Climate variability and indigenous adaptation strategies by Somali pastoralists in Ethiopia

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Research Article

Keywords: climate change, pastoralism, Indigenous strategies

Posted Date: October 19th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1990099/v1

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Abstract

Pastoralism is a fragile livelihood system for millions of people around the world and a significant number of that is found in Africa. Proper documentation and understanding of indigenous knowledge and strategies on pastoralism are limited and this study sheds light on location-specific indigenous knowledge and corresponding perceptions of local communities with the support of metrological patterns of weather and climate variability. This is an exploratory study that draws on orally existing indigenous knowledge of adaptation from qualitative data sources, analyzes climate data, and matches it with communities' oral records of major climatic events to validate the accuracy of their perceptions. The results reveals that there is a high climate variability as indicated with a Coefficient of Variation (CV) value of 30, the PCI indicated high rainfall intensity and longer dry periods indicated by the SI values. Almost every year the SI value predicted longer dry season. The community's perception matched with recorded climate data of the past 36 years and identified 10 major climate extremes orally recounted down in history. Indigenous strategies include indigenous weather forecasts, mating calendar, destocking, herd mobility, herd diversification, traditional rotational grazing system ('Seri'), and also lists of emerging adaptation strategies utilized as a result of the severity of climate variability and extremes in the region. The results indicates that uncommon adaptation strategies are replacing preexisting pastoralist livelihood system and that indigenous strategies are in need of support to withstand the current and predicted weather and climate variability in the sites. Pastoralists and agro- pastoralists will be in a better position to adapt to the consequences of climate variability and extremes if indigenous institutions are revitalized with innovations.

Key words: climate change, pastoralism, Indigenous strategies

1. Introduction

Climate change increases the frequency and severity of extreme weather events such as storms, floods, droughts, heat waves, cold waves, bush fires, and other ecological catastrophes. This in turn has hampered accessibility to water, food, and health services while creating a conducive environment for the spread of disease, resource-based conflict, migration, and disruption of livelihood, educational, and political systems (Oberg, Hodges & Masten 2013). The experienced exceptional climatic extremes in Africa are expected to recur more frequently in the future thereby subjecting the continent to remain liable to fatal damages (Meyer, 2015).

In addition to its contribution to the global economy, pastoralism provides a sole means of subsistence for about 200 million people worldwide, most of whom are in Africa (Ayele, Dedecha & Duba, 2020). Because of this, pastoralists in sub-Saharan Africa care for around one-third of all the cattle that pastoralists worldwide own. The pastoralists' dependency on livestock is a matter of survival for them. In Ethiopia, the pastoral sector contributes about 20% of the national GDP. However, the sector is constantly endangered due to recurrent drought, erratic rainfall, rangeland degradation, bush encroachment, expansion of cropland and obstruction of seasonal migration routes and hence, scarcity of pasture and water (Filho *et al.*, 2020; Ayele, Dedecha & Duba, 2020).

Arid and semi-arid rangelands, which occupy around two-thirds of the African continent, are expected to be severely impacted by climate change (Kimaro *et al.*, 2018). Pastoral and agro-pastoral communities of Ethiopia, which account for 60% of the total land area and 12% of the population, raise livestock in drought-prone areas (Gebreselassie, 2016). Thus, the recurrent drought is linked to the decline in livestock population and production in these areas (Berhe *et al.*, 2017). The majority of pastoral communities in arid and semi-arid areas rely on natural resources to make a living Guillaumont and Simonet (2011); Kimaro *et al.*, (2018), which makes them vulnerable to climate change. Pastoralists and agro-pastoralists are among the most impacted communities around the world Herrero *et al.*, (2016); Nkuba *et al.*, (2019), as they must continually respond to climate change and variability (Cuni-Sanchez *et al.*, 2019). Pastoralists are often found in less fertile, underdeveloped areas, and are historically, politically, and economically marginalized (Herrero *et al.*, 2016). The problem is further aggravated by deep rural poverty, limited government capacity, and vulnerability to cumulative challenges (Guillaumont and Simonet, 2011; Herrero *et al.*, 2016). Climate change's impacts on livestock and livestock systems may have a significant influence on pastoralists' livelihoods, food security, and health (Cuni-Sanchez *et al.*, 2019). Changes in herbage growth, pasture composition, and herbage quality will be impacted by the expected climate change (Herrero *et al.*, 2016). In many pastoral communities, climate-induced risks may result in reduced milk yields and significant livestock loss thereby spiraling the rate of poverty (Nkuba *et al.*, 2019).

The knowledge and perception of local communities about climate change and variability and the kind of indigenous strategies being used is a locally specific setting has seldom attracted scholarly attention (Balehegn and Tafere, 2013). Studies on coping and adaptation strategies for climate change and variability in Africa generally lack local specificity (Apraku *et al.*, 2021). Thus, understanding indigenous adaptation strategies at the micro-level is a necessary but emerging phenomenon (Nyong *et al.*, 2007). Moreover, understanding the perception and knowledge of people regarding climate change is important to inform policy making geared towards the promotion of successful adaptation strategies.

The Somali Regional State (SRS) is among the pastoral and agro-pastoral regions in Ethiopia. The federal and regional governments, as well as humanitarian organizations, are concerned about the region's repeated drought and chronic food insecurity problem (Girmay *et al.*, 2018). Inherently pastoral and agro-pastoral livelihood systems are sensitive to the negative effects of climate change and extremes Abbink *et al.,*(2014); Radeny *et al.*,(2019); Leal Filho *et al.*, (2021a), as they rely on basic natural resources like water and pastures to survive. For decades, pastoral and agro-pastoral communities have been adapting to climate variability and extremes. However, pastoral and agro-pastoral systems have recently become less adaptive to climate variability and extremes as a result of increasing tendencies of repeated droughts, high geographical and temporal rainfall variability, and poor socio-economic amenities (Ayal *et al.,* 2017).

