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Knowledge management practices and adoption of inclusive rangeland interventions in northern Kenya

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Knowledge management (KM) is increasingly recognized as important for integrating Indigenous and modern knowledge in rangeland management; however, evidence on the specific KM practices associated with the adoption of blended knowledge among pastoral communities remains limited. This study examined the association between KM practices and the adoption of inclusive rangeland interventions in Northern Kenya. A cross-sectional survey involving 475 pastoral households was conducted in Marsabit, Isiolo, and Samburu counties using a multistage sampling procedure. Data were collected using a structured questionnaire and analyzed using descriptive statistics and ordinal logistic regression. The outcome variable was the level of adoption of blended Indigenous and modern knowledge, categorized as not adopted, slightly adopted, moderately adopted, highly adopted, and fully adopted. Access to livestock extension services was positively associated with higher adoption of blended knowledge (OR = 2.13, 95% CI: 1.23–3.69, p = 0.007), as was membership in community organizations or associations (OR = 2.06, 95% CI: 1.32–3.20, p = 0.001) and access to digital tools (OR = 2.14, 95% CI: 1.00–4.55, p = 0.049). Knowledge sharing on coping mechanisms showed a strong positive association with adoption (OR = 1.57, 95% CI: 1.29–1.91, p < 0.001), while knowledge sharing on controlled grazing (OR = 1.25, 95% CI: 1.02–1.53, p = 0.035) and rangeland improvement (OR = 1.31, 95% CI: 1.04–1.64, p = 0.020) were also significant. Among knowledge-application practices, water harvesting (OR = 1.73, 95% CI: 1.29–2.33, p < 0.001) and herd splitting (OR = 1.35, 95% CI: 1.05–1.74, p = 0.019) were positively associated with higher adoption, whereas seasonal-migration knowledge application was negatively associated (OR = 0.71, 95% CI: 0.53–0.95, p = 0.020). Descriptively, water harvesting (mean = 3.90) and seasonal migration (mean = 3.87) received the highest ratings for knowledge-application success. The findings demonstrate that adoption of blended Indigenous and modern knowledge is associated with institutional support, collective participation, access to digital tools, and active knowledge sharing and application. Strengthening livestock extension services, community-based knowledge-sharing platforms, and context-appropriate digital tools may therefore support more inclusive and adaptive rangeland management in Northern Kenya.

KEYWORDS
blended knowledge, knowledge management, northern Kenya, ordinal logistic regression, rangeland management

Introduction

Rangelands support livestock production, biodiversity conservation and the livelihoods of communities living in arid and semi-arid environments. In Africa, rangeland ecosystems are central to pastoral production systems and support large human and livestock populations, while in Kenya the rangelands of Marsabit, Isiolo, and Samburu counties are fundamental to pastoral livelihoods (Liniger and Studer, 2019; Reid et al., 2014). However, climate variability, land degradation, governance challenges and socio-economic inequalities continue to undermine rangeland productivity and pastoral livelihoods (Liniger and Studer, 2019). Addressing these challenges requires both the development of appropriate rangeland management interventions and effective pathways through which relevant knowledge is accessed, shared and translated into practice.

Pastoral communities possess substantial Indigenous knowledge developed through continuous observation, livestock management and long-term interaction with their environments (Mahdavi et al., 2023). This knowledge can inform decisions concerning grazing, livestock mobility, forage resources and responses to environmental variability. Notably, pastoral communities increasingly interact with modern or explicit knowledge generated through extension services, scientific research, development programmes and digital information platforms. KM provides a framework for bringing these different forms of knowledge together through processes of knowledge identification, sharing, learning and application (Areed et al., 2021; Nderema et al., 2022).

The availability of knowledge, however, does not necessarily result in its adoption. For knowledge to influence rangeland management decisions, it must be accessible, relevant to local conditions, shared through trusted channels, and capable of being applied in practice. Previous studies have highlighted persistent gaps in the accessibility, relevance, and practical application of knowledge, particularly where interventions are designed around a narrow group of users or insufficiently incorporate local experience (Tilstone et al., 2014). In northern Kenya, Indigenous knowledge has demonstrated practical value in rangeland restoration and resource management, including knowledge related to grasses and forage resources (Omollo et al., 2023). Sustainable rangeland management practices, including grazing management, reseeding, and community-based natural resource management, similarly depend on the effective translation of knowledge into locally appropriate action (Mohamed Sala et al., 2020; Mureithi et al., 2016).

The adoption of rangeland interventions may also depend on the institutional and social pathways through which knowledge flows. Extension services can connect pastoralists with technical information, while community groups and collective platforms can facilitate interaction, learning, and exchange among households. Digital tools may provide additional opportunities for accessing information beyond conventional face-to-face channels. However, access to knowledge and participation in these processes are not always equitable. Restrictive social norms, inadequate services, and limited financial resources may constrain participation and access to innovations, particularly among marginalized groups (Bullock et al., 2022). Financial exclusion and gendered differences in access to digital technologies may further limit opportunities to obtain and use relevant information (Faton et al., 2025).

The importance of inclusion is particularly relevant in pastoral rangeland systems because different social groups possess distinct experiences and knowledge relevant to resource management. Women contribute substantially to livestock production, household livelihoods, and natural-resource management, although opportunities for participation in formal rangeland decision-making may vary across social and institutional contexts (Bullock et al., 2022; Galiè et al., 2013). Participatory approaches and inclusive knowledge systems may therefore strengthen the incorporation of diverse experiences into rangeland decision-making. Evidence from Marsabit County has similarly highlighted the importance of women's participation in community-based natural-resource management and climate-resilience initiatives (Ojuok and Ndayizigiye, 2021). Inclusive approaches may therefore strengthen the recognition and incorporation of diverse experiences and knowledge into rangeland decision-making.

The interaction between locally embedded knowledge and formal technical knowledge is also increasingly recognized as important in livestock and natural-resource management. Locally developed knowledge and practices can complement formal scientific and technical approaches when interventions are adapted to local production systems and environmental conditions (Mahdavi et al., 2023; Mutavi et al., 2018). More broadly, the integration of local and scientific knowledge requires approaches that recognize differences in how knowledge is produced, validated, and applied in natural-resource management (Yanou et al., 2023). Effective knowledge exchange is therefore not simply a matter of transferring technical information but requires processes that facilitate interaction between knowledge holders, knowledge users, and institutions (Reed et al., 2014).

Despite growing recognition of the importance of Indigenous and modern knowledge in pastoral systems, an important question remains regarding the specific KM practices associated with the adoption of blended knowledge. Existing research and development efforts have frequently emphasized knowledge generation, dissemination, or overall KM performance. However, the processes through which institutional access, collective participation, knowledge sharing, implementation, and practical application are associated with household-level adoption of integrated Indigenous and modern knowledge require further empirical examination. This distinction is important because the successful management of complex rangeland systems may depend not simply on possessing different forms of knowledge, but on the ability of households and communities to combine and apply them in ways that are relevant to local environmental and livelihood conditions.

