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Living in Droughts and Floods in Semi-Arid Lands: Knowledge Governance, Indigenous Adaptation and Institutional Mediation in Climate Risk Management

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A B S T R A C T

Climate variability in semi-arid lands is increasingly characterised by prolonged droughts interspersed with episodic flooding, creating complex risk environments that undermine agricultural productivity, water security, infrastructure stability, and rural livelihoods. Resilience outcomes in such contexts depend on the interaction between ecological assets, indigenous knowledge systems, and institutional governance mechanisms. A quantitative cross-sectional survey design was employed using a structured Likert-type questionnaire administered to 62 respondents in Ikanga–Kyatune Ward, Kitui County, Kenya. Data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) via SmartPLS 4, with outer model assessment, structural path estimation, and bootstrapped mediation testing (5,000 resamples). PLS-SEM was selected given the sample size of 62, which falls below the threshold conventionally required for Covariance-Based SEM. Indigenous knowledge systems significantly influenced drought and flood management effectiveness ($\beta = 0.341$, $p < 0.001$), as did academic institutions' engagement ($\beta = 0.318$, $p < 0.01$). A significant indirect effect of indigenous knowledge through institutional engagement was confirmed ($\beta = 0.124$, $p < 0.05$), indicating partial mediation. Prospects of seasonal rivers showed no significant direct or indirect effects on management outcomes. Effective drought and flood management in semi-arid lands is primarily a knowledge governance challenge. Indigenous knowledge systems and academic institutional engagement are central to resilience outcomes, while environmental resource potential alone is insufficient without enabling governance structures. Integrating indigenous knowledge into formal disaster management policies and strengthening university–community partnerships are priority interventions for climate-vulnerable ASAL communities.

Keywords: Drought management; indigenous knowledge systems; academic institutions' engagement; socio-ecological systems; climate resilience

Introduction

Climate variability and change continue to pose significant challenges to livelihoods, ecosystems, and socio-economic development in semi-arid regions globally. These areas are characterised by highly variable rainfall patterns, recurrent droughts, and increasing incidences of extreme weather events such as flash floods. Scientific evidence indicates that climate change is intensifying hydrological variability, particularly in dryland environments where even small changes in precipitation and temperature can have disproportionately large impacts on water availability, agricultural productivity, and ecosystem stability (Intergovernmental Panel on Climate Change [IPCC], 2022). For communities whose livelihoods depend heavily on rain-fed agriculture and pastoral systems, such variability undermines food security, income stability, and long-term development prospects (Food and Agriculture Organization [FAO], 2021).

Historically, climate adaptation efforts in semi-arid lands have largely focused on infrastructural and technological interventions, including irrigation development, water storage facilities, and flood control mechanisms.

While these approaches remain important, there is increasing recognition that resilience to climate shocks is not determined solely by the availability of physical resources. Rather, adaptation is increasingly understood as a socio-ecological process shaped by interactions among environmental systems, human actors, and institutional governance arrangements (Folke *et al.,* 2010; Ostrom, 2009). This perspective underscores the need to examine how local knowledge systems and formal institutions interact with ecological resources to influence climate risk management outcomes.

Seasonal rivers constitute a critical yet often underutilised hydrological resource in many semi-arid environments. These ephemeral watercourses can support groundwater recharge, livestock watering, and small-scale irrigation when effectively managed, thereby contributing to drought mitigation and livelihood stability (Reij and Garrity, 2016). At the same time, inadequate catchment management, unsustainable sand harvesting, and settlement expansion along riverbanks can exacerbate flood risks. This dual role illustrates how environmental resources can simultaneously reduce and increase vulnerability depending on governance practices and community management strategies.

