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EDITED BY
Carol Kerven,
University College London,
United Kingdom

*CORRESPONDENCE
Jaabir Hussein,
jiibka@yahoo.com,
djaabir.hussein@gmail.com

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Exploring smallholder farm resilience to climate change: intended and actual adaptation

Jaabir Hussein[1,2]*, Franco Bilotto[3,4], Damaris Mbui[5], Philip Omondi[6], Matthew Tom Harrison[3], Todd A. Crane[2] and Jason Sircely[2]

[1]Department of Earth and Climate Science, Institute for Climate Change and Adaptation (ICCA), University of Nairobi, Nairobi, Kenya, [2]Consultative Group for International Agricultural Research (CGIAR) Research Program on Climate Change, Agriculture and Food Security (CCAFS), International Livestock Research Institute, Nairobi, Kenya, [3]Tasmanian Institute of Agriculture, University of Tasmania, Newnham, Launceston, TAS, Australia, [4]Department of Global Development, College of Agriculture and Life Science, Cornell University, Ithaca, NY, United States, [5]Department of Chemistry, University of Nairobi, Nairobi, Kenya, [6]Inter-Governmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC), Kenya Polytechnic Institute of Agrticulture, Nairobi, Kenya

Low production potential of arid regions heightens vulnerability of farms to market shocks and extreme weather events. Here we examine African smallholder farmer perceptions of climate change, including perceived (intended) and actual adaptation strategies. We invoke survey questionnaires, focus group discussions, interviews and meteorological data to compare smallholder perceptions with actual weather events realised. We showed that most communities perceived climate change through the lens of perturbations to rainfall and temperature. Perceived increases in precipitation, indicated by 62% of respondents, and increased temperature, indicated by 77% of participants, aligned well with evidence shown by meteorological data. Around 88% of respondents identified prolonged drought as the most frequent extreme weather, followed by unseasonal rainfall (86% of respondents). Diversification of pasture fodder species and access to technology enabling timely weather forecasts were preferred actual and intended adaptation strategies, respectively. Recurrent and prolonged drought, spurious seasonal weather patterns, and lack of access to timely weather prognostics were the primary constraints to adoption of practices aimed at climate change adaptation. While farm size and practitioner experience were not associated with adaptive capacity, awareness of climate change impact potential and household income significantly influenced the rate and extent of adoption. We revealed a marked influence of gender in adaptation to the changing climate, with households where males made decisions exhibiting 76% adoption, compared with 34% of households adopting climate adaptations where decisions were made by females. Taken together, our study narrates critical roles of knowledge, finances, and gender in enabling or inhibiting adaptation to the climate crisis.

KEYWORDS
climate crisis, resilience, biodiversity crisis, adaptation, mitigation, food security, developing nation, sustainable development goals

Introduction

In the face of the escalating challenges posed by climate change, smallholder agricultural producers are positioned at the forefront of vulnerability. The IPCC Sixth Assessment Report (IPCC, 2023) defines vulnerability as the propensity or predisposition to be adversely affected, and encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. Majority of livestock production systems heavily rely on mixed agricultural systems, combining both crop and livestock production (Beddington et al., 2012; Harrison et al., 2014b; Langworthy et al., 2018). The livestock sector plays a crucial role in the livelihood of local communities and generates income in rural areas (Harrison et al., 2014a; Wetende et al., 2018). The sector employs 1.3 billion people around the world, supporting the livelihoods of 600 million poor smallholder farmers in developing countries and acts as a risk reduction strategy and provides important nutrients and traction for smallholder crop and pasture producers (Thornton, 2010). The IMF has estimated that Agriculture contributes 5.7 billion USD to Somalia's GDP, with livestock alone contributing 2.28 billion USD, which is equivalent to 40% of the total agricultural contribution to the GDP (Behnke and Muthami, 2011). The sector contributes more than 60% of the total GDP and 80% of foreign exchange earnings (Mire Mohamed et al., 2015). Despite its high contribution to the overall economy, this sector faces many challenges, including climate-related disasters such as unpredictable weather patterns, heightened risks of droughts, excessive floods, and limited access to essential resources like water and grazing lands (Etana et al., 2022; Kotir, 2011).

In the past few years, addressing the impacts of climate change has emerged as a significant issue for farmers, researchers, and policymakers alike. The process of adaptation in agriculture involves tailoring farmers perception and knowledge into the adaptation and decision-making process within the agricultural sector. Several reasons have been highlighted in the literature that emphasize the paramount importance of considering perception and adaptation strategies equally when dealing with climate change impacts (Karki et al., 2020; Savo et al., 2016; Singh et al., 2017). For instance, smallholder producers in Somalia observe their surroundings and make decisions based on their perceptions, which can lead to maladaptation due to incorrect perception, incomplete information, and biased cognitions. The success of any farmer, including smallholder producers, is influenced by their perceptions, peer networks, experience, capital availability, location, and previous strategies they have implemented for adaptation (Harrison et al., 2014b; Ibrahim et al., 2018; Meier et al., 2020; Phelan et al., 2015; Shahpari et al., 2021). Therefore, understanding farmer perspectives on climate change, the steps they have taken to adapt, and the factors influencing those actions are crucial for improving policy formulation aimed at addressing the difficulties farmer face due to climate change (Shahpari et al., 2021; Fosu-Mensah, et al., 2012). Efforts to understand how farmer perceive climate change and strategies in the context of fodder and livestock production has not been well studied (Masud et al., 2017; Niles and Mueller, 2016; Thornton, 2010).

While previous studies have explored the topic of adaptation strategies in the context of climate change (Chang-Fung-Martel et al., 2021; Harrison et al., 2014b; Harrison, 2021; Liu et al., 2020; Liu et al., 2021; Phelan et al., 2015), our study offers a unique contribution by focusing on "intended" adaptation strategies and their collective impact among smallholder fodder producers in Somalia. Existing literature has primarily concentrated on examining actual adaptation strategies (Arbuckle et al., 2014; Liu et al., 2021; Ogra et al., 2020; Phelan et al., 2015), with limited attention given to the intended strategies. By investigating the intended adaptation strategies (Niles et al., 2016), our study recognizes producers' forward-looking needs, priorities, and capacities in adapting to climate change. The inclusion of intended adaptation strategies promotes proactive risk management, a sense of ownership, and enhances the likelihood of successful adaptation outcomes (Muleke et al., 2022; van Aalst et al., 2008). Our research fills this gap in the literature and sheds light on the interconnectedness between perception and adaptation strategies in the context of smallholder fodder production in Somalia (Niles et al., 2016).

The objectives of this case study on Somaliland are to (1) analyse the perception of smallholder fodder producers regarding the influence of climate variability, (2) investigate the actual and intended adaptation strategies employed by these producers and identify barriers to adoption, and (3) examine the relationship between livelihood characteristics (household income, farm size, and years of production) and demographic factors (knowledge level and gender) in relation to adaptation strategy adoption. By addressing these objectives, the study seeks to enhance understanding of smallholder fodder producers' perceptions, adaptation strategies, and the factors that shape their decision-making processes in the face of climate change.

Materials and methods

Conceptual framework

Climate change and variability impact fodder and livestock production, as well as the livelihoods of smallholder fodder producers (SFPs) in Somalia. Farmers can reduce these losses by pinpointing the underlying causes and adapting their production methods accordingly. In this study, we assume adaptation to be a linear, three-step process from left to right in Figure 1. The first stage considers perception as the foundation