This study examines the association between KM practices and the adoption of blended Indigenous and modern knowledge for rangeland management among pastoral households in Marsabit, Isiolo and Samburu counties in northern Kenya. Specifically, the study assesses the role of institutional access, participation in collective knowledge systems, knowledge-sharing practices, implementation of rangeland innovations, and practical knowledge application in explaining variation in the level of adoption of blended knowledge. By focusing on adoption as the

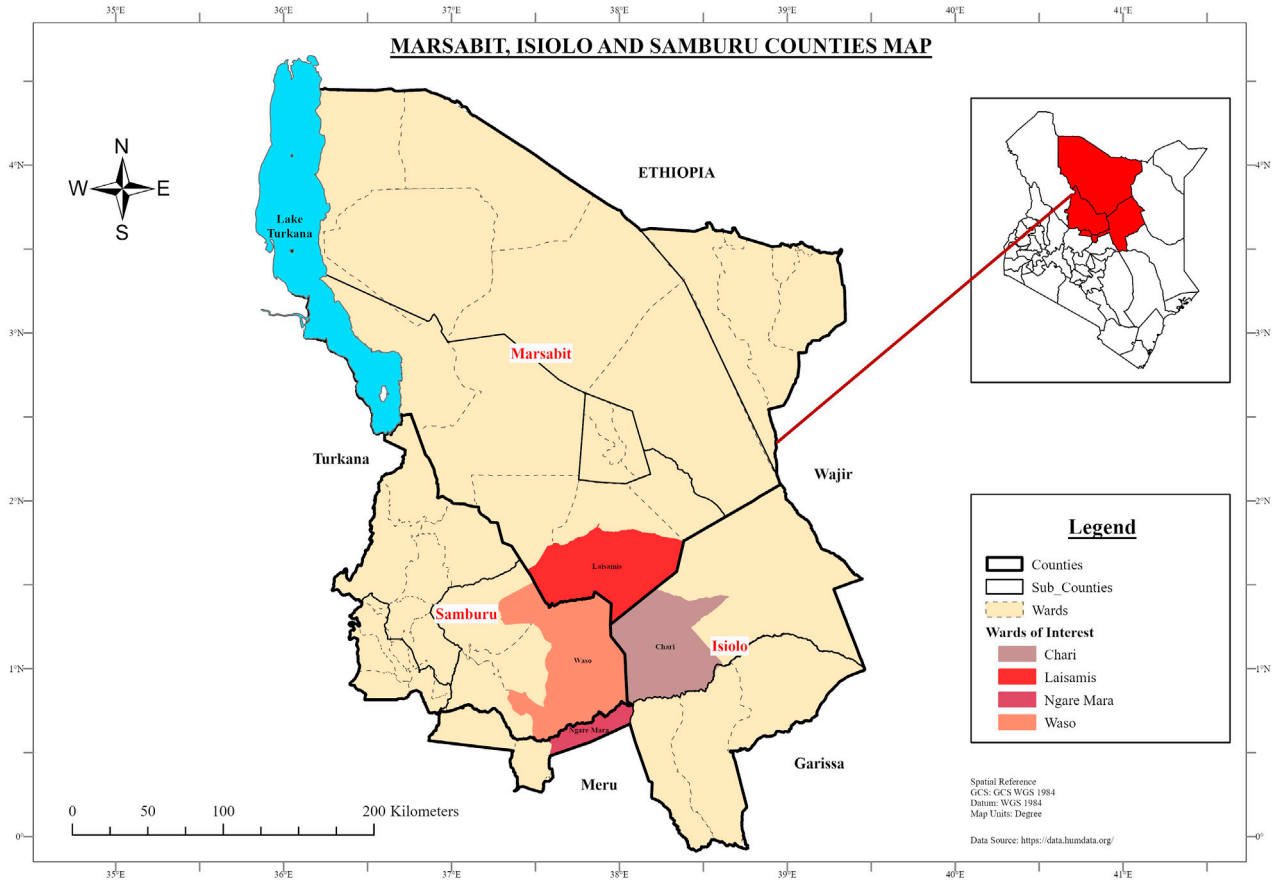


FIGURE 1
Study map of Marsabit, Isiolo and Samburu counties (GIS by Aaron).

primary outcome, the study provides evidence on the knowledge pathways that may support more inclusive and contextually appropriate rangeland management interventions.

Materials and methods

Study design and data sources

This study used a cross-sectional household survey to examine the association between KM practices and the adoption of blended Indigenous and modern knowledge for rangeland management among pastoral households in northern Kenya. Primary data were collected through structured Household questionnaire presented in Supplementary Material, while secondary information was obtained through a review of relevant policy documents, county planning documents, project reports, and published literature on KM and sustainable rangeland management. The secondary sources included the County Integrated Development Plans for Marsabit, Isiolo and Samburu counties (2023–2027), Sustainable Rangeland Management technical guidelines, project implementation documents and relevant published literature. These sources were used to contextualize the study area, identify major rangeland management interventions, and inform the development of the household questionnaire. They were not included as observations or variables in the statistical analysis. The study tested the null hypothesis that KM practices have no significant association with the adoption of inclusive rangeland management interventions, against the alternative hypothesis that KM practices are significantly associated with their adoption. Implementation was assessed by asking respondents to rate the perceived success with which selected rangeland management interventions had been put into practice within their communities. Knowledge application was assessed separately by asking respondents to rate the perceived success with which knowledge related to the respective interventions had been actively applied in practice. Both measures were assessed using five-point Likert-type response scales. The present analysis specifically focused on the adoption of blended Indigenous and modern knowledge as the primary outcome.

Study area

The study was conducted in selected pastoral areas of Marsabit, Isiolo and Samburu counties in northern Kenya, (Figure 1), (details presented in Figure 1). These counties are characterized predominantly by arid and semi-arid rangelands, where livestock production is a major livelihood activity and communities depend substantially on rangeland resources (Marsabit, Isiolo and Samburu

County Integrated Development Plan 2023-2027). The specific study locations were Laisamis Ward in Laisamis Sub-County, Marsabit County; Chari and Ngaremara wards in Merti Sub-County, Isiolo County; and Waso Ward in Samburu East Sub-County, Samburu County (Table 1). The sites were purposively selected because of their broadly comparable pastoral and agro-ecological characteristics, exposure to climate variability, and the presence of multiple rangeland management interventions (Supplementary Data Sheet 1).

Sampling procedure

A multistage sampling procedure was used to select study sites and households. In the first stage, the three counties, sub-counties, and study wards were purposively selected based on their pastoral production systems, exposure to climate variability, and implementation of rangeland management interventions. In the subsequent stage, the sample was distributed proportionately according to the population size of the selected wards. The required sample size was determined using the Yamane formula. A list of 93 villages was obtained with the support of local administrative structures. Household listing within the selected villages was subsequently undertaken with the assistance of village elders and local administrators. Proportionate and simple random sampling procedures were then used to select the required households from each village. Selected households were visited and informed about the purpose of the study before consent was sought. Interviews were administered to household heads or adult household representatives who were at least 18 years old, knowledgeable about household livelihood and rangeland management activities, and willing to participate. A total of 475 households were randomly selected and interviewed, resulting in a 100% response rate.

Equation 1 Sample calculation

$$n = \frac{N}{(1 + Ne^2)} \quad (1)$$

Where n is the sample size,

N is the number of households,
and e is the level of precision (0.08).