Alongside environmental resources, indigenous knowledge systems play a fundamental role in enabling communities to cope with climatic variability. In Ikanga–Kyatune and the wider Kitui South region, one such indigenous knowledge practice is locally known as *Kilumi*. *Kilumi* refers to traditional communal rituals and cultural practices through which communities seek spiritual intervention, social cohesion, and collective reflection during periods of prolonged drought, crop failure, or environmental stress. Beyond its spiritual dimensions, *Kilumi* functions as a socio-cultural mechanism for mobilising collective action, reinforcing shared responsibility for resource management, and fostering psychological resilience during climate crises. Indigenous and local knowledge systems encompass context-specific understandings of weather patterns, ecological indicators, and adaptive livelihood practices developed through long-term interaction with local environments. Research has shown that such knowledge can enhance adaptive capacity by supporting early warning systems, strengthening social networks, and promoting sustainable land management practices (Nyong *et al.,* 2007; Berkes, 2012). However, despite increasing recognition of its importance, indigenous knowledge is often insufficiently integrated into formal climate adaptation policies and disaster risk management frameworks.

Academic institutions have also emerged as significant actors in climate resilience building. Universities contribute through research generation, professional training, knowledge dissemination, and engagement with communities and policymakers. Higher education institutions are increasingly expected to play transformative roles in addressing sustainability challenges by linking scientific knowledge with societal needs (UNESCO, 2021). Their involvement can strengthen evidence-based decision-making, foster innovation, and support capacity development among stakeholders involved in climate risk management, particularly in vulnerable semi-arid contexts.

Despite the growing body of literature on climate adaptation, limited empirical research has examined how environmental resource potential, indigenous knowledge systems—including culturally embedded practices such as *Kilumi*—and academic institutional engagement interact to influence drought and flood management effectiveness in semi-arid settings. This study seeks to address this gap by investigating these relationships within a socio-ecological systems framework.

Specifically, it examines whether academic institutions function as mediating governance actors that translate local knowledge and environmental opportunities into improved resilience outcomes.

By providing empirical insights into the governance dynamics of climate adaptation in Ikanga–Kyatune, this study contributes to broader debates on sustainable development and resilience in climate-vulnerable landscapes. It emphasises the importance of integrating environmental resource management with indigenous knowledge systems and institutional collaboration to enhance preparedness, response, and recovery from climate-related hazards.

Theoretical Review

Socio-Ecological Systems Theory

Understanding climate risk management in semi-arid lands requires theoretical frameworks that integrate environmental dynamics, human behaviour, and institutional governance. The Socio-Ecological Systems (SES) theory provides a useful lens for examining such interactions. SES theory conceptualises resilience as an emergent property arising from the interactions between resource systems, resource users, governance arrangements, and ecological processes (Ostrom, 2009). Rather than viewing environmental risks as purely biophysical phenomena, the SES perspective emphasises the importance of social learning, adaptive capacity, and institutional coordination in shaping resilience outcomes.

Resilience thinking within SES scholarship further highlights the capacity of systems to absorb disturbances while maintaining core functions and structures (Folke *et al.,* 2010). In semi-arid regions where climatic shocks such as droughts and floods are recurrent, resilience depends not only on resource availability but also on the ability of communities and institutions to adaptively manage uncertainty. Adaptive governance mechanisms—including knowledge exchange platforms and collaborative decision-making structures—are therefore critical in enabling effective responses to environmental variability.

Within this theoretical framing, seasonal rivers can be conceptualised as components of the resource system, indigenous knowledge as a form of social capital and adaptive cognition, and academic institutions as part of the governance system that facilitates learning and coordination. The effectiveness of drought and flood management can thus be viewed as a system outcome resulting from interactions among these elements.

Adaptive Capacity and Knowledge Systems

Adaptive capacity refers to the ability of individuals and communities to anticipate, respond to, and recover from climatic shocks (Adger, 2006). It is shaped by access to resources, institutional support, knowledge networks, and livelihood diversification opportunities. Knowledge systems play a central role in enhancing adaptive capacity by enabling informed decision-making and collective action.

Indigenous knowledge systems represent locally grounded understandings of environmental processes and risk-coping strategies. Scholars argue that such knowledge complements scientific approaches by providing context-specific insights into climate variability and sustainable resource management (Berkes, 2012). Integrating indigenous knowledge with formal governance structures can therefore enhance the legitimacy and effectiveness of adaptation interventions.

Institutional Theory and Knowledge Mediation

Institutional theory emphasises the role of formal and informal rules, norms, and organisations in shaping socio-economic behaviour and development outcomes (North, 1990).

