International Journal of Ecology and Environmental Sciences 51: 235-249, 2025
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2025.0523

Climate Change Adaptation Strategies by Gabbra Pastoralists in Marsabit County, Kenya

MAMO BORU MAMO[1], JOHN MURIUKI[2] AND EZEKIEL NDUNDA[2]
[1]*National Environmental Management Authority, P.O. Box 67839-00200, Nairobi, Kenya*
[2]*Department of Environmental Science and Education, Kenyatta University, P.O. Box, 43844-00100, Nairobi, Kenya*
E-mail: boru_mamo@yahoo.com, muriuki.john@ku.ac.ke, ndunda.ezekiel@ku.ac.ke

ABSTRACT
Climate change is a pressing global issue that disrupts seasonal weather patterns, affecting ecosystems, agriculture, water availability, and food production. This study focuses on the Gabbra pastoralists in Marsabit County, Kenya, and explores their perceptions, impacts, and adaptation strategies. The research aims to assess the Gabbra pastoralists' understanding of climate change, identify specific impacts they have experienced, and establish their adaptation strategies. The findings reveal that Gabbra pastoralists perceive climate change primarily through decreasing rainfall intensity, significant variability in rainfall amounts, and unpredictability of rainfall seasons. They have also noted more extended periods of drought, deterioration of pastures and water sources, unexpected cold spells, increased daytime temperatures, and drying up of wetlands. Traditional knowledge for predicting the onset of the rainy season has become less accurate, leading to disruptions in their socio-economic activities and lifestyles. Adapting to climate change presents significant challenges due to the unpredictable nature and severity of climate-related phenomena. To enhance the capacity of Gabbra pastoralists to adapt, government agencies and aid organizations should facilitate access to financial resources and extension services. Promoting sustainable management practices for rangelands, including range reseeding initiatives and awareness-raising programs that incorporate Indigenous knowledge, will be crucial. In conclusion, addressing climate change challenges in Marsabit County requires a collaborative effort that empowers pastoral communities. Integrating traditional knowledge with modern practices and ensuring access to necessary resources can enhance resilience and adapt more effectively to climate change impacts.

Key words: Climate Change, Perceptions, Impacts, Adaptations, Sustainability

INTRODUCTION

Climate change is a global challenge that disrupts seasonal weather cycles, affecting ecosystems, agriculture, food supplies, water availability, and supply (Ejembi and Alfa 2012). The IPCC predicts that Africa's climate may become warmer and drier, leading to extreme climatic events like droughts, heat waves, violent storms, cyclones, and floods (Niang et al. 2014). Pastoral communities and agro-pastoralists in arid and semi-arid regions depend on natural resources for their livelihoods, making them frontline victims of climate shocks (Khanal and Mishra 2017, Shah et al. 2020, Mahmood et al. 2021). Extreme weather phenomena like flooding and droughts heavily tax civilizations, impacting biodiversity, landscapes, people, and socio-economic structures. The extent of these impacts depends on the force of climate change and the community's ability to withstand and adapt. The influence of climate change on perceptions, impacts, and adaptations is related to socio-economic factors (Johnson et al. 2020, Okunola et al. 2022).

Pastoralism, a traditional livestock-based economy, faces threats due to human population growth, deteriorating rangeland resources, and climate change (Dong et al. 2016, Tiwari et al. 2020, Belay and Siraj 2024). Water scarcity, increased livestock disease incidences, and droughts in semi-arid and arid landscapes are causing significant challenges to traditional livestock production systems, particularly in sub-Saharan Africa, where livelihoods depend on rainfed livestock-based economies. Pastoralists in livestock-keeping regions manage climate variability and risks to protect their economy and livelihoods (Sandford and Scoones 2006, Ericksen et al. 2013, Tessema et al. 2014). The pastoral communities in such regions employ strategies like herd manipulation, opportunistic grazing, and mobility to adapt to climate variations. Mobility, or transhumance, is part of indigenous knowledge and is crucial for securing water and pastures for livestock. It allows them to take advantage of new water sources and use new grass and fodder in marginal landscapes, utilizing indigenous knowledge in these mobility efforts (Nkuba et al. 2019).

Population dynamics in East Africa, particularly in Kenya, have led to significant landscape changes, particularly in vegetation and plant cover. Privatizing rangelands and sedentarizing pastoral communities have impacted nomadic pastoral life. Despite this, livestock rearing remains the primary economic source, providing milk, meat, income, and savings. Land-based investments in Kenya have led to subdivided and fenced-off areas, affecting nomadic pastoral life (Egeru et al. 2014). Understanding local communities' perspectives on climate change is crucial as its effects on landscapes and socio-economics continue reverberating. Perception affects the incentive to adopt adaptive action, and understanding these perceptions is essential for guiding decision-making and adaptation planning efforts in pastoral communities (Fosu-Mensah et al. 2012). Herding experience, knowledge of livestock-keeping value chains, and wealth status influence perceptions of climate change and adaptations (Akerlof et al. 2013). Older people have accumulated knowledge of localities, while wealth status allows access to leadership and extension services. Indigenous knowledge of pastoralism, livelihood systems, and response actions is crucial for effective and locally acceptable adaptations to climate change and variability (Semenza et al. 2008).