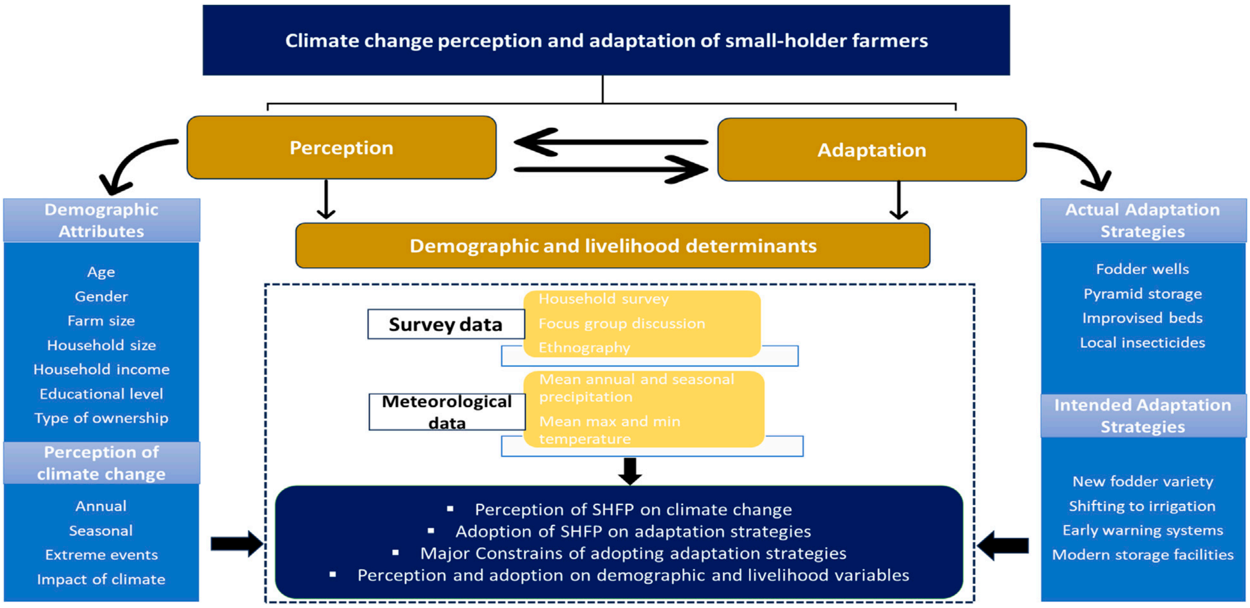

FIGURE 1
Shows the conceptual framework of the study. The conceptual process is depicted in two directions: one as a causal chain where perception and adaptation mutually influences each other, and the other where demographic and livelihood characteristics that change both perception and adaptation. Note: SFPs stands for Smallholder fodder producers.

of both adaptation and livelihoods because poor perceptions may lead to maladaptation and increased vulnerability (*viz.* Harrison et al., 2021) while good perceptions will enhance adaptation and resilience at the household and farm levels (Adger et al., 2003; Le Dang et al., 2014; Maponya and Mpandeli, 2013). Therefore, accurate perception and understanding of causes are important factors in determining farmers' adoption levels and intentions to adopt new strategies (Mertz et al., 2009), which, in turn, will help increase farmers' livelihoods. The perception level was assessed by comparing the survey questions (annual and seasonal rainfall and temperature; extreme events and the impact of climate change) with meteorological data.[1]

We further divided perceptions into four categories: perception of climate variables (rainfall and temperature), perception of seasonal climate change, perception of extreme weather events, and perception of impacts of climate change. The second stage, we look into considering the adaptation into two categories: actual adaptation strategies and intended adaptation strategies. We again formulated two hypotheses: 1) more accurate perception will lead to a higher adoption level of adaptation strategies; 2) a higher level of adoption rates of adaptation strategies will lead to increased resilience and reduced vulnerability of farmers to climate change. The final stage examines demographic and livelihood factors that determine both perception and adoption levels. In this stage, we developed and tested two hypotheses using a multi-linear regression model. We divided the factors into two demographic and livelihood factors, and each one was tested with several variables. For the demographic factors, we tested gender and knowledge, while for livelihood, we tested farming experience, farm size, and household income. Gender and knowledge of climate are binary variables that take either male or female and 0 and 1, respectively, while all other variables are continuous and measured in years, hectares, and dollars.

Description of the study area

This study was conducted in the northwestern region of Somalia (Somaliland), focusing on three specific locations as the main research sites: Wajaale (9.603°N, 43.341°E), Beer (9.9367°N, 45.749°E), and Xaaxi (9.350°N, 44.966°E) see Table 1, Figures 1, 2. We selected the sites because they are the main areas for fodder production and livestock transport routes in Somalia, and because they are agro-ecologically diverse, allowing them to serve as representative samples of the entire Somaliland region in terms of both fodder production and climatic conditions. Farmers in the area are agro pastoralists who heavily rely on livestock and commercial fodder production for their livelihoods. Their agricultural production is limited to small terraces, and they primarily use grass for sheep and goats, and maize stalks for

1 https://power.larc.nasa.gov/data-access-viewer/

TABLE 1 Climate characteristics of three agro-ecological zones in the study area.

Study sites	Fodder production zone	Mean rainfall (mm)	Mean min. temp. (°C)	Mean max. temp. (°C)	Mean temperature. (°C)
Beer	Rainfed – mainly with pasture production	315 (mm)	24	32	25°C
Wajaale	Mixed (rainfed and irrigation). Mainly with Maize stalks to feed for livestock	450 (mm)	20	26	23°C
Xaaxi	Primarily reliant on rainfall, mainly with pasture production	355 (mm)	24	33	26°C

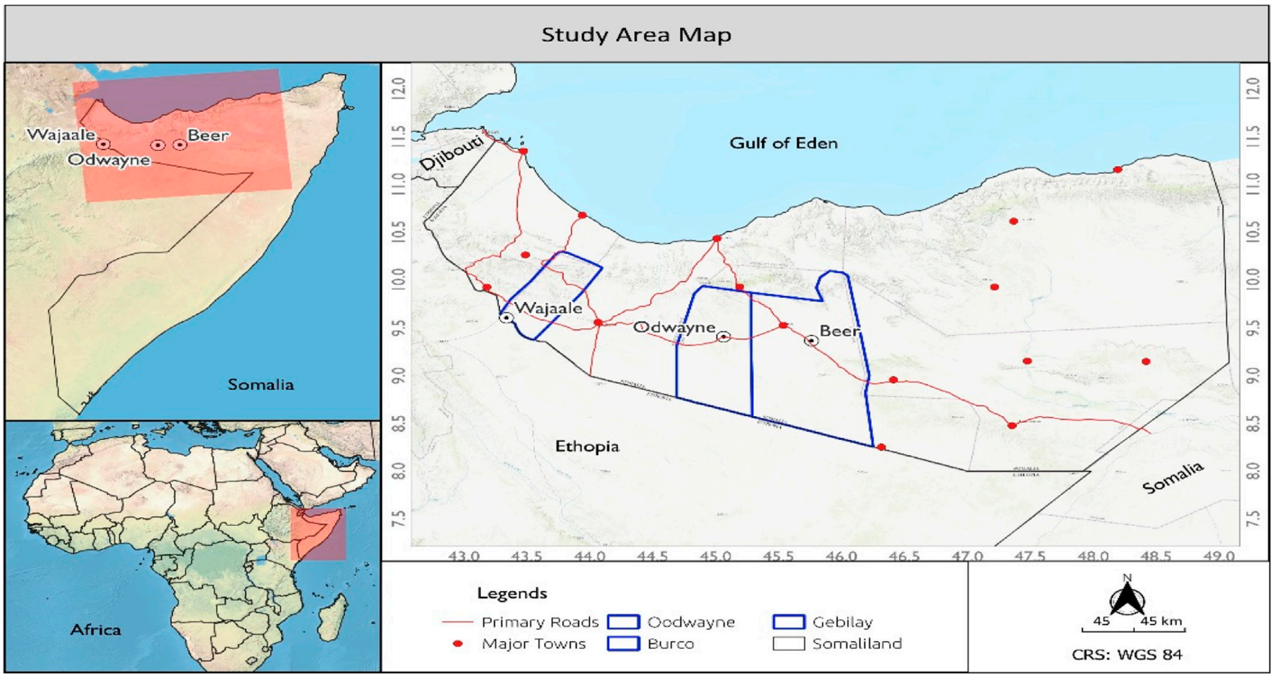

FIGURE 2
Study area. The highlighted border in blue indicates the three agro-ecological zones (Beer, Wajaale, and Xaaxi), which are part of administrative districts of Burao, Odwayne, and Gabiley, respectively.

cattle and camels as their primary source of fodder (Central Statistics Department at Ministry of Planning and Development in Somaliland, 2020). Gu (the main rainy season) and Hagaa (short rainy season) correspond to spring and summer, while Dayr (dry season) and Jiilaal (major dry season) correspond to autumn and winter, respectively (SLHDS, 2020). The mean elevation of the region is 410 m, with the lowest point being the Indian Ocean at 0 m and the highest point being Shimbiris at 2,416 m. The region is exposed to both climate-related and non-climate-related hazards, including factors such as fluctuating rainfall patterns, diminishing soil quality, limited water availability, delicate soils, unrestricted grazing, soil erosion, land fragmentation (Bryan et al., 2018; Deressa et al., 2011) scarcity of animal feed, livestock illnesses, deforestation, and soil degradation (Belay et al., 2022).

