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Measuring smallholder dairy farmers' social valuation of climate mitigation: a case study from Kenya

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Livestock systems in Sub-Saharan Africa contribute substantially to greenhouse gas emissions and are highly vulnerable to climate change. In Kenya, smallholder dairy farmers need to balance productivity with environmental sustainability while facing increasing climate pressures. This case study examines farmers' perceptions and social valuation of forage-based climate mitigation strategies, focusing on awareness, perceived value, and willingness to adopt improved forages for resilience. The study was conducted in Nandi and Uasin Gishu counties with 46 dairy farmers purposively selected from ongoing project-supported initiatives. A socio-ecological systems perspective informed the analysis. A composite social value indicator integrating knowledge, perception, and use dimensions was constructed using principal component analysis. Findings show high climate awareness and recognition of the benefits of forage-based mitigation. However, willingness to adopt these practices remains limited due to financial, technical, and institutional constraints. Support for improved forages is nonetheless strong, driven by perceived gains in productivity and environmental sustainability. While differences related to gender and age were observed, these were not explored in depth, as the study prioritizes methodological application rather than demographic analysis. Results reveal a persistent gap between awareness and action, indicating that social acceptance alone does not ensure adoption. Strengthening adoption will require improved access to forage seeds, inclusive extension services, capacity building, and targeted climate finance. The study demonstrates the utility of social valuation approaches to assess mitigation readiness and inform socially grounded climate strategies in smallholder dairy systems.

KEYWORDS

social valuation, climate change mitigation, dairy farming, smallholders, ecosystem services

Introduction

Climate change and livestock farming are intricately linked in a bidirectional relationship. On the one hand, livestock production, especially from ruminants, is a major source of greenhouse gas (GHG) emissions, particularly methane, which significantly contributes to global warming (Gerber et al., 2013; Nardone et al., 2010; Grossi et al., 2019). On the other hand, the sector is highly vulnerable to climate variability, facing challenges such as rising temperatures, erratic rainfall patterns, pest and disease pressure and pasture degradation, all of which are exacerbated by climate change (Thornton and Herrero, 2010; Godde et al., 2020). These stressors are especially pronounced in regions like Sub-Saharan Africa, where dairy systems face mounting threats to productivity and sustainability (Adegbeye et al., 2024). For instance, heat stress reduces milk yield and impairs reproductive performance in cows (Mugwe and Otieno, 2021). Smallholders, who dominate the dairy sector in Africa, are particularly vulnerable due to their limited adaptive capacity.

Nevertheless, a range of mitigation and adaptation strategies – such as improved forages, silvo-pastoral systems, and sustainable manure management – have shown promise in enhancing resilience while reducing GHG emissions (Ngongolo and Gayo, 2025; Mganga et al., 2024). The experience of dairy farmers in Kenya underscores this duality: while farmers contribute to climate change through traditional practices, they also bear the brunt of its most severe consequences. This illustrates the ongoing climate-livestock feedback loop, where both challenges and solutions are deeply interconnected.

Across Africa, numerous studies have shown a consensus on the reality of climate change and an awareness that it significantly impacts agricultural activities. They highlight the role of farmers' perceptions as crucial for adaptation. Researchers have identified consistent patterns in how farmers perceive and respond to these changes, underlining that perception is a key prerequisite for effective adaptation (Abazinab et al., 2022; Maluleke et al., 2020; Mahl et al., 2020; Popoola et al., 2019; Tadesse and Dereje, 2018; Wetende et al., 2018; Kasulo et al., 2012; Silvestri et al., 2012). These perceptions reflect lived experiences within stressed socio-ecological systems, underscoring the urgent need for adaptive strategies that are both ecologically and socially grounded.

One such strategy involves the promotion of improved forages, which can enhance the resilience of socio-ecological systems in dairy farming regions in countries like Kenya. Improved forages provide essential ecosystem services, including carbon sequestration in biomass, subsoil, and root systems, while also enhancing the quality of livestock feed and reducing enteric methane emissions. These multiple benefits not only support sustainable farming practices but also contribute to climate change mitigation efforts and environmental sustainability (Gonzalez Quintero et al., 2024a Sandoval et al., 2023; Gaviria-Uribe et al., 2020). In addition to ecological benefits, studies in several African contexts have highlighted the economic advantages of adopting improved forages, such as higher milk yields and increased income (Flórez et al., 2024c; Dey et al., 2022; Dey, 2021; Lukuyu et al., 2021; Njarui et al., 2021; Cheruiyot et al., 2020; Schiek et al., 2018). These synergies position improved forages as a strategic lever for both environmental resilience and rural livelihoods.

