water availability, emerging conflicts, and the need for collective action without depending on formal external bureaucratic mechanisms. In this regard, the governance structure supports not only the equitable distribution of water but also the long-term resilience of the spring system as a socio-ecological resource (Persada et al., 2018; Warawarin et al., 2017). The institutional structure of Negeri Soya demonstrates that community-driven governance in a small-island customary forest landscape is sustained through a coherent relationship between authority, participation, and ecological stewardship. The Council of Elders, the heads of *soa*, supporting kinship groups, operational customary actors, and end users each perform distinct but interconnected roles in regulating water access and safeguarding the source. By correcting the assumption of irrigation use and situating the findings within the village's actual spring-dependent context, this study shows that the water governance system of Negeri Soya is best understood as a customary, domestic, and conservation-oriented arrangement that is socially legitimate and ecologically adaptive.

3.4. Adaptive Mechanisms and Technology Integration

The findings indicate that water management in Negeri Soya is sustained through a locally developed mechanism that links customary regulation, ecological observation, ritual practice, and low-cost monitoring. This arrangement has emerged in response to seasonal variations in spring discharge, changes in water quality, and social pressures related to allocation, access, and customary obligations. Rather than relying on external technological systems, the community uses practical monitoring methods that remain compatible with local institutions and culturally legitimate decision-making processes. In this way, water governance remains socially accepted, operationally flexible, and responsive to ecological change within a spring-dependent customary forest landscape. Field observations show that the community employs several simple monitoring practices to assess spring

conditions at Perigi Soya and to monitor water movement into *Tempayan Soya* and *Bak Air Minum*. These include a manual depth gauge, a simple timer for estimating filling duration, and a handwritten daily flow log. Together, these tools allow users to monitor changes in water level, filling time, turbidity, odor, sediment accumulation, and visible reductions in outflow. Observations are commonly undertaken twice daily, in the morning and late afternoon, enabling the community to detect short-term fluctuation and anticipate reduced supply during prolonged dry periods (McDonald and Figueiredo, 2022; Vogel et al., 2022).

The evidence further indicates that these observations are not treated merely as technical measurements but as practical inputs for collective governance. Once recorded, the results are communicated through customary discussion involving operational officers, supporting *soa*, and, when necessary, senior customary actors. When declining water levels, slower filling rates, or deteriorating water quality are observed, the community responds by adjusting withdrawal orders, prioritizing domestic needs, strengthening supervision of *Bak Air Minum*, or applying temporary customary access restrictions. Accordingly, these simple tools function as a community-based early warning mechanism that helps align everyday water use with the spring's ecological conditions. A key strength of this arrangement lies in the interaction between routine measurement and long-term local experience. Community members interpret spring conditions not only through observable indicators but also through accumulated knowledge of seasonal patterns, color changes, odors, sediment behavior, and flow characteristics. Elders and customary actors provide interpretive judgment, while youth and operational customary officers contribute regular measurement and documentation. This combination supports decisions that are both ecologically informed and socially trusted, while reinforcing rather than weakening customary legitimacy (Mugambiwa and Makhubele, 2021).

Water allocation in Negeri Soya is therefore governed by a coordinated process that links customary authority, social monitoring, and direct observation of spring conditions. During periods of lower discharge, water stored in *Bak Air Minum* is prioritized for drinking and other essential household needs, while direct withdrawal points are monitored more closely. Community members engaged in household-scale livelihood activities are expected to adjust their use in accordance with collective agreements, and ritual needs are accommodated within the same governance framework (Sze et al., 2022; Westoby et al., 2020). This demonstrates that local water governance is not dependent on formal hydraulic infrastructure, but on a socially coordinated process through which ecological signals are translated into practical allocation decisions.

The results also show that these mechanisms are strongly participatory. Women play an important role in assessing domestic sufficiency and communicating household needs, while youth are actively involved in field measurement, note-taking, and spring-site maintenance. Operational customary officers supervise implementation, whereas senior customary leaders retain authority over broader regulatory decisions. Such cross-generational cooperation strengthens knowledge transmission, reinforces compliance, and sustains collective responsibility for spring protection (Warawarin et al., 2017). Overall, the findings demonstrate that the combination of traditional artifacts, ritual continuity, and simple monitoring practices forms a resilient, conservation-oriented model of water governance. *Perigi Soya* serves as the primary interface; Tempayan Soya reinforces customary legitimacy; Bak Air Minum provides storage and buffering capacity; and routine monitoring provides evidence for timely action. The technological dimension of this system is deliberately modest yet functionally effective. Its value lies not in technical sophistication, but in its compatibility with local institutions, community participation, and the ecological realities of a small-island spring system. In this regard, the Negeri Soya case offers important empirical insights into ecosystem-based, community-centered water conservation in forest-dependent island landscapes.