Research design

The research design entails a mixed-methods approach (Figure 3), combining qualitative and quantitative methods to explore climate change perceptions among smallholder fodder producers in Northwestern Somalia. The use of Participatory Rural Appraisal (PRA) tools such as Focused Group Discussions (FGD) and key informant interviews, along with a structured household questionnaire and direct observations, contributes to a comprehensive understanding of the topic (Chambers, 1994). The integration of NVIVO qualitative data analysis software (Welsh, 2011) and the R programming language (Ferraro and Giordani, 2015), enables robust analysis of qualitative and quantitative data, respectively. Stratified simple random sampling is used to ensure equal representation of participants from the three designated sites.

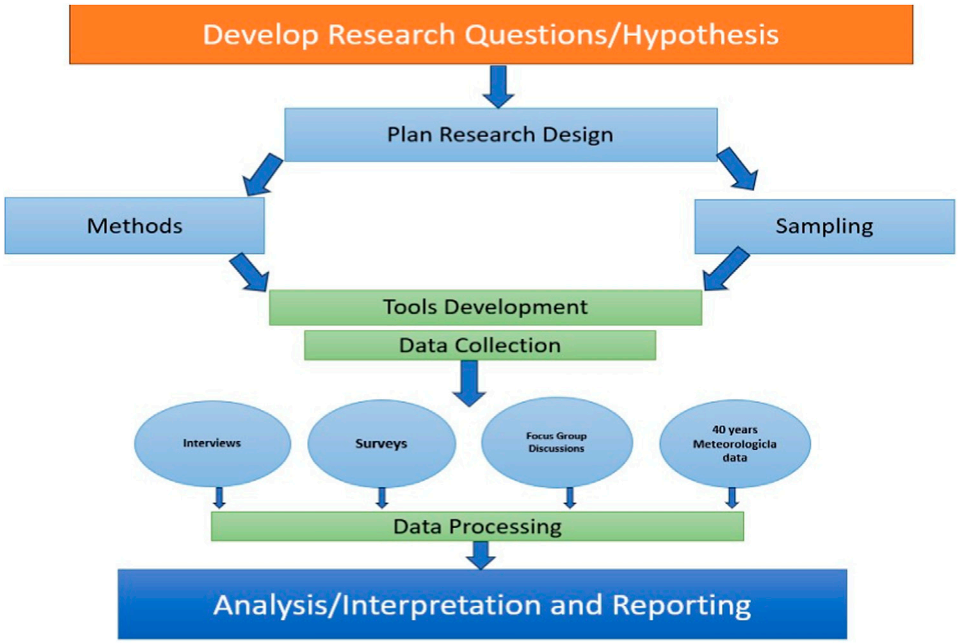

FIGURE 3
Flowchart for the methods applied.

Data collection and sampling

Three areas known for their significant production of fodder and their role as key livestock transport routes were selected. During field visits and interviews, data were collected from 198 households using a systematic sampling method. The selection of these farmers was done randomly from a population of 420 households residing across the study sites (Central Statistics Department at Ministry of Planning and Development in Somaliland, 2020), using the following equation:

$$\mathbf{K} = \frac{N}{n}$$

The households were drawn by selecting every K, where N is the total number of households in the community and n is the desired sample size (Ayanlade et al., 2017).

Here, we employed a mixed-methods approach, combining quantitative climate data analysis with qualitative individual interviews, focus group discussions, and key informant interviews. A total of 270 participants were involved as participants (Table 2). This comprehensive methodology allowed the researchers to capture both the objective climate trends and the nuanced, contextual perspectives of smallholder farmers in Somalia.

First, we conducted 12 in-depth key informant interviews, which lasted 60–90 min each. These experts – including community leaders, representatives from the Ministry of Environment, Agriculture, and Livestock, local NGO representatives working on climate change and food security, agricultural extension officers, meteorological agency staff, and representatives from women and youth groups – provided valuable insights that informed the design of the data collection instruments, refining the open-ended questions and developing the closed-ended questionnaire items. These key informants discussed smallholder farmers' perceptions of climate change, their current adaptation strategies, barriers and enablers of adaptation, the role of traditional knowledge, gendered dimensions of climate impacts, and potential policy interventions. Additionally, to further explore shared perspectives, experiences, and priorities within the farming community, we facilitated 6 focus group discussions - 2 in each of the 3 research sites, with separate sessions for male and female participants. Each FGD comprised approximately 10 male or 10 female participants, totalling 58 FGD participants across the 3 sites. This approach was adopted after recognizing that gender-specific cultural norms might prevent some respondents from voicing their views openly in mixed-gender settings. The Results section draws on these focus group insights to highlight common themes, divergent views, and the social dynamics underlying climate change adaptation.

Moreover, we conducted semi-structured interviews with 198 respondents. The interview was split into three main sections: demographics, perceptions of change, and adaptation strategies. The demographics and livelihoods section included standard questions about age, gender, household size, marital status, education, income,

TABLE 2 Summary of data collection methods for the interviews along the three agro-ecological zones (Survey, Focus Group Discussion and Key Informant).

	Wajaale	Beer	Xaaxi
Survey (n = 198)			
Subsistence fodder producers %	40	30	30
Commercial fodder producers %	30	40	40
Both subsistence and commercial producers %	30	30	30
Focus Group Discussion (n = 58)			
Number of people participating FGD	18	21	19
Male participants	10	12	9
Female participants	8	9	10
Key Interview (n = 14)			
Number of people participating KII	5	5	4
Fodder traders	2	2	2
Head of fodder cooperatives	2	2	2
Livestock farmers	1	1	0

and land-holding size. The rich, contextual data gathered from these interviews will elucidate the nuances and complexity of farmers' experiences and decision-making processes, thereby enhancing the Results section. Finally, the data collected were complemented with meteorological data[1] from Climate Hazard Group Infrared Precipitation with Station (CHIRPS) data on precipitation and temperature from the NASA satellite, which was then compared with ground meteorological data. This quantitative analysis of climate trends will form a central component of the Results section, allowing the researchers to assess the alignment (or discrepancies) between farmers' perceptions and the observed climatic changes. The integration of both subjective and objective data will enhance the credibility and depth of the findings.

Data analysis

Perception of climate change

The study categorized smallholder perceptions of climate change into four groups based on their views. These categories included: 1) perceptions of changes in temperature and rainfall, 2) perceptions of changes in seasonal climate, 3) perceptions of extreme weather events, and 4) perceptions of the impacts of climate change. The first section focused on farmers' perceptions of mean annual rainfall and temperature. The second section examined their perceptions of a delayed onset and early cessation of rainy seasons. The third section explored perceptions of erratic rainfall, prolonged and severe droughts, frequent floods, and intensified heatwaves. The final section delved into perceptions of the impact of climate change on fodder production, livestock productivity, water availability, and species extinction. Through this categorization, the study aimed to provide a more nuanced understanding of farmers' perceptions of climate change, which could inform policymaking and decision-making regarding climate change adaptation and mitigation in the region.

Severity index (SI) calculations

A Likert scale questionnaire was used to assess respondents' views on specific topics or issues, using statements or questions that measured their level of agreement or intensity. The collected data was analysed using statistical methods such as frequency analysis, simple percentages, and severity index calculations. Responses were recorded on a 0–3-point Likert Scale, and the severity index (SI) was calculated using a specific equation (Masud et al., 2017). The study employed the severity index (SI) method to calculate perceptions of climate change issues, including rainfall and temperature, seasonal climate change, perceptions of extreme climate events, and perceptions of the impact of climate change.

$$\text{Severity Index, } (SI) = \left(\frac{\sum_{i=0}^{4} Piqi}{\sum_{i=0}^{4} qi}\right)(100\%)$$

The valuation arrangement involves the use of the following formula: pi represents the index of a particular class, the constant denotes the weight assigned to that class, and qi denotes the frequency of response. The values for i range from 0 to 3, with p1, p2, and p3 representing the response frequencies corresponding to Q1 = 1, Q2 = 2, and Q3 = 3.