Data collection and questionnaire development

A field scoping exercise was conducted in Marsabit, Samburu and Isiolo counties from 1st to 4th September 2024. The exercise introduced the research to relevant county stakeholders, obtained contextual insights regarding the study areas, and assessed logistical considerations for the household survey. Data collection was conducted by 20 enumerators recruited from the study areas and able to communicate in the relevant local languages. The team included six Rendille speakers from Marsabit, six Samburu speakers from Samburu, four Turkana speakers working in Ngaremara, and four Borana speakers working in Chari. Enumerators received a two-day orientation and training from 4th to 5th November 2024 covering the study objectives, survey procedures, and questionnaire content. The household questionnaire was developed from the study objectives and guided by Wiig, (1993) KM framework. It also drew on previous literature on KM and sustainable rangeland management. Sustainable Rangeland Management guidelines informed the selection of rangeland management interventions included in the questionnaire (Liniger and Studer, 2019) county planning documents, project implementation documents, and information obtained during the field scoping exercise. The instrument was tailored to the pastoral context of Marsabit, Isiolo and Samburu counties. The questionnaire captured information on: socio-demographic and household characteristics; institutional access to knowledge and information; participation in groups and knowledge-sharing processes; knowledge sharing related to selected rangeland management practices; implementation of rangeland management interventions comprising (Herd Splitting, Seasonal migration, Rotational grazing, Control of livestock herd size and Composition, Livestock breed improvement, Pasture and fodder establishment, Supplementary feeding, Invasive species control, Physical fencing/enclosures, Soil erosion control, Tree Planting/Restoration, Water harvesting, Livestock insurance, Marketing information, promoted within the study areas); practical application of Indigenous and modern knowledge; and adoption of blended Indigenous and modern knowledge. The questionnaire was reviewed during enumerator training and pre-tested among 10 randomly selected households in Manyatta Zebra sub-location, Ngaremara Ward. The pre-test assessed the clarity and contextual appropriateness of the questions, suitability of response categories, sequencing of items, and feasibility of administering the questionnaire. Feedback from the pre-test was used to refine the wording and administration procedures before the main survey. The main household survey was conducted from 7th to 19th November 2024. Participation in the study was voluntary. The purpose of the study was explained to all selected participants before the interviews, and informed consent was obtained before data collection. Interviews were conducted only with adult household heads or representatives aged 18 years and above who agreed to participate. Ethical approval for the study was obtained from the National Commission for Science, Technology and Innovation (NACOSTI), approved License No.: NACOSTI/P/24/42188 can be found in Supplementary Data Sheets 2, 3.

Measurement of study variables

The dependent variable was the level of adoption of blended Indigenous and modern knowledge for rangeland management (Table 2). For this study, blended knowledge refers to the combined use of Indigenous and modern knowledge in decisions and practices relating to rangeland management.

Data analysis

SPSS version 28 and STATA 17.0 software were used for data analysis. Descriptive statistics, including frequencies, percentages, and means, were used to summarize the level of adoption of

Indigenous, modern, and blended knowledge. The primary inferential analysis used an ordinal logistic regression model (ologit) to examine factors associated with the level of adoption of blended Indigenous and modern knowledge. Ordinal logistic regression was appropriate because the dependent variable consisted of five ordered categories ranging from Not adopted to Fully adopted. The model estimates the association between explanatory variables and the likelihood of being in a higher category of the ordered outcome. The proportional-odds assumption was assessed and found to be satisfied. Therefore, the ordinal logistic regression model was retained as the appropriate model for the analysis. The OLR model was specified as:

Equation 2 OLR model

$$\text{Log}\left[\frac{P(Y \le j)}{1 - P(Y \le j)}\right] = \alpha_j + \beta_1 X_1 + \beta_2 X_2 + ..\beta_n X_n. \quad (2)$$

Where:

P (Y≤ j) is the cumulative probability of adoption KM as level *j* or below;
αj are threshold parameters for each level
βn Xn represents the coefficients for each explanatory variable Xn.

Regression coefficients (β), standard errors (SE), odds ratios (OR) and 95% confidence intervals (CI) were reported. Odds ratios were calculated as:

$$\text{OR} = e^{\beta}$$

and the 95% confidence interval for each odds ratio was calculated as:

$$95\%\ \text{CI} = \left(e^{\beta - 1.96(SE)}, e^{\beta + 196(SE)}\right)$$

An OR greater than 1 indicates that higher values of the predictor were associated with greater odds of being in a higher adoption category, whereas an OR below 1 indicates lower odds, subject to the coding and direction of the predictor. Statistical significance was assessed at the 5% level ($p < 0.05$).

Model diagnostics and goodness of fit

The ordinal logistic regression model was statistically significant overall (LR χ^2 (40) = 226.47, $p < 0.001$), indicating that the predictors jointly provided a better fit than the intercept-only model. The model produced a McFadden pseudo-R^2 of 0.172. This statistic indicates improvement in model fit relative to the null model and should not be interpreted as the percentage of variance in blended-knowledge adoption explained by the predictors. The proportional-odds assumption was satisfied, supporting the use of the ordinal logistic regression specification. To assess multicollinearity, the Variance Inflation Factor (VIF) values were examined. All variables had VIF values below the conventional threshold of 10, with a mean VIF of 1.78, confirming that there are no multicollinearity concerns. Additionally, the internal consistency of the KM construct was validated through Cronbach's Alpha (α = 0.877), confirming strong reliability of the items used in the index.

TABLE 1 Study area distribution.

County	Subcounty	Ward
Marsabit	Laisamis	Laisamis
Isiolo	Merti	Chari and ngaremara
Samburu	Samburu east	Waso

The results should therefore be interpreted in terms of the direction and magnitude of the estimated proportional odds ratios rather than as a percentage of variation explained.

Results

Levels of adoption of indigenous, modern and blended knowledge

Table 3 presents the reported levels of adoption of Indigenous, modern and blended knowledge for rangeland management among the 475 surveyed households. Indigenous knowledge had the highest mean adoption score (mean = 3.74, SD = 1.28), followed by blended Indigenous and modern knowledge (mean = 3.24, SD = 1.18) and modern knowledge (mean = 3.15, SD = 1.23). Indigenous knowledge was fully adopted by 40.0% of respondents, whereas 23.4% reported fully adopting blended knowledge and 23.0% fully adopted modern knowledge. The distribution indicates that Indigenous knowledge remained strongly embedded in household rangeland management practices. However, the moderate level of adoption of blended knowledge suggests that households were also combining Indigenous and modern knowledge to varying degrees. Because the present study specifically examines factors associated with this integration, adoption of blended Indigenous and modern knowledge was used as the dependent variable in the ordinal logistic regression analysis.

Respondents were asked to rate the perceived success of the implementation of selected rangeland management interventions using a five-point Likert scale ranging from 1 = Not very successful to 5 = Very successful. Table 4 shows variation in respondents' perceived success of implementing different rangeland management interventions. Seasonal migration recorded the highest mean implementation rating (mean = 3.89, SD = 0.82), followed by water harvesting (mean = 3.84, SD = 0.85) and tree planting/restoration (mean = 3.72, SD = 0.90). Other interventions with relatively high implementation ratings included soil erosion control and invasive species control (mean = 3.59 for each), as well as pasture and fodder establishment (mean = 3.52).

Respondents were also asked to rate the perceived success of applying knowledge related to the selected rangeland management interventions. Responses were measured on a five-point Likert scale ranging from 1 = Not very successful to 5 = Very successful. As shown in Table 5, water harvesting recorded the highest mean rating for successful knowledge application (mean = 3.90, SD = 0.81), followed closely by seasonal migration (mean = 3.87, SD = 0.82) and tree

TABLE 2 Description and measurement of variables included in the ordinal logistic regression model.

Variable category	Variable	Type of measurement	Measurement and coding
Dependent variable	Adoption of blended knowledge (indigenous + modern)	Ordinal	5-Point likert scale: 1 = not adopted, 2 = slightly adopted, 3 = moderately adopted, 4 = highly adopted, 5 = fully adopted
Independent variables			
Socio-demographic	Age of household head	Continuous	Completed years
	Sex of household head	Binary	1 = male, 0 = female
	Marital status	Categorical	Single, married, divorced, widowed
	Level of education	Continuous	Years of formal schooling
	Distance to livestock market (km)	Continuous	Distance (km) to markets
Information access	Mobile phone use for livestock market information	Binary	1 = yes, 0 = No
Institutional access	Access to livestock extension	Binary	1 = yes, 0 = No
Collective participation	Group membership association	Binary	1 = member of community group, 0 = non-member
Knowledge barriers	Cultural resistance to knowledge access, sharing, and use	Binary	1 = yes, 0 = No
	Language and communication barriers	Binary	1 = yes, 0 = No
	Limited access to knowledge resources	Binary	1 = yes, 0 = No
Knowledge integration	Integration of formal and indigenous knowledge systems	Binary	1 = yes, 0 = No
Knowledge participation	Participation in knowledge-sharing forums	Binary	1 = yes, 0 = No
Indigenous knowledge	Awareness of the value of indigenous knowledge	Binary	1 = yes, 0 = No
Digital access	Access to digital tools	Binary	1 = yes, 0 = No
Knowledge sharing	Controlled-grazing knowledge sharing	Ordinal	Five- point likert scale: 1 = never to 5 = Always
	Rangeland-improvement knowledge sharing	Ordinal	Five- point likert scale: 1 = never to 5 = Always
	Herd-splitting knowledge sharing	Ordinal	Five- point likert scale: 1 = never to 5 = Always
	Marketing-information knowledge sharing	Ordinal	Five- point likert scale: 1 = never to 5 = Always
	Coping-mechanism knowledge sharing	Ordinal	Five- point likert scale: 1 = never to 5 = Always
Implementation/Diffusion	Soil-erosion-control implementation	Ordinal	Likert scale
	Restoration implementation	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Water-harvesting implementation	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Marketing-information implementation	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Seasonal grazing implementation	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Rotational grazing implementation	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Herd-splitting implementation	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Invasive-species-control implementation	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Herd size-control implementation	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)