Studies on the trend of climate variables (e.g., temperature, rainfall, humidity etc.) and associated impacts on farmers livelihood as well as their indigenous adaptation strategies are abundant. This is particularly the case for the highland areas of Ethiopia where there is a relatively enabling environment for communities to respond better to the impacts of climate variability and extremes (Alemu and Mengistu, 2017). However, few studies have been conducted in marginal areas of pastoral and agro-pastoral communities (Lemma *et al.*, 2013; Debela *et al.*, 2019). The authors have highlighted the need for more research at the local and district levels as their study comes to a close. As a result, understanding the situation of climate variability and adaptation strategies of pastoralists and agro- pastoralists at a local level is critical for introducing feasible and appropriate adaptation options to create a climate resilient pastoral and agro-pastoral community. As a result, the purpose of this study was to answer the following research questions: 1) What are pastoralists’ and agro- pastoralists’ perceptions of climate variability and extremes in the Kebribeyah district, 2) How do their perceptions of climate variability and extremes tally with the recorded climate data? 3) What are the trends in climate variables in the research area?, and 4) What are the indigenous climate change adaptations strategies employed by pastoralists and agro- pastoralists households?

2. Methodology

2.1. Area description

This study was conducted in Kebribeyah district of the Somali National Regional State, eastern Ethiopia. Geographically, the district is located at latitudes 90°, 25’ and 90°, 44’, and longitudes 42°, 43’ and 43°, 32’. According to the district documentation; there are 165,422 people living in Kebribeyah, with 89644 men and 75777 women as its demographic distribution. The population is rapidly increasing, with 139,931 people living in rural areas and

25491 people living in urban areas. In terms of average household size, rural households are 6.7 in size while urban households are 6.3. The area is characterized as an arid and semiarid area where annual rainfall ranges from 400-500mm and average temperature ranges between 18-23°c (figure 1). The district has rain in two distinct rainy seasons, called "Gu" and "Deyr." The "Gu" season starts in the second half of March and gets more intense in May. The second rainy season, known as Deyr, starts in July and only lasts through September.

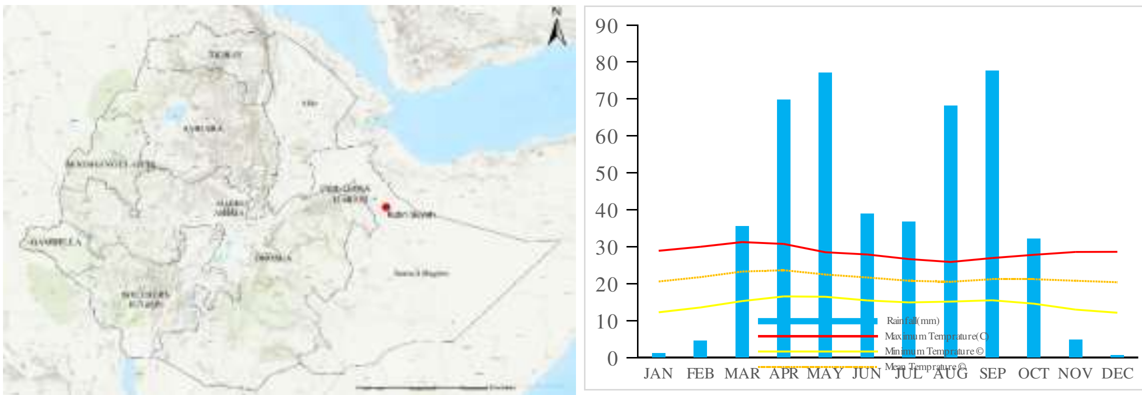

Figure 1: Location map of the study area and mean monthly rainfall, maximum and minimum temperature for Kebribeyah district

2.2. Sampling and data collection

The Kebribeyah district is characterized by repeated and consecutive droughts that occurred in the past decades. The district constitutes 29 villages. A purposive sampling procedure based on the type of the *Kebele* (urban or rural) and accessibility of the *Kebele* was used and selected two rural and one urban village to identify perceptions and indigenous adaptation strategies in response to the changing climate in both rural and semi-rural or urban settings. ‘Deneba’ was one of the urban villages selected while ‘Lebeshak’ and ‘Kotoroble’ were among the frequently affected and accessible rural villages chosen for this study. A proportional stratified random sampling technique was used to target the sample population based on the number of households from each of the chosen kebele.

A total of 12 key informant interviewees were selected purposively by taking into consideration their role, participation, and knowledge as well as their ability to provide valuable information for the study. Key informant individuals constituted representatives from each of the selected informant groups (religious, clan elders, NGOs, and governmental offices). Informants from government circles were drawn from agricultural office, kebele administrators, disaster risk preparedness office, and district pastoral office). NGOs were represented by ARRA, Save the Environment, and IRC). Besides, clan and religious leaders were also a part of the survey. Hence, a total of eight key informants participated in this study. Heterogeneous focus group discussion sessions drawn from three groups constituting pastorals and agro-pastorals community i.e., clan elders, women, and pastoralists were organized. Three major groups of discussions were undertaken. The first group constituted of elders along with religious group leaders and clan leaders. Second group incorporated representatives from agro-pastoral community members, pastoral community members, governmental office representatives, non-governmental offices, and, youth organizations. The third group constituted of women's association representatives, and other female representatives from respective Go's and Ngo's.

There were 1,600 household heads in the three villages as a whole. Out of these, in proportion to each respective total population, 47 households from Kotoroble, which had a total population of 500, 60 households from Lebeshak, which had a total population of 600, and 84 households from Deneba, which had a total population of 825, were chosen. The study also used data from the National Meteorological Agency in Addis Ababa. The Agency provided a daily record of data on rainfall and temperature for about three decades (1983-2021) which was used to reconstruct the nature and trend of climate change and variability.

2.3. Climate Data analysis

2.3.1. Rainfall variability and Trend

In this study, climate variability was analyzed using coefficient of variation (CV), standard precipitation evaporation index (SPEI), precipitation concentration Index (PCI), and Rainfall seasonality index (SI). Likewise, the rainfall time series trend was analyzed using the Mann-Kendall trend test (MK). The full descriptions of these indexes are described below.

