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How do agro-pastoralists cope with climate change? The case of the Nyangatom in the Lower Omo Valley of Ethiopia

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ABSTRACT

This study has examined traditional coping systems, emerging adaptation strategies and barriers to the adoption of these strategies. Structured questionnaires on coping and adaptation strategies were conducted among Nyangatom households, expounded by focus group discussions and key informant interviews. Correlations between times series (1987–2016) on rainfall, temperature and the local perceptions on CC were examined. The time series analysis confirmed pastoralists' perception that the frequency of extreme drought has increased since 1987. The Nyangatom responded by temporal migration and herd diversification. Other responses include flood cultivation and enhancing alliance formation with other ethnic groups. Multi-nominal logistic regression analyses indicated that age of household head (−), livestock ownership (+), crop productivity (+), off-farm income (+) and access to climate information (+) proved to be key determinants with a statistically significant (negative or positive) effect on adoption. Other factors that hindered climate change adaption include intermittent conflicts with neighbouring ethnic groups and limited access to alternative livelihood options. Interventions to facilitate transition towards sustainable, adaptation-based communities need to incorporate deliberate, longer-term, risk-reducing strategies, including rangeland management, water harvesting and small scale-irrigation schemes. Improved education access, extension services, and a conducive pastoral policy environment will help to enhance the Nyangatom adaptive capacity.

1. Introduction

The impact of climate change (CC) is prominently felt by many groups around the world, with serious environmental, economic, and social impacts particularly on the rural poor of Africa (Gbetibouo 2009). Climate change particularly affects the fragile ecology of arid and semi-arid lands (ASALs) and puts agro-pastoral communities under severe strains due to the adverse consequences of increasingly erratic rainfall patterns and higher temperatures (Bewket and Alemu 2011). Empirical studies (Belay et al., 2005; Nyong et al., 2007) indicate that the effects of CC could meaningfully be reduced by effectively combining coping and adaptation practices. Coping practices are ad hoc, short-term, and location-specific responses within existing structures (Ashraf and Routray 2013). Adaptation practices, in contrast, are planned, gradually developed, and long-term adjustments to anticipated CC (IPCC 2012).

Indeed, pastoralists in East Africa over centuries have gone through cycles of coping and adaptation to extreme weather conditions (Belay et al., 2005; Deressa et al., 2009; Opiyo et al., 2014), resulting in remarkably sustainable exploitation of arid and semi-arid lands (ASALs). Politically marginalized, they sustained their traditional regulations and agreements of sharing common rangelands. A study by Sonneveld et al. (2010) in the Afar region confirmed that traditional herd regulations resulted in stable exploitation of rangeland resources over a period of 30 years. Yet, the fragility of pastoralist systems came to the fore during the severe droughts of the early 1970s and 1980s, when crop failures and massive livestock deaths led to hunger and famine in the Horn of Africa (Funk et al., 2005).

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The International Panel on Climate Change (IPCC 2007) predicted mean annual temperature increases of 0.9–1.1 °C by 2030, 1.7–2.1 °C by 2050, and 2.7–3.4 °C by 2080 across Ethiopia. Similarly, high variability in rainy season onset and cessation was reported by EPCC (2015). The combination of increasing temperature and unpredictable rainfall will reduce the length of the plant growth period and, hence, affect rangeland productivity. As a consequence, facing water and fodder scarcity, pastoralists are forced to migrate over extended periods and longer distances to meet their demand for dry season fodder and water. The increased mobility, in turn, affects animal health and productivity and often leads to conflict with neighbouring communities (Abbink 1993; Glowacki and Wrangham 2014; Glowacki et al., 2016).

Climate change has become inevitable affecting a large population that has limited resources for adaption across the earth. It is not different for Ethiopian (agro)-pastoralists and farmers since their livelihood largely depends on the climate-sensitive production system (Deressa et al., 2009; Bewket and Alemu 2011). For the design and application of effective CC mitigation strategies, it is crucial to gain support and trust from local communities. The latter is more likely to happen when communities' perceptions of climate change and location-specific responses, of both coping and adaptation, have been taken into consideration. Coping and adaptation yield better results if both strategies are complementary (Bewket and Alemu 2011). This is particularly important for designing effective agro-pastoral strategies to reduce the risk associated with climate variability and change in the arid and semi-arid zone of the Omo basin (Opiyo et al., 2014; Opiyo et al., 2015). Perceptions of climate change may affect how people will respond and adapt to their multiple impacts. In other words, it is the perceived changes that are likely to motivate adaptive actions. Similarly, understanding local perceptions of climate change and variability and building consensus among local stakeholders on the impact of climate change are important to implement appropriate mitigation strategies.

Perception strongly affects how farmers/pastoralists deal with climate-induced risks and opportunities, and the precise nature of their behavioural responses to this perception will shape adaptation options, processes, and outcomes (Ashraf and Routray 2013). There are few studies of pastoralists' perception of climate change in Ethiopia, however, additional lessons can be learned from climate change perception studies held among smallholder farmers in the region. For example, different household and farm factors influence whether and to what extent farmers perceive climate change and its impact on local agriculture (Bewket and Alemu 2011; Ashraf and Routray 2013). The age of a subsistence farmer is closely related to farming experience and their accumulated knowledge of the environment including changes in climatic conditions (Deressa et al., 2009; Bewket and Alemu 2011) that may go back many decades. Studies of African smallholder farming systems have indicated that the level of formal education attained by farmers influences their ability to perceive climate change and its impact (Zampaligre et al., 2014; Opiyo et al., 2015). Larger households are more likely to engage in non-farm income-generating activities. Because non-farm income buffers financial losses from climate-sensitive farming, such households are less likely to perceive climate change (Deressa et al., 2009; Bewket and Alemu 2011). Access to support services such as extension services and climate information is purported to increase farmer perception of climate change and its associated risks (Deressa et al., 2009; Amare and Simane (2017).

In the study area, much needs to be done to implement adaptation measures. However, it is unclear how, and to what extent, agro-pastoralists' perception of climate change has influenced their behavioural responses. This raises the question of whether agro-pastoral coping and adaptation strategies are still based on traditional practices passed on from generation to generation and whether these are adequate to address the unprecedented challenges that are now posed by climate change in the ASALs. Besides limited knowledge of agro-pastoral communities' perception of climate change, there is little information on factors that influence agro-pastoralists' perception and enable or constrain their ways to adapt to climate change. Local perceptions influence local responses so the generation of knowledge on local perceptions, influential factors, and the extent to which perceptions match reality will be instrumental in designing effective CC mitigation strategies (Opiyo et al., 2015; Amare and Simane 2017).

This paper aims to narrow the knowledge gap on agro-pastoralists' views on climate change and associated coping and adaptation mechanisms, addressing the following questions:

1) What socio-economic characteristics play a role in CC responses of agro-pastoralists living in high-risk ASALs?
2) To what extent do agro-pastoralists' perceptions of CC correspond to local records of rainfall and temperature changes over the past three decades?
3) How do agro-pastoralists respond to CC, and
4) What are the barriers and enabling factors to CC adaptation?

The research is based on a cross-sectional survey among agro-pastoral communities of Nyangatom in the Lower Omo Valley (LOV) of Ethiopia. The survey was supplemented with focus group discussions, key-informant, and informal interviews. Furthermore, rainfall and temperature records between 1987 and 2016 from the nearest weather stations were used (see section 2.2).

2. Materials and methods

2.1. Study area and the community

The study was conducted in Nyangatom in southwest Ethiopia. The Nyangatom district, 2184 km^{-2}, is an autonomous local administrative unit since 2006 (Fig. 1). The average elevation is 360 m.a.s.l., the annual average precipitation 400 mm, and the annual average temperature 30 °C. Nyangatom has three distinct seasons: a long rainy season (*Kiremt*; period: Mach-May-MAM); a short rainy season (*Belg*; period: October–November) and a dry season for all remaining months. Agro-ecologically, Nyangatom is classified as arid to semi-arid, unsuitable to intensive permanent crop cultivation unless irrigation is supplied. The total population of the Nyangatom district was 20,999 (projection for 2017) (CSA, 2013). The Nyangatom, the dominant ethnic group, and Murle are the ethnic[1] groups selected for this study.

Livestock is the main, self-reproducing asset to generate income and savings. Pastoralism in Nyangatom is supplemented by small-scale rainfed and flood-recession crop cultivation along the Omo and Kibish (Naqua) Rivers (Tornay 1981). The Nyangatom have a distinct social structure, which includes age-groups (*ngigerea, sing. ajere*) that are responsible for all kinds of traditional decision-making (cf. Tornay 2001). The active age groups consisted of named sections such as Elephant, Ibex, Ostrich, and Buffalo. Each of these age groups has a functional role in Nyangatom society in terms of maintaining the socio-economic and environmental settings (grazing pattern) of the community. Also, the age groups have a socio-cultural and biophysical, event-based seasonal calendar based on which livestock mobility routes are identified.