(*Continued*)

TABLE 2 Continued

Variable category	Variable	Type of measurement	Measurement and coding
Knowledge application	Herd-splitting knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Seasonal-migration knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Rotational-grazing knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Herd-control knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Livestock-breed-improvement knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Supplementary-feeding knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Invasive-species knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Fencing knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Soil-erosion-control knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Water-harvesting knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)
	Livestock-insurance knowledge application	Ordinal	Five- point likert scale: (1 = not successful, 5 = very successful)

TABLE 3 Proportionate scoring of the level of adoption of the knowledge sources on rangeland management in the community.

Rangeland management innovations	Mean	Not adopted (%)	Slightly adopted)	Moderately adopted (%)	Highly adopted (%)	Fully adopted (%)	Std Dev
Indigenous knowledge	3.74	7.0	10.0	26.0	17.0	40.0	1.28
Modern knowledge	3.15	8.6	20.4	41.3	6.7	23	1.23
Blended knowledge (indigenous and explicit)	3.24	6.5	17.5	44.6	8	23.4	1.18

(n = 475).

planting/restoration (mean = 3.71, SD = 0.94). Relatively high ratings were also reported for soil erosion control (mean = 3.59), pasture and fodder establishment (mean = 3.58), invasive species control (mean = 3.58), and rotational grazing (mean = 3.55).

Ordinal logistic regression analysis of factors associated with adoption of blended knowledge

An ordinal logistic regression model (Table 6) was fitted to examine factors associated with household-level adoption of blended Indigenous and modern knowledge. The detailed regression results are presented in Supplementary Table 2. The dependent variable was measured on five ordered categories: 1 = not adopted, 2 = slightly adopted, 3 = moderately adopted, 4 = highly adopted, and 5 = fully adopted, with higher values representing higher levels of adoption. The proportional-odds assumption was satisfied, supporting the use of the ordinal logistic regression model. The model was statistically significant overall (LR χ^2 (40) = 226.47, $p < 0.001$), indicating that the set of explanatory variables jointly improved the model's fit relative to an intercept-only model. The model included 475 households.

TABLE 4 Respondents' ratings of the perceived success of implementation of selected rangeland management interventions.

Rangeland management innovations	Mean	Not very successful (%)	Not successful (%)	Moderately successful (%)	Successful (%)	Very successful (%)	Std Dev
Herd splitting	3.29	6.3	13.9	30.5	43.4	5.9	0.99
Seasonal migration	3.89	1.3	4.2	19.8	53.9	20.8	0.82
Rotational grazing	3.51	4.6	11.6	25.5	45	13.3	1.01
Control of livestock herd size and composition	3.35	5.5	13.7	29.7	42.7	8.4	0.99
Livestock breed improvement	3.44	3.2	14.7	29.9	39.8	12.4	0.99
Pasture and fodder establishment	3.52	4	11	29	44	12	0.97
Supplementary feeding	3.45	3.6	9.7	34	43	9.7	0.92
Invasive species control	3.59	3.2	9.7	27.1	44.6	15.4	0.97
Physical fencing/enclosures	3.35	3.8	17.5	28	41.7	9	0.99
Soil erosion control	3.59	2.1	9.5	28	48	12.4	0.90
Tree planting/restoration	3.72	0.8	9.3	25.7	45.5	18.7	0.90
Water harvesting	3.84	1.1	6.0	21.1	51.4	20.4	0.85
Livestock insurance	3.30	2.3	20.8	30.7	36.7	9.5	0.98
Access to marketing information	3.48	2.1	12.8	33.3	38.3	13.5	0.95

(n = 475).

Results are presented as regression coefficients (β), standard errors (SE), proportional odds ratios (OR), 95% confidence intervals (CI), and p-values. These findings are consistent with similar studies that report comparable pseudo-R^2 values when analyzing adoption and perception data in dryland contexts (Mwololo et al., 2019).

Institutional and household factors

Access to livestock extension services was positively associated with higher levels of blended-knowledge adoption. Households with access to livestock extension services had approximately 2.13 times the odds of being in a higher adoption category than households without access (OR = 2.13, 95% CI: 1.23–3.69, p = 0.007). Group membership association was positively associated with adoption. Members had approximately 2.06 times the odds of being in a higher adoption category compared with non-members (OR = 2.06, 95% CI: 1.32–3.20, p = 0.001). Access to digital tools was also positively associated with higher adoption. Households with access to digital tools had approximately 2.14 times the odds of being in a higher adoption category compared with households without access (OR = 2.14, 95% CI: 1.00–4.55, p = 0.049). In contrast, age of the household head (OR = 1.00, p = 0.810), gender (OR = 1.61, p = 0.051), marital status (OR = 0.88, p = 0.639), Leve of education (OR = 1.01, p = 0.519), distance to the livestock market (OR = 1.01, p = 0.123), and phone use for livestock production (OR = 1.14, p = 0.532) were not statistically significant at the 5% level.

KM barriers

Cultural resistance to knowledge access, sharing, and use was negatively associated with adoption, but the association was not statistically significant (OR = 0.73, 95% CI: 0.47–1.11, p = 0.144). Communication barriers (OR = 1.23, p = 0.351), limited resources (OR = 1.20, p = 0.528), lack of Indigenous Knowledge integration (OR = 0.84, p = 0.631), and low knowledge-sharing forums (OR = 0.78, p = 0.473) were also not statistically significant. Insufficient awareness was negatively associated with adoption (OR = 0.55, 95% CI: 0.30–1.00, p = 0.050).

Knowledge-sharing practices

The frequency of knowledge sharing on specific rangeland practices was positively associated with adoption for several practices. A one-unit increase in the frequency of sharing knowledge on controlled grazing was associated with approximately 1.25 times the odds of being in a higher adoption category (OR = 1.25, 95% CI: 1.02–1.53, p = 0.035). More frequent sharing of knowledge on rangeland improvement was associated with higher adoption (OR = 1.31, 95% CI: 1.04–1.64, p = 0.020). The strongest association among the knowledge-sharing variables was observed for coping mechanisms. A one-unit increase in the frequency of sharing knowledge on coping mechanisms was associated with approximately 1.57 times the odds of being in a higher adoption category (OR = 1.57, 95% CI: 1.29–1.91, p < 0.001). Herd-splitting knowledge sharing was not statistically significant

TABLE 5 Respondents' ratings of the perceived success of knowledge application across selected rangeland management interventions.