I. Coefficient of Variation

To assess the variability of the rainfall, CV was calculated by dividing the standard deviation by the average precipitation (Eq.1). Greater variability is indicated by a larger CV value, and vice versa. The variability of rainfall occurrences is categorized using the CV scale as low (CV 20), moderate (CV 20-30), or high (CV >30) (Hare, 2003).

$$CV = \frac{\sigma}{\mu} * 100 \qquad (1)$$

Where CV is coefficient of variation, σ is standard deviation and μ is mean precipitation.

II. Rainfall seasonality index (SI)

To characterize the distribution of precipitation throughout the year, the SI was used. SI is critical for categorizing the region's climate. The tool categorizes climate types based on water availability. The higher a region's seasonality index, the greater the variability and scarcity of water resources over time, and the greater the area's vulnerability to desertification (Table 2)(…..). The Seasonality Index (SI) of the study was calculated using Walsh & Lawler (1981) equation (equ...2):

$$SIi = \frac{1}{Ri} \sum_{n=1}^{n=12} \left| Xin - \frac{Ri}{12} \right| \qquad (2)$$

Where Ri is the total annual precipitation for the particular year and Xin is the actual monthly precipitation for month n.

III. 2.3.1.3 Precipitation Concentration Index (PCI)

The PCI represents the distribution of monthly rainfall and can be used to forecast hydrological hazards such as floods and droughts. It is powerful indicator to assess seasonal precipitation change. PCI values less than 10 indicate a uniform monthly rainfall distribution, values 11 to 15 indicate a moderate concentration, values 16 to 20 indicate a large concentration, and values 21 and above imply a very high concentration (Oliver, 1980).

$$PCI = \frac{\sum_{i=1}^{12} P_i^2}{¿.¿.¿}$$

Where PCI is precipitation concentration index and Pi is the rainfall amount of the month.

IV. Standardized Precipitation Evapotranspiration Index (SPEI)

The SPEI is an extension of widely used Standardized Precipitation Index (SPI). The SPEI considers both precipitation and potential evapotranspiration (PET) when determining drought. Therefore, it helps to capture the primary effect of rising temperatures on water demand. The SPEI is calculated using the Penman-Monteith equation Allen *et al.,*(1989) and is based on the monthly difference between precipitation and potential evapotranspiration (PET). The water balance is calculated as follows:

$$D_i = P_i - PET_i \qquad (3)$$

Where *P* and *PET* denote precipitation and potential evapotranspiration for the i^{th} months, respectively. Di is a simple measure of the water surplus or deficit for the analyzed month. As with the Standard Precipitation Index (SPI) McKee and Doesken (1993), the probability distribution of the cumulative Di series was aggregated at different time scales. The log-logistic distribution was selected for standardizing the D series. The probability density function of a three-parameter log-logistic distributed variable is expressed as:

$$f(x) = \frac{\beta}{\alpha} ¿$$

Where α, β and γ are scale, shape, and origin parameters respectively, for D values in the range (γ>D<1). The parameters of the Log-logistic distribution can be obtained following (Singh VP, Guo H, 1993). The probability distribution function for standardizing the D series for all time scales, according to the Log-logistic distribution is determined as:

$$F(X) = ¿$$

With F(*x*) the SPEI can easily be obtained as the standardized values of F(*x*):

$$SPEI = W - \frac{C_0 + C_1 W + C_2 W^2}{1 + d_1 W + d_2 W^2 + d_3 W^3} \quad (6)$$

$$W = \sqrt{-\ln(P)} \; for \; P \leq 0.5$$

Where P is the probability of exceeding a determined D value, P =1−F(x). If P>0.5, then P is replaced by 1−P and the sign of the resultant SPEI is reversed. The constants are C_0 = 2.515517, C_1 = 0.802853, C_2 = 0.010328, d_1 = 1.432788, d_2 = 0.189269, and d_3 = 0.001308 (Vicente-Serrano *et al.*, 2010). The average value of the SPEI is 0, and the standard deviation is 1. The SPEI is a standardized variable, and it can therefore be compared with other SPEI values over time and space (Vicente-Serrano *et al.*, 2010). The SPEI classification is described in Table 1 below

Table 1 Definition of SPEI and SI index

SPEI value	Classification	SI value	
≥ 2	Extremely wet	<0.19	Precipitation spread throughout the year
1.5 – 2.0	Very wet	0.20 - 0.39	Precipitation spread throughout the year, but with a definite wetter season
1.0 **– 1.5**	Modestly wet	0.40 – 0.59	Rather seasonal with a short dry season
(-1) – 1.0	Near normal	0.60 – 0.79	Seasonal
(-1.0) – (-1.5)	Modestly dry	0.80 – 0.99	Marked seasonal with a long dry season
(-1.5) – (-2.0)	Severely dry	1.00 – 1.19	Most precipitation in <3 months
≤ (-2.0)	Extremely dry		

V. Mann-Kendall trend test (MK)

The MK is a non-parametric test that is commonly used to detect monotonically (increasing or decreasing) trends in climate and hydrology time series data (Hirsch *and Slack,* 1984). The non-parametric MK test is appropriate for trend detection because it is less affected by outliers in the dataset (Asfaw *et al.*, 2018). In addition, the MK test can determine whether a previously established trend is statistically significant. The MK test statistic "S" is computed as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(xj - xi) \quad (7)$$

Where *xi* and *xj* denote sequential data values of the time series of j and i (j>i) and n is the number of days in the data series. The sign function can be calculated as:

$$Sgn(Xj - Xi) = \begin{cases} 1 \; if \; (xj - xi) > 0 \\ 0 \; if \; (xj - xi) = 0 \\ -1 \; if \; (xj - xi) < 0 \end{cases} \quad (8)$$