2.2. Methods of study

2.2.1. Research design and data collection

For the sampling design, ten qebeles representative for Nyangatom in terms of dominant livelihood strategies, proximity to basic infrastructures, susceptibility to conflict, and physical location were purposively selected. Households were selected in a two-stage sampling

[1] Murle is small in number (a few hundred) and inhabit only in one Qebele. *Qebele* is the smallest (community level) administrative unit in the government of Ethiopia.

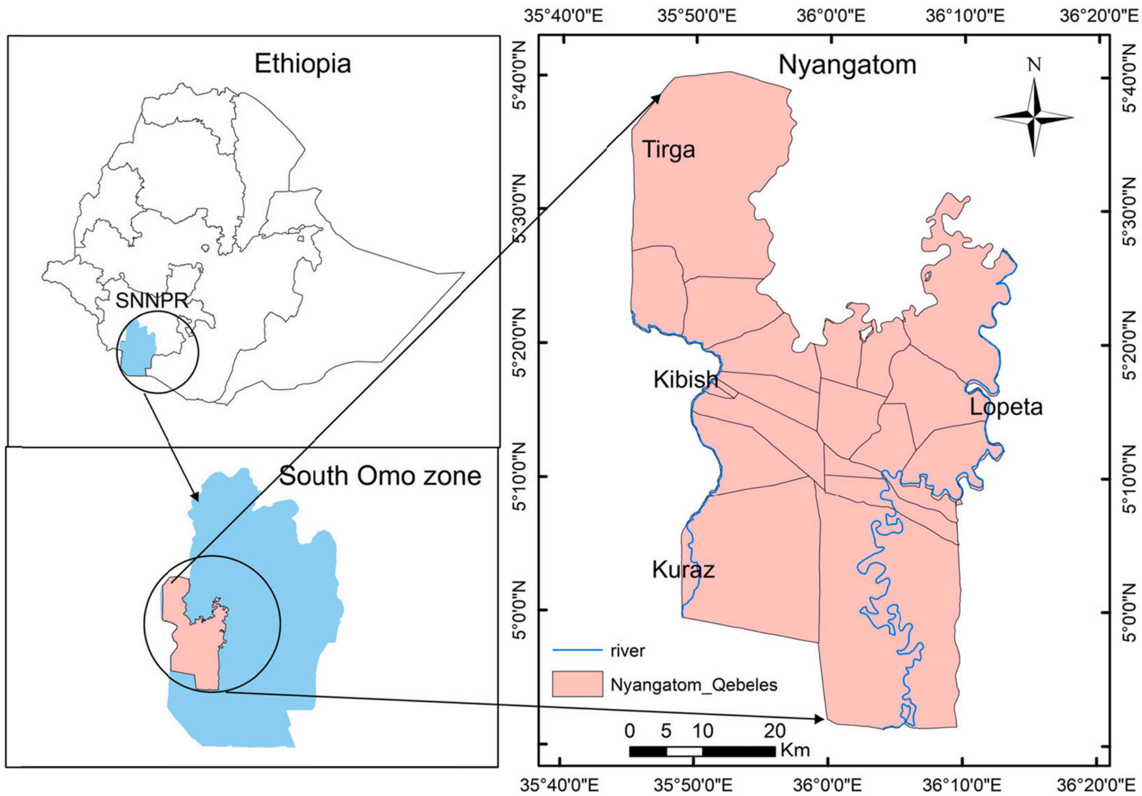

Fig. 1. Map of the study area (source: authors).

procedure. A total of 384 households were randomly selected from the 10 qebeles using a list of households obtained from the local administration.

The sample size was selected using the Cochran formula (1977).

$$\text{Sample size (n)} = \frac{Z^2pq}{e^2} \quad (1)$$

Where:

n = sample size of the study population
Z = the required confidence interval (for 95% CI, Z = 1.96),
p = the probability for an event to occur,
q = the probability for an event not to occur,
e = an acceptable error rate during sampling (0.05 associated with 95% CI).

A cross-sectional structured survey was conducted among 384 households, collecting data on agro-pastoral demographic and socio-economic characteristics, livelihood activities, perception on, and responses to climate change. The survey also addressed perceived barriers to CC adaptation. The interviews were held with community elders who have lived in the study community for a considerable length of time and know the culture and socio-structural organization of the community. Key informant interviews (n = 30), and focus group discussion (FGD) (n = 20) were conducted with elders, clan chiefs, members of different age-group groups, youth, women, and experts. The age-group groups who participated in this study consist of Elephant, Ostrich, Ibex, and Buffalos. Eight local enumerators, one translator, and a native senior field assistant were trained on data collection tools and interview procedures.

The study utilized station-based climate data obtained from the national meteorological agency of Ethiopia, Addis Ababa, between 1987 and 2016. Data were obtained from weather stations in the LOV which is consisting of daily rainfall, minimum and maximum temperature. The Ethiopian national meteorological agency reported that the Nyangatom has no weather station. Hence we have systematically selected three neighbouring weather stations, i.e. those in Turmi, Omorate, and Jinka, as proxy data sources to study trends in rainfall and temperature and compare these with local Nyangatom perceptions. The criteria for weather station selection include the distance between the weather stations and the study area, the similarity of the agro-ecological zone, and the relative completeness of the data sets. The Jinka station was the only station with a complete set of observations. A similar approach was applied by Meze-Hausken (2004) in Tigray and North Afar and Bewket and Conway (2007) in the Amhara region. However, Jinka is the only station closest to the study area with a continuous record over 30 years, which is categorized as upper 'qolla' (below 1500 m.a.s.l). The addition of Jinka station gave a full picture of the CC in LOV and enabled us to identify the upper limit of the change in rainfall and temperature. Also, this study makes use of the Omorate station which is recently established, incomplete but found in similar agro-ecologic zones (see Table 1). So using station data from the upper and lower 'qolla' agro-ecology provides a better understanding of the CC trends in areas like the Nyangatom where weather data are scanty. The data, therefore, were extrapolated for the study area to estimate the trends and substantiated with the local agro-pastoral perception.

2.2.2. Data analysis

The qualitative and quantitative data was cleared, edited, coded, and stored in Excel. Local perception of climate change and factors affecting the adaptation strategies were characterized using descriptive statistics. Data pertinent to household characteristics were analysed using bivariate descriptive statistics in the STATA 14 software package. The Agro-pastoralists in this study differ in the number and type of strategies that they use and perceive as measures of adaptation (rather than coping), i.e., some adopt 2-combination (36), 3-combination (271) strategies and yet others are not able to adopt any strategy at all (76). We applied binary logistic regression to understand whether the adoption (yes/no) of climate change adaptation strategies can be predicted based on some

Table 1
Framework of analysis of coping and adaptation activities (adapted from IPCC, 2012).

Dimension	Coping activity	Adaptation activity	Reference
Exigency (E) Weight: 0.35	**E1 score (0–4)*** 1. Responding to immediate stress 2. Survival-oriented 3. Resource limitations 4. Forced reaction 5. Interdependence 6. Traditional knowledge	**E2 score (0–4)** 1. Responding to recent past or anticipated future 2. Adjustment-oriented 3. No reference to resource limitations 4. Planned 5. Sustainable/independence 6. Common/Scientific knowledge	Wisner et al. (2004)
Constraint (C) Weight:0.35	**C1 score (0–4)** 1. Available knowledge 2. Basic experience and assets 3. Access to extension services 4. Conflicts, weak institutions, poor infrastructure 5. Geographic location (access and distance) 6. Animal diseases	**C2 score (0–4)** 1. Assumptions regarding future resource availability and trends 2. Wider experience and assets 3. Access to extension services on pastoral technologies 4. Not constrained by conflicts, more by weak institutions, poor infrastructure 5. Geographic location (access and distance) 6. Animal diseases to some extent	Bankoff (2004) Adger et al. (2005) Agarwal (2008)
Reactivity (R) Weight:0.20	**R1 score (0–4)** 1. Decisions are tactical 2. Decisions are passive 3. Decisions directed at basic human security 4. Short-term 5. Continuous (unplanned)	**R2 score (0–4)** 1. Decisions are strategic 2. Decisions are proactive 3. Decisions directed at anticipating change 4. Gradual, relatively long-term 5. Planned	Fussel (2007)
Orientation (O) Weight:0.10	**O1 score (0–4)** 1. Focus on past experiences and successful tactics 2. Focus on current changes	**O2 score (0–4)** 1. Focus on future conditions and strategies 2. Focus on past tactics and experiences relevant for future adjustment	Bankoff (2004)

*Score levels: 0 = 0–19% (no/almost none of the criteria met); 1 = 20–39% (some criteria are met); 2 = 40–59% (about half of the criteria are met); 3 = 60–79% (more than half of the criteria are met); 4: >80% (most of the criteria are met).

socio-economic and institutional variables such as age, age-groups, gender, and access to extension services (see B.2). Also, a multinomial logit model (MNL) was used to understand whether the type and number of adaptation strategies used by households can be likewise predicted based on socio-economic and environmental variables. We hereby distinguished three levels for the dependent variable of adaptation strategies: level 1: no adoption; level 2: use of a combination of two of the following three, most frequently used, strategies: irrigation, credit and livestock diversification (two-MIX); and level 3: use of the three strategies combined (three-MIX). The qualitative data were transcribed, carefully read, and divided into meaningful analytical units. The analysed transcripts were thematically examined, interpreted in the form of narratives. Then, the result of the analysis was discussed by juxtaposing with the qualitative data to elucidate the agro-pastoralists perception of CC impacts on local livelihood and households' coping and adaptation strategies.

