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Harnessing nature-based solutions and indigenous knowledge for community health and climate resilience: A case study of Ondiri Wetland, Kenya

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Abstract: Wetlands provide crucial services such as water purification, biodiversity conservation, and climate regulation, yet face rapid degradation from urbanization, pollution, and climate change. Ondiri Wetland, East Africa's largest highland bog and source of the Nairobi River, is severely degraded. This study explores how Indigenous Knowledge Systems (IKS) and Nature-Based Solutions (NbS) can restore Ondiri, enhance resilience, and support community health. The study was conducted between June to October 2025 and used a mixed-methods design, integrating ethnographic documentation, household surveys, interviews, focus groups, and ecological observations, GIS mapping, and policy analysis. Community perceptions of the effectiveness of small-scale NbS interventions, like agroforestry, wetland restoration, and urban greening, were assessed, and community opinions on ecological change, conventional conservation methods, and institutional gaps were gathered. According to community respondent**s,** food security, soil stability, water quality, and flood control were perceived to be improved following community-led NbS in Ondiri. IKS is still essential in spite of policy gaps. For scalable wetland management and sustainability, the report recommends funding restoration, mainstreaming NbS, and institutionalizing IKS. In order to inform policy and sustainability objectives, future research should assess the effects of IKS and NbS on wetlands while including hydrological and governance improvements.

Keywords: Biodiversity., Community., Indigenous knowledge system., Nature-based solution., Land use/cover., Wetland restoration.

Introduction

Wetlands are among the most productive ecosystems globally, providing essential services such as water purification, flood regulation, food production, climate regulation, and biodiversity conservation (Ramsar Convention, 2018). For many Indigenous and local communities, however, wetlands are not only ecological assets, but also cultural landscapes shaped by long-standing knowledge, beliefs, and customary practices. Across generations, communities have developed Indigenous Knowledge Systems (IKS) that guide how

wetlands are accessed, managed, and conserved through seasonal calendars, taboos, spiritual values, and customary laws (Berkes, 2018). These systems have historically supported sustainable resource use while reinforcing social cohesion and environmental stewardship.

Despite their importance, wetlands are being degraded at unprecedented rates due to urbanization, pollution, agricultural expansion, and climate change (Davidson, 2014; Gardner & Finlayson, 2018). Globally, approximately 35% of wetlands have disappeared since 1970 (Watson *et al*., 2019). While scientific and policy responses increasingly promote Nature-Based Solutions (NbS) such as wetland restoration and ecosystem-based adaptation, these interventions often overlook or marginalize Indigenous knowledge, particularly in the Global South. Yet, evidence suggests that integrating IKS into environmental governance enhances ecological outcomes, community ownership, and long-term sustainability (Adger *et al*., 2007).

In Africa, wetlands play a vital role in supporting livelihoods, including fishing, small-scale farming, livestock rearing, and traditional medicine (Rebelo *et al*., 2009). Many African societies have long regulated wetland use through customary institutions that restrict overexploitation and protect sacred sites. Practices such as seasonal fishing bans, controlled grazing, and ritual protection of water sources reflect deep ecological understanding embedded within cultural systems. Studies from Tanzania, Ghana, and Uganda demonstrate that where Indigenous governance structures are respected, wetland conservation is more effective and socially legitimate (Emmanuel, 2024).

However, modern environmental management frameworks frequently privilege technical and policy-driven approaches while sidelining local knowledge. In East Africa, wetlands are rapidly degrading due to land conversion, pollution, and weak governance (Muoria *et al*., 2015; Gimbo *et al*., 2023). Although regional policies emphasize ecosystem-based approaches, implementation remains limited by low community engagement and inadequate integration of Indigenous perspectives.

Kenya hosts over 500 wetlands, many of which are under severe pressure from urbanization and agricultural encroachment (Ongoro, 2017). Ondiri Wetland, Kenya's only highland bog and a key source of the Nairobi River, has experienced significant degradation from waste dumping, land encroachment, and water over-extraction (Wainaina, 2022). While community groups such as Friends of Ondiri Wetland have initiated restoration efforts, these initiatives remain largely disconnected from formal policy processes and insufficiently informed by documented Indigenous knowledge.