Pastoral groups use local knowledge to develop effective climate change adaptation strategies (Cuni-Sanchez et al. 2019). Research efforts on these strategies mainly focused on farming communities in rural areas. Pastoralist perspectives have been studied in Africa, mainly in East Africa's dry lowlands. Meteorological data can influence people's opinions and actions on climate change (Reyes-Garcia et al. 2016, Filho et al. 2020). Climate variability and change threaten the Sustainable Development Goals (SDGs) of eradicating poverty and food security in Saharan Africa. Ecosystem degradation, poor agricultural yields, and reduced food supply lead to maladaptation practices, worsening the situation (Biswas et al. 2021, Mahmood et al. 2021). Kenya's arid land is occupied by diverse ethnic communities engaged in pastoralism, with practices varying among different communities. The Gabbra pastoral community in Marsabit County, Kenya, faces increased climate variability, impacting livelihoods, economies, cultural assets, public health, and ecosystem services. This study aims to understand their perception of climate change, its effects on the environment and community livelihoods, and the necessary adaptations for policy response to climate change (Gudere et al. 2022). Gabbra uses a livestock management system where families primarily rely on milk for nutrition, with mature animals sold for economic needs and retained for prestige, wealth, and social status.

MATERIAL AND METHODS

Study area

Marsabit County is an arid and semi-arid region in the heart of northern Kenya. Ethiopia lies north of Marsabit County; Lake Turkana to the west; Samburu County to the south; and Wajir and Isiolo Counties to the east (Fig. 1).

The area has characteristic broad plains that rise to 300 to 900 m amsl and gently slope to the southwest, making up the most significant portion of Marsabit County. The plains are encircled by hills and mountain ranges on the West and North, several of which have calderas and volcanic cones. Mt. Kulal in the Northwest, which stands at 2,235 m, is the highest peak. Marsabit County receives an average annual precipitation ranging between 200 and 1000 mm, which make Marsabit one of the driest counties in Kenya (Kirui et al. 2022). There are a few isolated areas around Mt. Marsabit, Mt. Kulal, Hurri Hills, and the Moyale-Sololo escarpment, which, though typically semi-arid, are slightly cooler and whose surroundings are important dry-season livestock grazing grounds. The Gabbra ethnic group predominantlty resides in North Horr and Marsabit North sub-counties of Marsabit County and is slightly over 145000 individuals (Anonymous 2019). They practice nomadic pastoralism, with a few practicing agro-pastoralism.

Study design

A mixed (quantitative and qualitative) research design (Lund 2012) was used in this study. This included a descriptive study with (both quantitative