The weather data, covering 1987–2016, were thoroughly checked for outliers, negative values, and discontinuities. The Mann-Kendall test for trends and Sen's slope estimator was used to detect and estimate trends in annual and seasonal rainfall and temperature series (Mann 1945; Sen 1968; Kendall 1975). The temporal rainfall variability was represented by the coefficient of variation (CV) determined as the ratio of the standard deviation to the mean rainfall in a given period. The precipitation concentration index (PCI) was calculated to assess the monthly rainfall homogeneity of the study period for Jinka, Turmi, and. Omorate

$$PCI = 100*\frac{\sum Pi^2}{(\sum Pi)2} \quad (2)$$

Where P_i is the rainfall amount of the ith month. PCI values of <10 indicate homogeneous monthly rainfall distribution in a given year, whereas values from 11 to 20 indicate medium seasonality and above 20 correspond to large monthly variability in rainfall distribution. The number of wet and dry days was calculated (wet days: >0.1 mm rainfall; dry days: ≤ 0.1 mm rainfall) and dry spell (three or more consecutive dry days). Similarly, the standardized rainfall anomalies (SRA) were calculated for each of the three stations to understand yearly anomalies and observe the cyclical dryness (Bewket and Conway 2007).

$$SRA_{it}= (p_{it}-p_m)/\delta \quad (3)$$

Where P_{it} is the annual rainfall in year t at station i, P_m is long-term mean annual rainfall and δ is the standard deviation of annual rainfall over the period of observation. Positive SRA indicates rainfall amount above the annual mean whereas negative values show rainfall amount below the annual mean.

2.2.3. *Climate change coping and adaptation framework*

Table 1 shows the framework for analysis used to assess-based on four dimensions-the levels of coping and adaptation response to CC of the Nyangatom agro-pastoralists. According to IPCC (2012, p51), the set of dimensions, i.e., exigency, constraint, reactivity, and orientation, helps to distinguish coping and adaptation activities. This tool provides us with useful information to evaluate the categories of strategies employed by the Nyangatom. The four dimensions are broad and their outcomes may vary across cultures, and with the biophysical environment and socio-political context.

The dimensions making up the framework can be explained as follows:

1. Exigency: refers to the characterization and the level of urgency of responses to CC;
2. Constraint: refers to challenges hindering the implementation of CC responses; these can be of social, geographic location, cultural, economic or political nature;
3. Reactivity: refers to the nature of the decisions taken by households in relation to CC responses;
4. Orientation: refers to the positioning of the household responses to CC with respect to a given reference level in time or space.

To evaluate the Nyangatom coping and adaptation activities, weighted scores were assigned to each dimension based on predefined criteria derived from the literature, field data, and expert judgment (Table 1). Then, each household's coping and adaptation strategies were evaluated against the predefined criteria to assess the prevailing response to climate change and strategies that dominate their activities.

Finally, we sum up each weighted score under each dimension to reach into a single indicator for individual household's dominant CC response.

The Composite Index of Technology Adoption (CIA), developed by Barungi and Maona (2011), was adopted to understand the widely utilized coping and adaptation strategies and the categories response to climate change in the study area. The CIA is computed as:

$$CIA = \sum_{i=1}^{n} \left(\frac{Ta/T}{n} \right) \quad (4)$$

Where T_a = the total number of coping or adaptation strategies used by ith households; T = the total number of coping/adaptation strategies available; n = the sample size.

3. Results

3.1. Socio-economic characteristics

The socio-economic characteristics of the sampled households are summarised in B.1. The basic management and social unit in a community are the Nawi, consisting of a man, his wife (-ves), children, and other dependents and kinship. Each Nawi manages multiple livestock species - cattle, sheep, goats, and donkeys. Ethnic groups that participated in the study are Nyangatom (dominant) and Murle. Polygamy is practiced by 46.8% of the survey respondents. Most survey respondents were male (61%) with the mean age of 40.4 years. A large majority are illiterate (95%), with an average household size of 6.6. Most respondents (54.5%) are in the age category of 20–45; 39.3% in the 45–60 range; and 6% categorized as older than 60 years. The Ibex (39.1%), Ostrich (30.2%), Elephant (18.2%) and, Buffalo (12.5%) are age group members who participated in this study. Animal husbandry is the primary source of livelihood for most of the respondents (75%), followed by subsistence crop production (19%), and mixed livestock-crop production (18%). The mean herd size expressed in Tropical Livestock Unit (TLU[2]) was 63.9 (SD = 111.9). Mean household holdings of cattle, sheep, goats, and donkeys are 20.7, 5.4, 5.8, and 10.2, respectively. There are no reports on ownership of camels in the district. Some households were practicing river recession cultivation on the banks of Omo River making use of floodwater during the peak rainy season (Sept–December/January). Other households practising crop cultivation entirely depend on rainfall that is erratic in nature. The mean annual household income from livestock sale was €308 (SD 343) whereas that from crop sale (farm income) was about €46[3] (SD 69). Also, only 30% of households have access to credit. Few households (31%) are organized in social resource groups.

3.2. Climate change and agro-pastoralists' perceptions

This section addresses the question whether, and if so, how the local climate in Nyangatom has changed over the past 30 years (1987–2016), both annually and seasonally. Also, it examines to what extent the local perceptions of rainfall and temperature change correspond to the observed weather station data on climate variability and change.

3.2.1. Recorded changes in temperature and rainfall

The mean annual temperatures for Omorate and Turmi are 30.5 °C and 26.8 °C respectively. Similarly, the extrapolated data for Nyangatom shows a mean annual temperature of 30 °C and an increase of 0.047 °C annually. The annual mean minimum and maximum temperature for Jinka is 16.3 °C and 27.5 °C, corresponding to an increase of 0.037 °C and 0.046 °C from 1987 to 2016 respectively. The Mann-Kendall test indicates an increasing trend in maximum and minimum temperatures at 0.01, 0.05, and 0.1 significant levels and Sen's slope (Q = 4.38E-02) gives a positive slope at station Jinka (A.1) (see Fig. 1).

The mean annual rainfall at Jinka was 1326 mm with a standard deviation of 75 mm and the lowest mean rainfall was recorded at Omorate (303 mm) (Table 2). At Jinka station, annual total rainfall during the referred period decreased slightly with 8 mm. Mean annual rainfall decreased by 11.45 mm in between 1987 and 2016. Mann-Kendell and Sen's slope analysis of rainfall data at Jinka station shows non-significant ($p > 0.05$) decreasing trend in total annual rainfall over the same period. The PCI values show a high monthly rainfall variability in the lower Omo valley (Table 2). The number of dry days for Jinka was 210 days annually. PCI values for Jinka, Turmi, and Omorate are 12, 24 and 25, respectively. Similarly, the standardized rainfall anomaly (SRA) calculated for Jinka station indicates that 47% during the past 30 years exhibited negative anomalies whereas 50% at Turmi (Fig. 2) and 100% negative SRA at Omorate station between 2007 and 2015. The wettest months at Jinka station are MAM whereas the remaining months observed as relatively long dry days (>26 days/per month). Similarly, the Kiremt and Belg rain have shown non-seasonality and annual variation.

3.2.2. Agro-pastoralists' perception to climate change and its impacts on livelihood

Table 3 presents the households' perceptions of climate change impacts. In all qebeles, most interviewed agro-pastoralists perceived an increasing temperature (86%) and longer duration of the dry season (84%). Similarly, about 84% of the respondents perceived a decrease in rainfall amount, including more frequent drought (76%), late-onset (86%), and early cessation of rain (86%).

Most households (92%) reported a negative impact of climate change on the availability of livestock fodder. According to 78.5% of the respondents, livestock number is reduced because of droughts. Increased animal diseases (83%) and conflicts with neighbouring ethnic groups (27%) were other important factors that affect livestock productivity. A change in land use was identified by only 1% as a reason for the decrease in pasture productivity and increased fodder shortage. Furthermore, many of the agro-pastoralists (89%) indicated climate change as a major factor that affects crop productivity, specifically lack of rain (33%) and unpredictability of rainy seasons (23%). Additionally, crop diseases (21%), land fragmentation, and moving into less productive lands (17%) were mentioned as reasons for crop yield reduction. Declining water availability (68%) were also reported as the important impacts of climate change.