Q1 = Strongly Disagree $0.00 \leq SI < 33.33$
Q2 = Moderate $33.5 \leq SI < 66.00$
Q3 = Strongly Agree $66.5 \leq SI \leq 100$

To examine how farmers perceive, understand, and feel about climate change, the questionnaire items concerning this topic were grouped into three distinct clusters for the purposes of analysis: Perception of rainfall and temperature, seasonal climate change, extreme climate events and climate change impact.

Problem confrontation index calculations

To identify the main obstacles that hinder farmers from adopting adaptation practices, a ranking was conducted using the Problem Confrontation Index (PCI) (Ndamani and Watanabe, 2015). Participants were asked to rate the perceived obstacles using a Likert scale ranging from 0 to 3, with options such as "insignificant," "significant," "extremely significant," and "intense" or "highly problematic." The PCI score was calculated using the following formula:

$$PCI = Pn \times 0 + P1 \times 1 + Pm \times 2 + Ph \times 3$$

where PCI represents the Problem Confrontation Index, Pn is the number of respondents who rated the constraint as insignificant, Pl is the number of respondents who rated the constraint as significant, Pm is the number of respondents who rated the constraint as extremely significant, and Ph is the number of respondents who rated the constraint as intense.

Results

Perception of rainfall and temperature

Measured changes of seasonal rainfall and temperature

On average, the results suggest that winter seasonal rainfall has been decreasing over time in all three locations, but at different rates (Figures 4, 5). Beer experienced the most significant decrease in winter seasonal rainfall (y = −0.04x), followed by Xaaxi (y = −0.01x), and then Wajaale (y = −0.03). The R^2 values indicate that the linear regression model explains more of the variability in winter seasonal rainfall for Beer (65%) and Xaaxi (19%) compared to Wajaale (0.2%). In Figure 4B, it can be inferred that there is a mild upward linear association between spring seasonal precipitation and time in the three studied areas. The slopes of the regression lines demonstrate that, on average, spring seasonal rainfall has been increasing over time in these locations. However, the R^2 values suggest that the linear regression models do not account for a large proportion of the variability in spring seasonal rainfall across the locations, with only 3%, 6%, and 7% of the variability being explained in Xaaxi, Wajaale, and Beer, respectively. Figure 4C shows that there has been a slight upward trend in summer seasonal rainfall over time in the studied locations. However, the R^2 values indicate that the linear regression models can only explain a small proportion of the variability in summer seasonal rainfall, with only 0.17% and 5% of the variability being accounted for in Wajaale and Beer, respectively. In contrast, Xaaxi shows a significant discrepancy, with a moderate level of variation in summer seasonal rainfall at 13%. Figure 4D reveals a weak positive linear relationship between autumn seasonal rainfall and time in Xaaxi and Beer, while Wajaale shows a weak negative relationship. This means that Beer and Xaaxi are showing a relatively increasing trend in autumn seasonal rainfall, while Wajaale exhibits a decreasing trend. In the Beer district, rainfall trends show significant fluctuations across the seasons. There is a significant increase in rainfall during spring, a slight increase in summer and autumn, but a dramatic decline in winter. In contrast, Xaaxi shows a similar trend across all seasons over the 30-year period.

In general, all the study sites exhibit a substantial increasing trend in mean seasonal temperature, with the highest increase observed in summer, and lowest increase in winter (Figure 6). Beer had the highest mean temperature across the four seasons, with (R^2 0.38, 0.54, 0.55, and 0.54) for winter, spring, autumn, and summer, respectively. The highest average autumn temperature over the past three decades was recorded in Beer, with a mean temperature of 25.96°C, while Xaaxi exhibited the lowest average temperature 24.68°C. A significant proportion of smallholder farmers (72%) reported a marked rise in temperature, while a smaller percentage (23%) noted no discernible change, and a mere 5% indicated a decrease. These self-reported data were subsequently reinforced during the focus group discussions, where smallholder farmers unanimously concurred on the substantial temperature increase. Their collective observations of more frequent heat waves served as pivotal evidence for this consensus. Regions with greater deviations from the average seasonal temperature and precipitation tend to have a higher perception of climate change.

Perceived changes of seasonal rainfall and temperature

Results from focus group discussions (FGDs) and key informant interviews (KIs) revealed that the seasonal climate, particularly rainfall and temperature, has been observed to change and worsen over the past few decades. Despite the substantial interannual variability, producers have developed keen observational skills and adaptive strategies that enable them to discern subtle trends in rainfall patterns. They often rely on traditional knowledge, and their experiences to identify these shifts. However, the extinction of indigenous knowledge poses a significant threat, as younger generations may become disconnected from these valuable practices and insights. This loss can limit the community's ability to adapt effectively to changing climatic conditions. Additionally, the integration of modern forecasting tools assists them in making more informed decisions, allowing for effective management in the face of significant stochastic noise. The household survey conducted also supported these findings, with 66% of respondents strongly agreeing that rainfall is ceasing early in each season, and 77% strongly agreeing with the late onset of rainy seasons across the three sites. This indicates that people are experiencing late onset of rains more frequently than early cessation. Less than 30% of respondents moderately agreed, and only 25% strongly disagreed

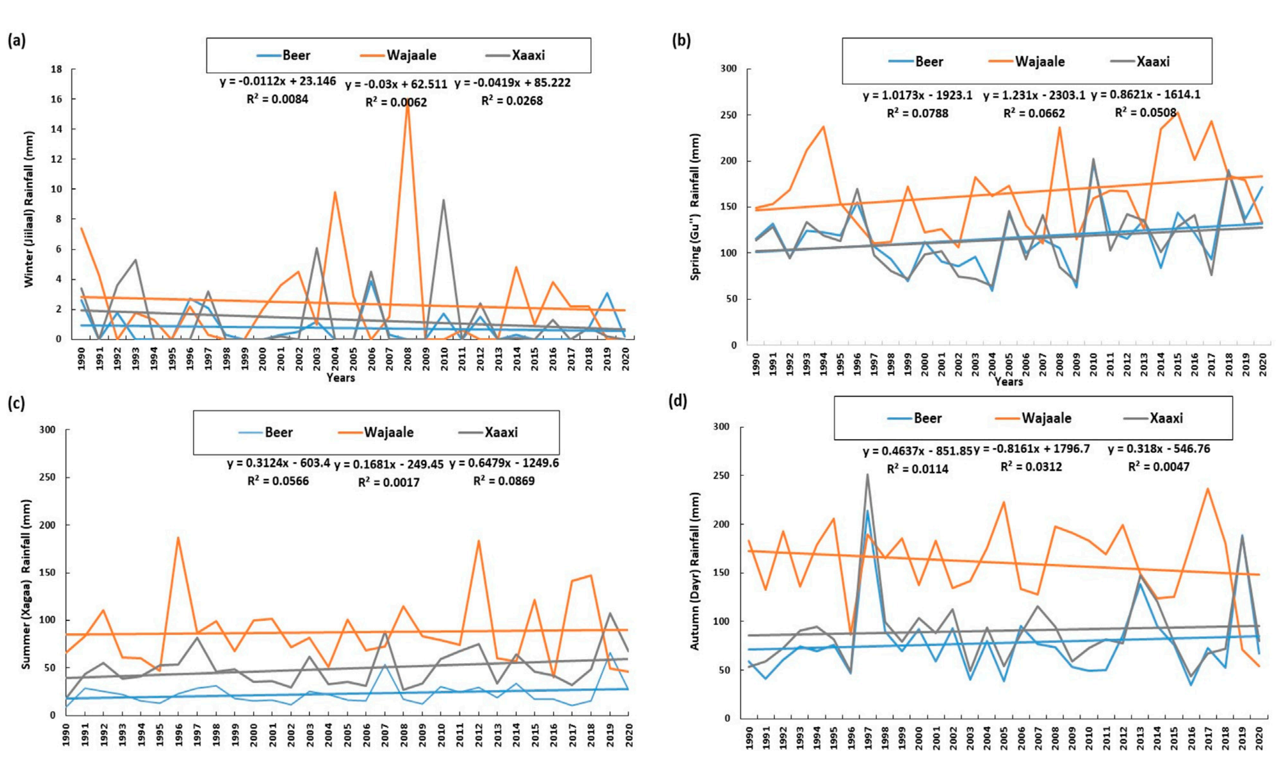

FIGURE 4
Seasonal rainfall changes in Beer, Wajaale and Xaaxi between 1990 and 2020. **(A)** Winter (Jiilaal), **(B)** Spring (Gu'), **(C)** Summer (Xagaa) and **(D)** Autumn (Dayr).

with the early ceasing and late onset, respectively. This suggests that smallholder producers perceive a late onset of rainy seasons more often than an early cessation of seasonal rainfall. The results of the chi-square test of independence indicated a significant difference between the proportions of smallholder producers who perceived a late onset of rainy seasons versus an early cessation of rainy seasons. The *p*-value (0.008) suggests that there is a significant difference in perception between smallholder producers regarding the late onset of rainy seasons and early cessation. These findings imply that smallholder fodder producers are more concerned about the late onset of rainy seasons than the early cessation of seasonal rainfall. This finding may have important implications for agricultural practices and water management in the region. The farmers' perceptions were compared with historical trends derived from meteorological data from three locations (Beer, Wajaale, and Xaaxi). The analysis was conducted using daily rainfall data from 1990 to 2020. The results indicate a persistent high variability in annual rainfall based on the 5-year moving average, as shown in Figures 4A-D.