Rangeland management innovations	Mean	Not very successful (%)	Not successful (%)	Moderately successful (%)	Successful (%)	Very successful (%)	Std Dev
Herd splitting	3.32	4.8	15.2	31.2	41	7.8	0.98
Seasonal migration	3.87	1.3	4.4	20	54.7	19.6	0.82
Rotational grazing	3.55	4.4	12	23	45.3	15.3	1.03
Control of livestock herd size and composition	3.37	8	10.7	28.6	42	10.7	1.07
Livestock breed improvement	3.48	1.3	13.7	31.6	42.3	11.1	0.91
Pasture and fodder establishment	3.58	2	7.4	31.8	47.8	11	0.86
Supplementary feeding	3.49	2.3	8.2	36.44	44.8	8.5	0.85
Invasive species control	3.58	4.2	10	24	47.8	14	0.99
Physical fencing/enclosures	3.44	4.8	12.6	26.5	46.1	10	0.99
Soil erosion control	3.59	2	11.2	24.8	50	12	0.91
Tree planting/restoration	3.71	2.1	9.1	22.5	48	18.3	0.94
Water harvesting	3.90	0.6	5.3	18.5	54.3	21.3	0.81
Livestock insurance	3.30	3.2	20.4	31	34.3	11.1	1.02
Access to marketing information	3.43	4.2	12.4	30.1	42.7	10.6	0.98

(n = 475).

(OR = 1.18, p = 0.095), nor was marketing-information knowledge sharing (OR = 1.02, p = 0.865).

Implementation and knowledge application

Among the implementation variables, only the implementation success of marketing-information innovation was significantly associated with adoption. A one-unit increase in reported implementation success was associated with approximately 1.38 times the odds of being in a higher adoption category (OR = 1.38, 95% CI: 1.08–1.76, p = 0.010). The implementation success of soil-erosion control, restoration, water harvesting, migration, rotational grazing, herd splitting, invasive-species control, and herd-control interventions did not reach statistical significance at the 5% level. Several knowledge-application variables were significantly associated with adoption. Herd-splitting knowledge application was positively associated with higher adoption (OR = 1.35, 95% CI: 1.05–1.74, p = 0.019). Water-harvesting knowledge application showed a stronger positive association, with approximately 1.73 times the odds of being in a higher adoption category (OR = 1.73, 95% CI: 1.29–2.33, p < 0.001). Livestock-insurance knowledge application was also positively associated with adoption (OR = 1.27, 95% CI: 1.01–1.59, p = 0.040). In contrast, seasonal-migration knowledge application was negatively associated with higher adoption categories (OR = 0.71, 95% CI: 0.53–0.95, p = 0.020), as was soil-erosion-control knowledge application (OR = 0.71, 95% CI: 0.54–0.93, p = 0.013). Rotational-grazing knowledge application showed a negative but borderline association (OR = 0.77, p = 0.052), while the remaining knowledge-application variables were not statistically significant.

Non-significant factors

Several socio-demographic variables were not significantly associated with the adoption of blended knowledge. These included age of the household head (OR = 0.998, p = 0.810), marital status (OR = 0.878, p = 0.639), years of schooling (OR = 1.012, p = 0.519), distance to the livestock market (OR = 1.008, p = 0.123) and mobile phone use for livestock market information (OR = 1.142, p = 0.532). Sex of the household head was borderline but did not meet the conventional 5% significance threshold (OR = 1.610, 95% CI: 0.999–2.595, p = 0.051). Similarly, cultural resistance, language and communication barriers, limited access to knowledge resources, integration of formal and Indigenous knowledge systems, and participation in knowledge-sharing forums were not statistically significant at the 5% level.

Discussion

Perceived implementation success of rangeland interventions

Table 4 provides important descriptive context for interpreting the regression findings. Respondents generally rated the

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TABLE 6 Ordinal logistic regression of factors associated with adoption of blended Indigenous and modern knowledge.

Predictor	β	SE	OR	95% CI for OR	p-value
Socio-demographic and information factors					
Age of household head	−0.0017	0.0072	0.998	0.984–1.013	0.81
Sex of household head	0.4762	0.2436	1.61	0.999–2.595	0.051
Marital status	−0.1304	0.2775	0.878	0.509–1.512	0.639
Level of education	0.0121	0.0187	1.012	0.976–1.050	0.519
Distance to livestock market (km)	0.0083	0.0054	1.008	0.998–1.019	0.123
Mobile phone use for livestock market information	0.1332	0.2131	1.142	0.752–1.735	0.532
Institutional factors					
Access to livestock extension	0.7569	0.2793	2.132	1.233–3.686	0.007
Group membership association	0.7206	0.2263	2.056	1.319–3.203	0.001
Cultural resistance to knowledge access, sharing, and use	−0.3187	0.2179	0.727	0.474–1.115	0.144
Language and communication barriers	0.2034	0.2181	1.226	0.799–1.879	0.351
KM factors					
Limited access to knowledge resources	0.1814	0.2874	1.199	0.683–2.106	0.528
Integration of formal and indigenous knowledge systems	−0.1719	0.3581	0.842	0.417–1.699	0.631
Participation in knowledge-sharing forums	−0.2452	0.3416	0.783	0.401–1.529	0.473
Awareness of the value of indigenous knowledge	−0.6027	0.308	0.547	0.299–1.001	0.05
Access to digital tools	0.7593	0.3852	2.137	1.004–4.547	0.049
Controlled-grazing knowledge sharing	0.2197	0.104	1.246	1.016–1.527	0.035
Rangeland-improvement knowledge sharing	0.2693	0.1157	1.309	1.043–1.642	0.02
Herd-splitting knowledge sharing	0.1691	0.1012	1.184	0.971–1.444	0.095
Marketing-information knowledge sharing	0.0169	0.0992	1.017	0.837–1.235	0.865
Coping-mechanism knowledge sharing	0.4494	0.1005	1.567	1.287–1.909	<0.001
Soil-erosion-control implementation	−0.1602	0.1377	0.852	0.650–1.116	0.245
Restoration implementation	−0.0579	0.1324	0.944	0.728–1.223	0.662
Water-harvesting implementation	0.1722	0.1398	1.188	0.903–1.562	0.218
Marketing-information implementation	0.3222	0.1253	1.38	1.080–1.765	0.01
Seasonal grazing implementation	−0.1783	0.1386	0.837	0.638–1.098	0.198
Rotational-grazing implementation	−0.2087	0.1346	0.812	0.623–1.057	0.121
Herd-splitting implementation	0.2119	0.1288	1.236	0.960–1.591	0.1
Invasive-species-control implementation	0.1314	0.1172	1.14	0.906–1.435	0.262
Herd size-control implementation	−0.0326	0.1305	0.968	0.750–1.250	0.803
Herd-splitting knowledge application	0.3006	0.1286	1.351	1.050–1.738	0.019
Seasonal-migration knowledge application	−0.3404	0.1467	0.711	0.534–0.948	0.02
Rotational-grazing knowledge application	−0.2571	0.1321	0.773	0.597–1.002	0.052
Herd-control knowledge application	−0.0779	0.1296	0.925	0.717–1.193	0.548
Livestock-breed-improvement knowledge application	0.1562	0.128	1.169	0.910–1.502	0.222
Supplementary-feeding knowledge application	−0.0806	0.1384	0.923	0.703–1.210	0.561

(*Continued*)

TABLE 6 Continued

Predictor	β	SE	OR	95% CI for OR	p-value
Invasive-species knowledge application	0.0793	0.1229	1.083	0.851–1.377	0.519
Fencing knowledge application	−0.1072	0.125	0.898	0.703–1.148	0.391
Soil-erosion-control knowledge application	−0.3474	0.1392	0.707	0.538–0.928	0.013
Water-harvesting knowledge application	0.5499	0.1511	1.733	1.289–2.330	<0.001
Livestock-insurance knowledge application	0.2375	0.1155	1.268	1.011–1.590	0.04

β = ordinal logistic regression coefficient; SE, standard error; OR, proportional odds ratio; CI, confidence interval; ORs, were calculated as exp(β), and 95% CIs, as exp [β ± 1.96(SE)]. OR > 1 indicates higher odds of being in a higher adoption category, while OR < 1 indicates lower odds, holding other variables constant. Statistical significance was assessed at $p < 0.05$.

implementation an element of diffusion of innovations, of the selected rangeland management interventions as moderately to highly successful, although perceived success varied across practices. Seasonal migration received the highest mean implementation rating (mean = 3.89), followed by water harvesting (mean = 3.84) and tree planting and restoration (mean = 3.72). In contrast, herd splitting (mean = 3.29) and livestock insurance (mean = 3.30) received comparatively lower ratings. The lower rating for livestock insurance may reflect the relatively limited uptake and familiarity of insurance products in extensive pastoral production systems. Previous evidence from Kenya indicates that livestock insurance uptake among extensive livestock producers remains low, highlighting challenges in translating insurance-based risk-management innovations into pastoral production contexts (Bostedt et al., 2025). Notably, Rogers, (2003) Diffusion of Innovation theory affirms that innovations perceived as compatible, observable, and experiential are more likely to be adopted.

