GeoJournal (2023) 88:5775–5793
https://doi.org/10.1007/s10708-023-10941-3

Climate change in the Sidama region, Ethiopia: linking perceptions and adaptation

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Accepted: 28 August 2023 / Published online: 19 September 2023

Abstract Climate change is expected to have serious socioeconomic impacts on smallholder agriculture, but overall impacts will also depend on the extent of household adaptation to climate change. This study investigates household-level factors that may help describe and explain perceptions about climate change and examine how these perceptions influence choices related to specific land-use adoption strategies. Logistic regressions were applied to address these objectives. Cross-sectional survey data were derived from 315 randomly selected smallholder mixed farmers in Ethiopia. The results indicate that a significant number of farmers believe that temperatures have increased over the last 10–20 years and that precipitation has declined. Education, agroecological settings, and social capital significantly influenced perceptions of increased temperature. Gender, distance, access to climate change information, and social capital significantly influenced perceptions of reduced rainfall. The odds of decisions to adopt specific land-use adaptation measures to climate change are significantly influenced by perceived changes in rainfall and temperature but also by social, human, and natural capital access. Adoption is also linked to gender, distance to markets, access to climate change information, and farm location. Thus, rural interventions aimed at addressing more general agricultural adaptation to climate change should account for these factors.

Keywords Climate change · Perceptions · Adaptation · Logistic regression

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Introduction

How smallholder farmers respond to climate variability and change-related events has become an area of great concern (Yiridomoh et al., 2021). Climate change affects agriculture mainly through changes in temperatures and rainfall during planting, growing or harvesting seasons (Mahato, 2014) and through changes in pests and diseases (Jacobs et al., 2019). Among African countries, Ethiopia is one of the most at risk from climate change impacts on agricultural productivity and food security (Mekonnen et al., 2021). Smallholder agriculture in Ethiopia contributes largely to the economy (Eshete et al., 2020). Nevertheless, smallholder farmers face impoverishment, malnutrition, and even forced migration due to severe climatic risks (Mati & Merrey, 2021).

The changes in temperature and precipitation have a direct impact on the quantity and quality of crop yield, feed, and surface and groundwater for humans and livestock (Gezie, 2019; Lemi & Hailu, 2019). Subsequent drought caused by too little rainfall, floods caused by too much seasonal rainfall, deep-rooted economic and livelihood reliance on smallholder agriculture with traditional farming techniques and very low productivity, and soil degradation caused by overgrazing and deforestation combined with poor complementary institutional services (extension, credit, marketing, infrastructure) have already impaired the capacity of smallholder farmers to adapt to climate change (Deressa et al, 2011).

A better understanding of how, why and under what conditions farmers perceive and adapt to climate change is thus needed to craft future adaptation policies. Therefore, this research aims to investigate household-level factors that may explain perceptions about climate change, examine how perceptions of climate change influence choices related to land-use adaptations, and examine those household-level factors that may explain specific land-use adaptation strategies. We hope that this information will contribute to a policy that can give explicit attention to climate-smart crops and livestock, natural resource management, and ecosystem services in the 10-year perspective plan in the country.

Literature review

A review of the literature indicates that Ethiopia has experienced droughts (including famine in some years) for hundreds of years, including 1888–92, 1899–1900, 1920–22, 1933–34, 1973–74, 1983–84, 1987–88, 1990–91, and 1993–94 (e.g., Adem et al., 2016). A previous study reported that droughts in Ethiopia can shrink household farm production by up to 90% compared to a normal year (Tazeze et al, 2012). Bogale and Temesgen (2021) demonstrated that the 1984/85 drought reduced Ethiopia's agricultural production by 21%, which led to a 9.7% decrease in GDP. General circulation models (GCMs) for Ethiopia further forecast that temperatures will increase by 0.9–1.1 °C by 2030, 1.7–2.1 °C by 2050, and 2.7–3.4 °C by 2080 compared to the 1961–1990 mean annual temperature (Zegeye, 2018).