When the sample size is greater than or equal to 10 ($n \geq 10$), the S statistic is approximately a standard normal distribution with the mean equal to zero then the variance is calculated with the following equation:

$$Var(S) = n¿¿$$

Where n is the number of data points, m is the number of tied groups (sample data with the same value, where there is zero variance between the compared values), and *ti* is the number of data values in the m^{th} group. The Z test is calculated with the following equation:

$$Z = \begin{cases} \frac{s-1}{\sigma} \; if \; s > 1 \\ 0 \; if \; s = 0 \\ \frac{s+1}{\sigma} \; if \; s < 0 \end{cases} \quad (10)$$

Where *s* denotes the variance and σ denote the square root of the variance. Positive Z values indicate an increasing trend while negative indicates a decreasing trend. The trend magnitude was calculated using Sen's Slope (S_i):

$$(S_i) = \frac{(X_j - X_i)}{j - i}, for \; i = 1,2 \ldots . N \; (11)$$

Where x_j and x_i denote the data value at time j and i ($j > i$) respectively. The median of these N values of Si is denoted as Sen's estimator of the slope, which is expressed as:

$$Qi = \begin{cases} \frac{S(N+1)}{2} \; if \; N \; is \; odd \; (12) \\ \frac{S\left(\frac{N}{2}\right) + Q(N+2)/2)}{2} \; if \; N \; is \; even \end{cases}$$

The sign of Qi shows whether the trend is increasing or decreasing. In this study, two specific significance levels $\alpha = 0.05$ and $\alpha = 0.01$ are used (the corresponding threshold values of the M-K value are ±1.96 and ±2.58 respectively). When the M-K value is greater than 1.96 or less than -1.96, the changing trend is significant. When the M-K value is greater than 2.58 or less than -2.58, the changing trend is extremely significant.

3. Results and discussion

3.1. Socioeconomic and demographic characteristics of respondents

The mean age of the households that were part of the survey from the three *kebeles* is 42. The results revealed that males made up 86.9% of households while females made up 13.1%. Regarding educational levels, the findings showed that 86.38% of the respondents were illiterate, with 8.9 % having only completed primary school and 2.62 % having completed secondary school (Table 2). Around 1.04 % of respondents had post-secondary education, which is a very small proportion and which illiteracy is a serious community issue. A high rate of illiteracy implies communities lack adequate skill and knowledge to deal with the adverse effect of climate variability and extremes. This is because lack of education could hinder pastoralists and agro-pastoralists exposure to valuable information and technology. Access to education could also play a vital role to adjust their subjective adaptive capacity; otherwise, it could distort their action (Ayal *et al.*, 2021). Agro-pastoralism and other alternative income sources made up the majority of respondents (52%) livelihood in the study area, suggesting that pastoralism is becoming a risky enterprise because most households had moved to other livelihood sources. Still, due to recurrent drought, highly variable rainfall, devoid of surface water, and attendant none climate stressors crop production is not a viable livelihood strategy in the study site. The survey result shows that respondents participated in various non-farms and off-farm activities including petty trade, charcoal production, daily labor, remittance, milk sells and meat sell. However, given the existence of large family sizes and almost all maladaptation strategies, households were not in a position to respond to the adverse effect of climate related shocks.

On the whole, the socio-economic and demographic profiles of the research target population is such that their capability to respond to innovative adaptation technologies is minimal. Therefore, the acceptance and efficacy of future adaptation technologies rests on the concerted effort of the government and the local people to significantly improve the socio-economic and demographic conditions of the area. In this regard, special emphasis should be placed on downsizing family size of households and expanding access to modern education. On the positive light, the fact that the people are embracing sources of income uncommon in a pastoral way of life, such as pottery trade, charcoal and daily labor, is a noteworthy development. However, it is imperative for concerned bodies to ensure that such non-pastoral engagements in the long run would not undermine the productivity of animal husbandry.

Table 2 Summary of demographic and socioeconomic characteristics of respondents

Variable	**Percentage (%)**
Family size 1-6	79.5
7-12	18.3
13-18	1.57
19-25	0.63
Gender Male	86.9
Female	13.1
Education	
Illiterate	86.38
Primary education	8.9
Secondary education	2.62
Post-secondary	1.04
Quranic	1.04
Income source	
Pastoralism	6,80
Agropastoralism	34.03

Crop farming	2.61
Agro+alternative income	52.35
Crop+alternative income	1.04
Pastoralism+alternative income	1.57
Non-farm income and sale of livestock	
Petty trade	17.2
Charcoal	17.2
Daily labor	2.09
Remittance	2.61
Livestock sell	6.80
Milk sells	3.66
Meat sell	4.18
Farm Size	
0.5-6ha	67.53
7-10ha	12.56
11-20ha	6.28
Livestock holding	Tropical Livestock Unit
	6.37

Livestock holding

As is the case elsewhere in Africa, livestock size is considered as indicator of household's economic affluence. In the study area in particular, the high size of camel population is regarded as a sure indictor of wealth. Key informants also underlined that the 'Somalis were never sedentary agriculturalists, they didn't do any farming; our ancestors used to be mobile pastoralists and that was the way during past times''. They further recounted that 'land was never a sign of wealth; a person can own two or twenty quota's (a local metric for measuring area) and this doesn't make much of a difference; because production depends on water' rather than land' In fact, it should be pointed out that pastoralists had no idea or practice of private ownership of land as the prevalent land use and administration was basically communal.
The number of livestock owned has an impact on a household's annual total income. According to estimates, increasing a household's livestock holding by one TLU will result in an annual gain in total revenue of ETB 2811.9 for that household (Aklilu *et al.*, 2016). Similar studies in the eastern Hararghe zone indicates that, an increase by one unit of TLU increases both in kind and financial savings of households (Girma *et al.*, 2014). The research site of this study is located in the driest parts of the country where the main source of livelihood activity was pastoralism which is being transformed into agro-pastoralism. Due to this process the average household livestock holding size is different among the three wealth categories. The mean TLU for the three kebele's is 6.37. According to Beyene (2011), the average TLU for the poor and medium households in Kebribeyah is (0-5.01) whereas for better-off livestock per TLU increases up to (>5.01). These values are extremely small compared to larger herd sizes of up to 128 TLU in the Maasai pastoralists (Caudell *et al.*, 2017).