The relatively high ratings for seasonal migration and water harvesting may reflect the long-standing relevance of these practices within pastoral production systems. Seasonal movement has historically been an important strategy through which pastoralists respond to spatial and temporal variation in pasture and water availability, while water management remains central to livelihoods in arid and semi-arid environments. Studies cited in the manuscript similarly recognize the importance of Indigenous and locally developed knowledge relating to grazing and water management in strengthening pastoral resilience (Mahdavi et al., 2023; Nyberg et al., 2019). The relatively favorable implementation ratings for tree restoration, soil erosion control, invasive species control, and pasture and fodder establishment also suggest that respondents recognized the value of interventions aimed at improving rangeland condition. Sustainable rangeland management involves a combination of practices intended to address land degradation while maintaining ecosystem functions and pastoral livelihoods (Liniger and Studer, 2019).

However, the descriptive ratings should not be interpreted as evidence that highly rated interventions necessarily contributed more strongly to blended-knowledge adoption. This distinction is important because the ordinal regression showed that, among the implementation variables included in the model, only marketing-information implementation was significantly associated with higher adoption (OR = 1.38, 95% CI: 1.08–1.76, p = 0.010). Implementation ratings for soil erosion control, tree planting and restoration, water harvesting, seasonal grazing, rotational grazing, herd splitting, invasive species control, and herd size control were not significantly associated with adoption after accounting for the other variables in the model. This difference between descriptive ratings and regression results demonstrates why both forms of analysis are useful. Table 4 describes how respondents perceived the success of implementation, whereas the regression analysis examines whether differences in reported implementation success were statistically associated with the likelihood of being in a higher blended-knowledge adoption category. The significant association observed for marketing-information implementation may indicate that interventions related to market information create a direct and practical connection between knowledge and livelihood decision-making. Timely information on livestock, fodder, and other markets may be readily translated into decisions concerning production and marketing. This interpretation is consistent with Liniger & Studer, (2019) recognizing the importance of knowledge-driven value chains and improved access to information in pastoral and rangeland systems.

Institutional access and collective participation in blended-knowledge adoption

The ordinal logistic regression showed that access to livestock extension services, group membership association, and access to digital tools were positively associated with higher levels of adoption of blended Indigenous and modern knowledge. Households with access to livestock extension services had approximately twice the odds of being in a higher adoption category (OR = 2.13, 95% CI: 1.23–3.69, $p = 0.007$), while group membership also had approximately twice the odds of higher adoption (OR = 2.06, 95% CI: 1.32–3.20, $p = 0.001$). Access to digital tools was similarly associated with higher adoption (OR = 2.14, 95% CI: 1.00–4.55, $p = 0.049$).

The positive association between extension access and adoption is consistent with the role of institutional knowledge channels in facilitating access to technical information and supporting its interpretation and application in local contexts. Tilstone et al. (2014) emphasize that KM systems in the drylands need to connect relevant knowledge with the people and institutions capable of applying it, while the present study suggests that livestock extension services may constitute one such pathway. The finding also aligns with the broader literature on knowledge exchange, which emphasizes interaction between knowledge holders rather than one-way dissemination of technical information (Reed

et al., 2014). The association between group membership and higher adoption further underscores the importance of collective institutions in facilitating knowledge exchange. Community organizations and other collective platforms can provide spaces in which pastoralists share experiences, compare practices, and interact with external actors. Such interactions may create opportunities for Indigenous and scientific knowledge to complement one another. This interpretation is consistent with Reed et al. (2014) who emphasize participation and interaction in knowledge exchange, and with Ojuok & Ndayizigiye, (2021), who highlight the importance of community participation in locally led natural-resource management and climate-resilience initiatives. Evidence from pastoral systems also demonstrates that experiential knowledge and scientific knowledge can interact to inform locally appropriate decisions (Mutavi et al., 2018).

Access to digital tools was also associated with higher levels of blended-knowledge adoption (OR = 2.14, 95% CI: 1.00–4.55, p = 0.049). This finding suggests that digital technologies may complement traditional and face-to-face knowledge systems by expanding opportunities to access and exchange information. In pastoral contexts, however, digital tools should not be viewed as substitutes for local knowledge systems. Instead, they can provide an additional channel through which pastoralists access weather, market, livestock, and rangeland-management information. This interpretation is consistent with Tilstone et al. (2014) who emphasize the importance of improving the accessibility, relevance, and usability of knowledge, and with Liniger & Studer, (2019), who highlight the role of knowledge and information systems in sustainable rangeland management.

Knowledge sharing and adoption of blended knowledge

The study found that the frequency of knowledge sharing on controlled grazing, rangeland improvement and coping mechanisms was positively associated with higher levels of blended-knowledge adoption. The odds of being in a higher adoption category increased by approximately 25% for controlled-grazing knowledge sharing (OR = 1.25, 95% CI: 1.02–1.53, p = 0.035), 31% for rangeland-improvement knowledge sharing (OR = 1.31, 95% CI: 1.04–1.64, p = 0.020), and 57% for coping-mechanism knowledge sharing (OR = 1.57, 95% CI: 1.29–1.91, $p < 0.001$). These findings directly support the KM framework underpinning the study (Wiig, 1993). KM involves possessing information, creating, sharing, contextualizing, and applying knowledge. The positive associations observed for knowledge sharing suggest that adoption may be strengthened when knowledge is exchanged repeatedly through processes that enable interaction between knowledge holders and users. This interpretation is consistent with the knowledge-exchange principles proposed by Reed et al. (2014), which emphasize the importance of context, stakeholder engagement, and effective processes for translating knowledge into environmental management practice. The positive association for controlled-grazing knowledge sharing is also supported by Augustine et al. (2020), emphasizing the role of adaptive, multi-paddock grazing management in improving rangeland outcomes.

The finding for rangeland-improvement knowledge sharing is similarly consistent with the argument that participatory knowledge exchange can facilitate the integration of different knowledge systems. Reed et al. (2014) emphasize the importance of participatory knowledge forums, while Yanou et al. (2023) argue for integrating local and scientific knowledge rather than treating them as separate systems. Knowledge sharing on coping mechanisms was relatively less frequent than several other knowledge-sharing practices. The combination of relatively lower sharing frequency and a strong association with adoption suggests that strengthening opportunities for exchanging experience around drought coping and adaptation may be particularly valuable. An important observation is that the descriptive results showed only moderate overall frequencies of knowledge sharing across the different practices. For instance, mean sharing scores ranged approximately from 2.99 to 3.27, indicating that knowledge exchange was not uniformly frequent across the interventions. This suggests that there remains considerable potential to strengthen regular and structured knowledge exchange within pastoral communities and between communities and external institutions. The findings are consistent with the KM perspective that knowledge becomes valuable not simply when it exists, but when it is exchanged, interpreted, and used in relevant decision-making contexts. They also broadly align with Rogers, (2003) Diffusion of Innovations framework, in which communication channels play an important role in the spread of ideas and practices. However, the present findings should be interpreted as associations rather than evidence that knowledge sharing directly causes adoption.