There is limited empirical understanding of how local communities around Ondiri Wetland perceive environmental change, apply traditional ecological knowledge, and contribute to ecosystem management. Furthermore, little evidence exists on how Indigenous practices can be integrated with Nature-Based Solutions to enhance wetland restoration, community health, and climate resilience.

This study addresses these gaps by examining community perceptions of how Indigenous Knowledge Systems can inform Nature-Based Solutions for the restoration of Ondiri Wetland. By centering community knowledge, values, and practices, the research aims to contribute context-sensitive insights for sustainable wetland governance, climate adaptation, and inclusive environmental policy in Kenya and beyond.

Rationale of the study

Ondiri Swamp is located in the Kikuyu Division of Kiambu County, one kilometer downhill from Kikuyu Township. Latitude 1°01.5'S and longitude 36°38'E are its coordinates. The division is bounded to the north by Limuru and to the west and south by Kajiado. At about 30 hectares with a perimeter of 3.3 kilometers, Ondiri is the second

deepest wetland in Africa and the largest quaking bog in East Africa (Miriti, 2016). Situated at the foot of the Aberdare Ranges in central Kenya, the swamp is a distinctive ecological feature. A diverse range of stakeholders, including farmers, educational institutions, private developers, and local government agencies, are interested in it because it is a shared resource. The wetland is encircled by both urban and rural communities, and due to its proximity to Kikuyu town, human encroachment poses a significant threat to it. Figures and plates illustrate its location and the current activities surrounding the wetland (Figure 1).

Kikuyu Ward, which contains hills, plateaus, and elevated structural plains, is home to Ondiri Wetland. At an elevation of approximately 1,800 meters above sea level, the wetland is located at the base of the Kikuyu Escarpments, which are about two kilometers to its west. Ondiri Wetland is the source of the Nairobi River, a major tributary of the Athi River. It is believed to have formed as a result of tectonic depression, which is a feature of the lower slopes of the Nyandarua-Aberdare Ranges (Gichuki, 1998). The depression where the swamp is located was probably formed by reverse faulting processes associated with the formation of the Great Rift Valley (Nyamweru, 1992).