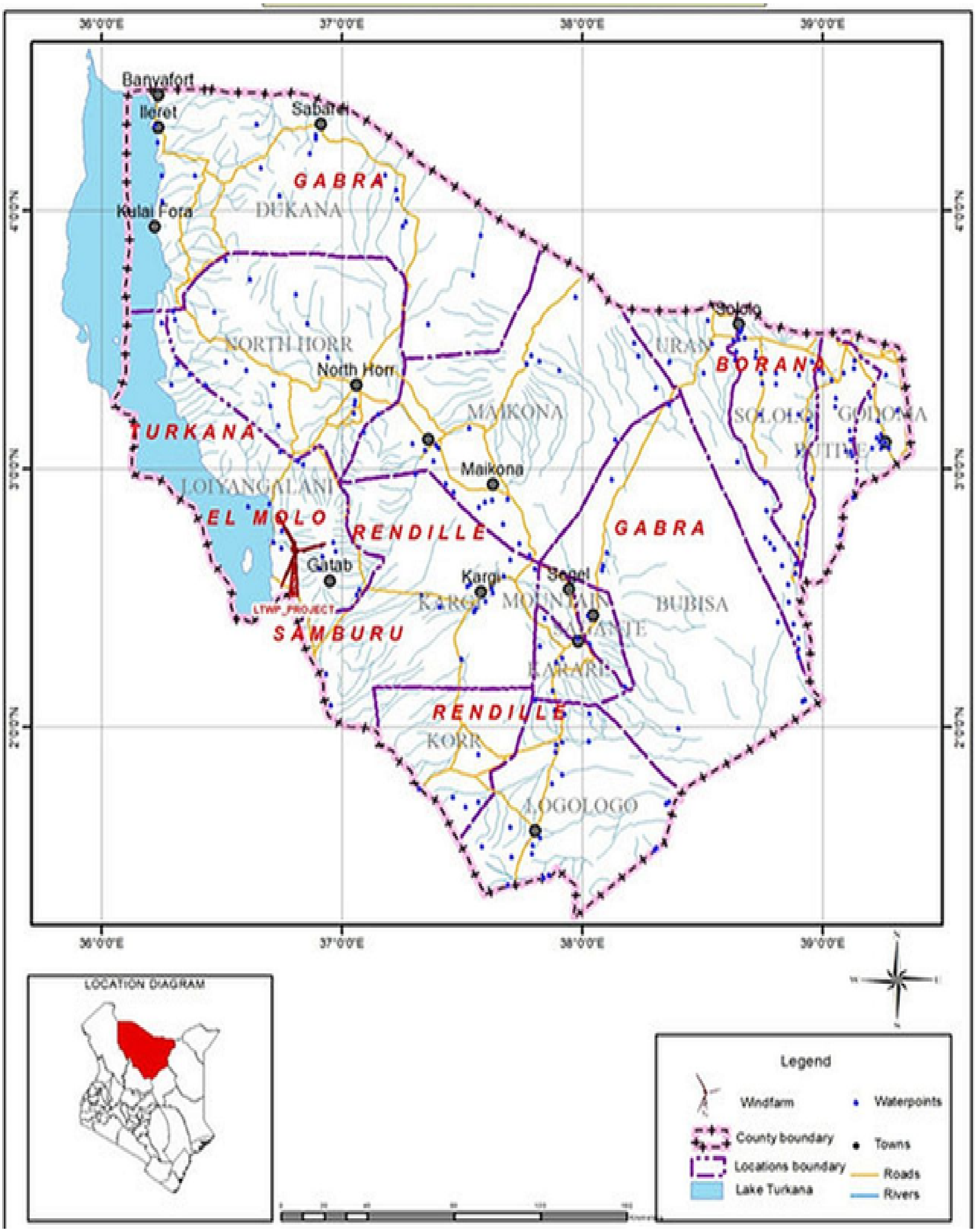

Figure1. Map of Marsabit County in Kenya

and qualitative aspects determinants of climate change adaptation choices, and vulnerability analysis. Also covered in the study was a cross-sectional analysis of perceptions about climate change and adaptation to climate change among the Gabbra agro-pastoralists.

Sampling procedure and sample size

All Gabbra households that practice pastoralism were included in the sampling frame. Following the calculated sample size, systematic random sampling (Kothari 2019) was used to select households from all sub-counties (Table 1). A random number generator was used in the study to ensure the randomness of the starting point.

Sample size

The sample of households was determined using the Yamane Formula (Yamane 1967)

$$\mathrm{N} = N/(1+Ne^2)$$

Where n = sample size; N = Households; e = error (0.05) reliability level 95.

Questionnaires, key informant interviews, focus group discussions, and observation schedules were the key research instruments used in the study. A 5-point Likert scale was used to capture perception data. A cross-sectional survey and an observation schedule were used to collect quantifiable data from many participants. The study used descriptive statistics and a multivariate probit regression model to describe the adopted perceptions, impacts, and adaptation strategies. The adaptation to climate change by the Gabbra agro-pastoralists included strategies targeting soils, crops, and livestock.

Table 1. Sample size of the pastoralists (Pastoralists) in Marsabit County

Sub-County	Households	Sample size
Loiyangalani	7774	40
Marsabit South	11615	60
Marsabit Central	15849	81
Marsabit North	7521	39
North Horr	9789	50
Moyale	17709	91
Sololo	7238	37
Total	**77495**	**398**

The study tested a null hypothesis that socio-economic, institutional, and ecological factors variables have no impact on the choice of dependent variables (cultivating early maturing cultivars as a mitigation strategy; destocking as a climate mitigation strategy; and using manure for soil amendment as a mitigation strategy) Agro-pastoralists chose an adaptation strategy if the expected utility from it exceeded that of other adaptation strategies such that:

$$Y^* \;= Y_i \text{ if } U_i > U_j \qquad (1)$$
$$\;= Y_i \text{ if } U_i < U_j$$

Where, Y_i represents the strategy type i, Y_j an alternative strategy type j, Ui and U_j are the expected indirect utility values of strategy type i and its alternate j, while Y^* represents the strategy type chosen. As a result, we may use a random utility discrete choice model to analyse agro-pastoralists' options regarding adaptation strategies. Because it is an indirect utility function that associates an average utility level with each possible adaptation method in a choice set - this is especially suitable for modeling discrete choice options, such as those between adaptation techniques. This framework assumes that every farmer knows the utility function; however, the researcher must be aware of its components. We treat this portion of the utility that is not observed as a random variable. Next, the expected indirect utility for the i strategy selection was modeled as the total of the observable variables plus the non-observed random component:

$$U_i = \beta'_i X_i + å_i \qquad (2)$$

The choice utility of implementing any alternatives can be expressed as follows, much like in Equation (1):

$$U_j = \beta'_j X_j + å_j \qquad (3)$$

where the parameter vectors are β'_i and β'_j Based on the vectors of the explanatory variables X_i and X_j, farmers can concurrently determine whether to select one or more adaptation techniques. With this method, we may examine the farmers' collective decisions on adaptation strategy by using a multivariate Probit model. Equations (2) and (3) are followed by empirical model specification, which is as follows:

$$Y_{ij}^* = U_i = \beta'_i X_i + \varepsilon_i \quad (4)$$

with i = 1, 2, 3; $Y_i = 1$ f $Y_i^* > 0$ and 0 otherwise

where, for i = 1 (cultivating early maturing cultivars as a mitigation strategy), i = 2 (destocking as a climate mitigation strategy), and i = 3 (use manure for soil amendment as a mitigation strategy), is an unobservable latent variable representing the likelihood of selecting j kind of adaptation strategy. Consequently, the model can be stated empirically as:

$$Y_i = \beta'_i X_i + \varepsilon_i \quad (5)$$

The following values correspond to different scenarios: for cultivating early maturing cultivars as a mitigation strategy (0 otherwise), for destocking as a climate mitigation strategy (0 otherwise), and for the use of manure for soil amendment as a mitigation strategy (0 otherwise) = vector of parameters (gender of household head, age of household head, education of household head, monthly income, household size, membership to social group, increasing temperature, unpredictable rainfall patterns, increased drought frequency, assistance from government, assistance from relatives, access to extension services, access to credit services, water availability, pasture availability, and own large herd of livestock) impacting the choice of strategy to mitigate climate change, and ε = is the error term.