In the context of climate adaptation, institutions influence how resources are allocated, how knowledge is disseminated, and how collective action is coordinated. Academic institutions, in particular, have been recognised as knowledge brokers capable of translating research findings into practical solutions and policy recommendations (Etzkowitz and Leydesdorff, 2000).

The concept of institutional mediation suggests that governance actors can strengthen the impact of environmental and social resources on resilience outcomes by facilitating learning processes, capacity building, and stakeholder collaboration. This theoretical perspective supports the proposition that academic institutional engagement may mediate the relationship between indigenous knowledge systems and drought–flood management effectiveness.

Empirical Review

Seasonal Rivers and Climate Risk Management

Empirical studies indicate that effective water resource management is central to climate adaptation in semi-arid regions. Research on farmer-managed natural regeneration and landscape restoration demonstrates that improved water retention and catchment management can enhance agricultural productivity and reduce vulnerability to drought (Reij and Garrity, 2016). Similarly, studies on dryland hydrology highlight the importance of utilising ephemeral water flows for groundwater recharge and small-scale irrigation (Rockström *et al.,* 2010).

However, the effectiveness of such environmental interventions often depends on governance arrangements and community participation.

Without institutional coordination, investments in water infrastructure may fail to deliver expected resilience benefits. This suggests that environmental resource potential alone is insufficient to guarantee improved climate risk management outcomes.

Indigenous Knowledge and Adaptive Strategies

There is substantial empirical evidence demonstrating the contribution of indigenous knowledge to climate adaptation in Africa and other vulnerable regions. Nyong *et al.,* (2007) found that indigenous forecasting methods based on ecological indicators enabled communities in the African Sahel to anticipate drought events and implement proactive coping strategies.

Similarly, studies in East Africa show that traditional soil and water conservation practices enhance agricultural resilience under variable rainfall conditions (Altieri and Koohafkan, 2008).

Despite these benefits, integration of indigenous knowledge into formal policy frameworks remains limited.

Institutional marginalisation and generational knowledge loss pose challenges for sustaining traditional adaptation practices. Empirical research therefore calls for stronger mechanisms to document, validate, and incorporate indigenous knowledge into climate governance systems.

Role of Academic Institutions in Climate Adaptation

Universities increasingly play a significant role in sustainability transitions through research innovation, capacity development, and community engagement initiatives. Studies on higher education for sustainable development highlight the importance of experiential learning models that connect students and researchers with real-world environmental challenges (Wiek *et al.,* 2011). Such engagement not only strengthens knowledge dissemination but also contributes to the co-production of locally relevant adaptation solutions.

In developing country contexts, academic–community partnerships have been shown to enhance adoption of climate-smart agricultural practices and improve stakeholder coordination in disaster management initiatives (Lang *et al.,* 2012). These findings suggest that academic institutions can function as mediating governance actors that amplify the impact of local knowledge systems on resilience outcomes.

Research Gap

While existing empirical studies have examined environmental resource management, indigenous knowledge systems, and institutional engagement separately, limited research has explored their integrated effects on drought and flood management effectiveness. Moreover, few quantitative studies have investigated institutional mediation pathways within socio-ecological systems frameworks in semi-arid contexts. This study seeks to address this gap by empirically modelling the relationships among seasonal river prospects, indigenous knowledge systems, academic institutional engagement, and climate risk management effectiveness.

Materials and Methods

Research Philosophy and Design

This study was guided by a positivist research philosophy which assumes that social phenomena can be objectively measured and analysed using quantitative methods. Positivism is appropriate where the objective is to test theoretically derived relationships among latent constructs and generate empirical evidence through statistical modelling. Relationships among prospects of seasonal rivers, indigenous knowledge systems, academic institutions' engagement, and drought and flood management effectiveness were examined using Partial Least Squares Structural Equation Modelling (PLS-SEM) via SmartPLS 4 (Ringle *et al.,* 2022), enabling simultaneous assessment of the outer (measurement) model and inner (structural) model. PLS-SEM was selected over Covariance-Based SEM (CB-SEM) because the study sample of 62 respondents falls below the minimum threshold typically required for maximum likelihood estimation in CB-SEM (Hair *et al.,* 2019). PLS-SEM is specifically suited to smaller samples, complex models with multiple constructs and indicators, and studies in exploratory socio-ecological contexts where predictive relevance is of research interest (Hair *et al.,* 2022).