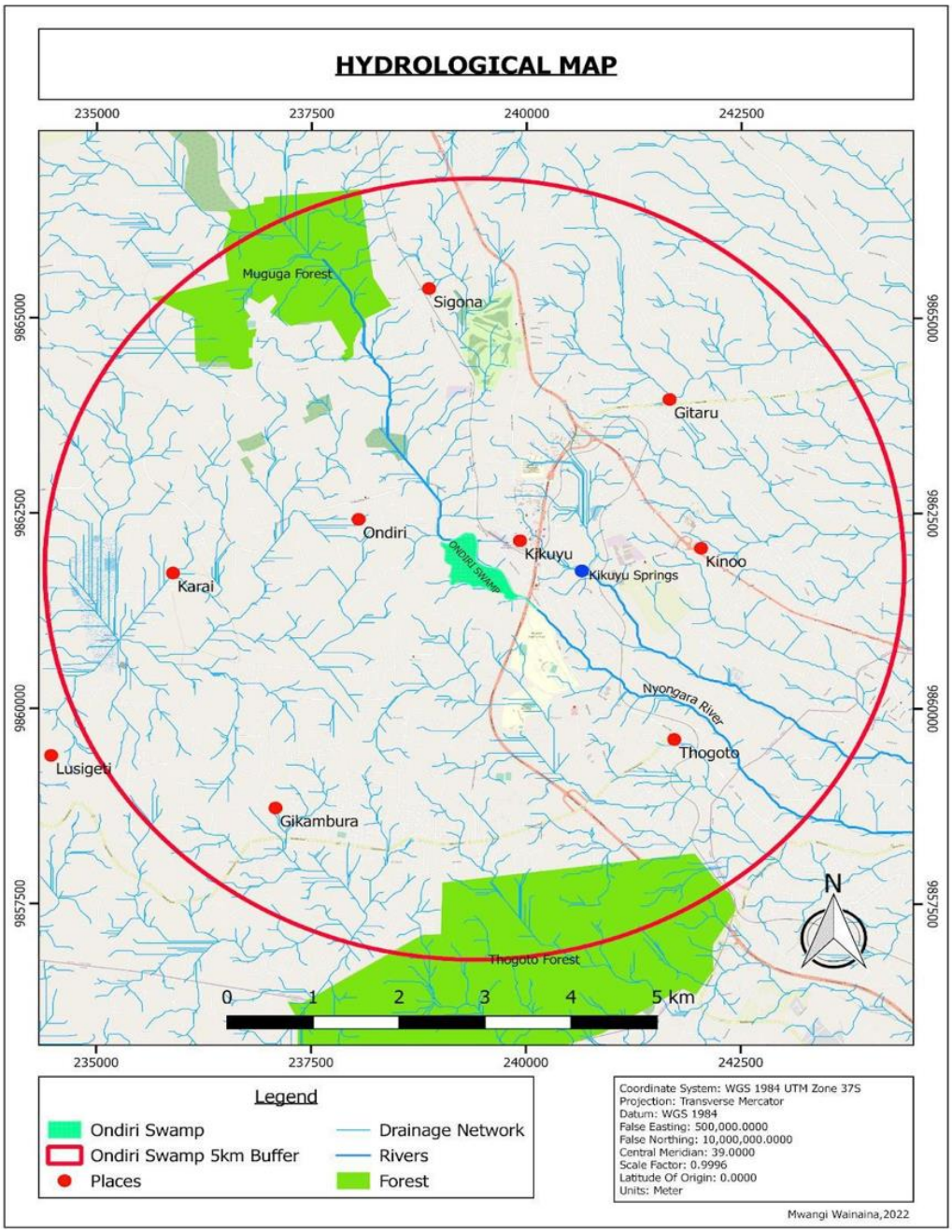

Figure 1. Map of location of Ondiri wetland.

Research Methodology

Study Design

This study adopted a convergent mixed-methods design, integrating quantitative and qualitative approaches to examine community perceptions of how Indigenous Knowledge Systems (IKS) and Nature-Based Solutions (NbS) contribute to wetland restoration and community resilience at Ondiri Wetland, Kiambu County, Kenya (Table 1). The mixed-methods approach was selected to allow for both statistical analysis of community perceptions and in-depth exploration of Indigenous ecological knowledge, cultural

practices, and governance structures. Combining multiple data sources enabled triangulation and strengthened the credibility of the findings.

Study Area and Population

The study was conducted in four villages surrounding Ondiri Wetland, which together have an estimated population of 4,236 households. These communities depend on the wetland for water supply, small-scale farming, grazing, cultural practices, and spiritual activities. The population of interest included household heads, community elders, youth, women, members of local conservation groups, and government and non-governmental stakeholders involved in wetland management.

Sampling Strategy and Sample Size

A probability sampling approach was used for the household survey to ensure representativeness, while purposive sampling was applied for key informant interviews and focus group discussions to capture Indigenous knowledge and institutional perspectives.

The household sample size was calculated using the Nassiuma (2000) formula, which is appropriate for large populations where variability is unknown:

$$n = \frac{NC_v^2}{C_v^2 + (N-1)e^2}$$

Where: N = is the target population n=Sample size
C_v = is coefficient of variation
e = is tolerance at desired level of confidence
(N) - in this case was 4236 for the four areas For this study:
C_v = coefficient of variation (0.5
e = tolerance at desired level of confidence (0.05)
Therefore: n= {NC ^{2}}/ {C ^{2}+ (N-1) e^2}
v v
n= 4,236 (0.5^2)/ 0.5^2+ (4,236-1) 0.05^2
n =1059 /10.84
n= 97.69
The sample size therefore was (n) 98

Household lists were obtained from local chiefs, and simple random sampling was used to select respondents proportionately across the four villages to minimize selection bias.

For qualitative data, 15 key informant interviews were conducted with elders, community leaders, wetland champions, and government officials. Four focus group discussions (FGDs) were held with women, youth, farmers, and conservation group members to capture diverse perspectives on wetland use, Indigenous practices, and restoration efforts.