Since multivariate Probit analysis performs better than other competing methods in terms of efficiency and effectiveness in minimising heteroscedasticity and the error term has a conventional normal distribution, it is the ideal model to prevent heteroscedasticity (Gudere et al. 2022). The variance inflation factor was used to determine whether there was multicollinearity among the explanatory variables (Salmerón-Gomez et al. 2025).

RESULTS AND DISCUSSION

Demographic profile of the respondents

The survey data for this study was obtained from a sample of 398 households in the Gabbra community in Marsabit County. The study obtained representative samples from North-Horr, Moyale, Marsabit North, Marsabit Central, Marsabit South, Loiyangalani, and Sololo sub-counties (Table 1). Out of the total respondents interviewed, female were 20% from North-Horr, 22% from Marsabit North, 30% from Loiyangalani, 38% from Loiyangalani, 38% from Sololo, 46% from Moyale, and 20% from Marsabit Central. The average age of household heads in North-Horr was found to be 49.52 yrs, while it is 49.76 yrs in Marsabit North, 47.96 yrs in Loiyangalani, 49.38 yrs in Sololo, 45.06 yrs in Moyale, and 45.06 yrs in Marsabit Central. Education status analysis indicates that most respondents had primary school education. The mean monthly income for household heads was low in most households. It is Ksh. 9980.00 (1 Ksh is 0.0077 US$) in North-Horr, Ksh. 8931.00 in Marsabit North, KSh. 6350.00 in Loiyangalani, Ksh. 6673.50 in Sololo, Ksh. 7320.00, Ksh. 9470.00 in Marsabit Central and, Ksh. 7698.00 in Marsabit South. Descriptive statistics of the survey data show that household sizes across the sub-counties are varied. In North-Horr, the average household size is 5.24, while it is 5.26 in Marsabit North, 5.18 in Loiyangalani, 5.12 in Sololo, 5.88 in Moyale, 6.32 in Marsabit Central, and 6.04 in Marsabit South (Table 2).

Gabbra community perceptions on climate change

A large number (over 90% of the sample) of Gabbra pastoralists reported the occurrence of climate change, which they perceived through disruptions of their normal socio-economic activities and lifestyles. In all sub-counties surveyed there was general concurrence on climate change perceptions, with most parameters being similar, except in areas with unique features such as wetlands or extensive plains. Rainfall and temperature changes were of great concern to the Gabbra, as both affected the availability of water and pasture conditions, which support livestock and are central to their livelihoods. Similarly, studies in other dryland areas occupied by pastoralists have shown that rising minimum and maximum temperatures and the erratic nature of rainfall have undermined the availability of pasture and water resources, especially during drought years resulting in the prevalence of livestock diseases (Tamene et al. 2023, Shibru et al. 2023).

The Gabbra pastoralists perceived extreme events or indicators associated directly with livelihood activities, such as crop failures, livestock loss, dried-

Table 2. Demographic profile of survey participants (N = 398)

Sub-County	**Variable**	**Mean**	**Std. Dev.**	**Min**	**Max**
North-Horr	Gender	0.20	0.40	0.00	1.00
	Age	49.52	14.25	30.00	82.00
	Education	0 .32	0.91	0.00	4.00
	Monthly income	9980.00	13862.56	2000.00	85000.00
	Household size	5.24	2.45	0.00	13.00
Marsabit North	Gender	0 .22	0.42	0.00	1.00
	Age	49.76	13.35	29.00	75.00
	Education	0.66	1.12	0.00	4.00
	Monthly income	8931.00	8829.71	550.00	50000.00
	Household size	5.26	1.77	2.00	10.00
Loiyangalani	Gender	0.30	0.46	0.00	1.00
	Age	47.96	11.99	27.00	75.00
	Education	0.34	0.77	0.00	3.00
	Monthly income	6350.00	4291.91	1200.00	15000.00
	Household size	5.18	2.01	2.00	12.00
Sololo	Gender	0.38	0.49	0.00	1.00
	Age	49.38	14.50	29.00	92.00
	Education	0.14	0.50	0.00	2.00
	Monthly income	6673.50	5314.74	0.00	20000.00
	Household size	5.12	1.96	2.00	12.00
Moyale	Gender	0.46	0.50	0.00	1.00
	Age	45.06	14.92	21.00	81.00
	Education	0.24	0.62	0.00	2.00
	Monthly income	7320.00	5454.67	0.00	20000.00
	Household size	5.88	2.13	2.00	11.00
Marsabit Central	Gender	0.12	0.33	0.00	1.00
	Age	51.70	15.12	20.00	85.00
	Education	0.38	0.81	0.00	3.00
	Monthly income	9470.00	8378.62	500.00	50000.00
	Household size	6.32	2.74	3.00	16.00
Marsabit South	Gender	0.20	0.40	0.00	1.00
	Age	51.80	15.47	30.00	99.00
	Education	0.18	0.66	0.00	3.00
	Monthly income	7698.00	8102.14	500.00	50000.00
	Household size	6.04	2.53	3.00	13.00

up water sources, and sand storms during droughts, among others, as most suppressing. These perceptions of climate change among the Gabbra were noted to be complemented by the existing indigenous knowledge of the Gabbra people, which they have used over the years to help them cope with consequential socio-economic disruptions.