3.2. Community perception of climate change

The majority of the local community reported that there has been a significant climate variable fluctuation and change during the past thirty years. While 16.3% of respondents reported an increase in rainfall, 83.7% of respondents said there had been a decrease in precipitation. About 88.9% of respondents claimed that the temperature had increased while 7.4% of them reported a decrease in temperatures. Only 3.7% of them didn't perceive change in temperature. The communities attribute climatic changes based on their cultural precepts. Mostly, climate variability and its horrible consequences are considered as the result of '*the cruelty of human being towards the environment. Put differently, they consider the phenomenon* as '*God's Punishment*' to the unmindful human deeds. One informant described the cultural impact of climate change on the cultural fabrics of the people as follows:

> "*People used to share every resource at their disposal, now scarce land and water made people fight each other and claim the remaining resource by clans. Sharing is off the table now*."

Kebribeyah district receive rainfall in two main seasons, known as the Gu (April-June) and the Deyr (July-September). These rainy seasons, which normally last from April to September, are crucial to pastoralists' ability to support their families because they replenish grassland and water sources, keeping animals alive through the dry season from December to April. The community claim that recent delays and unforeseen onset and cessation of rainfall are common phenomenon in the area. To conclude, the occurrence of climate variability and its impacts on local culture and economy is felt by the people who are attempting to withstand the challenges in different ways as discussed above.

3.3 Metrological evidence for climate change and variability

The metrological data supported the assertion that Kebribeyah district had endured an extremely variable climate during the previous four decades. The CV value for the site in terms of months and seasons is almost larger than 30%, suggesting considerable variability.

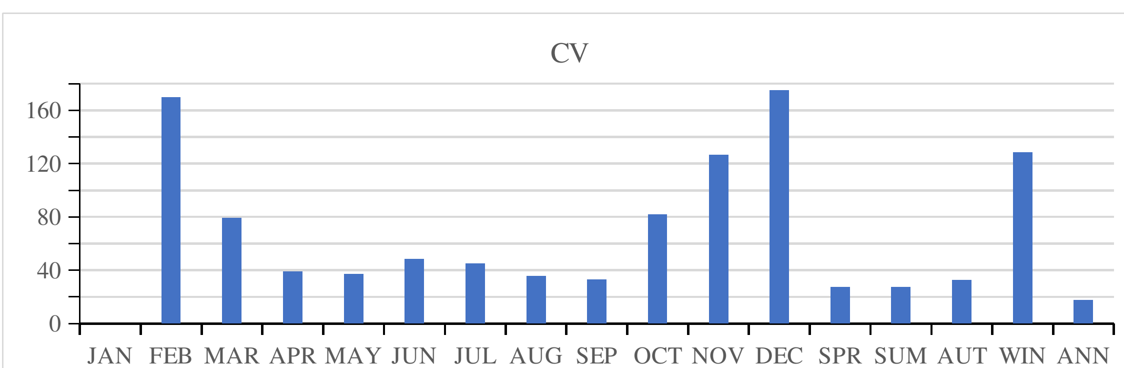

Figure 2 CV at Kebrybeyah district

The PCI confirmed irregular precipitation distribution in most of the years. The SI also estimates a prolonged dry season almost every year. Furthermore, the SPEI verified that 1984, 1991, 2003, 2008, 2009, 2015, 2017, and 2019 were years of extreme drought. In contrast, the years 1987, 1995–1998, 2010, and 2020 were extremely wet (Figure 3).