Data Collection Methods

Data were collected between June to October 2025 using the following tools:

1. Household Surveys: Structured questionnaires captured community perceptions of environmental change, wetland use, climate risks, and NbS effectiveness.

2. Key Informant Interviews (KIIs): Semi-structured interviews documented Indigenous ecological knowledge, customary governance systems, sacred sites, seasonal practices, and traditional conservation norms.
3. Focus Group Discussions (FGDs): FGDs explored collective memory, cultural values, and community-led restoration practices.
4. Participatory Mapping: Community members identified sacred zones, degraded areas, water sources, and restoration sites.
5. Direct Observation and GIS Mapping: Ecological conditions, land-use changes, and NbS interventions (tree planting, wetland restoration, agroforestry) were documented using field observations, photographs, and GIS tools.
6. Document Review: Policy documents, NEMA reports, Kiambu County Integrated Development Plans (CIDPs), and environmental assessments were analyzed to understand governance frameworks.

It is important to note that no biophysical measurements (e.g., water quality testing, soil nutrient analysis, temperature monitoring) were conducted in this study. The findings on ecological and health outcomes are based solely on community perceptions, self-reported data, and qualitative observations.

For the purposes of this study, an NbS intervention was operationally defined as having 'perceived success' if: (a) more than 50% of household survey respondents reported positive changes associated with that intervention, and (b) the positive changes were confirmed by at least two additional qualitative data sources (e.g., key informant interviews, focus group discussions, or direct observation). This definition acknowledges that the study measured community perceptions rather than biophysical outcomes.

Table 1. Summary of Data Sources by Objective

Research Objective	Primary Data Sources	Secondary Data Sources
Assess effectiveness of small-scale NbS	Field observations, GIS mapping, stakeholder interviews	NEMA reports, Kiambu CIDPs, academic studies
Understand community perceptions	Structured interviews, FGDs, household surveys	Local reports, grey literature
Document traditional practices	Key informant interviews, participatory mapping, ethnographic methods	Archival texts, indigenous knowledge literature
Provide policy recommendations	Policy review, government stakeholder interviews	National policies, institutional frameworks, NGO publications

Data Analysis

Quantitative data were coded and analyzed using descriptive statistics (frequencies, percentages) to summarize community perceptions and NbS adoption trends.

Qualitative data were analyzed using thematic content analysis, guided by Indigenous epistemology and socio-ecological systems theory. Transcripts were coded into themes such as:

- Indigenous conservation practices- Spiritual and cultural values
- Community governance
- Climate adaptation strategies
- Policy integration challenges

Photographic and spatial data were used to validate community narratives and ecological observations.

Ethical Considerations

Ethical approval was obtained from relevant authorities. Informed consent was secured from all participants. Cultural protocols were respected, particularly when discussing sacred sites and traditional knowledge. Anonymity and confidentiality were maintained, and findings were shared with community representatives.

Validity and Reliability

Triangulation of data sources (surveys, interviews, observations, documents) enhanced validity. Pilot testing of questionnaires improved reliability. Community feedback sessions were conducted to verify interpretations of Indigenous knowledge.

Results

Effectiveness of Nature-Based Solutions for Ecosystem Health and Community Well-being

Field observations and community feedback surrounding Ondiri Wetland provide ample evidence of community-perceived ecological and health benefits of small-scale Nature-Based Solutions (NbS) (Table 2). Respondents reported that wetland restoration was particularly effective in reducing erosion and flooding, improving water quality, and boosting local resilience to climate extremes, according to 62% of respondents. By improving air quality and creating natural carbon sinks, urban greening was perceived by 48% of respondents to have decreased heat stress in neighboring settlements. Agroforestry, which was embraced by 34% of respondents, was perceived to enhance food security and nutrition, stabilize soils, and increase water retention. Collectively, these efforts demonstrate how locally driven NbS is perceived to support ecosystem integrity, climate resilience, and human health.