This study examines the social valuation of climate change mitigation strategies in dairy farming in Kenya, with a particular focus on the adoption of improved forages. The social value presents three dimensions: *Knowledge* refers to individuals' understanding of a resource, which guides decisions on whether to engage with it. For example, the level of understanding dairy farmers have about climate change influences their perception and willingness to adopt mitigation strategies. *Perception* involves the beliefs, attitudes, and values associated with non-market goods and services. For dairy farmers, this includes recognizing climate change risks to their livelihoods and evaluating these risks. *Willingness to act* assesses individuals' readiness to engage with a resource in their daily lives. In the context of GHG emission mitigation, it gauges whether dairy farmers believe reducing emissions is feasible, whether they are willing to act, and if they have the knowledge and resources to implement these strategies effectively. Despite increasing interest in climate change mitigation strategies in dairy systems, there is limited evidence on farmers' perceptions and social valuation of specific interventions such as improved forages, particularly *Urochloa* hybrids. Moreover, the socio-economic and perceptual factors that influence farmers' willingness to adopt these practices remain poorly understood. Addressing these gaps is essential to develop a social value indicator that accurately reflects farmers' preferences and informs targeted strategies to enhance adoption of climate-smart practices.

Specifically, we use the social valuation method to assess the interest of dairy farmers in adopting *Urochloa* hybrids as a method to reduce GHG emissions on their farms. We implemented an empirical approach involving 46 dairy farmers from two counties in Kenya, who participated in a survey designed to capture their knowledge, perceptions, and potential for adopting climate change mitigation practices. The survey data forms the basis for developing and estimating a social value indicator. The study is guided by the following research questions: (i) How do dairy farmers perceive and understand climate change and its impact on production systems? (ii) What is the perceived value of improved forages, particularly *Urochloa* hybrids, as a climate change mitigation strategy? (iii) What socio-economic and perceptual factors influence farmers' willingness to adopt these improved forages? Based on these questions, our hypothesis posits that dairy farmers are aware of climate change and its effects on production and generally view mitigation measures – especially those involving improved forages – positively. However, economic constraints and other barriers significantly hinder their ability to adopt these practices.

The article is structured as follows: Section *Introduction* corresponds to the introduction. Section *Materials and methods* presents the theoretical framework on social value and mitigation adoption. Section *Results* describes the methodology and the construction of the social value indicator using Principal Component Analysis. Section *Discussion* reports the results, followed by a discussion in Section *Conclusions and recommendations*. Section *Conclusions and recommendations* concludes with key insights and implications for forage-based climate mitigation in Nandi and Uasin Gishu counties.

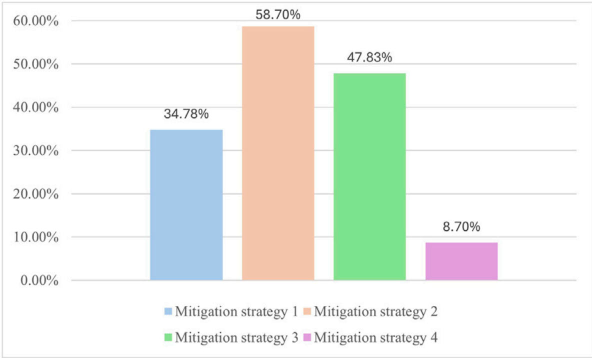

FIGURE 1
The concept of social valuation of ecosystem services.

Materials and methods

The social value framework

The interplay between dairy farming, climate change, and farmers can be effectively analyzed through the lens of socio-ecological systems. This approach provides a comprehensive understanding of how these elements interact and adapt within a dynamic, interconnected system. A socio-ecological system is a combination of biophysical and ecological units that interact with social systems shaped by stakeholders and institutions (Flórez et al., 2024b; Pallero et al., 2018; Martín-López et al., 2012; Glaser et al., 2008; Ostrom, 2009). Socio-ecological systems are defined by the dynamic interaction between their ecological and social components. The ecological system provides essential ecosystem services that sustain human life, economic activities, and production. In turn, the social system generates both positive (environmental benefits) and negative (externalities) impacts that influence the ecological system's functionality (Martín-López et al., 2012). Managing these systems effectively requires an ecosystem-based approach and strategies that are aligned with social, economic, and ecological contexts (Pallero et al., 2018).

Social valuation is essential for assessing socio-ecological systems, offering insights into how communities perceive, value, and interact with their environment. It examines cultural, social, and personal factors to better understand people's relationship with nature and its resources. According to Scholte et al. (2015), a complete social valuation of ecosystem services involves three core elements: knowledge (what we know), perception (how we perceive it), and use (how we engage with it). Integrating these elements provides a comprehensive understanding of human-environment interactions (see Figure 1).

Social valuation bridges individual attitudes with actionable strategies, ensuring a holistic approach to valuing goods and services and informing policies for sustainable outcomes. While studies on social valuation in the livestock sector are emerging, existing literature often treats knowledge, perception, and use of mitigation strategies separately, lacking an integrated framework for understanding their social value. This fragmented view limits understanding of how these components intersect to influence farmers' engagement with mitigation, particularly in terms of their values, beliefs, and decision-making. This gap is especially significant in regions like Africa, where socio-ecological vulnerabilities and resource constraints are more pronounced. The following subsections provide an overview of existing literature on these topics.