3.3. Agro-pastoralists' responses to CC

Table 4 shows locally available coping and adaptation portfolios.

Table 2
Station characteristics, including altitude (m), mean temperatures (T in °C), mean rainfall (mm) Coefficient of Variation (CV) and Precipitation Concentration Index (PCI).

Parameters	Jinka	Turmi	Omorate
Altitude	1373	934	365
Year of observation	1987–2016	1987–2015	2006–2016
Mean annual T	21.9	26.8	30.5
Mean T-max	27.5	33.1	36.9
Mean T-min	16.3	20.4	24.1
Mean annual rainfall	1326	528	303
CV	0.78	0.59	0.43
Mean *Kiremt* rainfall	155.9	344.6	212.3
CV	0.22	0.64	0.23
Mean *Belg* rainfall	95.0	58.5	81.6
CV	0.61	2.68	0.55
PCI	12	24	25
No. of dry days (2015)	210	307	331

[2] TLU is a standard unit that converts all stock into a common unit.
[3] €1 = 24.0774 Birr (National Bank of Ethiopia (www.http/:nbebank.com), 2017 data).

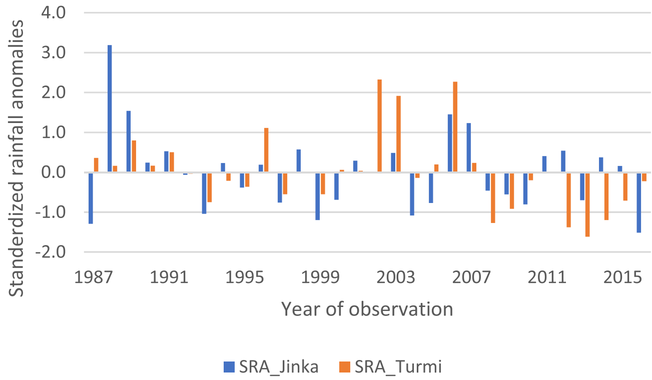

Fig. 2. Standardized rainfall anomalies at Jinka and Turmi stations.

Table 3
Agro-pastoralists' perceptions on climate change indicators and its impacts.

Variables	N	Household perception of CC and its effects on local livelihood (%)			
		Agree	Disagree	Do not know	No change
Decreased rainfall amount	383	84	14		2
Increased irregularity of rain	384	79	16	5	
Increased rainfall duration	384	14	76	6	4
Late rainfall onset	382	86	14		
Early rainfall cessation	382	86	14		
Increased temperature	384	86	14		
Increased flooding	381	46	41	13	
Prolonged drought period	384	84	15	1	
More frequent drought over past 1–2 years	376	76	24		
Increased prevalence of animal diseases	384	83	14	3	
Increased prevalence of malaria	384	71	13	16	
Increased water shortage	383	68	27	5	
Decreased pasture productivity	384	75	23	2	
Decreased crop production	383	79	17	4	
Increased fodder shortage	381	92	8		
Increased animal mobility	383	83	15	2	
Decreased livestock number	383	78.5	21	.5	

Table 4
Major CC coping and adaptation strategies practised by Nyangatom agro-pastoralists.

Coping/adaptation strategies	% of Households (n = 384)		
	Yes	No	Don't Know
Mutual support	96	–	4
Herd insurance Network	93	7	
Herd rejuvenation	12	88	
Livestock mobility	87	11	2
Livestock diversification	95	5	
Selling NTFP	61	24	15
Sell HH asset	21	79	
Credit	30	70	
Remittance	29	71	
Food Aid	82	13	5
Migrate to urban center	15	74	11
Irrigation	14	86	
Flood recession	47	53	
SWC-community	88	12	

Livestock mobility (87%) was mentioned as the most important coping strategy employed by Nyangatom herders. Preferred dry season grazing areas are Tirga, Narus, Mt. Kuraz, and Naita on the South Sudan-Ethiopia border, depending on various socio-environmental and political factors. Other responses, typically perceived as coping strategies by the Nyangatom, include mutual community support[4] (96%), food aid (82%), sales of household assets (21%), and temporary migration to urban centres (9%). Widening of traditional livestock insurance network (93%) such as herd splitting (giving animals to trustworthy relatives and friends) and livestock diversification (95%) are among important strategies. Consuming wild fruits, seeds, and leaves during the time of drought are other coping strategies.

Similarly, respondents have reported four locally available climate change adaptation options (Table 4). In general, only 13% were reported that they are implementing only limited adaptation strategies. Although mentioned as the most important strategy, small-scale irrigation was reported by relatively few respondents (14%). The soil and water conservation (SWC) including rangeland management (88%) was practiced only at the community level and agreed on its importance to mitigate CC impacts. Similarly, (30%) respondents reported access to rural credit as an important adaptation option. Anticipated adaptation options in response to climate change in the district such as livelihood diversification through wage remittance at large-scale farms (29%) in parallel with pastoralism were reported.

3.3.1. *Determinants of agro-pastoralists' climate change adaptation*

Table 5 summarises important determinants that affect the adaptation strategies of the agro-pastoralists in this study. The "two-mix" and "three-mix" variable levels refer to combinations of, respectively, two and three of the following strategies, perceived by the Nyangatom as measures of adaptation (rather than coping): irrigation, credit and livestock diversification (see also section 2.2.2). The likelihood of households adopting CC adaptation strategies - rather than not adopting strategies at all - is negatively related to crop production and age of household head ($p < 0.01$ in both cases) and positively related to livestock ownership and access to climate information ($p < 0.05$ in both cases). For example, for every 10 years increase in household head's age, the odds that a household will adopt CC adaptation strategies - rather than not adopting any strategy at all - will be multiplied by 0.958, i.e., it will decrease the odds by 42%. Yet, for every increase of 10 TLU owned by a household, the odds that household will adopt CC adaptation strategies - rather than not adopting any strategy at all - will be multiplied by 1.01, i.e., it will increase the odds by 10%. Similar variables' results can be observed for the likelihood of households adopting a combination of two CC adaptation strategies (two-mix). However, the likelihood of households adopting a combination of three strategies (three-mix) is significantly influenced by both off-farm income ($p < 0.01$) and access to CC information ($p < 0.05$; see also B.1&B.2): the odds that a household with off-farm income or access to CC information will *adopt a combination of three CC adaptation strategies - rather than not adopting any strategy at all* - is 19.03 or 5.778 times higher than the odds of a household without off-farm income or access to CC information, i.e., an increase of 1803% or 478% respectively (or an increase of 670% or 270% respectively when comparing households *that adopt a combination of three rather two CC adaptation strategies*). However, about 80% of the adaptation strategies are explained with other socio-economic factors such as age-groups, and hence age-group based decision making proves to play a minor role (insignificant based on the current study) in the adoption or non-adoption and the adoption of two CC adaptation strategies. These results point at a potential impairment of the traditional system of decision-making based on communal, age-group consensus rather individual households.

[4] Sharing of the crop with members of the same sub-clan, including Toposa relatives.

Table 5
Estimated coefficients and standard errors for model variables, i.e., determinants of households' strategies of CC adaptation (based on binary and multi-nominal logistic regression analyses).

Variables	Binary		Multi-Nominal (Ref: Non Adopt)			
	Adopt (Yes/No)		Two-Mix		Three-Mix	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Age (HH head)	−0.043***	0.017	−0.044***	0.017	−0.028	0.027
Gender	0.147	0.295	0.177	0.297	−0.490	0.494
Marital status	0.587	0.903	0.680	0.914	−1.207	1.388
Family size	0.040	0.062	0.041	0.062	0.036	0.085
Membership cross-age group traditional institutions	−0.091	0.421	−0.170	0.422	1.181*	0.691
Livestock ownership (TLU)	0.010**	0.005	0.010**	0.005	0.009*	0.005
Crop production	−1.126***	0.426	−1.141***	0.430	−1.504*	0.847
Credit	0.532	0.481	0.519	0.482	0.500	0.714
Access to CC information	0.702**	0.289	0.650**	0.290	1.754**	0.720
Information on animal health	0.334	0.322	0.389	0.324	−1.061	0.759
Off farm income	0.689	0.458	0.440	0.461	2.946***	0.729
Constant	1.199	1.159	1.096	1.167	−0.975	1.920
Number of observations	377		377		377	
R-squared	0.1504		0.1967			

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

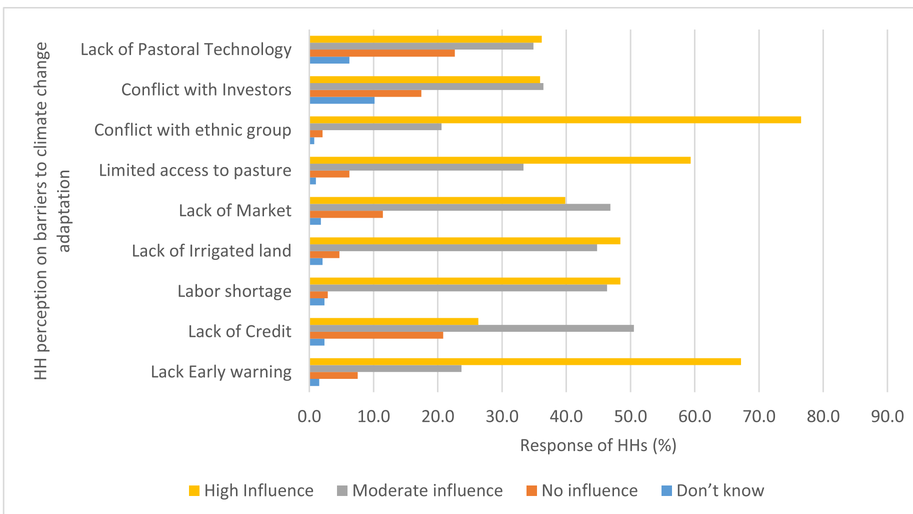

Fig. 3. Agro-pastoralists' perceptions on barriers to climate change adaptation.