However, forecasts for rainfall show a mix of increasing and decreasing trends with high intra-annual variability over the country (Asfaw et al., 2018). Additionally, a study confirms that rainfall variability in the growing season and its onset, offset, and duration have multiple impacts on the Ethiopian economy in general and on smallholder agriculture in particular (Matewos & Tefera, 2020). Figure 1 (above) derived from 25 (1991–2016) years of rainfall data in the study districts confirms a mix of increasing and decreasing rainfall trends, during which farmers might have experienced difficulties with establishing plans for crop and livestock production. Climatic extremes and enormous variability between years, seasons, months, and rainy days are concerning in Ethiopia, necessitating adaptations to guide future adaptation strategies to guarantee future rural livelihood outcomes (increased food security, improved wellbeing, reduced poverty and vulnerability, increased income and sustained natural resource bases) (Deressa et al., 2011; Esham & Garforth, 2013).

The impacts of climate change will not be equally distributed among people; they are likely to vary depending on the ability of the system to adjust to climate changes by moderating potential damages, exploiting related opportunities or coping with the consequences (Kurukulasuriya & Rosenthal, 2003). Thus, knowledge of perceived adaptation methods and socioeconomic and environmental factors may assist in developing policies that can strengthen adaptation via investment in these factors (Deressa et al., 2009). Ecological security, livelihoods, and the long-term viability of rural development all depend on the success of agricultural livelihood/adaptive strategies, which may be primarily influenced by livelihood assets/capital along with other factors (Chen et al., 2018).

Adaptation can be undertaken by an individual for their own benefit, or it can be composed of actions by governments and public bodies to protect their citizens (Adger et al., 2005; Agrawal, 2008; Warner, 2007). Similar to the IPCC (2001), we define adaptation to climate change as an adjustment in a system (ecological, social, or economic) in response to observed or expected changes in climatic stimuli and their effects and impacts to alleviate adverse impacts of change or exploit new opportunities induced by climate change.

Adaptation patterns are quite varied, and in our analysis, they are mediated by climate change perceptions on the one hand and on the other hand by a combination of household capital assets, institutions and agroecology-related variables, which collectively