In Africa, livestock farmers' knowledge of climate change is shaped by education, media exposure, and local experience, with better-informed communities showing higher awareness (Mahl et al., 2020; Silvestri et al., 2012; Wetende et al., 2018). While farmers broadly recognize climate impacts such as feed scarcity, heat stress, and shifting rainfall, understanding of GHG emissions and specific mitigation options remains limited (Tadesse and Dereje, 2018; Feliciano et al., 2022). Perceptions and adaptive responses vary by socio-demographic factors including age and gender, often differing from meteorological records (Abazinab et al., 2022; Kasulo et al., 2012; Kumar et al., 2023; Bryan et al., 2023). Evidence from dairy systems in Northern Ethiopia highlights ongoing adoption challenges in climate-smart agriculture and the increasing risk of heat stress in cattle (Balcha et al., 2023; Balcha et al., 2024). Common adaptation strategies include livestock and crop diversification, seasonal mobility, feed conservation, improved pastures, crop–livestock integration, and drought-tolerant forages, combining traditional and modern knowledge (Descheemaeker et al., 2016; Popoola et al., 2019; Silvestri et al., 2012; Tadesse and Dereje, 2018). Although interest in climate-smart forages is increasing (Flórez et al., 2024c; Junca Paredes et al., 2023), adoption remains constrained by limited resources, weak institutional support, and competing socio-economic priorities (Feliciano et al., 2022; Wetende et al., 2018; Mahl et al., 2020).

Site selection

To estimate the social value of climate change mitigation strategies, we developed a social value indicator structured around three conceptually grounded components commonly used in social valuation frameworks: knowledge (understanding), perception (perceived relevance and benefits), and use (current or intended application of the practice). A total of 46 dairy farmers participated in the social valuation survey, selected through purposive sampling from CIAT[1]-supported projects to ensure prior exposure to forage-based climate mitigation practices. While participants were not tested through a formal knowledge assessment, their involvement in training activities and demonstration farms provided baseline familiarity with the practices evaluated. This study is a case study conducted in Nandi and Uasin Gishu counties, two dairy-producing regions in Kenya engaged in CIAT forage and livestock initiatives. As such, results reflect local conditions and are not intended to be statistically representative of other regions in Kenya.

Data collection

Two data collection workshops were held in July 2024 – one with 20 women dairy farmers and the other with 26 men. Each workshop was divided into two segments: a field visit to demonstration farms and a conference room session. During these sessions, participants were engaged in presentations, discussions, and exercises addressing the social and technical aspects of adopting GHG mitigation strategies. The workshop was structured in two segments to balance experiential learning with standardized data collection. The field visit allowed participants to observe mitigation practices in a real farm setting, ensuring a shared reference point, while the conference session provided a controlled environment for discussion and survey implementation. To minimize bias, no performance evaluation or persuasive messaging was delivered during the field visit, and the social valuation survey was administered individually before group discussions or technical presentations to reduce social desirability and peer-influence effects. This research was developed as a case study involving farmers participating in CIAT-led projects in Kenya, and it is not intended to provide statistically representative results. Instead, the study aims to demonstrate the application of the social valuation methodology and its potential for future research with larger sample sizes and expanded sampling designs. The data collection process followed these sequential steps:

1 CIAT: The International Center for Tropical Agriculture.

1. Participant recruitment through purposive sampling from CIAT-supported dairy projects.
2. Field visit to demonstration farms to observe *Urochloa*-based mitigation practices (no evaluative or persuasive information provided).
3. Transition to conference venue for structured workshop session.
4. Individual administration of the social valuation survey (before any technical presentations or group discussions).
5. Group discussions and technical presentations on climate change and mitigation strategies.
6. Documentation and systematization of survey responses.

The social valuation survey was conducted incorporating an individual exercise structured into the following sections:

Section *Introduction* - Demographic, socioeconomic, and dairy production information: Participants completed a detailed survey to collect essential demographic and socioeconomic information, including farm size, number of cattle, milk production levels, and income sources.

Section *Materials and methods* - Social valuation of GHG mitigation strategies: This section assessed participants' knowledge and perceptions of climate change and GHG emissions, their willingness to adopt mitigation strategies, and their readiness to invest in such strategies. *Urochloa* hybrids were selected as mitigation strategy because they are among the most familiar and contextually relevant mitigation practice for farmers involved in CIAT projects in Kenya. *Urochloa* hybrids are a particularly attractive climate change mitigation option because their deep root systems build soil carbon and they perform well even under low soil fertility, achieving high yields and nutritional quality. This allows for the intensification of livestock production, increasing carrying capacity on a smaller land area, freeing land traditionally occupied by native or naturalized pastures, and ultimately reducing greenhouse gas emissions per unit of meat or milk (Enciso et al., 2019). As this is a case study focused on applying the social valuation methodology, the research does not compare multiple mitigation options. Future studies could expand the analysis to other alternative strategies.

The survey questions were inspired by the National Climate Change Perception Survey conducted in Costa Rica (MINAE, 2021) (see Table 3 in the results section for its components).

Data analysis

The survey included numerous questions related to social value; to simplify the analysis, we generated composite indicators that summarize this information into a few key variables. We used Principal Component Analysis (PCA), a statistical method that reduces the dimensionality of datasets with interrelated variables by transforming them into a smaller set of

TABLE 1 Interpretation of indicators.