A quantitative cross-sectional survey design was adopted to capture respondents' perceptions at a single point in time. Cross-sectional designs are widely applied in resilience and climate adaptation research because they facilitate assessment of prevailing socio-ecological conditions, governance arrangements, and adaptive responses within specific contexts.

Study Area

The study was conducted in Ikanga–Kyatune Ward in Kitui South Sub-County, Kitui County, Kenya, an area classified among Kenya's Arid and Semi-Arid Lands (ASALs). The region is characterised by low and unreliable rainfall, recurrent droughts, occasional flash floods, and progressive land degradation. Livelihoods are predominantly dependent on rain-fed crop farming, livestock keeping, and small-scale trade, making households highly vulnerable to climatic shocks. Seasonal rivers play an important role in supporting local livelihood systems through livestock watering, sand harvesting, groundwater recharge, and small-scale irrigation during rainy seasons. Over time, local communities have developed indigenous coping mechanisms including traditional weather forecasting, drought-tolerant cropping practices, and communal resource management strategies such as *Kilumi*.

Sampling and Participants

The target population comprised adult residents and stakeholders in Ikanga–Kyatune Ward who had direct or indirect experience with drought and flood events or were involved in climate adaptation initiatives. These included smallholder farmers, pastoralists, community leaders, extension officers, development practitioners, and individuals affiliated with academic or research programmes. A purposive sampling technique was employed to select respondents with relevant contextual knowledge, resulting in 62 valid responses.

Data Collection Instrument

Data were collected using a structured questionnaire measuring four latent constructs: prospects of seasonal rivers (PSR), indigenous knowledge systems (IKS), academic institutions' engagement (AIE), and drought and flood management effectiveness (DFM). Each construct was operationalised using multiple reflective indicators measured on a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Questionnaire items were informed by socio-ecological systems theory and climate adaptation literature. Data collection was conducted through electronically administered questionnaires distributed to respondents within the study area.

Data Analysis

Data analysis followed the two-stage PLS-SEM approach recommended by Hair *et al.,* (2022) using SmartPLS 4 (Ringle *et al.,* 2022). The first stage involved assessment of the outer (measurement) model, examining indicator (outer) loadings, internal consistency reliability via composite reliability (CR) and Cronbach's alpha, convergent validity via average variance extracted (AVE), and discriminant validity via the Heterotrait-Monotrait ratio of correlations (HTMT). The HTMT criterion was applied as it offers superior discriminant validity detection compared to the Fornell–Larcker criterion, particularly in small samples (Henseler *et al.,* 2015).

The second stage involved assessment of the inner (structural) model. Collinearity among predictor constructs was evaluated using variance inflation factors (VIF). Structural path coefficients and their significance were obtained via bootstrapping with 5,000 resamples, generating bias-corrected confidence intervals at the 95% level. Model predictive accuracy was assessed using the coefficient of determination (R^2) and Stone–Geisser Q^2 predictive relevance via blindfolding. Overall model fit was evaluated using the standardised root mean square residual (SRMR), with values below 0.08 indicating acceptable fit (Henseler *et al.,* 2015). Mediation effects were tested following the procedure outlined by Hair *et* *al.,* (2022) using bootstrapped indirect effects with 5,000 resamples.

Ethical Considerations

Participation was based on informed consent, and respondents were assured of anonymity and confidentiality. No personally identifiable information was collected, and data were securely stored and used solely for academic purposes.

Results and Discussion

This section presents findings based on PLS-SEM procedures executed in SmartPLS 4. The analysis followed the two-stage sequence recommended for PLS-SEM: outer (measurement) model assessment followed by inner (structural) model evaluation, examining how prospects of seasonal rivers (PSR), indigenous knowledge systems (IKS), and academic institutions' engagement (AIE) influence drought and flood management effectiveness (DFM).

Descriptive Statistics

Composite scores were generated for each latent construct. Table 1 presents the mean and standard deviation for all constructs. Respondents expressed moderately positive perceptions regarding seasonal river prospects (M = 4.35, SD = 0.49) and institutional engagement (M = 4.29, SD = 1.04), while overall drought and flood management effectiveness was rated relatively low (M = 3.37, SD = 0.85).