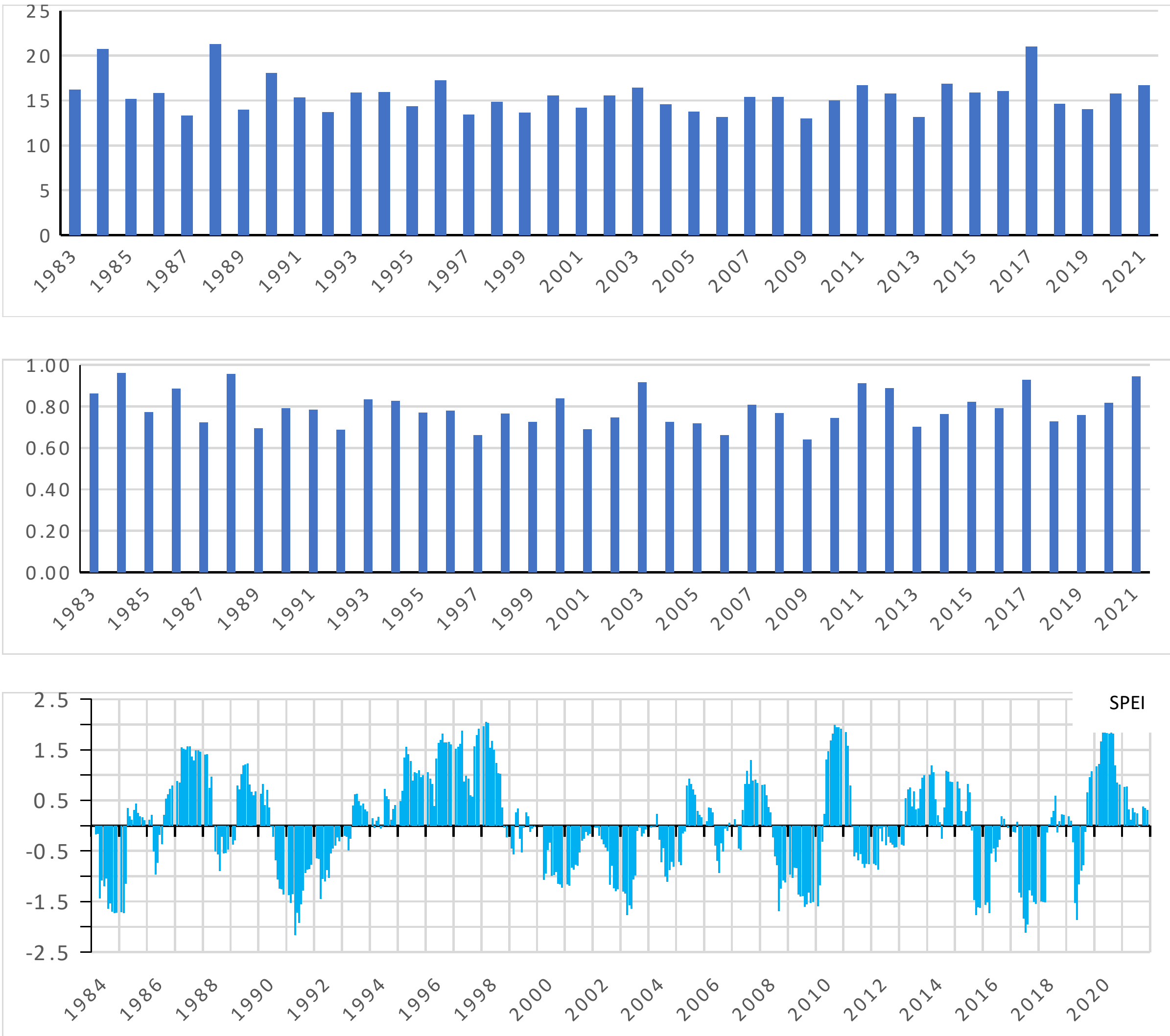

Figure 3 PCI, SI, and SPEI at Kebri Beyah district

Despite extreme climate variability in the region, rainfall has not changed significantly over the last four decades. However, there was a downward trend from December to June. In contrast, with the exception of July and August, minimum and maximum temperatures increased in almost all months. Minimum temperatures rose significantly between March and May, and September and November. The maximum temperature rose significantly in February and March.

Table 3 Mk trend test result for rainfall and temperature (*The negative sign represents a downward trend, whereas the positive sign represents an upward trend. The star sign indicates the level of significance)*.

Month	Rainfall		Minimum Temperature		Maximum temperature	
	Sen's slope (mm)	Z Value	Sen's slope (ºC)	Z Value	Sen's slope (ºC)	Z Value
JAN	0.00	-0.62	0.00	0.05	0.01	1.11
FEB	0.00	-1.76	0.02	1.11	**0.02**	**2.08***
MAR	-0.10	-0.51	**0.03**	**2.10***	**0.04**	**3.34***
APR	-0.60	-0.99	**0.03**	**2.18***	0.04	1.67
MAY	-0.13	-0.29	**0.02**	**3.44***	0.02	0.65
JUN	-0.09	-0.56	0.01	1.16	0.01	0.56
JUL	0.09	0.51	0.01	0.90	-0.02	-0.90
AUG	0.56	1.33	0.02	1.79	-0.01	-0.41
SEP	0.05	0.07	**0.02**	**2.08***	0.00	0.05
OCT	0.20	0.94	**0.03**	**2.18***	0.03	1.31
NOV	**0.00**	**2.01***	**0.03**	**2.83***	0.03	1.43
DEC	0.00	-1.13	0.01	0.65	0.01	0.82
SPR	-0.84	-1.26				
SUM	0.47	0.87				
AUT	0.40	0.85				
WIN	**-0.09**	**-2.06***				
ANN	0.47	0.53	**0.02**	**3.48***	0.01	1.72

3.4. Indigenous climate change adaptation strategies

Adaptation to climate change is a two-step process in which pastoralists and agro-pastoralists must first perceive climate variability and extremes and then respond to it in the second step. Pastoralists' and agro-pastoralists' perceptions of climate variability and extremes and the actions they take to reduce its negative effects were used to identify adaptation strategies. The main indigenous climate variability adaptations used by pastoral and agro-pastoral households are presented in Figure 4 and discussed as follows:

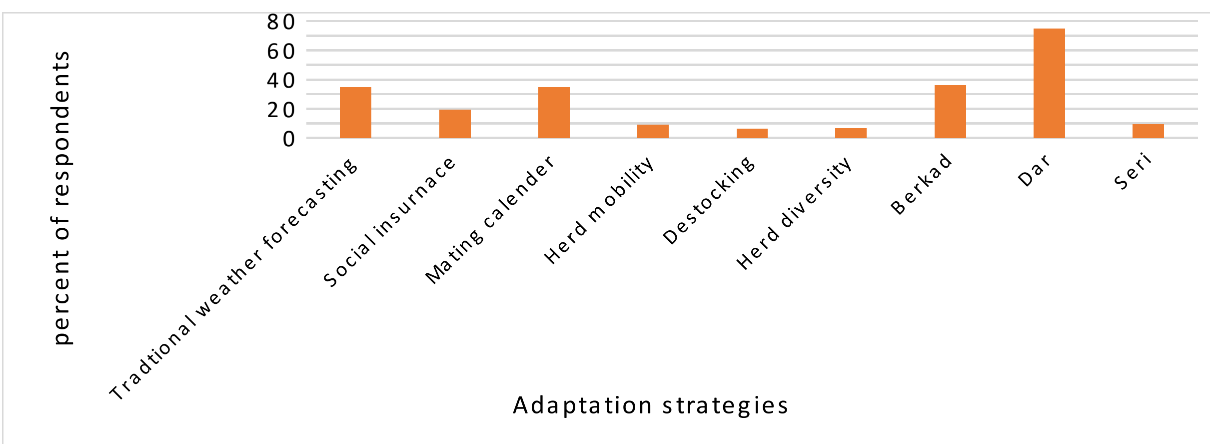

Figure 4 Indigenous strategies to climate change

3.4.1. Indigenous weather forecasting system

The elders (usually men) of the Somali people use an event called "Xidaar" to forecast the forthcoming weather. The key informants claim that predictions made by "Xidaar" have historically been correct. The timing of rain for a certain year, a drought, a conflict, and other significant weather events are frequently predicted using ancient astronomical knowledge gained by studying the alignment of two stars called “Sugra” and “Xidigis”. These forecasts were what pastoralists used to change the time when ewes and rams mated, as well as the timing of migration and the resolution of previous conflicts. Elders and other community members, however, expressed the impression that these indigenous weather conventional forecasting methods were no longer reliable due to climate change and variability. "Things have changed," they claimed. ‘There is no need to foresee the future because the timing and erratic rainfall distribution behavior are just not what they formerly were’. This study was in line with a study on indigenous weather forecasting system among Borana and Afar pastoralists. The Borana and Afar indigenous weather forecasters keep an eye out for changes in the pattern and constellations of various celestial bodies, such as the sky, the sun, the moon, and other stars. Observed celestial bodies include the constellations of various stars, variations in the color of the sky, the sun, and the moon, as well as the direction and timing of the crescent moon. Of all these, stargazing is the most involved since the Afar have a tradition of recognizing and characterizing three different kinds of stars: the Dohra, the Kaihima, and the Malhino (Balehegn *et al.*, 2019). There are several bio physical indicators such as Ant routes for predicting rainfall Balehegn *et al.*, (2019), traditional plant and tree indicators Chisadza *et al.*, (2015), phenological and behavioral changes of bio indicators (Acharya, 2011).

3.4.2. Traditional Social insurance

Somali pastoralists support one another through conventional social insurance mechanisms throughout this historic period of drought and flooding. According to the key informants in the past, people would donate livestock to families whose herds were destroyed by calamities. This social insurance is known as ‘Gergar’ in Somali culture. It demonstrates that close ties that local communities have vital social insurances to absorb economic shocks. Link the study sites, this risk experience which used to support the victims is currently weakened due to recurrent drought and secondary disaster (Radeny *et al.*, 2019).

3.4.3. The Mating calendar

The Somali have a striking animal mating calendar with which they regulate livestock reproduction according to a particular weather phenomenon. The mating calendar is known as ‘GUGA’. Normally, the end of the dry season and the beginning of the ‘GU’ season, ewes and rams’ mate on the night of ‘Dambasame’ so that lambs are born at the start of the ‘GU’ season, which typically occurs between April and June. It is strictly prohibited for ewes and rams to mate during the dry season. Mating won't be a problem after the dry season when the ‘GU’ season starts. Additionally, highly adaptable to changes is the timing of sheep births and mating pairs in relation to the "Dambasame," or the nights when particular ewes and rams first mate. Lambs are born when ‘GU’ season, which typically occurs between April and June, begins. It won't be able for ewes and rams to mate on the Dambasame night if the 'GU' rain begins later than planned. Therefore, the process will eventually begin when it does (Hartmann and Sugulle, 2009). According to a household study, the situation is quite limited for camels because their gestation period is longer than that of cattle or goats. At this point, camel fertility rates are likewise high. One person was citing a statistic about a man who owned 350 camels, just one of which was a female. Therefore, preventing animals from mating during the dry season is the best way to reduce mortality from drought or starvation.

3.4.4. Herd mobility and rotational grazing system

The Somali community have traditional land and water management systems that have been functional for a long. The community members used the conventional 'Seri' system of rotational grazing to share grazing areas. The Seri system used to conserve pasture for the dry seasons and managed communally is barely exists right at the moment. Elders in the focus group discussions reported that 'rangelands were shared resources; everyone has equal rights and are administered by the same rules. In Somali culture, land has never been private. These common resources are distributed equally among the twenty-five clans. However, the current climate situation distorted the old way of life and rangeland utilization and management system. The repeated adverse effect of climate variability and extremes erode the Somali cultural identity i.e., strong social bond, trust as well as sharing of resources and risk. The recent decrease of herd mobility is also related to the changes in land ownership conditions which put restrictions on the access of communal resources such as grazing land and water which previously were traditionally accessed and managed. As land is owned by the state in Ethiopia; pastoralists indicated their concerns about the weakening of their indigenous institutions as this is overpowered mostly by formal institutions in which land is taken away without compensation resulting in pastoralists reluctant to practice mobility or invest in their communal resources (Senda *et al.*, 2020). An example of the impact of the loss of communal resources is demonstrated by the traditional practice of Seri, a grazing land that used to be communally owned and became less functional due to changes brought by ownership and loss of land productivity resulting from severe climate variability.

As pasture and water grew scarce in recent years and people began to hunt for alternative revenue sources like farming, Seri has become less common. This stands in a stark contrast with Berhanu and Beyene (2014); Mekuyie *et al.*, (2018); Debela *et al.*,(2019) who concluded that among the Afar and the Borena herd mobility to remote areas to supplementary feeding of animals is the most commonly used coping strategy. Among the Somali, there is a resort to farming Khat, maize, and sorghum. Respondents who still work as pastoralists remarked that it is exhaustive to search for available pasture and water because it can take days of walking without success. Therefore, it appears that herd mobility as a coping strategy among the Somali pastoralists is withering away.

3.4.5. Destocking

When there is an emergency, such as a severe drought or other environmental hazards, livestock is sold right away. Typically, unproductive male and female animals are sold to get income to buy grains or seeds. "I buy vegetable seeds and put them in my backyard; it's worth a lot in the market," a man from Deneba said. Renting tractors will also be done with the money. Homestead gardens were seen specifically among the residents of Deneba during the survey. Vegetables including tomatoes, carrots, and onions, among others, are also cultivated grown by store owners in Deneba and are a significant source of revenue during the dry seasons. This finding is consistent with research by Siraje and Bekele (2013); Alemayehu and Bewket (2017); Mekuyie *et al.*, (2018) who showed that selling livestock is a key coping mechanism in the face of climatic shocks. Caudell *et al.*, (2017) and Terrence (2004), indicated at times of need; the Massai pastoralists tend to sell their small herd but are reluctant in selling their cattle. Small herds are particularly important as a source of meat for subsistence consumption or sold for cash.