Knowledge and perceptions of weather and climate change can influence individual and community strategies to reduce their vulnerability to climate change (Filho et al. 2022, Nega et al. 2015). In the context of the Gabbra community, the present study established that they have intertwined weather and climatic knowledge systems into their customary lifestyles and livelihood systems, which are imperative for adaptation actions.

The Gabbra Pastoralists have several climatic experiences and observations that they perceive to indicate climate change occurrence in their area. Most indicators related to rainfall changes, while others were on temperature, wind, and fog conditions. When subjected to Likert scale weighting (Table 3), these indicators showed high levels of support and were clear evidence of climate change perception in the community. In the present study "increasing temperatures in the dry season" as an indicator was supported by 80.2% of the respondents who strongly agreed and 18.71% agreed, and an indicator "early onset of rainfall" was highly disagreed by 77.3% respondents and 22.33% disagreed. These parameters reported by Gabbra pastoralists indicate climate change but through differing perceptions. Similar parameters have been observed among pastoral communities of northern Tanzania (Kimaro et al. 2018), where climate change perceptions have been reported to include more erratic and reduced amounts of rainfall, temperature rise, and prolonged and frequent periods of drought. Other important parameters on climate change perception identified by Gabbra were pasture grass changes, foggy conditions, and wind occurrences in the dry season. Variations in rainfall and temperature have been known to be critical causes of various impacts on the livelihoods of pastoralists and an increase in their vulnerability (Fu 2022). A thorough understanding of these climate change indicators was noted to be very important in guiding the socio-economics and livelihoods of the Gabbra. How individuals understand or perceive climate change is essential in developing policies addressing the problem and their willingness to change behaviour (Sraku-Lartey et al. 2020).

Gabbra Pastoralists

Several impact parameters were identified by Gabbra, covering various climatic factors of rainfall, temperature, fog, winds, and related elements and how climate change impacted them, and consequently on the Gabbra landscapes and pastoral-based socio-economics. Results showed overwhelming negative impacts on these elements, especially rainfall anomalies, with most reflecting decreases, resulting in droughts, pasture loss, water scarcity, livestock deterioration, and deaths. Respondents also reported that heavy rainfall would occasionally be experienced for very short durations of 1-3 weeks. During that time, severe floods would occur, leading to the Gabbra pastoralists incurring huge livestock losses. Impact detection parameters included delayed onset, delayed ending of rains, decreased rainfall amounts, very short rain, and more dry spells.

Table 3. Perception (%) on climate change by Gabbra Pastoralists

Perceptions	Strongly agree	Agree	Unaware	Disagree	Strongly disagree
Increased temperature in dry season	80.72	18.71	-	-	0.61
Increased variability of rainfall	55.83	29.05	15.14	-	-
Early onset of rainfall	0.41	22.33	-	-	77.3
Late onset of rainfall	28.72	22.62	5.83	42.92	-
Rain Season has shortened	31.6	42.91	25.52	-	-
Delay in rains onset and ends early	53.23	30.01	0.32	16.5	-
Rainfall has remained the same	0.21	0.06	2.9	18.51	78.32
Rainfall has increased	0.32	0.04	41.62	58.02	-
More dry spells	37.09	30.32	32.51	0.11	-
Periods of no rainfall have widened	70.21	26.31	1.13	2.11	-
Foggy days have become fewer	51.22	31.02	16.62	1.22	-
Extreme droughts have increased	72.92	23.43	0.01	-	2.76
Rainfall has decreased	65.42	26.45	0.64	1.42	0.10
Increased temperatures	53.33	41.03	-	0.64	5.02
Rainfall amounts have decreased	70.95	19.67	9.47	-	-
Rainfall ending early	41.29	39.03	-	19.67	-

The Gabbra have been experiencing climate change impacts and can identify those factors that affect them directly or indirectly. These factors range from droughts occasioned by scarcity of rains to floods, conversely due to very intense rains, most of which fall heavily over short durations. Between extremes of droughts and floods are related impacts, which are either related to weather, their local ecosystems, or socio-economic activities. The respondents identified some impacts, including livestock losses due to drought floods, frequent crop failures, and food insecurity (Table 4).

These impacts were found to be interlinked in one way or another. Respondents reported that lack of rain would often lead to prolonged droughts, water scarcity, and loss of pastures, which may lead to conflicts and climate-induced migration. The impact of climate change on the Gabbra community depends on many factors, including how the impacting variables are perceived, other linking factors, the magnitude of impact and shifts in the factors, and community vulnerability factors, among others. Similar results were by other studies (Kabue 2016, Ayele et al. 2020, Mekuyie and Mulu 2021).