Value	(0–0.20)	(0.20–0.40)	(0.40–0.60)	(0.60–0.80)	(0.80–1)
Interpretation	Very low	Low	Moderate	High	Very high

uncorrelated principal components that retain most of the original variance (Jolliffe and Cadima, 2016). In a sample of n individuals described by p variables (X_1, X_2, . . ., X_p), PCA identifies z components ($z < p$) that explain most of the variance. Each of these z variables is called a principal component (Greenacre et al., 2022; Amat-Rodrigo, 2017).

Indicators were calculated as weighted averages of the principal components, with weights based on the proportion of variance explained. Because survey items were measured on different scales, all values were standardized to a 0–1 scale using each variable's maximum possible value. PCA was performed using R software (R Core Team, 2023). The number of principal components was determined using scree plot inspection to retain only components explaining meaningful variance. The survey items used different response scales (binary, Likert, and ordinal) because they capture distinct dimensions (knowledge, perception, and use), which require different measurement approaches. To ensure comparability across variables in the PCA, all indicators were standardized prior to analysis to mitigate scale effects.

The PCA results enabled the construction of a consolidated indicator by integrating the original variables, the most relevant principal components, and their respective variance contributions. The proportion of variance explained was calculated from the eigenvalues of each principal component relative to the total variance, as is standard in PCA; no statistical significance testing was applied, as component retention was based on explained variance and interpretability rather than hypothesis testing. Following the generation of components, we applied the methodology of Peña Méndez and Gutiérrez Sánchez (2014), Saldarriaga-Isaza et al. (2025), and Flórez (2022). This approach involves calculating a weighted sum of key variables within each significant principal component, proportional to the variance each explains. For example, if PCA identifies three principal components as relevant, with PC_1 defined by X_1 and X_2, PC_2 by X_3 and X_4, and PC_3 by X_5, then the indicator (I) is calculated as:

$$I = \frac{PropVar\,(PC1)}{\sum_{i=1}^{n} PC_i} * \frac{X_1 + X_2}{Max\,(X_1 + X_2)} * \frac{PropVar\,(PC2)}{\sum_{i=1}^{n} PC_i} * \frac{X_3 + X_4}{Max\,(X_3 + X_4)} * \frac{PropVar\,(PC3)}{\sum_{i=1}^{n} PC_i} * \frac{X_5}{Max\,(X_5)}$$

The formula is adapted based on the number of relevant principal components identified and the dominant variables within each. It enables the calculation of indicators on a standardized scale: within the range [0, 1] when all variable values are positive, or [-1, 1] when the dataset includes both positive and negative values.

The social value indicator comprises three sub-indicators aligned with the core dimensions of social value:

- *Knowledge:* Measures participants' awareness and understanding of climate change and its impacts.
- *Perception:* Captures beliefs, attitudes, and concerns related to climate change and GHG emissions.
- *Willingness to Act:* Assesses the readiness to adopt and invest in mitigation strategies.

These sub-indicators are derived from specific survey questions, and their interpretations are detailed in Table 1. To support comparability and interpretation, indicator values were categorized into five equally sized ranges using the equal interval classification method, which is recommended for analyzing continuous data. An equal-interval classification was applied, as it is widely used for emerging research topics where empirical evidence is still limited and no standardized thresholds exist to support more specific distributions (Meyer, 2024). This approach offers a clear and nuanced understanding of the social factors influencing the adoption of GHG mitigation strategies in dairy systems.

Results

Characteristics of the dairy farmer sample

Table 2 presents the basic characteristics of the dairy farmer sample surveyed in Nandi and Uasin Gishu counties (46 respondents). The data shows a slightly higher proportion of respondents from Uasin Gishu. The gender distribution was balanced, and the average age of participants was just over 42 years. The average education level was 2.2, which likely corresponds to completion of secondary school. Farmers reported large household sizes and high numbers of dependents, indicative of the elevated dependency ratios commonly observed in rural agricultural communities. Dairy farming emerged as the principal livelihood for nearly all respondents, who had an average of 13 years of experience in the sector. Despite their experience, household incomes remained low, with a monthly *per capita* income of just under USD 37, reflecting the economic challenges many smallholders face.

TABLE 2 Main characteristics of the sample.

Item	Value
Farm location (county)	
Nandi	43.5%
Uasin gishu	56.5%
Sex	
Male	56.5%
Female	43.5%
Average age (years)	42.2
Average education (level)	2.2
Average household size (people)	6.4
Average number of dependents (people)	6.5
Average income *per capita* (USD/month/person)	36.9
Dairy farming is the principal activity in farm (yes)	95.7%
Average experience with dairy farming (years)	13
Support received from	
Government	23.9%
Research institutions	26.1%
NGO's	32.6%
Cooperatives	71.7%
Private companies	8.7%
Type of support	
Training	78.3%
Rural extension	34.8%
Productions inputs	37.0%
Monetary subsidies	13.0%
Credits	23.9%
Technology transfer	17.4%
Milk marketing support	39.1%
No support	19.6%
Cooperative affiliation	95.7%

A significant majority of respondents reported receiving support from external sources. Cooperatives were the most common providers of support, followed by NGOs, research institutions, and government agencies. Private sector involvement was minimal, suggesting a potential gap in public–private collaboration in these areas. The types of support most frequently received included training, milk marketing assistance, production inputs, and rural extension. Less commonly, farmers accessed credit, technology transfer, or monetary subsidies. Notably, around one-fifth of respondents reported receiving no external support at all.