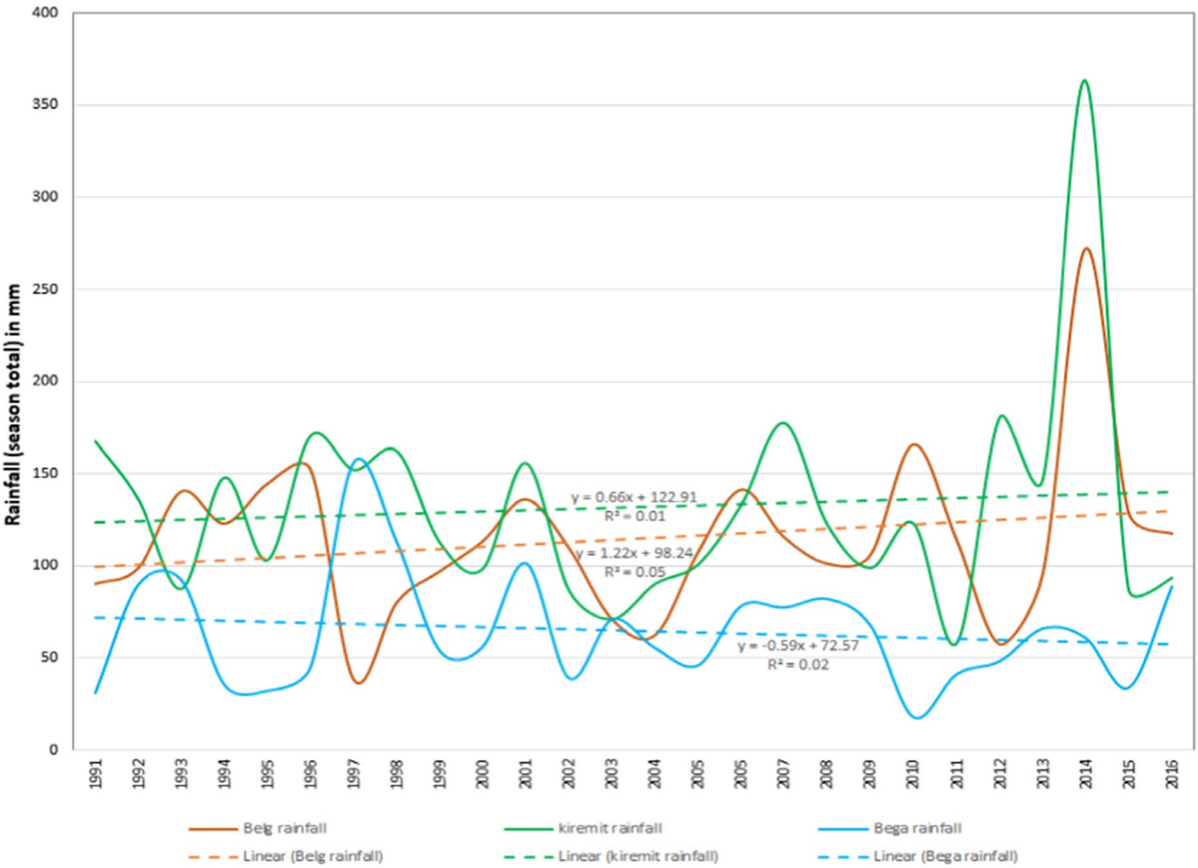

Fig. 1 Seasonal rainfall trends over the past 25 years (1991–2016) in the study area, Sidama, Ethiopia (Meteorological Agency of Ethiopia, 2019)

determine different sets of optimal adaptations for different groups of households (Deressa et al., 2011). Micro -level adaptation options encompass on-farm micro-level adaptations (irrigation, crops, and livestock intensification), income-related responses (insurance and credit schemes, income diversification, nonfarm migration), institutional changes (prices, subsidies, agricultural support, and trade), and technological innovations (crop and livestock varieties, water and soil management, improved animal health) (Kurukulasuriya & Rosenthal, 2003; Smit & Skinner, 2002).

Human cognitive factors such as the perception of risk and uncertainty influence adaptation behaviour (Grothmann & Patt, 2005). A previous study supports that the concept of "perception" is central to understanding and reacting to risks related to climate change, as well as to capturing how we interpret reality and experience to discern and inform our reaction to form, behaviour, and action (Friedman et al., 2015). Farmers' perceptions of climate change are of great concern because farmers who perceive potential consequences from climate change are more likely to support policies and programs that aim to address problems related to climate change (Niles et al., 2013). Maddison (2007) argues that adaptation to climate change first requires farmers to notice that the climate has changed and then identify and implement potential adaptation strategies. Nevertheless, perceptions alone are not sufficient for adaptation to occur since farmers who have perceived the change in climate may not adapt (Maddison, 2007; Mertz et al., 2009).

The majority of the population in both developing and developed world has perceived climate change (Deressa et al., 2011); however, perceptions or awareness of climate change are influenced by different contextual socioeconomic, institutional and environmental factors (Maddison, 2007; Semenza et al., 2008). Deressa et al. (2011), for instance, indicated that in Ethiopia, age, wealth, access to information, and social capital are likely to influence perceptions of climate change. Gbetibouo (2009) found that in South Africa, fertile soil, access to irrigation, and location in wetter areas negatively influenced perceptions of climate change. However, the author found a positive association between farmers' perceptions and education and larger farm size. Semenza et al. (2008) also reported that higher incomes are more likely to influence farmers' perceptions of climate change. Diggs (1991) indicated that households in dry land are more likely to describe climate change.

Few studies in Ethiopia have attempted to investigate the empirical association between perceptions of and adaptation to climate change. However, most of these studies were undertaken at regional levels (Kurukulasuriya & Mendelsohn, 2008; Maddison, 2006, 2007); were confined to the Nile basin and mainly relied on data collected during 2004/2005 (Addisu et al., 2016; Asrat & Simane, 2018; Deressa et al., 2011; Tilahun & Bedemo, 2014); or applied qualitative methods (Hameso, 2018) to link perceptions to adaptation to climate change. Although these studies are informative, their results are intentionally broad so that they can be empirically associated with perceptions regarding and the likelihood of adaptations made at the specific farm level. These studies focused on aggregated adaptation strategies; however, factors influencing the adoption of adaptive measures may vary depending on the specific adaptation measures suggested. Moreover, studies using the sustainable livelihood approach (SLA) to understand factors influencing the likelihood of the decision to adopt an adaptive measure are scarce.