When the identified impacts were weighted using a 5-point Likert scale, over 70% of the respondents strongly agreed on each one of them. The identified key impacts of climate change include increased incidences of diseases, increased reliance on food aid, frequent crop failure, livestock loss, weather pattern changes, livestock pasture declining, reduced crop and livestock production, food insecurity, severe loss of pasture grass and other, severe water scarcity, out-migration of human and livestock, climate change-related resource conflicts, severe droughts, and severe flooding. Adapting to these factors was cited as a significant challenge primarily due to the unpredictable nature of their occurrence and severity levels. The Gabbra community, however, does try to cope with the impacts, including integrating their indigenous knowledge in their measures (Dejene and Yetebarek 2022).

Adaptation strategies to climate change

Pastoralists in Africa face various climate change challenges that suppress their livelihoods and constrain their ability to adapt to fluctuations in the external environment (Fu 2022). Adaptation strategies reported by the Gabbra agro-pastoralists were centered around livestock production, crop production, and soil management (Table 5). The key adaptation strategies identified in livestock production include destocking, separating males from females, migration and herd splitting, and reliance on fodder aid. The strategies for crop production were reducing farm size, drought-

Table 4. Perceptions (%) on climate change impacts

Climate Change Impacts	Strongly agree	Agreed	Unaware	Disagree	Strongly disagree
Increased incidences of diseases	78.06	5.48	16.12	0.32	0
Increased reliance on food aid	85.80	8.70	5.16	0.30	0
Frequent crop failure	73.87	12.58	10.64	2.58	0.32
Livestock loss	86.77	11.29	1.62	0.32	0
Weather pattern changes	85.46	13.20	1.31	0	0
Livestock pasture declining	84.51	14.19	1.29	0	0
Reduced crop and livestock production	81.29	15.48	2.90	0.32	0
Food insecurity	86.13	12.58	0.96	0.30	0
Severe loss of pasture grass and other	82.25	15.77	0.61	0.32	0.64
Severe water scarcity	76.12	5.481	4.19	3.22	0.97
Out migration of human and livestock	78.39	17.42	0.93	0.63	2.56
Climate change related resource conflicts	80.64	17.09	0.13	0.32	1.82
Severe droughts	83.23	16.13	0.32	0.33	0
Severe flooding	70.03	29.32	0.62	0.03	0

Table 5. Proportions of adaptation strategies to climate change undertaken by Gabbra pastoralist

Adaptation strategy	Proportion	SE.
Crop Production		
Reduce Farm size	14.19	0.019
Drought Resistant Crops	28.71	0.025
Early Planting	10	0.017
Crop Diversification	16.13	0.02
Plant Early Maturing Crops	30.97	0.026
Livestock Production		
Destocking	54.84	0.028
Separating Males from Females	36.77	0.027
Migration and Heard Splitting	3.54	0.015
Reliance on Fodder Aid	4.83	0.012
Soil Management		
Crop Rotation	2.26	0.008
Using Manure	84.19	0.021
Mulching	11.61	0.182

resistant crops, early planting, crop diversification, and planting early maturing crops. The identified strategies for soil management are crop rotation, application of manure, and mulching.

Livestock adaptation strategies among the Gabbra

The main livestock adaptation strategy to climate change impacts adopted by Gabbra pastoralists is destocking (54.84%). This is mainly done at the onset of drought when the pastoralists would either sell some stock or redistribute among their kinsmen in areas further away, separating males from females (36.77%). This is done to prevent breeding during drought periods and ensure that each animal has enough energy reserves to see them through the drought and related adversities. Other adaptation strategies include migration and herd splitting (3.54) and, at times, reliance on fodder aid (36.77%), as well as supplementing livestock fodder by utilizing tree leaves.

The Gabbra pastoralists also strictly adhere to dry and wet grazing patterns (range management) and community governance. Such adaptations relate to those other pastoralists undertake elsewhere but with minor differences and are largely conditioned by climate change factors, e.g., drought, intensity, landscape conditions, and resources available. Idrissou et al. (2020) found that cattle keepers in Benin's dry and sub-humid tropical zones cited mobility, crop husbandry integration, concentrate feed provision, herd size reduction, livestock diversification, and forage cropping as the most crucial adaptation strategies. Gabbra pastoralists reported being able to identify the shift in climate before these adaptation activities began. Livestock farmers are somewhat conscious of climate change, particularly the rise in temperature, according to Idrissou et al. (2020).

According to cattle ranchers, mobility, integrating livestock with crop husbandry, offering concentrate feed, reducing herd size, animal variety, and forage cropping were the most crucial adaptation tactics. According to Salmora et al. (2020), farmers typically use three main strategies in response to droughts: managing the amount of grazing and feed that is available; selling livestock to reduce feed demand and to obtain income; and purchasing additional feed. These strategies are reactive, short-term coping mechanisms meant to address feed shortages.