Cooperative affiliation was nearly universal among participants, indicating that cooperatives play a crucial role in connecting dairy farmers with essential services, training opportunities, and access to markets. Overall, the data reflects a population of experienced dairy farmers operating under modest economic conditions, with cooperatives serving as key channels for institutional support and development.

Results of the social valuation survey

Table 3 provides an overview of the basic results of the social valuation survey. The surveyed dairy farmers demonstrated a high level of *awareness (knowledge)* of climate change and GHG emissions, with nearly all respondents acknowledging their existence and anthropogenic origins. This reflects a strong foundational understanding across the sample. Notably, women were equally – or in some cases more – likely than men to recognize that climate change is occurring, though a slightly lower proportion attributed it primarily to human activity. These findings underscore the importance of designing gender-sensitive awareness campaigns that reinforce scientific explanations and actively engage women.

In terms of *perception*, both male and female respondents view climate change as a current and pressing issue rather than a distant threat. However, women reported slightly lower levels of discussion on the topic in social settings and a lower perceived personal impact. This may reflect differentiated roles in household and community decision-making, but also gender-differentiated levels of education, and points to the need for inclusive communication strategies that foster dialogue across genders.

Regarding the *willingness to act*, a large majority of farmers expressed belief in the feasibility of reducing GHG emissions and indicated readiness to adopt mitigation practices. Women expressed slightly greater optimism about the potential to reduce emissions (100% vs. 96% among men), yet they also reported lower levels of preparedness (65% vs. 81%) and no perceived access to necessary resources (0% vs. 12%). These disparities suggest that women face systemic barriers, including limited access to technical training, financial capital, and decision-making authority on the farm. Despite these constraints, women expressed full willingness to participate in training (100%), highlighting a valuable opportunity for targeted capacity-building efforts. Addressing these gender-specific barriers will be essential to ensure the equitable and effective implementation of climate change mitigation strategies in Kenya's dairy sector.

Indicator results and disaggregated insights

Table 4 provides an overview of the indicators derived from our analysis. Our analysis estimated a *knowledge indicator* of 0.962 and a *perception indicator* of 0.807, both classified as *very high*. These results suggest that dairy farmers in the sample are well-informed about climate change and GHG emissions and

TABLE 3 Basic results of the social valuation survey.

Component	Question	Value			Scale
		Total sample	Men	Women	
Knowledge	Do you think that the climate in Kenya has changed in recent years?	0.96	0.96	1.0	0–1
	Do you know or have you heard about CC?	1.00	1.00	1.00	0–1
	Who do you think is causing CC?	1.70	1.85	1.50	0–2
	Mainly due to natural changes in the environment: 1	0.30	0.15	0.50	0–1
	Mainly human activities: 2	0.70	0.85	0.50	0–1
	None of the above, because CC is not happening: 0	0.00	0.00	0.00	0–1
	Do you believe CC is happening in Kenya?	1.00	1.00	1.00	0–1
	Do you know or have heard about GHG emissions?	0.91	0.92	0.90	0–1
Perception	How much have you thought about CC before today?	1.70	1.65	1.75	0–3
	How often do you talk about CC with family/friends?	2.00	2.00	1.95	0–3
	How much damage do you think CC will do to you, your family, and your farm?	2.67	2.81	2.50	0–3
	When do you think CC will start to do damage to you, your family, and your farm?	3.93	3.88	4.00	0–4
Willingness to act	Do you think it is possible to reduce GHG emissions on your farm?	0.98	0.96	1.00	0–1
	Would you be willing to implement GHG emissions mitigation strategies on your farm?	0.87	0.96	0.75	0–1
	Do you feel prepared from a knowledge point of view to implement GHG emission mitigation strategies on your farm?	0.74	0.81	0.65	0–1
	Do you think you have enough resources on your farm to implement GHG emission mitigation strategies?	0.07	0.12	0.00	0–1
	Would you like to receive training on the implementation of GHG emission mitigation strategies on dairy farms?	1.00	1.00	1.00	0–1

Notes: CC, climate change; GHG, greenhouse gas. The "scale" column indicates the response measurement type used for each survey item (e.g., binary, Likert, or categorical), which informed both data coding and indicator construction.

TABLE 4 Indicators derived from the analysis.

Characteristics	Group	Indicator			
		Knowledge	*Perception*	*Willingness to act*	*Social value*
Total sample	Total sample	0.926	0.807	0.380	0.723
Location	Nandi	0.941	0.818	0.359	0.726
	Uasin gishu	0.915	0.799	0.395	0.721
Gender	Male	0.927	0.818	0.406	0.735
	Female	0.926	0.793	0.345	0.707
Age	Youths (18–26 years)	0.823	0.688	0.399	0.646
	Adults (27–59 years)	0.932	0.836	0.366	0.734
	Older adults (>60 years)	0.973	0.792	0.408	0.737

perceive them as pressing concerns affecting Kenya, their farms, and their families. Farmers broadly acknowledge the reality of climate change and recognize its risks and impacts on their livelihoods. Despite this high awareness, the *willingness to act indicator* is *low* (0.380), largely due to knowledge gaps in implementation strategies and, more critically, financial