3.4. Agro-pastoralists' perception of barriers to CC responses

Fig. 3 shows constraints adapt to climate change. Nyangatom agro-pastoralists perceive limited access to an early warning system that has high to moderate influence (91%) and limited access to credit facility (77%) as two important barriers to climate change adaptation respectively. Also, a shortage of household labour (93%) and lack of irrigable land was mentioned. Limited access to good pasturelands was reported as a factor impeding livestock mobility (94%). Conflict with other ethnic groups (98%) has a high influence on households' climate change adaption efforts. Focus group discussions confirmed that conflict with neighbouring groups (Dassanech, Hamer, and Surma) and Kenyan Turkana are major obstacles for practicing livestock mobility. Currently, conflicts with investors (54%) seemed less important. Lack of agro-pastoral technology (71%) has a moderate influence on their adaptive capacity and strategies.

4. Discussion

4.1. Socio-economic characteristics and their role in agro-pastoralists' perceptions of CC responses

Studies suggest that agro-pastoralists' perceptions of climate change adaptation largely depend on a combination of factors including household head's age (Deressa et al., 2009; Cherinet and Mekonnen 2019), sex (Deressa et al., 2009), education (Zampaligre et al., 2014), access to climate information, wealth and social capital (Deressa et al., 2009), and access to credit (Amare and Simane 2017). Most respondents are illiterate and have poor access to climate information, suggesting their perceptions of climate change adaptation are primarily based on knowledge passed from one generation to the next.

Traditionally, the Nyangatom are organized into an age-set structure whereby age-groups differ in decision-making power. Among the age-groups, the Elephants being the community decision-makers and the other groups are consulted implementers, concerning traditional drought-coping strategies, resource sharing, livestock mobility, and management of conflicts with ethnic groups in neighbouring territorial areas, as confirmed by Tornay (1981). Whereas the structure facilitates the sharing of information and decisions about actions to avert the negative impacts of climate change, some households sell ruminants without consulting the age-groups during prolonged drought and climate variability. According to local communities and experts, the role of age-groups in local politics and the economy has been declining recently with the rise of modern administration by regional and local governments. On the other hand, this can partially be explained by the failure of traditional strategies to cope with or adapt to CC since recently. The MNL result shows that membership to traditional cross age-group thematic institutions and age-groups plays a minor role in the adoption or non-adoption choices of households. Also, the government is implementing a few adaptation options (such as SWC, rangeland management) with the consultation of the age-groups at district and qebele.

Polygamy is also a common practice in the Nyangatom traditional system, which is a way of showing social status and wealth. Glowacki and Wrangham (2014) also reported similar cultural practices in Nyangatom. According to Nyangatom tradition, having more than one wife is a strategy to cope with drought and other environmental challenges. It is a means to overcome the labour shortage resulting from the splitting and distribution of herds over diverse pasturelands during times of drought, and the diversification of livelihood and crop cultivation to increase households' resilience to climate change-induced shocks. Studies conducted by Deressa et al. (2009) and Amare and Simane (2017) in the Nile basin, Ethiopia, confirm that having large family size helps households to diversify their livelihood incomes and split livestock. The women in Nyangatom reported to benefit from polygamy since the younger wife(s) helps with household's income-generating and livelihood activities such as crop cultivation (either rain-fed or river cessation), wild-food collection, water, and firewood fetching.

Income from livestock and crop production and access to a loan (including remittances) are important indicators of the financial asset and wellbeing of households in the Nyangatom economy. Livestock is the main source of income for the Nyangatom: aside from using animal products such as milk, meat, and blood for home consumption, they use livestock for exchange and sale to cover household's expenditures, buy machine guns for self-protection and guarding livestock along migration routes, respond to climate change risks and diversify household assets. Owning a large herd serves as insurance and makes the household resilient to climatic shocks and, yet, it is also raising risks to predation and conflict. Livestock is important for Nyangatom self-identification. According to survey participants and FGD, the "Nyangatom cannot be a man of the society without livestock ownership, particularly the cattle". Cattle ownership provides a means of paying dowry and, as such, is a prerequisite for marriage, as confirmed by Glowacki and Wrangham (2014). These observations support the findings of Glowacki et al. (2016) that livestock ownership is a source of both conflict and alliance formation.

4.2. Agro-pastoralists' perceptions of climate change and its impact on livelihood

4.2.1. Do agro-pastoralists' perceptions of CC match with weather station records?

The observed local climate changes are expressed in terms of changes in temperature trends, rainfall patterns, and seasonality. Similar expressions of awareness by agro-pastoralists about climate change have been reported in studies conducted in Ethiopia (Bewket and Alemu 2011; EPCC, 2015; Cherinet and Mekonnen 2019). Local perceptions of climate change in Nyangatom are in line with the analysis of the weather-station records pointing at climate change trends. Most survey respondents identified erratic rainfall and drought as major indicators of climate change. One of the elderly KI explains this situation as: "we used to have decadal hunger and drought, but today it comes more frequently". They characterized rainfall change by a declining amount, a discontinuous distribution, an erratic onset and cessation, and increasing drought frequency, i.e., trends that are likewise observed based on the weather records. For all stations, the high PCI values (>10) indicate a poor monthly and annual rainfall distribution. Similarly, the negative SRA values point at relatively low observed rainfall amounts in Jinka (1373 m.a.s.l.) and Turmi (934 m.a.s.l.) stations, i.e., below the reference level for the 1987–2016 period. The data at the Turmi station further shows an increase in the number of dry years since 2008, and for all weather stations, the high CV values point at a rainfall variability, hence more unpredictable start and end of the (MAM) rainy season (Table 2). As shown in Table 2 Jinka experiences most of its rain outside of the main rainy season. Contrary to the Turmi and Omorate stations, most rainfall at Jinka station falls outside the two rainy season mainly due to its higher elevation at the windward-side of a mountain complex gives a higher and more even distribution of rainfall throughout the year.

The temperature perception likewise matches the increasing trends in T-max and T-min recorded for the weather stations. The FGD participants in the Kibish area expressed this condition as: "*The rain is only spitting on our land; the next day it is hot again and the sun is burning the grass, the heat becomes intolerable*".

Various studies in Kenya (Opiyo et al., 2015), Ethiopia (Bewket and Conway 2007; Meze-Hausken 2004), and Burkina Faso (Zampaligre et al., 2014) confirm a similar trend in increasing drought, erratic rainfall, and rising temperature. Moreover, Bewket and Conway (2007) reported high PCI values for low land areas in Amhara regional state, whereas Enyew and Hutjis (2015) made similar observations on temperature increase for Jinka but significant changes in rainfall patterns were not reported. Similarly, perceptions of rainfall variability and increase of hot days and temperature were reported by (Cherinet and Mekonnen 2019).

4.2.2. Agro-pastoral perceptions of climate-change impact on livelihood

Impacts of climate change on agro-pastoral communities are complex, particularly in the ASAL of Africa (Thornton et al., 2011). The Nyangatom typically perceive climate change through its impact on their livelihood activities, particularly those of livestock and crop production, rather than relating it to meteorological definitions. Focus group discussion participants in Lorenkachawo qebele, for example, reflecting on more favorable climatic conditions in earlier times, with sufficient fodder and water resources in the vicinity, state that "In the past, we used to have to cultivate sorghum using rain and Omo River and most of the time our animals stay with us". Most respondents identified increasing drought, irregular and erratic rain, and rising temperatures as key indicators of climate change (Table 3) with adverse impact on livelihood, which is confirmed by other studies (e.g., Kassie et al., 2014).