Crops adaptation strategies among the Gabbra

Though the Gabbra community are pastoralists, a few households practise limited farming, which women mainly do. In crop farming, adaptations concentrated mainly on crop and soil management. Adaptations targeting crops included planting different crops, changing crop varieties, changing planting dates, early planting, planting early maturing crops, increasing irrigation, crop diversification, and changing the extent of land under cultivation, mainly by reducing crop farm size. Concerning soils, application of manure, mulching, and crop rotation were the most common forms of adaptation. However, these agricultural adaptations targeting crops were done on a very limited scale since crop farming is still limited among the Gabbra pastoralists.

Adaptation strategies for soil improvement among the Gabbra

There are few strategies to improve soil fertility and moisture content undertaken by the Gabbra community, as crop farming is only undertaken in very few households and at a shallow scale. Manure application was most common given that it is readily available due to large numbers of livestock. Other soil management measures included crop rotation and mulching. The application of manure in Gabbra farmer gardens, managed mainly by women and sedentary families, contributes to increased soil fertility, water retention, and crop yields. Using manure in farming also helps store carbon in the soil and reduces its release into the atmosphere from livestock sheds, and in this way, communities contribute to reducing climate-changing emissions (Nyariki and Amwata 2019). Manure is also used on pastureland by pastoralists to allow for good pasture-stand establishment, promotes early growth, increases yield and quality, and improves dry spell

Adaptation and resilience

In addition to indigenous knowledge of weather prediction and indigenous adaptation strategies, the provision of a range of climate-related information, such as the severity of drought, variations in temperature, and rainfall, will serve multiple purposes within the communities (Sraku-Lartey et al. 2020). This is especially true when efforts are directed towards achieving resilience. Pastoralism experience, literacy level, household size, surrounding ecosystems and pastures, income, and community group cohesion were factors that contributed enormously to pastoralists' adaptation to climate change. Understanding pastoralists' perception of and response to climatic change is necessary for sustainable adaptation strategies (Nkuba et al. 2023). Perception strongly affects how farmers deal with climate-induced risks and opportunities, and the precise nature of their behavioural responses to this perception will shape adaptation options, the process involved, and adaptation outcomes (Adger et al. 2009).

Local Gabbra communities were found to have yet to actively participate in decisions that ultimately influenced national policies on semi-arid and arid lands. Policies in place have been mainly ascribed with prejudice against modern arid lands agriculture and largely disapprove of the views of the pastoralists, whose occupation tends to be perceived as a declining way of life. Because of this mindset, the needs and goals for developing Pastoralist-farming communities were found to be at the edge of increasing climate change.

Pastoralists, agro-pastoralists, and the communities they live in are acutely aware of the changing climate and its unpredictability, and they are pretty gloomy about how this could affect their means of subsistence in the future, even though different support and technological interventions are available. However, despite different types of support, including technological interventions that may be available, constraints such as lack of finances, lack of information, and shortage of expertise have been noted (Mulinya 2017, Salmoral et al. 2020) as major constraints to coping with climate change effects in Africa. In order to implement adaptation programs and create policies that drive the need for adaptation, it is imperative to secure the willing collaboration of the intended beneficiaries. Furthermore, it is essential to improve their comprehension of the dangers of climate change so that they may set reasonable expectations and be better equipped to seize any opportunities that climate change may present and prepare for any potential adverse effects (Debela et al. 2015).

Factors influencing agro pastoralists' decision on adaptation to climate change

A Multivariate Probit (MVP) model was used to analyse the factors affecting the decisions of Gabbra agro-pastoralists to cultivate early maturing cultivars, adopt destocking as a climate mitigation strategy and use manure for soil amendment as a mitigation strategy (Table 6). Gender of household head, age of household head, education of household head, monthly income (ln), household size, membership to social group, increasing temperature, unpredictable rainfall patterns, increased drought frequency, assistance from government, assistance from relatives, access to extension services, access to credit services, water availability, pasture availability, and own large herd of livestock significantly ($p \leq 0.01$) affected the adoption of all the three adaptive practices among the Gabbra agro-pastoralists. Similar findings were also reported by Nhemachena and Hassan (2007) and Kibue et al. (2016) on how farmers in some African countries and China adapted to climate change.

In terms of specific adaptive strategies, households with heads with formal education are more likely to cultivate early maturing cultivars varieties and adopt destocking as a climate mitigation strategy to cope with climate change. Households with high monthly incomes are more likely to cultivate early maturing cultivars and use manure

Table 6. Estimated result of the Multivariate Probit Model of determinants of agropastoralists' adaptive practice to climate change