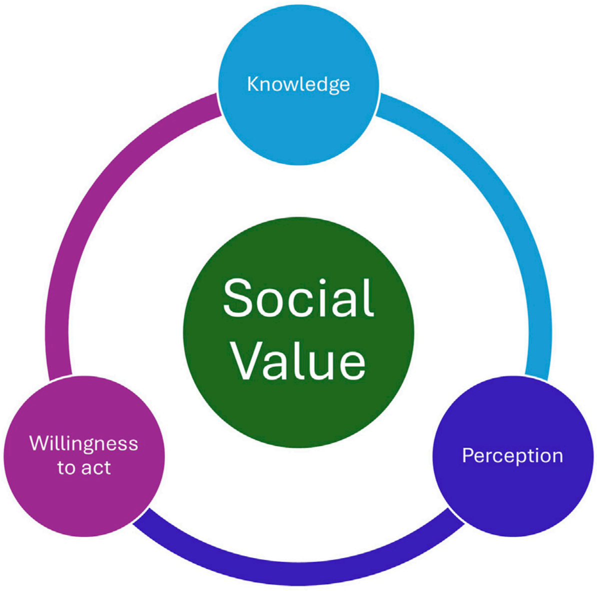

FIGURE 2
Preferred mitigation strategies of the surveyed dairy farmers. Notes: Mitigation Strategy 1: Replacement of 50% of natural pasture with *Urochloa* hybrid cv. Mulato II; Mitigation Strategy 2: Replacement of 50% of natural pasture with *Urochloa* hybrid cv. Mulato II combined with herd management by removing male animals, simulating access to artificial insemination; Mitigation Strategy 3: Replacement of 50% of natural pasture with *Urochloa* hybrid cv. Mulato II and replacement of all cows with purebred Friesians; Mitigation Strategy 4: Improved manure management. Source: Own elaboration.

resource constraints. Notably, 93% of respondents reported lacking sufficient resources to adopt GHG mitigation measures. These limitations significantly reduce their capacity to translate concern into action.

Combining the three sub-indicators yields a *social value indicator* of 0.723, categorized as *high*. The values were consistent across the two counties surveyed, with Nandi scoring 0.723 and Uasin Gishu 0.721, indicating no significant regional variation. However, meaningful differences emerged by gender and age. Men had a higher social value indicator (0.735) than women (0.707), driven primarily by the latter's lower willingness to act score (0.345). This gap may reflect gender-specific barriers such as limited access to training, financial capital, or decision-making authority on the farm and in the household. Similarly, youth scored lower (0.646) than adults (0.734) and older adults (0.737), likely due to a lower perception score (0.688) and less farming experience.

While these patterns are observable in the data, further research is needed to understand the root causes of gender and age disparities–whether they stem from resource access, information availability, decision-making roles, or broader sociocultural dynamics.

Preferred mitigation strategies

Finally, we asked dairy farmers to identify their preferred GHG mitigation strategies for implementation on their farms (Figure 2). The most preferred strategy, chosen by the majority of respondents, was to replace half of their natural pastures with *Urochloa* hybrids and remove male animals from the herd – an approach that simulates the use of artificial insemination. The second most favored option involved combining *Urochloa* hybrids with the replacement of local cows by purebred Friesians. Additionally, still one-third of respondents were interested in adopting *Urochloa* hybrids alone, without any complementary herd management practices. In contrast, improved manure management was the least attractive option, with few farmers indicating a willingness to adopt it. These preferences appear to be driven primarily by the perceived productivity and income benefits associated with improved feeding and genetic upgrading, while the GHG mitigation impact is seen as an added co-benefit rather than the main motivation. This highlights the importance of aligning climate-smart interventions with farmers' economic incentives, ensuring that mitigation strategies are both technically viable and perceived as beneficial to farm productivity and livelihoods.

Discussion

This study assessed the social valuation of climate change mitigation strategies among smallholder dairy farmers in Kenya, focusing on their *knowledge*, *perceptions*, and *willingness to act*. Our findings reveal a high level of awareness and concern about climate change and GHG emissions, as reflected in the very high *knowledge* and *perception* indicator scores. These results suggest that Kenyan dairy farmers recognize climate change as a pressing and ongoing threat, both globally and in their immediate context. This aligns with studies across Sub-Saharan Africa that document widespread climate awareness among smallholder farmers. For instance, in Ethiopia, smallholder farmers, agro-pastoralists, and pastoralists exhibit a high level of awareness about climate change (FAO, 2011; UNPD, 2025). Similar patterns are evident in Kenya, where Silvestri et al. (2012) found that farmers are well-informed about climate change and its implications for agricultural productivity. Likewise, Wetende et al. (2018) reported that farmers in Western Kenya perceive climate change as a substantial threat to their dairy farming systems.