Lack of water hampers rain-fed agriculture, reduces palatable fodder biomass, constrain river cessation crop production, and, hence, becomes a threat to the community's food security. Respondents explain the CC impact on livestock and crop production mainly through perceived food shortages, reduced availability of fodder and water, shorter growing period, an increased incidence of animal diseases (Table 3). The pastoral development department of the zone administrative explains the current situation in Nyangatom by referring to the following causal chain: "*The breakdown of rain-fed cultivation, as well as the falling of river retreat agriculture, is, therefore, resulting in a high dependency on unreliable food aid, causing hunger for children, woman, and elders, and increase long-distance livestock migration to conflict-prone area in the LOV*". Respondents stated that a more regular food shortage affects the traditional "*culture of sharing during a time of scarcity*" which is part of the Nyangatom mutual support system to cope with drought. They explained complained that "*no one is going to ask for sorghum because nowadays we all equally affected by drought*" and "*most of us depend on the food aid*".

Respondents frequently reported that rising temperatures and frequent drought resulted in regular fodder shortages which led to increased livestock migration. The Nyangatom stated that the prolongation of the dry season reduced pasture quality and quantity in nearby places, forcing pastoralists to spend more time on livestock herding and move to different, more distant grazing areas with higher risks of resource-based ethnic conflicts. The latter are typically for the tri-nation border areas of Ethiopia, Kenya, and south-Sudan, as described in various studies (e.g., Abbink 1993; Adano 2012). The increased herding time, long distances, and forced migration towards risky pasture areas have caused much stress among pastoralists.

Similar cases of reduced pasture quality increased fodder shortages and herd mobility was reported for Afar in Ethiopia (Sonneveld et al., 2010) and Turkana in Kenya (Opiyo et al., 2015). According to the FGD and KIIs, some fodder resources which were abundant 10 years ago are now no longer locally available due to the invasion of a new plant (weed) species in the district. The emergence of invasive species particularly Prosopis juliflora ('lopoliso') and the herbaceous weed Heliotropium longiflorum ('losigira') has hindered animal mobility and suppressed grass production, respectively. '*Losigra*' is widely distributed in Nyangatom qebeles including *Aipa, Lorenkachwo, Naragoy, Chunkura, Chare, and Kopiriyai*. Experts reported that invasive plant species typically grow in rain-deficient areas where local vegetation is not able to withstand prolonged drought (Adnew et al., 2019).

4.3. Agro-pastoralists' responses to climate change: coping and adaptation strategies

This study revealed the different strategies used by Nyangatom agro-pastoralist to cope with or adapt to climate change and its variability. Coping strategies, differently from adaptation, are more responsive to climate change in the short-term and concentrate on temporary rather than permanent adjustments of local livelihood activities (IPCC 2012). Climate-change coping and adaptation literature shows that the livelihood of most (agro)-pastoralists has evolved to some extent under variable climatic conditions in arid and semi-arid environments (Nyong et al., 2007). Similarly, the Nyangatom has developed a diverse complementary system of traditional strategies to cope with and adapt to climate variability (Table 4).

4.4. Mutual support and alliance formation

The formation of an *ethnic alliance* plays a critical role in coping with climate change in the lower Omo valley. The Nyangatom has a long history of living with neighbouring ethnic groups such as the Turkana and the Toposa with whom they have formed a cross-border alliance. The latter denotes a long-term relationship based on mutual respect and sharing of resources during good and bad times. The Nyangatom maintains a special relationship with the Toposa, which is evident from special terms they use to refer to one another such as '*the thigh of grandmother*' or '*Amuro ka-ata*', i.e., an expression to show a strong kinship. A good relationship does not only provide free access to pastureland but also opportunities for exchanging livestock with the cereals to supplement household diets and meet food demand.

However, Nyangatom pastoralists also experience hostility, particularly when extending migration routes towards the '*Ilemi Triangle*' situated at the periphery of the study area to the west of Lake Turkana and Mt. Kuraz. Since colonial times the area has been constantly disputed, e.g., claimed by South Sudan and Kenya while also bordering Ethiopia. The disputes have constrained various pastoral indigenous groups such as the Ethiopian Dassanech and Nyangatom, the Kenyan Turkana, and the Sudanese Toposa who use the '*Ilemi Triangle's*' vast pasturelands during the dry season.

4.5. Harvesting wild food and selling of forest products

The Nyangatom harvest "wild" foods during times of drought, as reported by key informants. This nature-based coping mechanism supplements their livelihood and enables them to survive the time of paucity (see Gebresenbet and Kefale 2012). Recently the Nyangatom also engage in the selling of tree products, such as firewood, charcoal, and wood for house construction which shows high demand due to the growing population at Kangaten, an extension of road networks and sugar project. Grade (2012) reported similar coping strategies in the Karamojong cluster in Uganda.

4.6. Territorial expansion and herd mobility

Territorial expansion and herd mobility are among the most important coping mechanisms to reduce the effects of drought-induced resource scarcity. Adano (2012) was reported similar trends in the LOV.

When resources are critical, agro-pastoralists in Nyangatom migrate with their livestock towards mountainous areas and beyond their territorial sections. They usually move away with most of their cattle and shoats, leaving few lactating cattle, shoat, and donkey behind at Nawi. This traditional rotational grazing which is guided by all age groups regardless of their hierarchy is important to manage the fragile environment, reduce conflict and pressure on pasturelands. Furthermore, the Nyangatom has a tradition of using astrology, cloud pattern, and intestine readings of goats or sheep to predict not only the local weather but also safe routes for livestock migration. Winnie et al. (2002) and Gebresenbet and Kefale (2012), reported similar practices among pastoralists in Nyangatom and Borana of Ethiopia and Kenya.

4.7. Herd diversification and herd splitting

Livestock diversification refers to a change in herd composition whereby a herd with cattle is being transformed into a herd with a variety of animals, such as sheep, goats, donkeys, and poultry. In response to recurrent droughts and shortage of livestock fodder, especially grasses, agro-pastoral communities in Nyangatom have long experiences using diverse animal species. Livestock diversification is a common practice of risk-aversion and coping with the dry environment in Nyangatom, as practiced elsewhere Tornay (1981). Similarly, livestock diversification was outlined as an effective adaption strategy for many agro-pastoral and pastoral communities in the ASALs of Africa (Speranza 2010; Opiyo et al., 2015). Although the Nyangatom have adopted *drought-resistant* animal species as a means of coping, they face inadequate animal extension services. Similarly, respondents attested that-in contrast to other areas - there was limited or no supply of improved *drought-resistant* crop varieties. The lack of drought-resistant crop varieties restrains the adaptive capacity of households, as confirmed by Maddison (2006). The households in Nyangatom further practice herd splitting: they give part of their stock to relatives and friends who are trustworthy and have access to better pasture and water. This traditional practice is not only implemented to deal with drier conditions during Akamu but also to escape from (potential) conflict-related damage. Similar studies indicate that herd splitting and diversification are an essential component of agro-pastoralists' coping strategies (Zampaligre et al., 2014; Opiyo et al., 2015).

4.8. Flood recession cultivation

The seasonal flooding of the Omo River is vital for the survival of the Nyangatom and the surrounding ethnic groups in LOV, as confirmed by Hodbod et al. (2019). The floods bring fertile soil and swamp the banks with water and minerals, making the riverbank cultivable. The crops grown in the flood-prone areas serve for both household consumption and commercial purposes, providing an additional income. During good years, they also serve as a means of exchange with relatives and neighbours and establish alliances via the culture of sharing. Moreover, sorghum, widely cultivated in Nyangatom, is considered as a holy crop due to its association with cultural ceremonies. However, recent declines in Omo river flooding – and its elimination since the large state-built Omo Gibe-3 dam began operation in 2016 - had a significant effect on flood recession cultivation, reducing crop yields to almost zero.

This, in turn, led to food scarcity, with no excesses to share and forcing the Nyangatom to become dependent on external supports such as food aid. The district and zone productive safety-net coordination offices also confirmed an increase in food-aid dependent households from 2450 in 2015–3500 in 2018. Similarly, informal credit and remittance from various sources are also getting much attention in response to frequent drought.

4.9. Irrigation

Study shows that adoption of irrigation can be a key strategy in minimizing the impacts of climate change (Amare and Simane 2017). Nyangatom also showed that river-cessation crop cultivation is an important adaptation strategy they used for decades. This practice is perceived as both a key adaptation and coping strategy by experts, communities, and clan chiefs. While the land along the Omo River has been available for the Nyangatom traditionally, it was recently leased to investors. Thus, the Nyangatom are forced to depend on erratic rain-fed and pond cultivation.

4.10. Soil and water conservation (SWC) techniques

Empirical studies show that farmers use SWC and rangeland management to deal with the impacts of climate change (Amare and Simane 2017; Ayal et al., 2017). Agro-pastoralists in Nyangatom is likewise perceived as innovative and able to overcome the hardship in arid and semi-arid environments by developing *SWC* techniques and rangeland management at the community level. However, during the FGD, the agro-pastoralists in Nyangatom claimed that '*we have started to implement SWC within the area enclosures, but nothing was harvested due to persisted drought*'.