Materials and methods

Conceptual framework: a sustainable livelihood approach (SLA)

This study used a modified version of the SLA as its analytical tool. This approach can take perceptions of climate change into account as a prerequisite for climate change adaptation on the one hand and can consider factors affecting the livelihoods of poor smallholder farmers on the other hand (DFID, 1999). The most important assumption with SLA is that a sustainable livelihood can cope/adapt and is able to recover from stress and shocks, thereby maintaining or enhancing its capabilities and assets without undermining the natural resource base (Chambers & Conway, 1992; De Kock, 2015).

The first assumption in this further modified version of SLA is that farmers' perceptions of climate change are influenced by a combination of the five livelihood capital assets, institutional factors such as access to climate change-related information, agro-ecological settings and other control variables. The second assumption is that the probability of choosing a farm-level specific adaptive strategy is influenced by a combination of these factors, including perceptions of changes in temperature and rainfall.

Another important assumption in this concept is that farmers choose a given strategy at a point in time only by assuming maximum livelihood outcomes defined as increased income, improved wellbeing, food security, resilience to shocks and improved sustainable natural resources. These livelihood outcomes may be used to smooth household consumption, solve liquidity problems, and accumulate wealth for future investment, which may be used to invest in alternative adaptive/livelihood strategies (see Fig. 2).

The third assumption is that exogenous factors, including the vulnerability context, climatic stressors and their adverse impact on wellbeing, crops, livestock, water, and other livelihood resources, affect the speed of climate change perceptions and the rate of adopting adaptive/livelihood strategies. Damage to or the erosion of livelihood assets may occur if they are sold to address various household-level socioeconomic scenarios induced by interplay among these factors (see Fig. 2).

The study was conducted in Sidama Regional State located 275 km southwest of Ethiopia. Rainfed smallholder agriculture forms the main source of farm household outcomes and is crucial for the regional economy (Hameso, 2015). Vulnerability and poverty at household and regional levels have deepened in response to land fragmentation and degradation exacerbated by a high population density (690/km sq.) that is six times higher than the national population density (115 person/km sq.); a warming climate; and increasing weather extremes, including

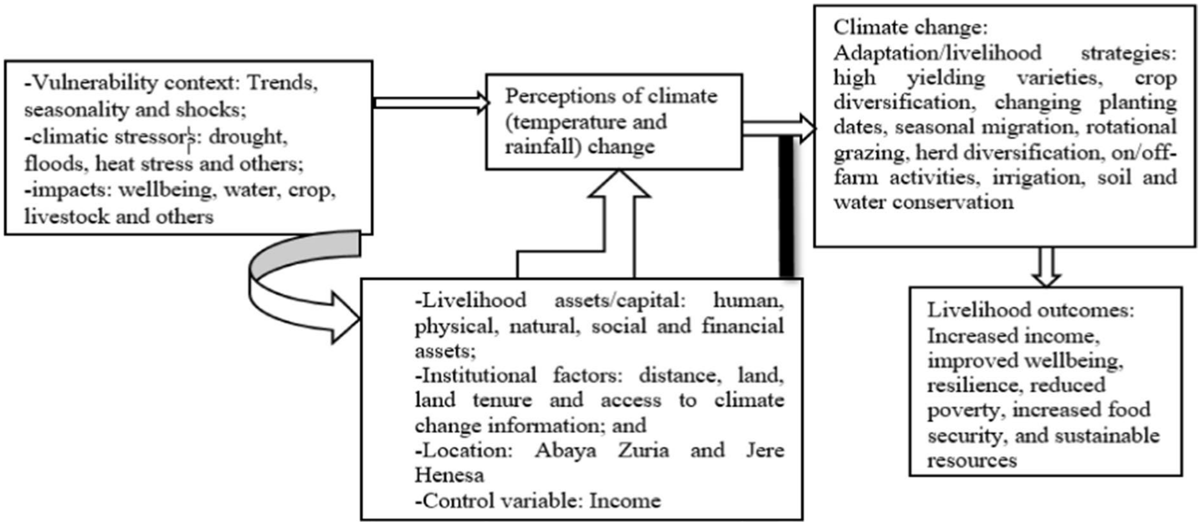

Fig. 2 The modified version of the sustainable livelihood framework (SLA). Source: Adapted from IISD (2003) and DFID (1999, 2001)