Perceived changes of rainfall and temperature

Farmer perceptions of climate change, whether transient or chronic, are crucial to success in adaptation (Muleke et al., 2022). This is because their perceptions can serve as an early indicator of their ability to adjust to the changing conditions.Also argues that perception plays a significant role as farmers' perceptions of the risks associated with climate change determine whether policies are accepted or rejected. Figure 4 demonstrates the responses of local smallholder producers regarding their perception of rainfall and temperature changes. Overall, 62% of the respondents agreed that precipitation has decreased, and 79% agreed that temperatures are increasing. However, notable variations in responses were observed across different locations. In Wajaale, for example, only 30% of the respondents agreed that rainfall has decreased, while 70% expressed either moderate agreement or disagreement with this statement.

Perceptions of extreme climate events

Supplementary Table S1 presents the results of the perception of extreme climate events. The study found that the severity index (SI) values calculated for each perception were related to the farmers' views on climate change vulnerability. The SI values ranged from 72% to 88%, falling within the agreed opinion range of $66.5 \leq SI \leq 100$, except for heatwaves, which fell within the moderately agreed opinion range of $33 \leq SI < 66$.

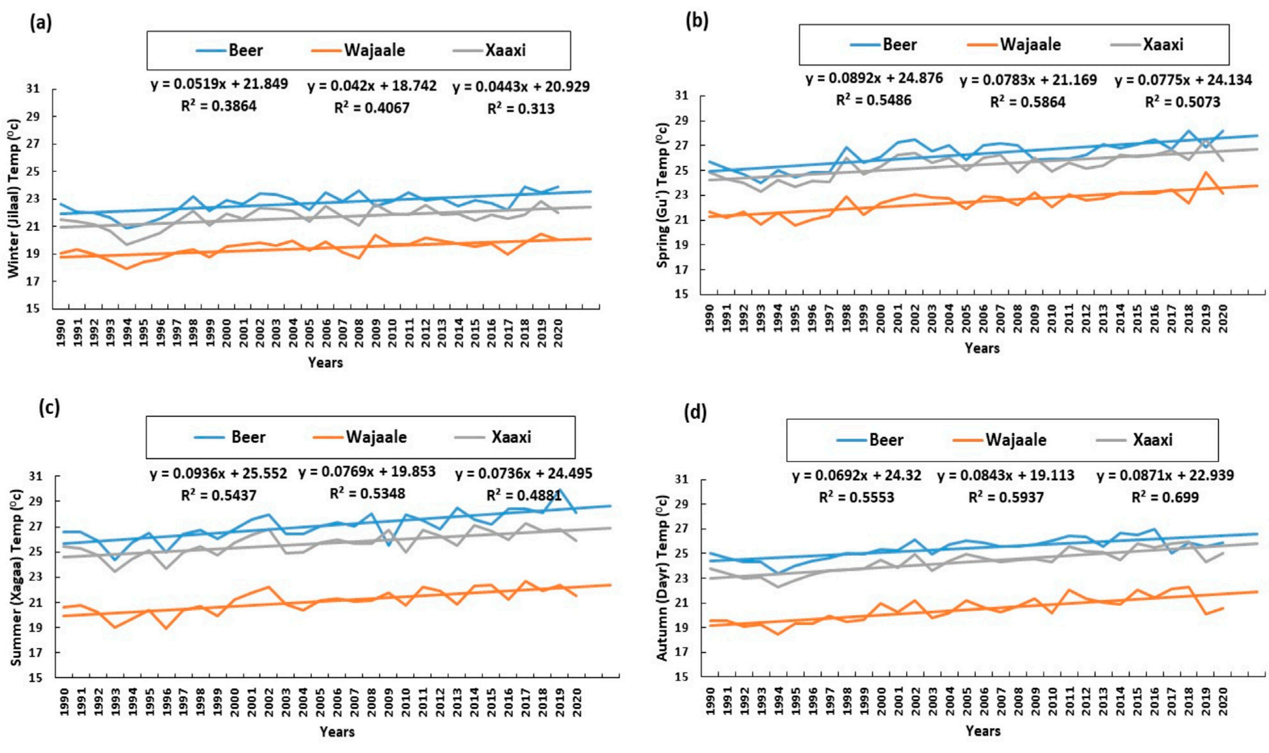

FIGURE 5
Seasonal temperature changes in Beer, Wajaale and Xaaxi between 1990 and 2020. **(A)** Winter, **(B)** Spring, **(C)** Autumn and **(D)** Summer.

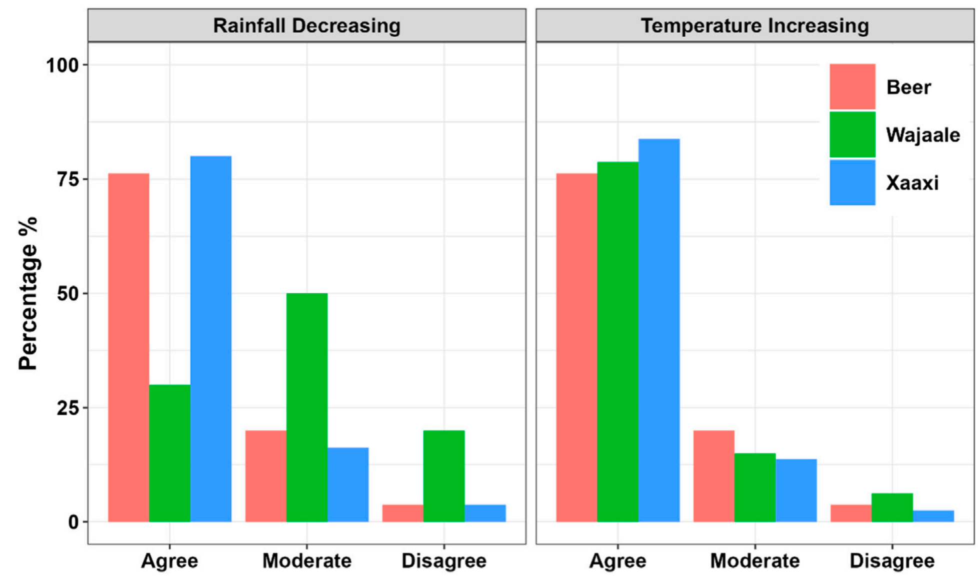

FIGURE 6
Shows the results of Likert scale data. It portrays the percentage of respondents who either agree, say moderate (meaning neither agree nor disagree), or disagree.