Knowledge application and adoption of blended knowledge

Table 5 complements the implementation findings by describing respondents' perceptions of the success of applying knowledge related to different rangeland management interventions. Water harvesting received the highest mean rating for knowledge application (mean = 3.90), followed by seasonal migration (mean = 3.87) and tree planting/restoration (mean = 3.71). Livestock insurance received the lowest rating (mean = 3.30), while herd splitting also received a comparatively lower rating (mean = 3.32). The similarity between the patterns observed in Tables 4, 5 suggests that interventions perceived as successfully implemented were often also perceived as successfully applied. Nevertheless, implementation and knowledge application represent analytically distinct dimensions. Implementation concerns the extent to which an intervention is successfully put into practice (Rogers, 2003) whereas knowledge application concerns the extent to which relevant knowledge is actively used in practice. It's pivotal to note these distinctions because the regression results indicate that their relationships with blended-knowledge adoption are not identical.

Several knowledge-application variables were significantly associated with adoption. Herd-splitting knowledge application was positively associated with higher adoption (OR = 1.35, 95% CI: 1.05–1.74, p = 0.019), while water-harvesting knowledge application showed the strongest positive association among the application variables (OR = 1.73, 95% CI: 1.29–2.33, p < 0.001).

Livestock-insurance knowledge application was also positively associated with higher adoption (OR = 1.27, 95% CI: 1.01–1.59, p = 0.040). The strong association observed for water-harvesting knowledge application is consistent with the importance of water management in dryland pastoral systems. Water harvesting can draw on both locally developed knowledge and modern technical approaches, making it a potentially important example of the practical interaction between Indigenous and scientific knowledge. The broader literature cited in the manuscript recognizes the contribution of Indigenous knowledge relating to water and grazing management to resilience, while sustainable rangeland-management approaches also emphasize technical and institutional interventions that improve resource management (Liniger and Studer, 2019; Mahdavi et al., 2023; Nyberg et al., 2019). The positive association between herd-splitting knowledge application and adoption may similarly reflect the practical relevance of this strategy in pastoral production. Herd splitting allows pastoral households to manage livestock differently according to age, sex, productivity, and resource availability. Such practices are embedded in pastoral experience but may also be strengthened through technical knowledge relating to livestock management. The finding therefore supports the broader argument that knowledge adoption in rangeland systems may be enhanced when locally grounded practices interact constructively with external sources of technical knowledge. The positive association between livestock-insurance knowledge application and adoption is particularly interesting because livestock insurance received one of the lowest descriptive ratings in Table 5. This apparent contrast should not be interpreted as a contradiction. A lower average rating indicates that successful knowledge application was less widely perceived across the sample, whereas the regression result indicates that, among households reporting greater success in applying livestock-insurance knowledge, the odds of being in a higher blended-knowledge adoption category were also greater.

This distinction may be important for understanding newer or more technically complex innovations. Livestock insurance may not yet be widely or successfully applied by all households, but those able to understand and apply relevant knowledge may be more integrated into broader systems of knowledge exchange and innovation. Financial exclusion and unequal access to information can limit participation in formal services and markets, particularly among marginalized groups (Bullock et al., 2022; Galwab et al., 2024).

Negative associations: seasonal migration and soil-erosion-control knowledge application

Two knowledge-application variables showed statistically significant negative associations with higher adoption categories: seasonal migration (OR = 0.71, 95% CI: 0.53–0.95, p = 0.020) and soil-erosion-control knowledge application (OR = 0.71, 95% CI: 0.54–0.93, p = 0.013). For seasonal migration, mobility is deeply embedded in pastoral production systems and may rely substantially on established experiential and Indigenous knowledge. Liniger & Studer, (2019) highlights mobility as a fundamental pastoral adaptation to spatial and temporal variation in forage and water availability, affecting land-use changes and resource constraints on pastoral management. Similarly, the negative association for soil-erosion-control knowledge application should not be interpreted as evidence that soil conservation is ineffective. Mureithi et al. (2016) demonstrate the benefits that can arise from rehabilitation of degraded semi-arid rangelands in Kenya. The negative association in the present analysis may instead reflect differences in the resources, institutional support or knowledge pathways required to implement soil-conservation measures. Future qualitative research would therefore be valuable for determining why these practices show negative statistical associations with the blended-knowledge outcome.

Understanding the contrasting associations across interventions

An important finding of this study is that not all positively rated interventions were positively associated with higher blended-knowledge adoption in the regression model. In particular, seasonal migration and soil erosion control received relatively favorable descriptive ratings, yet knowledge application relating to both practices was negatively associated with higher adoption categories. Seasonal-migration knowledge application had an OR of 0.71 (95% CI: 0.53–0.95, p = 0.020), while soil-erosion-control knowledge application had an OR of 0.71 (95% CI: 0.54–0.93, p = 0.013).

These findings do not mean that seasonal migration or soil erosion control reduces the adoption of blended knowledge. Rather, they indicate that, after adjusting for the other variables included in the ordinal logistic regression model, higher reported scores on these specific knowledge-application variables were associated with lower odds of being in a higher category of the composite blended-knowledge adoption outcome.

A possible explanation is that the adoption of blended knowledge is context-specific and does not occur uniformly across all interventions. Seasonal migration, for instance, is a deeply established pastoral strategy that may depend heavily on accumulated experiential knowledge, customary institutions, and locally negotiated access to grazing resources. Consequently, households that rely strongly on this practice may not necessarily demonstrate equally high adoption of the broader combination of Indigenous and modern knowledge captured by the dependent variable. Existing literature recognizes the importance of Indigenous and experiential knowledge in pastoral resource management (Mahdavi et al., 2023; Nyberg et al., 2019), but this does not imply that every Indigenous practice will have the same relationship with the adoption of blended knowledge. Similarly, soil erosion control may involve technical, institutional, and resource requirements that vary substantially across households and locations. The negative association may therefore reflect differences in the contexts in which households engage with the practice rather than an adverse effect of soil erosion-control knowledge itself. Because the study uses cross-sectional data, these associations cannot establish causal relationships. They should therefore be interpreted as patterns of association that warrant further investigation rather than as evidence that particular rangeland practices promote or inhibit adoption. This

variation across interventions supports the argument that KM should not treat all innovations as requiring the same dissemination or adoption strategy. Rogers, (2003) Diffusion of Innovations framework emphasizes that the adoption of innovations can vary according to the characteristics of the innovation and the context in which potential adopters encounter and evaluate it. The present findings suggest that KM approaches in pastoral rangelands similarly need to be tailored to the specific characteristics and knowledge requirements of different interventions.

Non-significant factors and implications for inclusive KM

Several variables were not significantly associated with higher levels of blended-knowledge adoption in the final ordinal logistic regression model. These included age, marital status, level of education, distance to livestock markets, mobile-phone use for livestock market information, cultural resistance, language and communication barriers, limited access to knowledge resources, integration of formal and Indigenous knowledge systems, and participation in knowledge-sharing forums. The absence of statistically significant associations should not be interpreted as evidence that these factors are unimportant in pastoral knowledge systems. Rather, within the multivariable model used in this study, they did not show independent associations with the ordinal adoption outcome at the conventional 5% significance level. Although cultural and communication barriers were not independently associated with adoption in the adjusted model, broader research continues to demonstrate that social differentiation and unequal participation can shape whose knowledge is recognized and whose voices are included in rangeland decision-makingm (Bullock et al., 2022; Galwab et al., 2024). The present results indicate that their independent statistical relationships with the specific outcome of blended-knowledge adoption were not significant after considering the other variables in the model. Although the finding regarding the integration of formal and Indigenous knowledge was not statistically significant, the conceptual importance of knowledge integration remains central to the study. The non-significant result may indicate that simply recognizing the integration of knowledge systems is insufficient; meaningful adoption may depend more strongly on the practical mechanisms through which knowledge is accessed, shared, and applied. The significant associations observed for extension access, group membership, digital access, knowledge sharing, and selected application practices support this interpretation.