Outer (Measurement) Model Assessment

The outer model was assessed to evaluate construct validity and reliability. Indicator outer loadings ranged from 0.612 to 0.841, with all retained indicators meeting the recommended threshold of ≥ 0.708 (Hair *et al.,* 2022). Two indicators under the PSR construct returned initial loadings below 0.60 and were removed from the model following cross-loading examination, which is standard procedure in PLS-SEM refinement.

Internal consistency was confirmed via composite reliability (CR) and Cronbach's alpha. Convergent validity was supported where AVE ≥ 0.50 for three of the four constructs. The PSR construct returned an AVE of 0.41, marginally below the threshold, which is acceptable given that CR exceeded 0.70, indicating adequate reliability (Hair *et al.,* 2022).

Table 2 presents composite reliability (CR) and average variance extracted (AVE) for all constructs. Academic institutions' engagement demonstrated the strongest convergent validity (CR = 0.85, AVE = 0.55). The seasonal rivers construct showed weaker AVE (0.39), suggesting scale refinement may be required in future studies. For discriminant validity, the square root of AVE for each construct exceeded inter-construct correlations, supporting construct distinctiveness.

Collinearity Assessment and Model Fit

Prior to structural path estimation, collinearity among predictor constructs was assessed using variance inflation factors (VIF). All VIF values were below the threshold of 3.3, confirming that collinearity was not a concern in the structural model (PSR: VIF = 1.23; IKS: VIF = 1.47; AIE: VIF = 1.38). Table 3 presents the PLS-SEM model fit and predictive accuracy indices.

The SRMR value of 0.061 fell below the 0.08 threshold, indicating acceptable model fit. R^2 values indicate that the predictors collectively explained 41.3% of the variance in DFM and 15.2% of the variance in AIE, representing moderate to substantial predictive accuracy for social science research (Hair *et al.,* 2022). Q^2 values derived from blindfolding (omission distance = 7) were positive for both endogenous constructs, confirming predictive relevance of the structural model.

Structural Path Results

Bootstrapped path coefficients (5,000 resamples, bias-corrected 95% confidence intervals) were examined to test the hypothesised relationships. Table 4 presents the structural path coefficients, t-statistics, and decision outcomes.

The results confirm that indigenous knowledge systems significantly improve drought and flood management effectiveness both directly and through academic institutional engagement, while academic institutions' engagement also exerts a significant positive direct effect. Prospects of seasonal rivers did not show statistically significant influence on either institutional engagement or management effectiveness, with confidence intervals spanning zero in both cases.

Table.1 Descriptive Statistics (N = 62)

Construct	Mean	Std. Deviation
Prospects of Seasonal Rivers (PSR)	4.35	0.49
Indigenous Knowledge Systems (IKS)	3.66	0.94
Academic Institutions' Engagement (AIE)	4.29	1.04
Drought & Flood Management Effectiveness (DFM)	3.37	0.85

Table.2 Outer Model Reliability and Validity Statistics

Construct	Cronbach's α	AVE
PSR	0.634 / 0.712	0.41
IKS	0.701 / 0.784	0.51
AIE	0.85	0.570
DFM	0.726 / 0.801	0.502

Table.3 PLS-SEM Model Fit and Predictive Accuracy

Fit Index	Value	Threshold	Interpretation
Q^2 (AIE)	0.061	> 0 (predictive relevance confirmed)	Acceptable fit
R^2 (DFM)	0.413	≥ 0.26 (moderate)	Moderate predictive accuracy
R^2 (AIE)	0.152	≥ 0.10 (weak but acceptable)	Moderate predictive accuracy
Q^2 (DFM)	0.183	> 0 (predictive relevance confirmed)	Acceptable fit
Q^2 (AIE)	0.071	> 0 (predictive relevance confirmed)	Acceptable fit

Table.4 Structural Path Coefficients

Path	Standardised β	t-statistic / p-value	Decision
PSR → DFM	−0.094	0.941 / > 0.05	Not supported
IKS → DFM	0.341	3.872 / < 0.001	Supported
AIE → DFM	0.318	3.143 / < 0.01	Supported
IKS → AIE	0.41	3.412 / < 0.01	Supported
PSR → AIE	−0.037	0.384 / > 0.05	Not supported

Mediation Analysis

Mediation analysis was conducted using bootstrapped indirect effects with 5,000 resamples, following Hair *et al.,* (2022).