However, this awareness has not translated into proportionate action, in line with the low *willingness to act* score. This gap between awareness and implementation is well-documented in agricultural and livestock systems across Africa (UNPD, 2025; Feliciano et al., 2022; Wetende et al., 2018; FAO, 2011), where structural constraints – particularly limited financial resources, insufficient access to technical training, and insecure land tenure – continue to impede the adoption of climate change mitigation strategies. Our survey findings corroborate this pattern: 93% of respondents reported lacking the financial means to implement GHG mitigation measures, with the adoption of hybrid forages such as *Urochloa* identified as particularly challenging. Existing literature highlights the high cost of improved forage seeds and restricted access to agricultural credit and technical assistance as persistent barriers in the region – although successful pilot projects with climate-smart forage solutions have been conducted (Flórez et al., 2024c; Maina et al., 2022; Paul et al., 2020; Osiemo et al., 2024).

Despite these constraints, our results also highlight significant entry points for scaling mitigation strategies in Kenyan dairy systems. *Urochloa* hybrids, for instance, were strongly favored by 58.7% of farmers, particularly when combined with herd management practices like removing unproductive male animals. These preferences reflect the perceived productivity and income-enhancing potential of these practices, with climate mitigation seen as an added benefit rather than the primary motivation. This aligns with broader evidence from Latin America and Africa, where improved forages enhance both ecosystem services (e.g., carbon sequestration, methane reduction) and farm-level productivity (through enhanced feed quality and quantity), ultimately leading to increased household incomes and strengthened rural livelihoods (Gonzalez-Quintero et al., 2024b; Sandoval et al., 2023 Flórez et al., 2023; Worku et al., 2022; Dey et al., 2022; Lukuyu et al., 2021; Njarui et al., 2021; Schiek et al., 2018). This dual impact makes improved forages a key strategy for building resilient socio-ecological systems and advancing rural development (Cohn et al., 2014; Congio et al., 2021; Thornton and Herrero, 2010). Conversely, manure management – a strategy widely promoted in Europe and other Global North contexts (Glenk et al., 2014; Burbi, 2014) – was the least preferred option among Kenyan farmers (8.7%). This may reflect limited technical knowledge, labor intensity, or cultural norms, and indicates a need for targeted communication and demonstration of its co-benefits within the Kenyan context.

Gender and age disparities in the social value indicator were also evident. Women exhibited lower overall social value scores compared to men, primarily due to reduced willingness to act. This finding is consistent with existing literature that documents women's limited access to training, credit, and decision-making authority (Bryan et al., 2023; Kumar et al., 2023; Lukuyu et al., 2023; Galiè et al., 2022; Ravichandran et al., 2021). Although women reported equal or higher levels of awareness and interest in receiving training, they were more likely to perceive themselves as unprepared or lacking the necessary resources to implement mitigation strategies. This contradiction – high motivation but low capacity – underscores the need for gender-responsive interventions that not only provide information but also address structural inequalities and foster women's empowerment (Galiè et al., 2022; Ravichandran et al., 2021; Murage et al., 2015). This also suggests the need for gender-sensitive interventions such as flexible, hands-on training programs, certification schemes to enhance access to resources, and targeted leadership initiatives, acknowledging that women (as reported in different studies), have less access to climate related information and climate resilient technologies (Bryan et al., 2023; Kumar et al., 2023).

Women's willingness to participate in training presents a valuable opportunity for inclusive capacity-building, which enhances their role in climate action. This aligns with findings from similar studies in Africa (Kumar et al., 2023; Murage et al., 2015). However, it underscores the importance of addressing gender norms that perpetuate inequalities, restricting women's participation, agency, and empowerment in rural organizations and livestock systems. These norms limit women's bargaining power across various domains, including income opportunities, market access, and decision-making regarding the adoption of mitigation strategies and climate-smart technologies (Galiè et al., 2022; Bryan et al., 2023).

Youth farmers also recorded lower social value relative to adults and older adults, largely driven by weaker perceptions of climate risk. This may reflect limited farming experience and a broader trend of rural-to-urban migration and disinterest in agriculture among younger populations (Díaz Baca et al., 2024; Triana Ángel and Burkart, 2023; Giampaolo and Ianni, 2021). The preferred mitigation strategies, centered on productivity-enhancing practices like improved forages and breeding, highlight the importance of aligning climate goals with economic incentives. Although education data was not explicitly correlated in this study, the findings suggest that access to education and information channels shape both understanding and action-readiness, particularly for women and younger farmers. Interventions to re-engage youth – such as digital extension tools, internship programs, and technology-driven agribusiness models – could enhance their participation in climate-smart dairy systems (Triana Ángel and Burkart, 2023). Although differences by gender, age, and education emerged in the findings, an in-depth analysis of these disparities was beyond the scope of this case study, which primarily aims to demonstrate the applicability of the social valuation methodology. These socio-demographic dimensions merit further investigation in future research with larger and statistically representative samples.

Taken together, the results reflect the characteristics of a stressed socio-ecological system (Flórez et al., 2024b; Ostrom, 2009), where high awareness exists alongside constrained capacity for behavioral change. The socio-ecological systems framework employed in this study emphasizes the interdependence between ecological functions and social structures. Our findings illustrate how farmers' attitudes and decisions are shaped not only by their perceptions of climate change but also by institutional support, access to information, and resource availability.