3.4.6. Build Water well

Water storage wells called Birkads are built with cement and stones. Due to the need for cement and manpower during construction, a typical Birkad may have a 4 m depth and is typically costly to build. It did become apparent during the study that each of the surveyed kebeles had at least one community Birkad in addition to individual Birkad which is privately owned and not commonly present in most households. In addition, most people use "Dar" which is a traditional water storage structures made of cheap local material that captures rain water; established with local material and satisfy water. This tradition of use of rainwater harvesting storage is a common strategy used by most pastoralists' communities in Africa (Leal Filho *et al.*, 2020).

3.5. Emerging adaptation strategies

The emerging adaptations strategies are presented in Figure 5. It was performed by both the local and refugee communities living in the study area. In response to climate shocks, the local communities have been engaged in charcoal making and firewood production business. The extensive engagement of the youth in charcoal sales in the study area has threatened the remaining bushland. Although there is bylaw that bans this activity despite of which the clearing of bushlands for charcoal production has continued unabated. This finding was not in line with Shiferaw *et al.*, (2020) where charcoal production is encouraged in the Northeastern part of Ethiopia with an aim to fight some invasive species like Prosopis juliflora. As an income diversification strategy charcoal production is among the least lucrative business that pastoralists engage and earn about 100 ETB per month. On balance, it is necessary to remark that charcoal production is a maladaptive practice that needs to be discouraged. The practice cannot be allowed to proceed at the expense of the ecology.

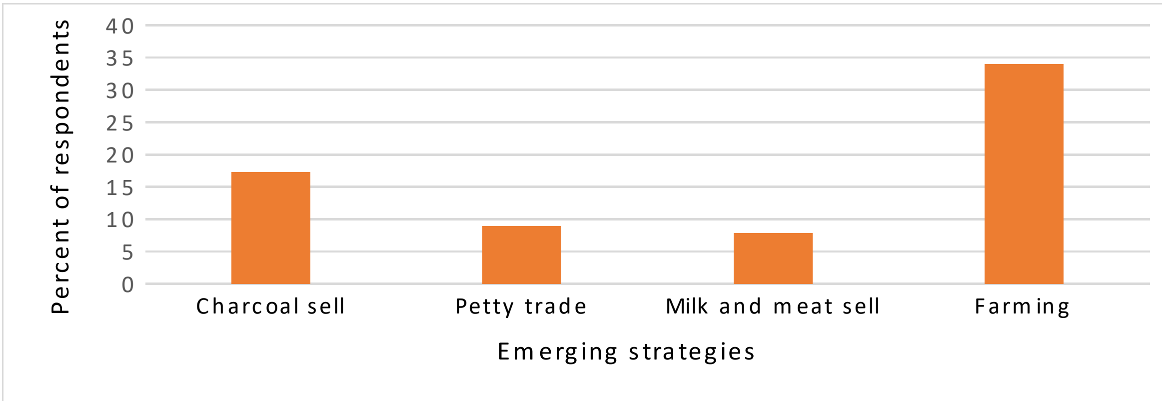

Figure 5. Emerging strategies to climate change adaptation

Petty trading, such as shopping and livestock trading, was another emerging strategy pursued by the local residents in the study area. This is strikingly prevalent among women. Recently, the Somail women have been engaged in meat sales traditionally called 'HILIBELE' a to support their families. Female focus group discussant recalls than previously the Somalis were not used to the sale of animal products as it was considered a taboo to sell milk or meat. Such items were given for free to nearby people in the neighborhood as a gesture of respect. This practice has long been an established lucrative business among the pastoralists of Kenya (Elhadi *et al.*, 2015). Ayele, Dedecha and Duba (2020) also reported that pastoralists shifted to farming, petty trade, handcraft, charcoal sale, and casual labor, the majority of which were identified as emerging strategies in our study.

Khat farming has been increasingly practiced by people who have abandoned pastoralism. They provide to local market and export Khat to neighboring towns such as Degehabour, Harshin, and Kebridahar. Previous pastoralists have switched Khat to production along with other major crops during the wet seasons of 'GU' rain. Khat is mostly farmed in Ethiopia, Yemen, and Kenya. Currently, it is a widely consumed stimulant cash crop. Farmers view Khat as a more effective small-scale farming alternative in conditions of soil degradation and shortage (Ademe *et al.*, 2017). Several researches castigate Khat farming on grounds that it diminishes land available for food crop production. In the context to the study area, however Khat production is an attractive emerging strategy from which ex-pastoralists gained far greater income from cultivating sorghum or maize.

Focus group discussion with the youth members indicated the extent of out-migration of young men and women looking for jobs to the nearby towns like Jigjiga and Degehabour were a common scene. Also from the discussions, it was clear that the extent of out-migration also increased through time to far states like Saudi Arabia and Libya.

4. Conclusion and recommendation

It is concluded that pastoral households in the study area perceived an increase in annual temperature and a decrease in annual and seasonal rainfall. Mann- Kendall's trend analysis confirmed pastoral communities' perceptions of increased temperatures and rainfall variability, with the exception of a long-term decrease in rainfall. Temperature trends in the study area are also increasing significantly. However, no significant changes in long-term annual rainfall were observed. The annual rainfall distributions were highly irregular.

The effect of climate change on local economy and culture cannot be overstated. People manage to withstand the effects of climate change through the declining indigenous weather forecasting system, social insurance, mating calendar. Herd mobility is dwindling as a common adaptation strategy while crop farming and petty trading in milk and meat, charcoal, and outmigration were the emerging adaptation strategies. Under such precarious livelihood foundations, the Somali people are hardly immune the catastrophic impacts of the ongoing climate change and the recent mass death of animals in the Somali region is a clear indicator of their susceptibility. Future research should focus on sound modern adaptation technologies to replace unhelpful and fading indigenous adaptation strategies.

Pastoral communities will be more able to adapt to the changing climate if indigenous institutions are strengthened. They will also be better able to put sound climate change adaptation strategies into practice if the pastoral community has better access to education. If pastoral households are to be climate resilient, water-related interventions such as water harvesting during good rainy seasons are essential.