frequent water stress, droughts and floods, and unpredictable rains heralded by climate variability and change (Eakin et al., 2014). To continue food production in this region, therefore, farmers would have to take perceived adaptive measures to reduce their vulnerability to climate change.

This study purposively selected two highly vulnerable districts (Lokka Abaya and Hawassa) among 19 districts in the region (Fig. 3). Abaya Zuria and Jere Henesa kebeles (the smallest administrative unit) were randomly selected from the respective districts.

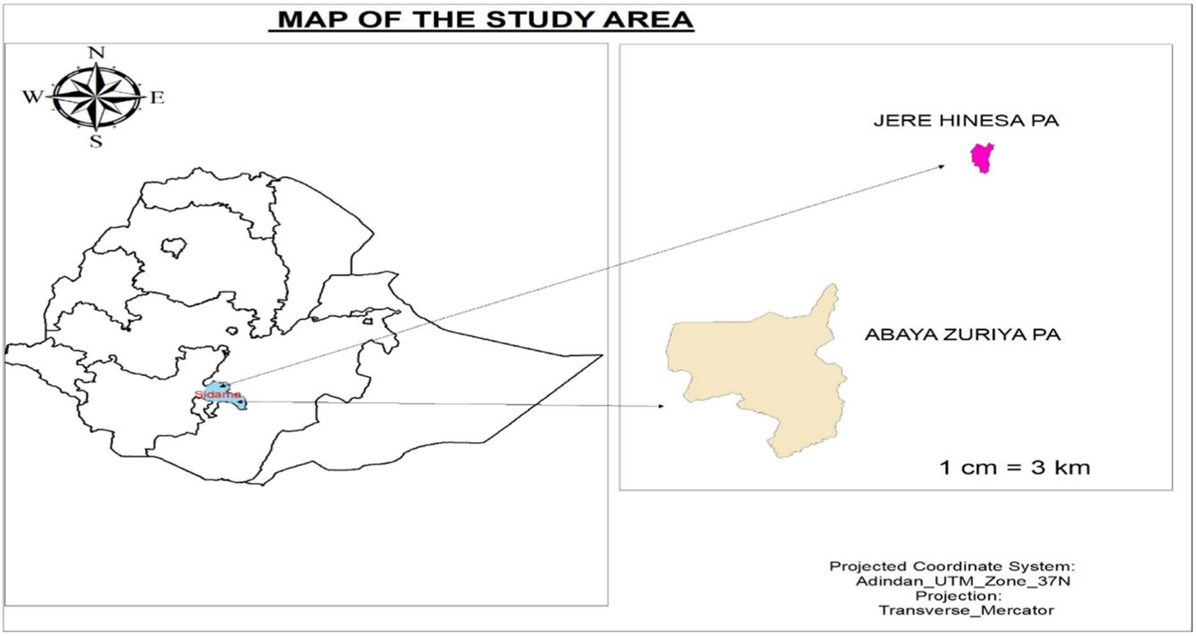

Fig. 3 Map of the study areas

Their vulnerabilities can be attributed to differences in elevation, agro-ecological settings, population density, access to markets and grazing land, and potential livelihood implications (see Table 1). The areas also have similarities in terms of livestock-driven livelihood strategies and their susceptibility to climate-related challenges. Moreover, these areas were recently declared to be drought disaster areas. Table 1 presents a summary of details on the study locations.

Data

A preliminary survey and several focus group discussions (FGDs) conducted before the actual survey helped the researchers understand the study areas and obtain information on what farmers knew about climate change, its related hazards, vulnerable local groups, and the existing adaptation strategies. This information also helped restructure the survey questionnaires. The data were collected from 315 randomly selected households. There were 1003 households in Abaya Zuria and 801 households in Jere Henesa. Accordingly, to address the study objectives, a larger sample size (175 out of 1003 households) was drawn from Abaya Zuria, and a smaller sample size (140 out of 801 households) was drawn from Jere Henesa.