Table 2. Perceived Effectiveness of Nature-Based Solutions Around Ondiri Wetland

NbS Type	% of Respondents Reporting (n/N)	Perceived Health Benefits	Climate Resilience Benefits
Urban Greening	48% (47/98)	Improved air quality	Perceived reduced urban heat; perceived enhanced carbon sink
Wetland Restoration	62% (61/98)	Improved water quality	Perceived reduced flooding and erosion
Agroforestry	34% (33/98)	Improved nutrition; food security	Perceived soil stabilization; perceived water retention

Drivers of Wetland Degradation and Governance Challenges

According to community perceptions obtained through surveys and focus groups, Ondiri Wetland's rapid degradation over the past 20 years has caused widespread concern (Table 3). Poor governance (71%), infrastructure development (85%), and agricultural expansion and encroachment (92%), were found to be the primary causes. Other major pressures included sewage and solid waste pollution (47%), unsustainable water abstraction (58%), and invasive species (49%). Low awareness (36%) and inadequate monitoring (37%) further undermined conservation efforts, while climate variability (42%) and

overgrazing (44%) made the problem worse. Together, these findings highlight the complex socio-environmental problems threatening Ondiri's ecological integrity and community resilience.

Table 3. Perceived Drivers of Ondiri Wetland Degradation

Driver	% of Respondents (n/N)
Agricultural Encroachment & Expansion	92% (90/98)
Physical Alteration & Infrastructure expansion	85% (83/98)
Pollution (Sewage, Solid Waste)	47% (46/98)
Water Abstraction	58% (57/98)
Invasive Plant Species	49% (48/98)
Overgrazing	44% (43/98)
Population Pressure & Poverty	21% (21/98)
Weak Governance & Enforcement	71% (70/98)
Climate Variability (Drought)	42% (41/98)
Lack of Awareness	36% (35/98)
Inadequate Monitoring & Data	37% (36/98)

Indigenous Knowledge Systems as Foundations for Wetland Stewardship

Participatory mapping and ethnographic interviews revealed the critical role that Indigenous Knowledge Systems (IKS) play in preserving Ondiri Wetland. Sacred zones safeguard biodiversity hotspots, while elder-enforced seasonal grazing and fishing bans encourage ecosystem regeneration (Table 4). Destructive behaviors like dumping and deforestation are discouraged by strong cultural ethics that are embedded through taboos and rituals. Wetland fringe stabilization is accomplished by planting native buffers, and adaptive agriculture is directed by ecological indicators. Generations of ecological wisdom are preserved through oral traditions, and equitable access and dispute resolution are ensured by communal governance structures. These customs demonstrate the enduring cultural and ecological significance of traditional wetland management practices.

Table 4. Documented Traditional Wetland Conservation Practices

Practice	Decision-Making Unit	Perceived Long-Term Impact
Seasonal Grazing and Fishing Bans	Village elders and local clan councils	Permits vegetation and aquatic life to naturally regenerate; limits overexploitation
Sacred Wetland Zones (trees, springs)	Clan-based leadership / spiritual elders	Limits human disturbance in delicate ecological zones and safeguards hotspots for biodiversity
Rituals and Taboos (e.g., water taboos)	Community consensus, elders, and cultural leaders	Reduces destructive practices like dumping and deforestation and instils environmental ethics
Use of Ecological Indicators	Individual farmers guided by oral knowledge	Encourages water-use and adaptive farming methods based on seasonal natural cues
Indigenous Buffer Planting (e.g., grasses)	Community groups and traditional farmers	Minimizes siltation and erosion while stabilizing wetland fringes
Communal Resource Governance	Clan councils and land committees	Ensures equitable access and conflict resolution
Oral Knowledge Transmission	Elders, teachers, storytellers	Ensures that local history and ecological knowledge are passed down through generations

According to community members, there is still a strong belief in the significance of ceremonial wetlands, river sources, and sacred trees, even though modernization has decreased adherence to some customs. More than 60% of elder respondents said that traditional norms were used to promote sustainable use by limiting access to specific wetland areas.

Discussion

Perceived Effectiveness of Nature-Based Solutions for Ecosystem Health and Community Well-being

The findings from Ondiri Wetland demonstrate that community perceptions associate community-led Nature-Based Solutions (NbS), particularly wetland restoration, urban greening, and agroforestry, with improved water quality, reduced flooding, soil stabilization, and enhanced food security. These outcomes align with global evidence showing that NbS can simultaneously address environmental degradation, climate risks, and public health challenges (Chausson *et al*., 2020; Seddon *et al*., 2021).