The indirect effect of indigenous knowledge systems on drought and flood management effectiveness through academic institutions' engagement was significant (β = 0.124, 95% CI [0.031, 0.249], $p < 0.05$).

Given the retained significance of the direct path IKS → DFM (β = 0.341, $p < 0.001$), these findings confirm partial mediation.

Academic institutions thus enhance the effectiveness of indigenous knowledge by facilitating knowledge dissemination, training, and coordination mechanisms.

The indirect effect for seasonal rivers was non-significant (β = −0.014, 95% CI [−0.092, 0.031]), confirming the absence of mediation along the PSR → AIE → DFM pathway.

Summary of Key SEM Findings

The PLS-SEM results from SmartPLS 4 demonstrate that: (i) indigenous knowledge systems are a primary determinant of drought and flood management effectiveness ($\beta = 0.341$, $p < 0.001$, $R^2 = 0.413$); (ii) academic institutions play a mediating governance role that strengthens resilience outcomes (indirect effect $\beta = 0.124$, 95% CI [0.031, 0.249]); and (iii) environmental resource potential (seasonal rivers) does not automatically translate into improved management effectiveness without enabling governance structures that facilitate knowledge integration, stakeholder coordination, and adaptive decision-making. These findings highlight the centrality of knowledge governance and institutional collaboration in enhancing climate resilience in semi-arid landscapes.

This study examined structural relationships among prospects of seasonal rivers, indigenous knowledge systems, academic institutions' engagement, and drought and flood management effectiveness in Ikanga–Kyatune Ward using PLS-SEM in SmartPLS 4. The discussion interprets findings in relation to socio-ecological systems theory, adaptive capacity literature, and institutional governance perspectives.

Knowledge Systems as Primary Drivers of Climate Risk Management Effectiveness

The PLS-SEM results demonstrate that indigenous knowledge systems exert the strongest direct influence on drought and flood management effectiveness ($\beta = 0.341$, $p < 0.001$). This finding confirms the central role of locally embedded knowledge in shaping adaptive responses to climate variability. In Ikanga–Kyatune, indigenous practices such as *Kilumi*, traditional rainfall prediction, drought-tolerant cropping strategies, communal resource sharing, and soil moisture conservation provide communities with practical mechanisms for anticipating and coping with climatic shocks.

From a socio-ecological systems perspective, this result reinforces the argument that resilience outcomes are not solely determined by ecological resource endowments but are significantly influenced by the cognitive and social capacities of resource users (Ostrom, 2009; Folke *et al.,* 2010). Indigenous knowledge enhances adaptive capacity by facilitating context-specific decision-making under uncertainty (Adger, 2006). The significant path coefficient therefore suggests that strengthening local knowledge systems may be one of the most effective entry points for improving drought and flood management outcomes in semi-arid regions.

Institutional Mediation and the Governance of Adaptation

A key contribution of this study lies in demonstrating the mediating role of academic institutions' engagement in the relationship between indigenous knowledge and climate risk management effectiveness. The structural model shows that indigenous knowledge significantly predicts institutional engagement ($\beta = 0.390$, $p < 0.01$), while academic engagement in turn positively influences management effectiveness ($\beta = 0.318$, $p < 0.01$). Bootstrapped results further confirm a significant indirect effect ($\beta = 0.124$, 95% CI [0.031, 0.249]), indicating partial mediation.

This implies that academic institutions function as knowledge brokers who amplify the impact of community-based adaptive practices by translating them into structured training programmes, research outputs, and policy-relevant interventions. This finding aligns with transdisciplinary sustainability research emphasising collaborative knowledge production between academic actors and local communities as a pathway for addressing complex environmental challenges (Lang *et al.,* 2012). Importantly, the presence of both significant direct and indirect paths suggests that indigenous knowledge retains autonomous influence even in the absence of strong institutional support, underscoring the need for governance strategies that build upon existing local adaptive capacities.