4.11. Credit facilities

Similarly, various studies show that households with better access to credit facilities and remittance have enhanced adaptive capacity to climate change (Deressa et al., 2009; Amare and Simane 2017). However, only a few Nyangatom households make use of credit and saving schemes to buy food items, diversify livelihood incomes through take up activities not sensitive to climate change.

4.12. Migrate to urban center and wage employment

According to the community, desperate migration looking for wage employment is the less preferred option. Thus most of them are not engaged in wage employment but it is expected the demand to grow up with increasing awareness of income-earning opportunities provided by NGOs, government extension works, and investment projects.

Adaptation, in contrast to coping, is the adjustment or preparation for changing climate, to moderate potential harm. It is a complex process involving actions and strategies at several scales. Zampaligre et al. (2014) argue that (agro)-pastoralism provides more rational adaptation options against farming having the advantage of mobility. An agro-pastoral production system is characterized as an important adaptation strategy in that it combines livestock with crop production (Tornay 1981). It is argued that it would be more cost-effective to enable and strengthen the inherent adaptive capacity of agro-pastoralists and find ways to encourage their autonomous adaptation, rather than imposing new adaptation strategies. It is important, therefore, to build on indigenous knowledge to enhance adaptive capacity to climate change.

4.13. Use of multiple strategies

The results (Table 5) show that the likelihood of adopting a combination of two or three adaptation strategies decreases when the age of the household head is advancing. This implies that the aged households are less likely to adopt, adaptation options which might be associated with older people may tend to stick to traditional coping strategies rather than trying out the new adaptation strategies. This finding is contradicting with climate change adaptation studies among smallholder farmers in the Blue Nile basin in Ethiopia (Deressa et al., 2009; Amare and Simane 2017). Similarly, with increasing age, the likelihood of a non-adopter to adopt a combination of two strategies (two-MIX) increase. Also, the agro-pastoralists with CC experience observes the changes over time and compare such changes with the current climatic conditions, which enable them to respond to climate change. This result is consistent with a study conducted by Mabe et al. (2014).

With the increase in livestock holding, the likelihood that the non-adopter is shifting to adopting a combination of two or three adaptation strategies has increased. Similarly, an increase in livestock number decreases the likelihood of being non-adopter. With increasing crop production (income increase), the likelihood of a non-adopter (ref) to adopt a combination of two or three adaptation strategies increases compared to the adopters. In contrast, crop production decreases the likelihood of adopting two or three combinations of adaptation strategies. This is because high-income HHs may be less risk-averse, and as a result, they may not pay attention to adaptation measures against climate change. A study by Mandleni and Anim (2011) has shown that non-farm income decreased the likelihood of adaptation measures. In contrast, off-farm income (selling of forest and non-timber forest products, wage employment at road construction, sugar project, and private farms) significantly increases the probability of investing in and adopting a combination of three adaptation strategies. Similar findings were also reported in studies by Deressa et al. (2009) and Mabe et al. (2014), where household income is positively associated with adaptation measures.

Climate information (seasonal forecasts or early warnings) was an important determinant in response to CC. The sources of information required to decide on types of adaptation strategies are obtained from the age-groups (age-set), government, and NGO-extension services. The local mass media and personal observation were other sources of climate change information. A household with access to climate information is more likely to take action to reduce risks related to climate change. This is confirmed by the model results of this study (Table 5): the agro-pastoralists with access to CC information are more likely to adopt a combination of two or three adaptation strategies compared to those who lack CC information. Another study also reports a strong positive relationship between access to CC information and adaptation (e.g., Deressa et al., 2009). Household membership to traditional cross-age group institutions positively and significantly determines the adoption of a combination of three-MIX adaptation strategies. This is probably so because the agro-pastoralists obtain information on adaptation options from their traditional cross-age group thematic institutions and gatherings.

Nyangatom responses to climate change and their differential levels of coping and adaption.

The responses to climate change by agro-pastoralists in Nyangatom can be differentiated based on their function as a coping strategy, an adaption strategy, or a mixture of both. A functional assessment was conducted on the Nyangatom important responses to climate change to determine households' overall relative level of coping and adaptation efforts. The score for each response was evaluated against the weighted criteria shown in Table 1. Fig. 4 is a visual representation of the assessment results. It shows that responses mainly functioning as coping strategy are migration, remittance, food aid, and selling of household assets whereas those that mainly serve as adaption strategy include (small-scale) irrigation and herd diversification. The use of food aid as a means of coping was likewise reported in studies of the Nile basin (Deressa et al., 2009) and Qobo areas (Kassie et al., 2014). Traditional herd insurance and herd rejuvenation are examples of responses that function as both coping and adaption strategies.

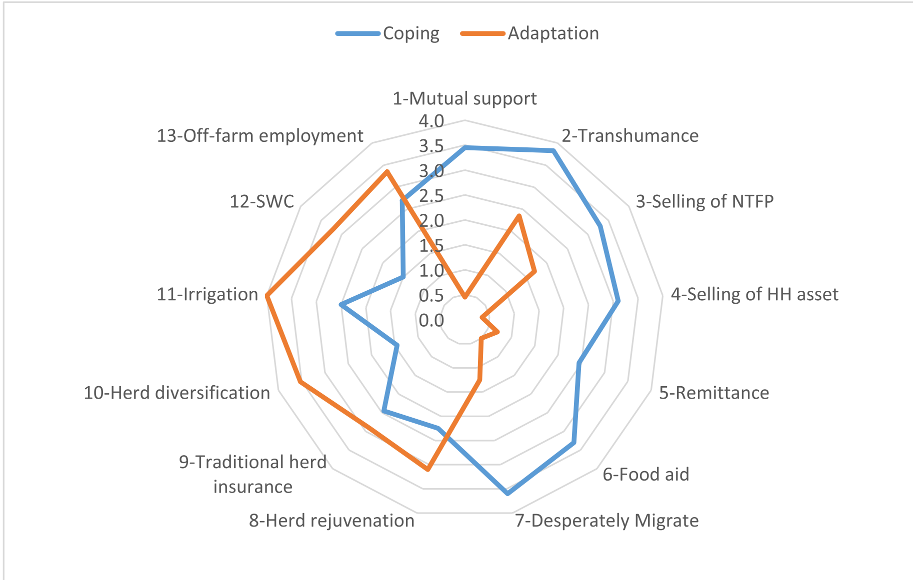

Fig. 4. Relative coping and adaptation indexed scores for different climate-change response strategies used by the Nyangatom agro-pastoralists.

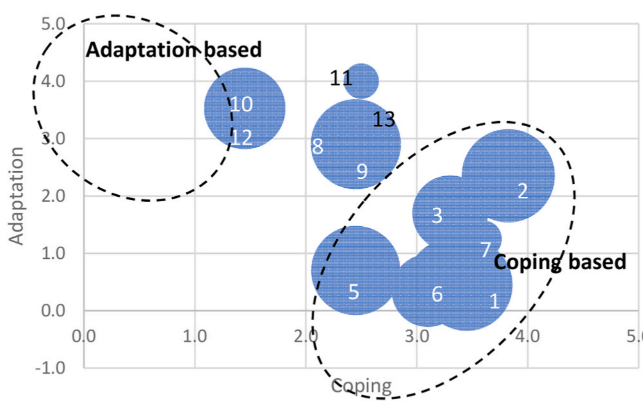

Fig. 5. Relative distribution of Nyangatom agro-pastoralists responses to CC.

Fig. 5 shows the relative distribution of Nyangatom households along the coping and adaptation index axes. The circles correspond to the thirteen household's strategies in Fig. 4, and the circle size corresponds to the number of households using a given strategy. Additionally, the composite index of technology adoption (CIA) was computed (see section 2.2.3). The index for the number of applied adaptation strategies is about 0.19 which is much lower compared to the index of 0.68 for the number of applied coping strategies. These results correspond with the outcomes in Figs. 4 and 5: the majority of the Nyangatom households are coping-based and lags behind a transformation towards more sustainable adaptation-based strategies. Although the coping strategies are not the most optimal pathway of responding to climate change, they are affordable and therefore employed by the Nyangatom agro-pastoralists. Policies directed at enhancing access to CC information and off-farm income may significantly increase the adoption of a combination of CC adaptation strategies as shown in this study (section 3.3).

4.14. Towards CC adaptation: overcoming barriers and strengthening facilitators

The adaptation measures employed by the Nyangatom were few in number and consisted of short-term adjustments. This probes the question of what factors limit the agro-pastoralists from adopting a greater variety of long-term CC adaptation strategies. The most common barriers to climate change adaptation, as reported by respondents in this study, are poor rural infrastructure, conflicts, lack of human capital, and the dwindling of traditional social capital. Also, the erratic nature of rain and recurrent drought, limited access to alternative livelihood options, and reduced flooding of Omo River were mentioned. Other studies confirm the importance of CC adaptation barriers related to accessibility to climate information (Roncoli et al., 2002), the socio-economic status of the household (Ziervogel et al., 2006), and policy and institutional environment (Agarwal 2008).