The high proportion of respondents (62%) who reported reduced flooding and improved water quality following wetland restoration reflects the role of wetlands in regulating hydrological flows and filtering pollutants (Ramsar Convention, 2018). Similar benefits have been observed in Uganda's Lubigi Wetland, where restoration improved water retention and reduced urban flooding (Nsubuga *et al*., 2014). In Ethiopia, community-based wetland rehabilitation enhanced soil moisture and agricultural productivity (Van Oudenhoven *et al*., 2018).

Urban greening initiatives around Ondiri, reported by 48% of respondents to perceptibly improve air quality and reduce heat stress, mirror findings from European cities where green infrastructure mitigates urban heat islands and improves mental and physical health (Kabisch *et al*., 2017). Agroforestry's contribution to food security and soil conservation also aligns with African studies showing that tree-based farming systems enhance resilience to climate variability (Shackleton *et al*., 2009; Munishi *et al*., 2014).

These results confirm that even small-scale, locally implemented NbS can generate significant co-benefits when adapted to ecological and social contexts. Ondiri's case contributes to the growing evidence base that NbS are not only environmental tools but also public health and livelihood interventions, while recognizing that these findings are based on community perceptions rather than biophysical measurements.

Drivers of Wetland Degradation and Governance Challenges

Community perceptions identified agricultural encroachment, infrastructure expansion, and weak governance as the primary drivers of Ondiri Wetland's degradation. These findings are consistent with regional and global assessments that highlight land-use change, urbanization, and institutional failures as major threats to wetland ecosystems (Davidson, 2014; Rebelo *et al*., 2010; Stephenson *et al*., 2020).

Similar patterns have been documented in Kenya's Yala Swamp, where agricultural expansion and inadequate enforcement undermined conservation efforts (Muthama *et al*., 2015). In Nigeria's Hadejia-Nguru wetlands, dam construction and intensive rice farming caused hydrological disruption and biodiversity loss (Adekola & Mitchell, 2011).

The prominence of weak governance (71%) in Ondiri reflects persistent institutional gaps in environmental management. Kenya's wetland policies often lack effective community participation mechanisms, resulting in low compliance and limited local

ownership (Ongoro, 2017). This study reinforces earlier calls for participatory governance models that integrate local actors into decision-making processes (Muoria *et al*., 2015).

Indigenous Knowledge Systems as Foundations for Wetland Stewardship

Ethnographic and participatory findings show that Indigenous Knowledge Systems (IKS) remain central to wetland management in Ondiri. Practices such as sacred site protection, seasonal grazing bans, ritual taboos, and clan-based governance regulate resource use and reinforce conservation ethics. These findings support Berkes' (2017) argument that Indigenous knowledge is rooted in long-term ecological observation, cultural values, and spiritual relationships with nature.

Comparable systems exist across Africa. In Tanzania's Malagarasi-Muyovozi wetlands, Indigenous institutions regulate fishing and grazing through customary laws (Emmanuel, 2024). In Ghana, sacred groves protect biodiversity hotspots (Salick & Byg, 2007). Uganda's customary wetland rules similarly restrict overexploitation (Nsubuga *et al*., 2014).

What distinguishes Ondiri is the persistence of these practices despite rapid urbanization. Over 60% of elders reported continued reliance on traditional norms, indicating cultural resilience. This supports the view that Indigenous epistemologies based on relational worldviews and collective stewardship remain relevant in modern conservation (Mistry & Berardi, 2016).

Integrating Indigenous Knowledge and Nature-Based Solutions: Synergies and Evidence

The Ondiri case illustrates how IKS and NbS can complement each other. Traditional practices provide governance structures and ethical frameworks, while NbS offer scientifically recognized restoration techniques. This synergy aligns with international conservation frameworks that advocate integrating Indigenous knowledge into ecosystem management (CBD, 2020; Ramsar Convention, 2018).

Similar integration has proven effective elsewhere. In Brazil's Atlantic Forest, community knowledge guided reforestation priorities, improving biodiversity outcomes (Marshall *et al*., 2023). In Ethiopia, local ecological knowledge enhanced wetland restoration success (Van Oudenhoven *et al*., 2018).