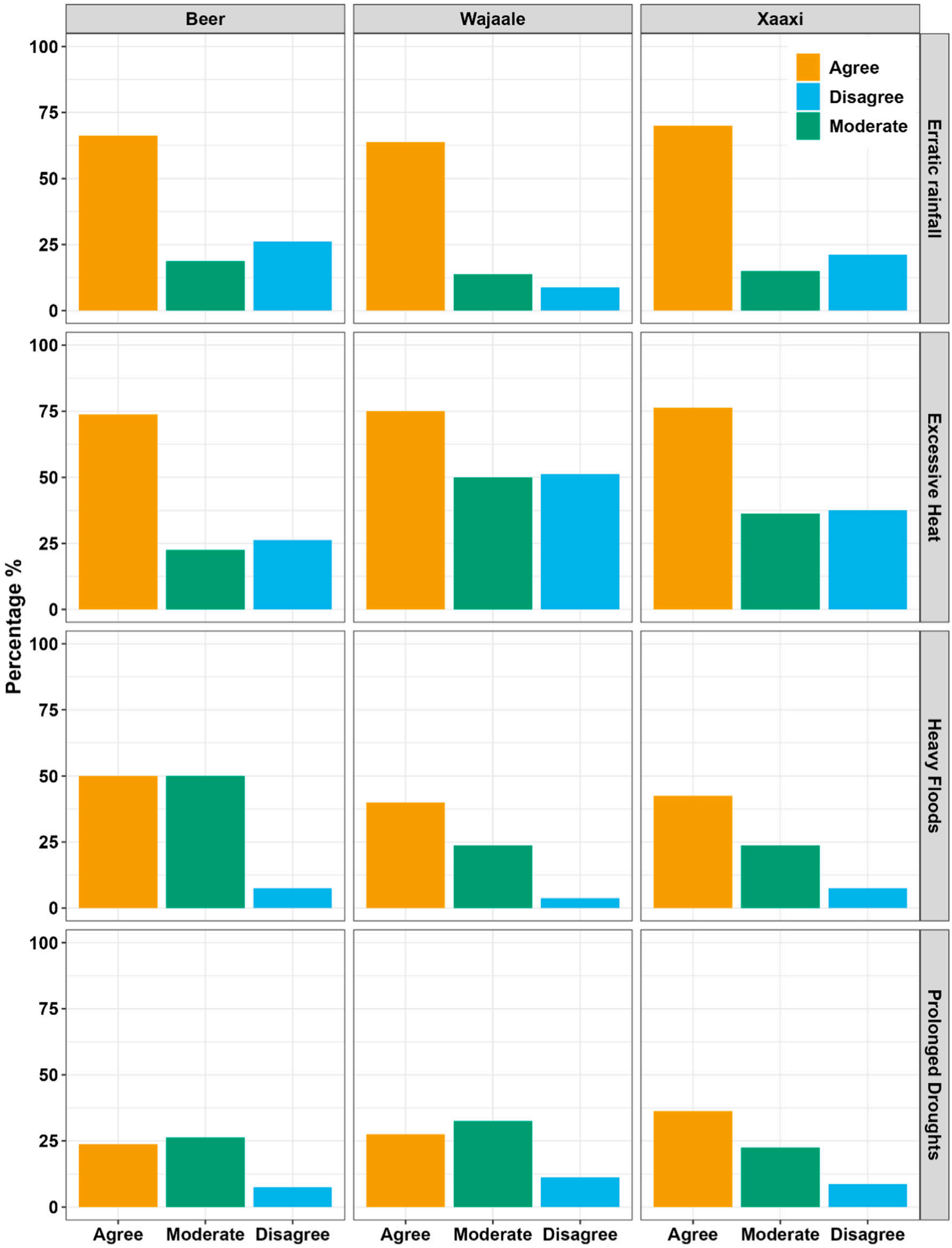

FIGURE 7
Distribution of Respondents Opinion on Extreme Climate Events, categorized by agreement levels (Agree, Moderately Agree, and Disagree).

The severity index (SI) ranked "Prolonged Droughts," "Erratic Rainfall," and "Frequent Floods" with corresponding SI values of 88%, 86%, and 72%, respectively (Figure 7). These rankings align with the findings of the focus group discussions (FGDs), which identified severe and prolonged drought as the primary impact of climate change affecting smallholder producers. In summary, the study indicates that most of the fodder producers' perceptions of climate change vulnerability remained consistent, with most perceptions falling within the agreed opinion range. However, there was one perception that fell into the moderately agreed opinion range.

Perception of impacts of climate change

Overall, most respondents perceived significant impacts of climate change, particularly in terms of the loss of fodder production, decreased livestock by-products, drying water points, and species extinction Table 3. There were some variations in responses between the locations regarding the assessed impacts. The survey findings revealed that the respondents expressed a higher level of concern regarding the reduction in livestock by-products and the decline in fodder production, with 63%–68%, respectively. In contrast, the deterioration of water points and the potential extinction of species garnered a relatively lower level of agreement, ranging from 54% to 57% respectively. These findings are consistent with discussions and in-depth interviews with farmers, who have experienced the physical impacts of climate change on fodder and livestock production. The results of the survey revealed some variations across the different locations, with Beer and Xaaxi recording the highest number of respondents who strongly agreed (77%) with the statement on the loss of fodder production, compared to with only 52%. These differences could be attributed to the fact that Beer and Xaaxi may have experienced more severe drought or other environmental stresses that negatively impacted the availability of feed for livestock. On the other hand, respondents in Wajaale perceived a greater decrease in livestock production (78%) compared to Xaaxi and Beer, with only 52%–60% agreement, respectively. This result suggests that there may be non-climate factors in Wajaale negatively impacting livestock production, such as disease outbreaks, poor animal health management, or reduced access to grazing lands. Alternatively, it's possible that respondents in Wajaale have a different perception of what constitutes a decrease in livestock production compared to respondents in Xaaxi and Beer. Further investigation is necessary to better understand the reasons for the differences in responses across the three locations. Conclusively, the survey results suggest that SFPs (Smallholder Fodder Producers) in the surveyed locations perceive significant impacts of climate change on livestock and fodder production.

Intended and actual adaptation strategies of small-holder fodder producers

Given the fact that adaptation studies have traditionally focused on current (actual) adaptation strategies (Arbuckle et al., 2014), while giving little attention to anticipated (intended) adaptation strategies (Niles et al., 2016), this study combines both approaches to link present responses with aspirational priorities for adaptation. The combination of both approaches provides a more comprehensive understanding of the adaptive process, contributes to more informed and effective decision-making, and helps anticipate future adaptation needs or patterns.

Actual adaptation strategies

Ahead of rainy season, SFPs excavated pits near their fields, providing ample storage space to hold maize stalks for use as livestock fodder during dry season. Pits can be a valuable adaptation strategy to the challenges posed by climate change. The controlled underground environment of pits helps regulate temperature and moisture levels, preventing spoilage and protecting stored goods from pests and pathogens – issues exacerbated by climate change disruptions (Izah and Ogwu, 2023). Furthermore, pit storage allows for longer-term reserves of essential resources, enabling communities to better withstand periods of scarcity or supply chain disruptions resulting from the impacts of climate change (Akinyi et al., 2021; Gruda et al., 2019). Typical Somali smallholder storage pits are 1.5–3 m deep and 2–4 m wide, lined with clay, straw, or hides to create an airtight, temperature-regulated environment. These underground pits can store 500–2,000 kg of grains, dried foods, and seeds, varying based on household needs, labour, soil, and tradition.

Additionally, farmers construct pyramid-like structures to store fodder, protecting it from high temperatures and heavy rainfall. This approach results in minimal losses, with only about 5% of the outer layer compromised, while the rest retains its quality over time. Elevated temperatures foster prolific pest and disease outbreaks, with termites posing a grave threat. To safeguard against this, communities construct elevated platforms that shield the grass from termites and soil-borne rot. SFP systems rely on naturally regenerative grass, but recurrent drought is not favouring. SFPs then cultivate maize and sorghum stalks as a supplementary fodder. If prolonged drought depletes these reserves, livestock are fed imported wheat bran from Ethiopia or the Gulf states.

> "In addition to grass, maize, sorghum stalks, and wheat bran, local communities in the study region rely on various locally available plants as alternative fodder sources. For instance, Juliflora, an exotic plant with addictive properties, is used as livestock feed. During drought periods, cactus, preferably thornless species, is also utilized. Moreover, plants known as 'Jilaab, Gagabood, Maydhaxda Galoolka, Maydhaxda

TABLE 3 Perception of climate change impact obtained during the survey questionnaire.

Impact type	Likert scale measurement	%	N = 198	Beer	Wajaale	Xaaxi
Fodder productivity	Increase	11	164	62	41	62
	No change	21	51	12	27	13
	Decrease	68	25	6	13	6
Livestock productivity	Increase	10	152	48	63	42
	No change	27	64	22	17	26
	Decrease	63	24	10	1	13
Water point availability	Increase	17	130	48	42	40
	No change	29	69	22	22	26
	Decrease	54	41	11	16	14
Pasture availability	Increase	16	137	50	45	42
	No change	27	64	20	19	25
	Decrease	57	39	10	16	13

TABLE 4 The relative importance index (RII) for the actual (current) adaptation strategies in the three-study area using Likert scale.