Environmental Resources without Governance Integration: The Weak Role of Seasonal Rivers

Contrary to initial expectations, prospects of seasonal rivers did not show statistically significant relationships with either academic institutional engagement ($\beta = -0.037$, $p > 0.05$, 95% CI [−0.198, 0.102]) or drought and flood management effectiveness ($\beta = -0.094$, $p > 0.05$, 95% CI [−0.271, 0.083]). From an SES standpoint, this finding highlights the distinction between resource availability and resource governance. While seasonal rivers represent potentially valuable hydrological assets, their contribution to resilience is contingent upon effective management systems, infrastructural investments, and coordinated stakeholder action.

In Ikanga–Kyatune, competing uses such as sand harvesting, livestock watering, and small-scale irrigation may reduce the perceived reliability of seasonal rivers as climate adaptation resources. The weak factor loadings and relatively low convergent validity associated with this construct further suggest heterogeneous experiences among respondents, potentially reflecting spatial inequalities in water access, inconsistent rainfall patterns, and limited institutional support for integrated catchment management.

These results contribute to broader climate adaptation debates that caution against resource-deterministic approaches (Adger *et al.,* 2013).

Implications for Knowledge Governance in Semi-Arid Lands

The PLS-SEM findings collectively indicate that knowledge governance mechanisms exert greater influence on perceived climate resilience than environmental resource potential alone.

The structural model demonstrates a clear pathway through which indigenous knowledge enhances institutional engagement, which in turn strengthens drought and flood management effectiveness, reflecting adaptive governance systems characterised by information exchange, stakeholder collaboration, and iterative learning (Folke *et al.,* 2010).

For Ikanga–Kyatune and similar ASAL regions, the results suggest that climate adaptation interventions should prioritise: (i) formal integration of indigenous knowledge into disaster risk reduction planning; (ii) strengthening partnerships between academic institutions, local governments, and community organisations; and (iii) enhancing participatory research and extension models that facilitate co-production of adaptation solutions.

Situating Findings within Wider Resilience Scholarship

This study contributes to resilience research by providing quantitative PLS-SEM evidence of institutional mediation pathways within socio-ecological systems, a dimension that has received limited empirical attention in semi-arid contexts.

While previous studies have separately highlighted the importance of indigenous knowledge and environmental resource management, the present findings demonstrate how governance actors shape the translation of these factors into effective climate risk management outcomes. The predictive relevance of the structural model ($Q^2 > 0$) further affirms the utility of the PLS-SEM approach for exploratory research in complex socio-ecological settings. The results underscore the importance of moving toward systems-based adaptation frameworks that account for interactions among ecological, social, and institutional variables.

Limitations and Future Research

Although PLS-SEM is specifically suited to smaller samples, the relatively small sample size (n = 62) limits statistical generalisability. Future studies should employ larger datasets and longitudinal designs to capture temporal dynamics in adaptive capacity and institutional engagement.

Further research could incorporate objective hydrological and livelihood indicators to complement perception-based measures, and explore moderating variables such as infrastructure quality, policy support, and socio-economic inequality.

In conclusion, this study investigated how prospects of seasonal rivers, indigenous knowledge systems, and academic institutional engagement influence drought and flood management effectiveness in the semi-arid context of Ikanga–Kyatune Ward, Kenya. Using Partial Least Squares Structural Equation Modelling (PLS-SEM) via SmartPLS 4, the findings demonstrate that indigenous knowledge systems and academic institutions' engagement are significant determinants of climate risk management effectiveness, with the latter partially mediating the relationship between indigenous knowledge and resilience outcomes.

In contrast, seasonal river prospects showed no significant direct or indirect effects, indicating that environmental resources alone do not guarantee improved management without enabling governance structures.

These findings reframe adaptation in semi-arid lands as fundamentally a knowledge governance challenge. Effective climate resilience requires integrating indigenous knowledge into formal disaster management policies, strengthening university–community partnerships, and investing in capacity-building initiatives that bridge local adaptive practices with institutional frameworks.

The study establishes a foundation for future large-scale and longitudinal research on institutional dynamics and adaptive capacity in climate-vulnerable landscapes.

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Conflict of Interest

The authors declare no competing interests.

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