3.5. Implications

The findings of this study indicate that ethnohydrological practices in Negeri Soya provide a relevant model for community-based water governance in small-island environments. The observed system, which combines traditional artifacts, customary rituals, social regulation, collective deliberation, and simple monitoring practices, demonstrates how ecological, social, and spiritual needs can be addressed within a single governance framework. The implications of these findings may be considered from practical, policy, and scientific perspectives. From a practical perspective, the Negeri Soya case

offers a workable example of how spring-dependent communities can manage water resources under ecological uncertainty. The use of customary restrictions, social sanctions, ritual maintenance, and basic flow observation enables timely and socially legitimate responses to seasonal variability, reduced discharge, and water distribution pressures (Sarkar et al., 2025). Cross-generational participation, particularly involving women and youth, further strengthens continuity, knowledge transfer, and ecological awareness (Neftenov and Collins, 2025). These findings suggest that community-based approaches can provide realistic and low-cost responses to challenges such as prolonged drought, declining spring quality, and hydrological instability associated with climate change.

From a policy perspective, the study highlights the importance of recognizing customary institutions as legitimate actors in water conservation. The Negeri Soya model suggests that conservation programs on tropical small islands can be strengthened by formally recognizing local governance structures, supporting community monitoring initiatives, and facilitating inclusive participation in water management. Such an approach aligns with adaptive governance principles, where resource management is collaborative, context-sensitive, and grounded in locally generated knowledge through participatory planning and stakeholder engagement (Massiri et al., 2025). The findings also suggest that simple monitoring practices can be incorporated into policy design without undermining customary authority, thereby providing a practical bridge between local knowledge and formal conservation planning. From a scientific perspective, this study contributes empirical evidence to debates on water governance, ethnohydrology, and socio-ecological adaptation. The quantitative results show that customary sanctions and temporary restrictions play an important role in compliance and water regulation. At the same time, the ethnographic findings reveal how rituals, artifacts, and institutional arrangements work together to sustain spring management (Truong, 2026). These results support the use of multidimensional analytical approaches that combine social, cultural, and technical perspectives when examining water governance in small-island settings.

Conceptually, the study reinforces the view that water governance cannot be understood apart from cultural values, spiritual meaning, and local institutional arrangements. The Negeri Soya case demonstrates that modest technologies can be effective when embedded within socially legitimate systems of collective action. More broadly, the findings have relevance beyond the local context, offering a transferable reference for ecosystem-based and community-centered water conservation in other small islands facing comparable ecological and social pressures. In this sense, the study contributes to the broader literature by showing that sustainable water governance depends not only on infrastructure, but also on the strength of culturally grounded institutions and shared ecological responsibility.

4. Conclusion

This study provides three principal conclusions that are systematically aligned with the research objectives. First, the study documents that water governance in Negeri Soya is structured through an integrated ethnohydrological system comprising local knowledge, indigenous governance structures, ritual practices, and water-related artifacts. Elements such as *Perigi Soya*, *Tempayan Soya*, *Bak Air Minum*, and the *Cuci Negeri* ritual function not only as cultural expressions but also as operational components of a community-based system that regulates access to water and maintains the integrity of spring ecosystems. These findings demonstrate that water governance in a customary forest landscape is deeply embedded in socio-cultural values and ecological understanding. Second, the analysis shows that adaptive mechanisms in Negeri Soya are characterized by the integration of customary regulation with simple monitoring practices. Community-based tools, such as manual water-level observation, basic flow measurement, and daily recording systems, are used to assess spring conditions and guide collective decision-making. These practices are reinforced through customary authority, deliberation, and social monitoring, enabling the community to respond effectively to ecological pressures such as seasonal variability and declining discharge. Importantly, the effectiveness of these mechanisms lies not in technological complexity but in their compatibility with local institutional structures and cultural norms. Third, the study evaluates the contribution of customary governance mechanisms to spring conservation and sustainable water management. The findings indicate that customary sanctions and temporary access restrictions play a significant role in maintaining compliance, regulating water use, and preventing over-extraction. At the same time, ritual practices and intergenerational participation strengthen ecological awareness, reinforce social legitimacy, and support long-term adaptive capacity.

The integration of local knowledge with simple empirical observation creates a technocultural system that enhances socio-ecological resilience within a spring-dependent environment. From a broader perspective, this research advances ethnohydrology and community-based environmental governance by providing empirical evidence that conservation-oriented water management can be effectively achieved through culturally embedded practices. The case of Negeri Soya demonstrates that sustainable water governance in small-island forest landscapes depends on the interplay among ecological processes, customary institutions, and collective action rather than on formal infrastructure or advanced technology alone. Accordingly, the ethnohydrological system observed in Negeri Soya offers a relevant model for ecosystem-based, community-centered water conservation strategies. It highlights the importance of recognizing customary institutions, strengthening participatory mechanisms, and integrating local knowledge into policy frameworks to enhance water security and socio-ecological resilience in tropical small-island environments.

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