Description	SDA (0)	DA (1)	M (2)	A (3)	SA (4)	RII	RII Rank
Digging wells for fodder storage	0	2	69	107	2	0.6	3
Constructing pyramid-like structure for storage	1	6	40	113	20	0.7	2
Construction of elevated platform structure for storage	3	8	72	93	3	0.6	4
Diversification of fodder species such as Grasses, maize and sorghum stalks, Cactus among others.	3	55	122	180	8	0.9	1
Use locally available insecticides such as Ash, limestone, and Oil	3	4	104	68	1	0.5	5

> Qudhaca, Garanwaaga,' and others play a significant role in providing feed for livestock in the region (Male participant from FGD sessions, Xaaxi)."

Results of the Relative Importance Index (RII) regarding the current adaptation strategies in the three study areas, using a Likert scale are presented in Table 4. The findings indicate that respondents considered the diversification of fodder species as the most important adaptation strategy currently employed, with an RII of 0.91. This suggests that respondents recognized the value of incorporating a variety of fodder species to ensure a mixed and diverse feed source for livestock. These findings are consistent with the discussion narratives from the Focus Group Discussions (FGDs). One participant highlighted the reasons for diversifying fodder species as an adaptation mechanism and stated:

> "The reasons can include providing a range of nutritional options for livestock, avoiding the risk of relying solely on a single type of feed, and probability to extinct (female participants, FGD sessions, Beer)."

> "Maintaining multiple variety of fodder plants preserve the local ecosystem's biodiversity and make fodder supply more resilient to the impacts of climate change, such as droughts or pests that may target specific plants species (Key informant, Ministry of Environment and Climate Change, Somaliland)."

Another important adaptation strategy mentioned by the respondents is the construction of pyramid-shaped structures for storing fodder, which ranks as the second most crucial strategy with an RII of 0.7 (Table 4). According to most respondents, this strategy offers effective protection against extreme temperatures and rainfall. Moreover, it is considered a cost-effective option compared to alternative storage methods. These findings are supported by a study conducted by Lukuyu et al. (2011), which also emphasizes the availability of locally sourced construction materials such as wood and sandbags.

Intended adaptation strategy

Smallholder farmers in all three study sites highlighted intended (anticipated) adaptation strategies against the impact of climate

TABLE 5 Key Intended adaptation strategies ranked in order of importance.

No	Description of intended strategy	N	RII (%)	Rank
1	Access to timely weather information	77	38	1
2	Adoption of climate-resilient fodder variety	50	25	2
3	Availability of modern fodder storage facilities	43	22	3
4	Shifting to irrigation schemes	30	15	4

change on fodder production (Table 5). Numerous strategies were noted in the survey and focus group discussions, including the introduction of new fodder varieties that are flood, temperature, insect, and drought tolerant; the construction of modern fodder storage facilities; access to timely weather information; and shifting to irrigation and improving water management systems. Respondents emphasized the challenges associated with each strategy, followed by a set of recommendations. The Relative Importance Index (RII) of all intended strategies was calculated using data obtained during the survey interviews.

In the survey, the establishment of early warning systems, particularly access to timely weather information, emerged as the most preferred climate adaptation strategy. This highlights the widespread recognition of the importance of such systems in addressing climate-related risks and underscores the need for policymakers and stakeholders to prioritize their development and implementation. Furthermore, the adoption of climate-resilient fodder varieties was identified as the second most preferred adaptation strategy among SFPs, with 25% (n = 50) of respondents indicating their intention to adopt this approach. Concerns related to trust and weed potential were identified as barriers to adoption, emphasizing the need for rigorous scientific research and field trials to validate the efficacy and resilience of these varieties. Additionally, approximately 22% (n = 43) of respondents identified the construction of modern storage facilities as the third intended adaptation strategy. The absence of innovative technology and high construction costs were recognized as significant barriers. To overcome these challenges, the adoption of appropriate technological solutions is recommended. Shifting to irrigation-dependency was the least intended adaptation strategy among SFPs, with only 15% (n = 30) of respondents expressing their inclination towards this approach (n = 198, $p < 0.05$). Limited understanding of irrigation systems among farmers was identified as an obstacle. To promote adoption, comprehensive training and education programs should be provided to enhance farmers' understanding.

Adaptation strategy constraints

Table 6 displays the extent of constraints hindering the implementation of intended and actual adaptation strategies among smallholder farmers in Somalia. Respondents were asked to rank the degree of constraint for each description on a scale from negligible (0) to intense (3). The "PCI" column represents the cumulative scores for each constraint, while the "Rank" column indicates their ranking based on these scores. The findings reveal that smallholder farmers in Somalia perceive various barriers to implementing adaptation strategies. Recurrent and prolonged droughts were identified as the primary constraint, signifying their significant impact. The lack of suitable fodder storage facilities was ranked second, posing a major obstacle to adaptation efforts. Unpredictable weather was reported as the third most significant barrier, impeding the development and implementation of effective plans. In addition, smallholder farmers also acknowledged additional challenges, including limited access to timely weather information, pests, and diseases (termites, rats, and locust invasion), restricted subsidies, insufficient knowledge of fodder conservation and management practices, and high costs of fodder farm inputs. Although these constraints scored lower cumulatively, they are still considered major obstacles to successful adaptation efforts.

Livelihood and demographic characteristics as determinants of adoption level

This section presents the outcomes of the regression model that compares livelihood and demographic factors with the adoption level. We showed that farm size, and tenure are not significantly associated with the adoption of climate change adaptation strategies Table 7. The data also show that household income, and knowledge of climate change are all significantly associated with adoption. We found marked influence of gender in adaptation to the changing climate, with households where males make decisions exhibiting a 76% adoption, compared with 34% of households where decisions were made by females.

Discussions

In contrast to numerous other areas, (Akponikpè et al., 2010; Arshad et al., 2022; Khan et al., 2020; Niles et al., 2016), we showed that most Smallholder Fodder Producers (SFPs) perceived climate change through a lens of changes in rainfall and temperature. However, the perceptions of climatic trends exhibit pronounced spatial heterogeneity across the study sites.

TABLE 6 Degree of constrains affecting implementation of actual and intended adaptation practices (N = 198).

Description of PC	Degree of constrain				PCI	Rank
	Insignificant (0)	Significant (1)	Extremely significant (2)	Intense (3)		
Recurrent and prolonged droughts	4	8	28	158	542	1
Unpredictable weather	17	20	34	127	469	3
Lack of access to timely weather information	26	25	34	113	432	4
Lack of proper fodder storage facility	10	12	29	147	511	2
High cost of fodder farm inputs	61	53	24	60	281	8
Lack of knowledge (fodder conservation and management practices)	46	64	24	64	298	7
Limited access to subsidies	26	53	34	85	376	6
Incidence of pests and diseases (locust invasion, termites, and rodents)	26	40	34	98	402	5

TABLE 7 Shows the regression results the correlation between demographic and livelihood factors with adoption level.

	Standard Error	t Stat	*p*-value
Farm Size	0.001	0.3	0.91
Tenure	0.002	0.5	0.85
Knowledge of climate change	0.039	3.5	0.02*
Household income	3.58E	−11.7	0.00**

* Significant at $p < 0.05$, ** significant at $p < 0.01$.

Although a ubiquitous increase in temperature was reported (Kima et al., 2015), the precipitation trends showed divergent patterns. In Wajaale, only 30% of respondents concurred that rainfall has declined, in contrast to the higher proportions in Beer and Xaaxi. This difference is attributed to the prevailing weather patterns, as Wajaale experiences greater mean annual rainfall relative to other study locations (Abdulkadir, 2017; Hartmann and Sugelle 2009). The meteorological analysis corroborates these perceptions, illustrating a more pronounced increasing trend in precipitation for Wajaale. Conversely, the eastern regions of Somaliland have witnessed more frequent and prolonged drought episodes during the study periods, which likely shapes the respondents' perspectives on the decreasing rainfall trends in those areas (Abdulkadir, 2017).