To address these interlinked challenges, our results and existing literature suggest three strategic priorities: (i) financial strengthening, including expanded credit access and reduced adoption costs for mitigation strategies, such as improved forages; (ii) expanded technical assistance, delivered through practical, context-specific training models; and (iii) decentralized, community-based extension networks that prioritize inclusivity and participatory learning. These approaches are essential for transitioning from awareness to implementation and for ensuring equitable access to the benefits of climate-smart livestock development (Flórez et al., 2024c; Lukuyu et al., 2023; Maina et al., 2022; Feliciano et al., 2022; Wetende et al., 2018; Silvestri et al., 2012; UNPD, 2025; FAO, 2011). Beyond household-level constraints, institutional and policy barriers also limit the adoption of mitigation strategies. These include limited access to formal climate finance mechanisms, insufficient extension service coverage, fragmented coordination between governmental, private, and research actors, and the absence of policy instruments tailored to smallholder dairy systems (Burkart et al., 2025a; Burkart et al., 2025b; Mejía Tejada et al., 2024; Flórez et al., 2024c; Burkart and Mwendia, 2024; Enciso et al., 2022). While the strategies discussed are actionable at household and community levels, their long-term effectiveness depends on alignment with national and international policy instruments, such as extension services, climate financing mechanisms, and NDC implementation, to create enabling conditions for sustained adoption. Although these institutional and policy dimensions were not the central focus of this case study, they constitute critical structural conditions shaping farmers' capacity to adopt mitigation practices and should be explicitly addressed in future research and policy design.

Ultimately, the high *social value indicator* signals strong potential for engagement and uptake if systemic barriers can be addressed. Bridging the gap between knowledge and action will require integrated policies that align environmental, economic, and social goals – linking dairy productivity, climate mitigation, and rural development in a holistic and inclusive manner.

Conclusions and recommendations

This study contributes critical insights into the social dimensions of climate change mitigation in livestock systems by examining the perceptions, knowledge, and willingness to act among smallholder dairy farmers in Kenya.

As global efforts intensify toward meeting climate and development goals, integrating farmers' social realities into the design and scaling of mitigation interventions is imperative. Climate policies must bridge the gap between awareness and action by aligning incentives, building local capacities, and embedding equity at the heart of agricultural transformation. Institutional coordination is essential to translate community-led efforts into sustained action and can be enabled through multi-stakeholder platforms such as county extension systems, dairy cooperatives, public-private partnerships, and national climate-smart agriculture task forces that align local implementation with government planning, finance, and accountability mechanisms.

Based on the evidence and analysis presented in this study, several interconnected recommendations can be proposed to enhance the adoption of climate change mitigation strategies in smallholder dairy systems in Kenya and similar contexts across the Global South:

- Financial support should be strengthened by subsidizing key inputs such as improved forage seeds and expanding access to agricultural credit and tailored microfinance, particularly for women and youth. Farmers should be linked to broader climate finance mechanisms, including the Green Climate Fund and national adaptation programs, to scale adoption.
- Technical assistance should be enhanced through decentralized, hands-on training programs tailored to local contexts, with flexible schedules, local language delivery, and gender-sensitive approaches. Public and community-based extension networks, including cooperatives and NGOs, should be strengthened to support grassroots knowledge dissemination.
- Gender and youth inclusion should be promoted by addressing structural barriers to land, credit, training, and leadership opportunities. Investments should be made in mentorship initiatives, institutional reforms, and youth-oriented tools such as digital extension services, internships, and agribusiness programs to enable their active participation in sustainable dairy systems.
- Climate policy design should integrate socio-ecological perspectives by aligning mitigation with food security, poverty reduction, and environmental sustainability. Policymakers should apply integral valuation frameworks and participatory mechanisms to ensure that national strategies such as Kenya's Nationally Determined Contributions (NDCs) reflect localized needs and farmer priorities.
- Mitigation strategies with dual benefits, such as improved forages, should be prioritized for their potential to enhance both productivity and environmental outcomes. These should be promoted through demonstration farms and innovation hubs that foster visibility, trust, and co-learning among stakeholders.
- Communication strategies should be improved to present mitigation not only as an environmental imperative but also as a path to greater productivity and cost-effectiveness. Channels such as radio, community media, and farmer field schools should be leveraged to reach and engage diverse rural audiences.

- Monitoring and research should be strengthened to track adoption patterns, assess long-term outcomes, and inform adaptive policymaking. Studies should explore willingness to pay, institutional enablers, and the impacts of youth migration on rural labor and sustainability.

Collectively, these recommendations point to a holistic strategy that addresses not only the technological dimensions of climate change mitigation but also the structural and social conditions that influence farmer behavior. By integrating financial incentives, practical support, gender and youth inclusion, and participatory governance, Kenya's dairy sector, and others like it, can move from awareness to action and contribute meaningfully to the Sustainable Development Goals.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institutional Review Board of the Alliance of Bioversity International and CIAT. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

JF and SB: conceptualization. JF, RG-Q, VE, and KW: resources. JF and SB: methodology. JF: formal analysis. JF, RG-Q, MP, NT, VE, KW, AN, and SB: writing the original draft and review and editing. SB: supervision, funding acquisition, and project administration. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research 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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