Overall, the findings suggest that inclusive KM in Northern Kenya should transition beyond the simple dissemination of technical information. Effective approaches should strengthen the institutional, social, and technological pathways through which knowledge is accessed and exchanged. Extension services and community organizations can provide opportunities for interaction between knowledge holders, while appropriately designed digital tools may expand access to information. At the same time, the variation observed across implementation and application practices demonstrates that interventions should be supported through context-specific KM strategies rather than standardized approaches.

Limitations of the study

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design captures knowledge access, sharing, application, and adoption at one point in time and therefore does not establish temporal or causal relationships between KM practices and adoption. The associations identified through OLR should consequently be interpreted as statistical relationships rather than causal effects. Second, the dependent variable represents respondents' perceived level of adoption of blended Indigenous and modern knowledge measured across five ordered categories. Although this approach is appropriate for ordinal responses and preserves the ordering of adoption levels, it relies on self-reported perceptions and may therefore be affected by recall or social-desirability bias. Third, the analysis was conducted using data from 475 households in four wards of Laisamis ward (Marsabit county), Ngaremara and Chari wards in (Isiolo County) and Waso ward in (Samburu County). The multi-ward design provides coverage across different pastoral communities within the study area, but the findings should not automatically be generalized to all pastoralist communities in Kenya or to other dryland contexts with different institutional, cultural, and ecological conditions. Fourth, although the model included demographic, institutional, cultural, and KM variables, other factors that were not measured may also influence blended-knowledge adoption. These may include household wealth, social networks, exposure to specific projects, leadership structures, market conditions and the duration or intensity of participation in rangeland-management programmes. The observed associations should therefore be interpreted within the variables included in the model. Finally, the study focuses on household-level perceptions and does not directly measure the ecological outcomes of the adopted rangeland interventions. Future longitudinal and mixed-methods studies could examine how knowledge is exchanged among different social groups over time and whether higher levels of blended-knowledge adoption translate into measurable improvements in rangeland condition, livelihood resilience and equitable participation in governance.

Conclusion and recommendation

This study examined the association between KM practices and the adoption of blended Indigenous and modern knowledge for inclusive rangeland management among pastoral households in Northern Kenya. The findings demonstrate that adoption is associated with multiple and interconnected dimensions of KM, particularly institutional access, collective participation, knowledge sharing, and the practical application of knowledge. Access to livestock extension services, membership in community organizations or associations, and access to digital tools were positively associated with higher levels of blended-knowledge adoption. These findings suggest that strengthening the pathways

through which pastoralists access and exchange knowledge is important for supporting inclusive rangeland management. Similarly, more frequent knowledge sharing on controlled grazing, rangeland improvement, and coping mechanisms was associated with higher adoption, highlighting the importance of regular interaction and exchange of practical knowledge within pastoral communities and between communities and external knowledge providers.

The findings further show that the relationship between implementation, knowledge application, and blended-knowledge adoption varies across rangeland interventions. Marketing-information implementation was positively associated with higher adoption, while the application of knowledge related to herd splitting, water harvesting, and livestock insurance was also positively associated with higher adoption. Water harvesting and seasonal migration received the highest descriptive ratings for implementation and knowledge application, demonstrating their continued importance within pastoral production systems. However, favorable descriptive ratings did not always correspond to positive associations in the multivariable model. This was particularly evident for seasonal-migration and soil-erosion-control knowledge application, which were negatively associated with the higher categories of the composite adoption outcome after adjustment for other factors. These differences indicate that the adoption of blended knowledge is not a uniform process across all rangeland interventions. Rather, the contribution of KM appears to depend on the nature of the intervention, existing local experience, institutional support, and the opportunities available for knowledge to be shared and practically applied. Therefore, efforts to promote inclusive rangeland management should avoid treating knowledge dissemination as a one-size-fits-all process. The study therefore recommends strengthening inclusive KM systems that combine accessible extension services, community-based knowledge-sharing platforms, and appropriate digital tools. Such systems should facilitate meaningful interaction between Indigenous and modern knowledge rather than simply transmitting external technical information. County governments, development partners, and rangeland-management institutions should support participatory learning and collective knowledge exchange while recognizing the value of locally embedded pastoral knowledge. Overall, the findings suggest that strengthening access to, sharing of, and application of knowledge can increase adoption of blended Indigenous and modern knowledge in Northern Kenya's rangelands. Context-responsive KM approaches that build on existing pastoral knowledge systems while improving access to relevant scientific and technical information may contribute to more inclusive, adaptive, and sustainable rangeland management.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the National Commission for Science, Technology & Innovation (NACOSTI), License No.: NACOSTI/P/24/42188. Informed consent was obtained from respondents before the commencement of each interview. The consent procedure was incorporated into the electronic questionnaire administered using KoboCollect. At the beginning of the questionnaire, enumerators presented respondents with an introductory statement explaining the purpose of the study, the topics covered by the survey, the voluntary nature of participation, the confidentiality of their responses, and the use of the information for research purposes. Participants were also informed that formal research authorization had been obtained and that the study followed the conditions of the licence. Following this explanation, respondents were asked whether they were willing to proceed with the interview, with the response options "Yes" and "No" recorded in the electronic questionnaire. Only respondents who agreed to participate proceeded with the interview, while those who declined were not interviewed. Consent was therefore obtained through an affirmative response recordedin KoboCollect rather than through a separately signed paper consent form. The electronic questionnaire provided a record of the respondent's consent decision. No separate written signature or thumbprint was collected through this procedure.

Author contributions

VK: Conceptualization of the study, interpretation of findings, writing of the original manuscript, revisions and editing of the final manuscript. RW and EC: Supervision, conception and design of the study, interpretation and validation of the findings, and critical review of the manuscript. CO: Funding acquisition, Project administration, conception and design of the study, review of the manuscript.

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There are two research papers originating from my MSc research study at the University of Nairobi, titled "Effect of Knowledge Management on Inclusive Rangeland Management in Northern Kenya." The study was structured around two distinct and pre-specified objectives: 1. To assess the determinants influencing knowledge management practices for inclusive rangeland management in Northern Kenya; and 2. To evaluate the role of knowledge management practices in influencing the adoption of rangeland management interventions. The authors disclose that this manuscript draws on the same household survey dataset of 475 households in Marsabit, Isiolo, and Samburu counties in Northern Kenya used in the unpublished paper on "KM for Inclusive Rangeland Management in Northern Kenya." This study addresses the first objective and examined the socio-economic, institutional, and experiential factors associated with households' KM practices for inclusive rangeland management. In particular, it focuses on determinants of KM practices, including household resources, institutional access, participation, knowledge sources, and pastoral experience. In contrast, the present manuscript examines KM Practices and Adoption of Inclusive Rangeland Interventions in Northern Kenya. It focuses on the subsequent analytical question of how KM practices influence the adoption of rangeland management interventions. Its outcome is the adoption of rangeland management interventions, while KM practices and related factors are examined as explanatory factors. Thus, although the two studies share the same sample, study area, sampling procedure, and survey methodology, they address different research questions, outcomes, and analytical relationships. The current manuscript presents analyses and findings that were not reported in the unpublished manuscript "KM for Inclusive Rangeland Management in Northern Kenya" study. Any shared description of the study setting, sample, or survey methodology reflects the common underlying dataset and is disclosed here for transparency.

Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontierspartnerships.org/articles/10.3389/past.2026.15457/full#supplementary-material

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