We found that majority of SFPs observed a greater incidence of late onset rather than early cessation of rainfall across the study sites. These observations suggest that SFPs are more preoccupied with the late onset of rainy seasons, which may have adverse implications, rendering their planning and decision-making processes more challenging and leading to suboptimal decisions and diminished productivity (Mugalavai et al., 2008; Ngetich et al., 2014). We analyzed the perception of extreme weather events and drought singled out the most perceived extreme climatic event across the three study sites, with Severity Index (SI) of 87%. These drought occurrences have far-reaching implications for smallholder farmers, including decline in production, exacerbation of social instability (Ahmad et al., 2022), facilitation of migration and poverty, (Bahta and Myeki, 2022), and the distressed selling of livestock by impoverished rural households to meet their food needs (Vetter et al., 2020). We suggest that development and use of appropriate decision support tools (Phelan et al., 2018) may help producers compare available options for adaptation to drought, including destocking, purchasing of external feed, and agistment.

Our findings indicate that 74% of SPFs have been practicing fodder production for 15–20 years, suggesting their long-standing engagement in this sector, which can be attributed to the intricate interplay of several key factors. Foremost, the favorable market demand and price incentives for fodder, particularly linked to the burgeoning live livestock export trade to Gulf states, have provided a strong economic impetus for smallholders to continue investing in fodder cultivation over an extended period (Mohamud et al., 2022). For instance, the prices of fodder in Somaliland vary between seasons, where six-ton full truck load is $300 or 7 kg bale is $6 in dry season and peak during the dry season when the price of full truck load goes up to $1,000 or 7 kg bale is sold $15. Somaliland's annual small ruminant export demands around 60,000 tons of grass, which translates to livestock exporters spending between $3,000,000 and $5,000,000 on fodder, subject to seasonal variations. Additionally, the early establishment of strategic quarantine centers heightened demand for fodder, as livestock undergo mandatory resting periods and rigorous health inspections prior to export, necessitating increased feed supply to sustain the animals during this transitional phase (Mamo, 2019; Mtimet et al., 2021). Finally, the minimum input effort and the size and composition of smallholders livestock herds to feed their livestock can influence the demand for fodder production (Wanyoike et al., 2023).

Our analysis revealed that the primary actual adaptation strategies adopted include construction of fodder storage facilities, fodder diversification, and use of local available chemicals to protect insects – all of which are indigenous approaches (Berhe et al., 2017). This highlights the minimal role of external entities such as government agencies, NGOs or development organizations in supporting adaptation in the region. Corroborating this observation, a recent study by Hasibuan et al. (2023) insists that the areas solely relying on indigenous adaptation strategies tend to receive less external adaptation support. In contrast, the intended adaptation strategies identified in the region encompass the introduction of drought-tolerant fodder varieties, the development of modern fodder storage facilities, the provision of reliable and timely early warning information, as well as the adoption of irrigation systems (Simotwo et al., 2018). This underscores the perceived need for technological (Thomas and Thomas, 2019) and informational (Angerer, 2012) interventions to sustain the fodder production sector, as also evidenced by prior studies (Balehegn et al., 2020; Mengistu et al., 2021).

We also showed the strong connection between SFPs perceptions of climate change and their adaptation strategies (Khan et al., 2020). Their perception of a reduction in precipitation and sustained rise in temperature reflect some of the intended adaptation strategies detailed in the study. For instance, their intention to introduce heat resistant and drought tolerant varieties to extreme weather events have a connection on the perceived precipitation reduction and sustained rise in temperature and generally shed light the connection between their perception and adaptation strategies. Smallholder farmers agreed unanimously in the FGD that they intend to adopt irrigation and innovative modern storage facilities. This is good indicator that SFPs not only perceive reduction in precipitation, but also worried about how this reduction will impact their fodder production and eventually their livelihoods (Batungwanayo et al., 2023).

Unlike farm size and tenure, we showed that knowledge of climate change, and household income are significantly associated with the adoption level (Berhe et al., 2017; Simotwo et al., 2018). Meaning initiatives such as awareness campaigns, workshops, training, and the integration of relevant coursework into educational curricula, can significantly bolster the adoption of adaptation strategies among SFPs. For instance, a study by Ayanlade et al. (2017) found that farmers with a better understanding of climate change trends were more likely to adopt adaptation strategies, such as changing planting dates, diversifying crop varieties, and implementing soil and water conservation techniques. Wealthier farmers are often better positioned to adopt by investing in costly adaptation measures, daring decisions like destocking during drought periods, construction of modern fodder storage facilities or the buying drought-resistant fodder varieties (Singh et al., 2017; Taylor et al., 2021). In contrary, It's also presumed that larger farm sizes may have lower ability to adopt, thereby weakening the capabilities of SFPs. This finding supports other research, which show an inverse proportional relationship between farm size and adoption (Manandhar et al., 2011). In general, these results underscore the crucial role that awareness and financial resources play in influencing the adoption of climate change adaptation strategies among the studied population. Increased risk-taking capacity and improved access to information and markets contribute to the significant relationship between higher household income and adoption levels.

While the study provides valuable insights into the perceptions and adaptation strategies of SFPs in dryland areas, it is important to acknowledge the limitations that may affect its generalizability to other contexts. The regional specificity and focus on commercially oriented producers restrict the broader applicability of the findings. However, the study still offers informative insights for similar dryland areas, highlighting the need for future research to address these constraints and explore diverse smallholder farming contexts. The significance of this study is multifaceted. It validates SFPs observations of climate change impacts and identifies their actual and intended adaptation strategies, while also revealing key constraints to adoption of these practices and underscoring the critical roles of knowledge, financial resources, and gender dynamics in enabling or inhibiting adaptive potential. Importantly, these insights can inform the development of more effective and inclusive policies and interventions to support climate change adaptation in vulnerable smallholder farming communities.

Conclusion

To enhance climate change adaptation among SFPs in dryland areas, we recommend the government, international partners and other stakeholders to implement a comprehensive awareness, workshops, and educational initiatives that improve SFPs understanding of climate change trends and impacts. The provision of targeted financial support, such as subsidies or credit programs (Mohamed Sala et al., 2020), would enable these farmers to invest in improved adaptation measures, such as fodder storage facilities and drought-resistant fodder varieties. The main limitations of modern fodder storage facilities include higher capital costs, complex operational requirements, technological complexity, and potential incompatibility with existing practices (Barsila et al., 2022; Wang et al., 2021) Additionally, shared community storage can raise conflicts over usage and control. The existing low-tech fodder storage methods, such as fodder pits, may have limited storage capacity, lead to fodder quality degradation, be susceptible to spoilage and wastage, and require labor-intensive management (Sharma et al., 2020). Given these trade-offs, our study recommends supporting the improvement and streamlining of simple, low-tech, locally available fodder storage methods, rather than pushing for costly modern facilities. This approach builds on farmers' existing knowledge and resource constraints, providing financial assistance to enhance or expand their traditional storage infrastructure as needed and create better outcomes (Sima et al., 2015).

Given that drought is a prevalent and impactful concern, and SFPs are particularly vulnerable to the adverse effects of late onset rainfall, which can lead to economic losses, hence recommended the adoption of irrigation systems (Sima et al., 2015). Given the limited resources of many pastoral communities, the most appropriate irrigation solutions are likely to be simple, easy-to-maintain systems that can be operated with minimal machinery and technical expertise, such as treadle pumps or gravity-fed drip irrigation (Awotide et al., 2016). Strengthening early warning systems and improving the timely dissemination of climate information would support SFPs decision-making and adaptation planning (Tofu et al., 2023). The integration of locally grounded and externally sourced adaptation strategies, facilitated through collaboration among SFPs, governments and other partners, is likely to be more effective than a single, isolated approach. To this end, our study encourages the introduction of the role of external entities, such as government agencies, NGOs or development organizations while also supporting further the development of existing ones. This way will bolster the resilience of local communities in a more sustainable way.

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 Ministry of Agriculture, Somaliland. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

Conceptualization: JH and MTH; Methodology: JH and FB; Validation: JH and FB; Formal analysis: JH and FB; Investigation: TC, JH, and FB; Writing—original draft: JH, FB, and MTH; Writing—review and editing: JH, FB, JS, DM, PO, MTH, and TC. 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.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontierspartnerships.org/articles/10.3389/past.2024.13424/full#supplementary-material

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