Many households in Nyangatom anticipated that the implementation of various adaptation strategies can limit the impact of climate change. However, some of the options are not viable due to cultural, economic, and political barriers (Fig. 3). Persistent drought and conflict are the most disruptive factor undermining Nyangatom adaptive strategies. Currently, the herders are forced to move further down to *Lomolomur* towards the Surma territory in search of pasture and water due to prolonged drought and conflict with Turkana. Similarly, the intermittent conflict with Dassanech and Hamer also restricts the access and use of dry-period pasturelands located south and southeast of the Nyangatom including part of the Mt. Kuraz. The discussion with FGs and KIs confirmed that most agro-pastoralists in Nyangatom decided not to move towards Kuraz bordering the Turkana. Some communities reported the leasing of the agro-pastoral grazing land to agricultural investors as an emerging challenge that is expected to hinder the free mobility of livestock and the cultivation of riverbanks. Similar studies on (agro)-pastoral areas show conflict as a key factor hampering livelihood and adaptation efforts in the LOV and Omo-Turkana basin (Abbink 1993; Opiyo et al., 2015).

The Nyangatom lacks socio-economic and infrastructural environments that facilitate the local CC adaption efforts. Most respondents reported limited access to credit facilities, extension services, climate change information, education, and markets. Furthermore, the FGD participants, KI, and experts confirmed that most desired adaptation options such as irrigation, livelihood diversification, credit facility, market outlets are not easily accessible or do not exist at all in the district. Different studies confirm the lack of these infrastructure has reduced the adaptive capacity of households, particularly those engaged in climate-sensitive economic activities (Nhemachena and Hassan 2007; Deressa et al., 2009).

5. Conclusions

Agro-pastoralism is the predominant livelihood system in Nyangatom. It is highly dependent on livestock mobility because of seasonal variations in pasture and water, and where possible is combined with subsistence crop cultivation. The Nyangatom increasingly suffer from climate change. The analysis of rainfall and temperature data recorded at local weather stations shows that CC is indeed happening in the Nyangatom which is well confirmed with the local perceptions. To come up with feasible strategies to support the Nyangatom to adapt to CC, it is important to understand the nature of the CC impacts, the perceptions of the Nyangatom communities, and their current coping and adaptation practices.

Over the years, the Nyangatom agro-pastoralist communities in LOV have developed multiple strategies of coping and adaptation to climate change, including livestock mobility, herd diversification, flood cultivation, remittance, food aid, and collecting wild fruits and leaves. However, respondents agreed that more frequent exposure to extreme climatic events has increased their vulnerability in recent decades. Generally, the Nyangatom agro-pastoralists have become more reliant on food aid and remittances to cope with the effects of a changing climate as their culture of sharing is fading away. Conflict with neighbouring ethnic groups was mentioned as a major factor in limiting livestock mobility, in addition to a prolonged drought that deters coping strategies. Limited access to extension services, climate change and agricultural information, and off-farm income further deteriorate their position.

Creating a conducive environment in which agro-pastoralists are supported in strengthening their livelihood and generating off-farm income will contribute to more sustainable CC adaptation practices. Improvements of local infrastructures, by providing appropriate credit facilities and enhancing market access, animal extension services, asset-based assistance rather than food aid, and basic services such as education will help to improve agro-pastoralists' resilience against climate change. Furthermore, an integrated action is required to combine and gradually replace local ad-hoc, short-term strategies with long-term adaptation strategies. This will bring about a gradual transformation from coping-based towards adaption-based communities. This action, in turn, will require a regular consultation of local communities and the engagement of traditional agro-pastoralist institutions.

CRediT authorship contribution statement

Adane Kebede Gebeyehu: Investigation, Formal analysis, Writing – original draft, the main investigator involved in planning, design, data collection, analysis, and drafted the manuscript and designed the figures and tables. He develops a map of the study area. All authors discussed the results and commented on the manuscript. **Denyse Snelder:** Supervision, Writing – original draft, supervised data analysis, drafting the manuscript, and layout. All authors discussed the results and commented on the manuscript. **Ben Sonneveld:** Supervision, supervised the whole research work, assisted in interpreting the results, and worked on the manuscript. All authors discussed the results and commented on the manuscript. **Jon Abbink:** Supervision, supervised the whole research work, assisted in interpreting the results, and worked on the manuscript. All authors discussed the results and commented on the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices.

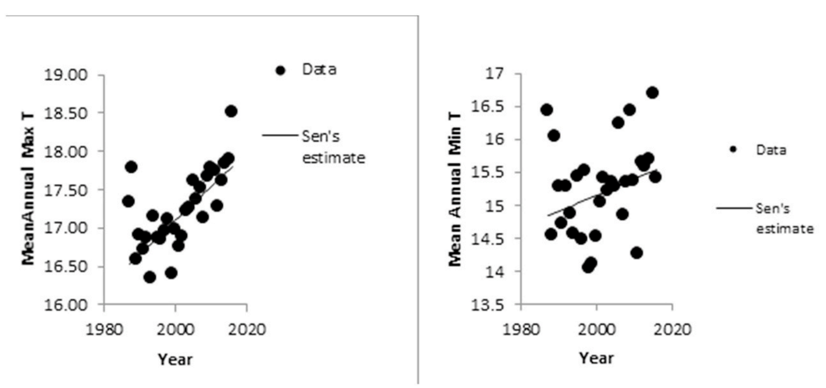

Fig. A.1. Mean annual maximum and minimum temperature at station Jinka (Test Z = 3.50; Q = 3.96E-02; significant @0.001)-right- Mean min temperature at station Jinka (significant @0.01).

Table B.1
Socio-demographic characteristic of survey respondents, Nyangatom (2017)

Variables	Frequency	Percent	Mean (SD)	Adopter		Non adopter	
				Mean	SD	Mean	SD
Age			40.4 (8.93)	42.77	7.59	39.79	9.16
20–45	210	54.96					
46–60	151	39.32					
>60	23	5.99					
Education-dummy				.066	0.25	.046	0.21
Illiterate	364	95.04	1.05 (0.217)				
Literate	19	4.96					
Gender of HH head-dummy				.579	0.50	.616	0.48
Female	149	38.80	1.39 (0.49)				
Male	235	61.20					
Marital status-dummy				.974	0.16	.977	0.15
Single	12	3	1.97 (0.17)				
Married	372	97					
Ethnic group							
Nyangatom	344	89.58					
Kwegu	2	0.54					
Murule	38	9.90					
Number of partners			1.59 (0.73)				
1-wife	202	53					
2-wives	139	37					
3-wives	31	8					
4-wives	8	2					
Family size			6.56 (2.95)	5.961	2.3	6.7	3.1
0	2	0.52					
1–5	167	43.49					
6–10	172	44.79					
>10	43	11.2					
Access to credit-dummy			1.7 (0.46)	.11	0.31	.35	0.48
Yes	115	29.95					
No	269	70.05					
Livestock ownership			99.8 (193.67)	25.87	38.08	72.89	121.72
Cattle	384		88.59 (186.27)				
Goat	373	–	5.29 (8.75)				
Sheep	347	–	5.50 (9.56)				
Donkey	270	–	2.46 (3.61)				
Membership to traditional institutions				.171	0.38	.346	0.48
Yes	119	31.1	1.69 (0.46)				
No	264	68.9					
Age-groups/age-set							
Elephant	70	18.2	2.45 (0.93)				
Ostrich	116	30.2					
Ibex	150	39.1					
Buffalo	48	12.5					

Table B.2
Description of explanatory variables used to determine factors affecting Nyangatom adaptation strategies.

Category of variable	Variable	Type of variable	Variable measurement and (sign)
Household's socio-economic characteristics	Education	Dummy	1 literate '0' otherwise (+)
	Age	Continuous	# of years since birth (+)
	Sex/gender	Dummy	'1' if male otherwise 0 (±)
	Household size	Continuous	# number of individuals in the HHs (+)
	Farm income	Continuous	Income from farming activities (+)
	Crop productivity	Dummy	'1' if crop productivity increase '0' otherwise (+)
	Off-farm income	Dummy	'1' if HH obtain off farm income '0' otherwise (+)
	Marital status	Dummy	'1'if married otherwise '0' (±)
	# of partner	Continuous	# of partner for male headed HH
	Livestock ownership	Continuous	# of livestock owned in TLU (+)
Institutional factors	Access to extension services (crop/animal)	Dummy	'1' if farmer has access and '0' otherwise (+)
	Information on climate change	Dummy	'1' if farmer has information on CC and '0' otherwise (+)
	Access to credit/loan facility	Dummy	'1' if farmer has easy access to credit/loan and '0' otherwise (+)
	Access to market	Dummy	'1' if farmer has access to market '0' otherwise (+)
	Membership to TI	Dummy	'1'if member and '0'otherwise
	Info on RM	Dummy	'1' if access information and '0' otherwise
Age-set	Age-group	Dummy	'1' if involved in decision making and '0' otherwise

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