Ondiri contributes new empirical evidence from a highland bog ecosystem---an under-researched wetland type in East Africa. The findings suggest that Indigenous governance can strengthen NbS legitimacy, compliance, and sustainability, though further research across multiple sites is needed to confirm these patterns.

Knowledge Contributions of This Study

This study contributes to the literature by:

1. Documenting Indigenous wetland governance in a highland bog ecosystem based on community perceptions
2. Demonstrating perceived health and climate co-benefits of community-led NbS
3. Bridging Indigenous epistemology and scientific frameworks through mixed methods
4. Providing policy-relevant insights for inclusive wetland governance in Kenya

Ondiri offers preliminary lessons that may inform replication efforts for community-centered wetland restoration across East Africa.

Policy Implications and Recommendations

The findings of this study, while based on community perceptions and a single-site case, offer several implications for policy and practice in Kenya and similar contexts. The following recommendations are organized by target stakeholder and are drawn from the documented perceptions of community members, elders, and local leaders.

For national and county governments:

- Formal recognition of Indigenous Knowledge Systems in wetland governance frameworks, including County Integrated Development Plans (CIDPs) and the National Wetlands Conservation and Management Policy
- Establishment of Community Wetland Committees (CWCs) with legal decision-making authority
- Creation of payment-for-ecosystem-services (PES) programs to incentivize community-led conservation
- Enhancement of coordination across water, environment, health, and land management sectors through interministerial working groups

For educational institutions:

- Integration of IKS and NbS into school and university curricula
- Support for community-based research partnerships between universities and Indigenous knowledge holders

For international donors and NGOs:

- Prioritization of locally-led NbS in climate finance proposals, including Kenya's Nationally Determined Contributions (NDCs)
- Support for participatory GIS and community mapping initiatives

For researchers:

- Multi-site, longitudinal studies that combine perception data with biophysical measurements
- Documentation of Indigenous knowledge before further knowledge loss occurs
- These implications should be interpreted as preliminary insights that require context-specific adaptation rather than prescriptive templates.

Conclusion

This study documents community perceptions of how Indigenous Knowledge Systems and community-led Nature-Based Solutions interact at Ondiri Wetland, Kenya. The findings indicate that local respondents associate NbS interventions (wetland restoration, urban greening, and agroforestry) with perceived improvements in water quality, food security, and flood regulation. Concurrently, Indigenous practices including sacred site protection, seasonal bans, and clan-based governance continue to inform local wetland stewardship despite pressures from urbanization and weak enforcement.

The primary limitations of this study are its reliance on perception data, absence of biophysical measurements, and single-site focus. As such, the findings should be interpreted as an exploratory case study that generates hypotheses for future testing rather than providing conclusive evidence of causal effectiveness.

For Kenya to meet its commitments under the Ramsar Convention, the Convention on Biological Diversity, and its own Vision 2030, institutional reforms that recognize and resource community-led conservation will be necessary. Ondiri Wetland offers preliminary lessons for how such reforms might be designed, but replication and scaling will require context-specific adaptation and further research.

Limitations

This study has several limitations. First, the focus on Ondiri, a single wetland, limits the findings' applicability to other wetlands in Kenya or the region with distinct ecological and socioeconomic settings. Second, the mixed-methods approach relied primarily on self-reported data and community perceptions, which are subject to several biases. Recall bias may have affected respondents' ability to accurately remember past environmental conditions or changes over the 20-year reference period. Social desirability bias may have influenced respondents to report positive views of conservation efforts or to overstate adherence to traditional practices. Selection bias may have occurred if households with stronger environmental interests were more willing to participate. Third, no biophysical measurements were conducted; therefore, all findings on ecological and health outcomes are based on perception data only. Fourth, the absence of a longitudinal design means that changes attributed to NbS cannot be separated from other concurrent variables. Finally, logistical and financial constraints limited the scope of data collection, particularly with regard to long-term monitoring and quantitative health outcomes. Future research should employ multi-site, longitudinal designs that combine perception data with biophysical measurements to address these limitations.

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