	Cultivating early maturing cultivars as a strategy			**Destocking as a climate mitigation strategy**			**Using manure for soil amendment as a mitigation strategy**		
Variable	**Coef.**	**SE.**	**z**	**Coef.**	**SE.**	**z**	**Coef.**	**SE.**	**z**
Gender of household head	0.134	0.187	0.719	0.008	0.192	0.042	-0.456**	0.218	-2.095
Age of household head	-0.034*	0.016	-2.135	0.017***	0.006	2.727	-0.007	0.007	-0.979
Education of household head	0.864***	0.200	4.319	0.637***	0.229	2.784	-0.488*	0.262	-1.859
Monthly income (ln)	0.470***	0.094	4.984	0.074	0.091	0.806	0.123**	0.055	2.247
Household size	0.021	0.036	0.572	0.011	0.037	0.308	0.170***	0.042	4.058
Membership to social group	0.012	0.158	0.076	0.444***	0.165	2.694	0.379**	0.191	1.989
Increasing temperature	0.383**	0.167	2.292	0.435**	0.174	2.496	0.552***	0.206	2.686
Unpredictable rainfall patterns	0.481***	0.158	3.036	-0.349**	0.165	-2.119	0.722***	0.200	3.612
Increased drought frequency	0.087	0.176	0.496	-0.135	0.183	-0.739	0.986***	0.213	4.618
Assistance from government	-0.181	0.165	-1.096	-0.513***	0.169	-3.026	-0.457**	0.204	-2.237
Assistance from relatives	-0.055	0.166	-0.334	-0.398**	0.175	-2.268	-0.833***	0.190	-4.373
Access to extension services	0.494***	0.188	2.632	0.713***	0.193	3.685	0.160	0.225	0.710
Access to credit services	0.519**	0.259	2.005	0.584**	0.251	2.330	0.852***	0.301	2.835
Water availability	0.474**	0.208	2.284	0.584***	0.213	2.740	0.683***	0.241	2.836
Pasture availability	-0.425**	0.185	-2.302	0.399**	0.192	2.072	-0.544**	0.212	-2.562
Own large herd of livestock	-0.581**	0.280	-2.076	0.858***	0.280	3.061	-0.697**	0.355	-1.966
Constant	1.064	0.874	1.216	-0.892	0.862	-1.035	-0.825	0.997	-0.827

Likelihood ratio test of rho21 = rho31 = rho32 = 0;

$Chi^2(3) = 8.24381$ Prob > $chi^2 = 0.0412$;

*** = significant at 1%; ** = significant at 5%; and * = significant at 10%

for soil amendment as a mitigation strategy. The results show that agro-pastoralists with large households are likely to use manure for soil amendment as a mitigation strategy. When a farmer is a member of a social group, the household is likely to use the destocking of livestock and manure use as mitigation strategies. We found that a farmer who perceives increasing temperature is likely to adopt early maturing cultivars, destock livestock, and use manure for soil amendment as climate mitigation strategies. This is similar to the findings by Thoai et al. (2018), which found that access to credit and membership in local organizations significantly influence farmers' adaptive practices to climate change.

Our study showed that agro-pastoralists who perceive unpredictable rainfall patterns will likely cultivate early maturing cultivars and use manure for soil amendment as a mitigation strategy. However, perceived unpredictable rainfall patterns reduce the likelihood of destocking as a climate mitigation strategy. The agro-pastoralists who receive assistance from the government are likely to avoid adopting destocking or using manure for soil amendment as a mitigation strategy. Households receiving assistance from relatives are less likely to adopt destocking or use manure for soil amendment as a mitigation strategy. The farmers who have access to extension services were found to be likely to cultivate early maturing cultivar varieties and use the destocking of livestock as a mitigation strategy. Access to credit services for agro-pastoralists increases the likelihood of cultivating early maturing cultivars, adopting destocking, and using manure for soil amendment as a climate change mitigation strategy.

Water availability increases the likelihood of adopting early maturing cultivars, destocking livestock, and using manure for soil amendment to mitigate climate change's impact among the Gabbra agro-pastoralists in Marsabit County. The present study also shows that farmers with adequate pasture availability are likely to adopt livestock destocking as a climate change mitigation strategy. However, these households are not likely to either cultivate early maturing cultivars or use manure for soil amendment as a climate change mitigation strategy. The agro-pastoralists who own large herds of livestock are likely to adopt destocking strategies to mitigate the impact of climate mitigation. However, households are not likely to cultivate early maturing cultivars as a mitigation strategy, nor are they likely to use manure for soil amendment as a mitigation strategy.

CONCLUSIONS

The Gabbra pastoralists perceive climate as disrupting their normal socio-economic activities and lifestyles. Most parameters on climate change detection from the pastoralists were delayed rainfall, prolonged droughts, and extensive flood disasters. Most perception parameters used in perception were broadly similar across the locations. Climate change impacts among the Gabbra pastoralists are largely occasioned by rainfall scarcity, which leads to prolonged drought and pasture losses, or by very short and intense rainfall, leading to flooding, which leads to enormous livestock losses and consequential livelihood deterioration.

Among the Gabbra pastoralists, adapting to climate change is a significant challenge mainly due to the unpredictable nature of the occurrence of its various elements and severity levels. While adaptations have been through varied interventions, indigenous knowledge among Gabbra pastoralists was found to be critical in predicting and interpreting climate variability and change, as well as in adaptation actions.

The selection of strategies to address the effects of climate change in Marsabit County is greatly affected by factors such as the gender, age, and education level of the household head, as well as their monthly income, household size, membership in social groups, rising temperatures, erratic rainfall patterns, frequent droughts, government and family assistance, access to extension and credit services, water and pasture availability, and ownership of a large livestock herd.

Authors' contributions: All authors contributed equally.

Conflict of interest: Authors declare no conflict of interest.

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Received:23rd September 2024
Accepted:18th February 2025