Model specification

To analyse the factors that influence the likelihood of perceived change in climate (temperature and rainfall) and the decision to adapt to perceived climate changes in two of the study locations, a discrete choice model is used. Data from both study locations were pooled, and the dependent variables for perceived change in climate and adaptation to perceived change in climate were created. The dependent variables were dummy variables equal to 1 if the farmer perceived decreasing rainfall and increasing temperature and adopted any of the adaptation options in response to perceived changes in temperature or rainfall and 0 otherwise.

Analysis of this dependent variable requires a binary response model. In this case, we have two options, the logit and probit models. Logit and probit models can be derived from an underlying latent variable model (Moustaki, 2000).

$$y^* = \beta_0 + x\beta + e_i,\ y = 1(y^* > 0);\ y = 0(y^* \leq 0)$$

where y* is the unobserved, or latent, variable; x denotes the set of explanatory variables, β is a vector of parameters to be estimated; 1 is normally distributed disturbance term with 0 mean; a constant standard deviation of d e_i is the error term; and 1 [y* > 0] defines the binary outcome.

Table 1 Socio-economic and biophysical features of the study locations

Features	The study locations	
	Abaya Zuriya	Jere Henesa
Mean distance to regional capital (km)	126	26
Road condition	Dry-season, bumpy	All-weather, slightly bumpy
Access to inst. Services	Poor	Average
Staple foods crops	Maize	Maize, ensete
Dominant livelihood strategy	Livestock keeping followed by farming	Farming followed by livestock keeping
Altitude (a.s.l)	1500–1768	1700–1850
Rainfall pattern	Bimodal	Bimodal
Annual rainfall (mm)	833–1574	900–1400
Mean annual temperature (^{0}C)	26–29	23–27
Main agroecology	Lowland, rugged	Dry midland, rolling plain
Soil type	Loamy, average fertility	Eutric and hablic cambisol, poor
Main water sources	Lake Abaya and River Bilate	Lake Hawassa
Mean distance, common pastures (km)	1.7	7.2

Source: District Office of Agriculture and Rural Development, 2020

Therefore, to avoid the problems associated with the linear probability model, this study used the logit model to determine the factors that influence farmers' perceived change in climatic factors (rainfall and temperature) and the likelihood of farmers' decisions to adapt to perceived climate change. A set of independent variables was used to draw particular conclusions about the ways in which perceived adaptation could be promoted within the given context (see Table 2).

The model variables

Results and discussion

Changes in temperature and rainfall

Our results in Table 3 revealed that 92% and 65% of respondents perceived increasing temperature and decreasing rainfall over the last one and two

Table 2 Description of the model variables

Dependent variables	Description	Expected sign
Perceived changes in rainfall	Binary = 1 if the respondent perceives decreasing rainfall trend in the past 10–20 years; 0 otherwise	
Perceived changes in temperature	Binary = 1 if the respondent perceives increasing temperature trend in the past 10–20 years; 0 otherwise	
Independent variables		
Age	Continuous, age of the respondents measured in years	(+)
Gender	Dummy = 1 if male; 0 otherwise	(±)
Family size	Continuous, number of persons living together in the last six months	(+)
Cultivated land	Continuous, measured in hectares	(+)
Tropical livestock	Continuous, measured in tropical livestock units	(+)
Natural capital	Continuous, aggregated value (birr) of cultivated land and livestock	(+)
Physical capital	Continuous, aggregated value (birr) of fixed and current assets except land and livestock	(+)
Financial capital	Continuous, savings minus debt (birr) or net savings	(+)
Human capital	Continuous, measured in schooling years	(+)
Social capital		
Bonding social capital	Dummy = 1 if there is access to family, friends, relatives and neighbourhood ties; 0 otherwise	(+)
Bridging social capital	Dummy = 1 if there is connectedness to a development agent (DA) and local administrative workers; 0 otherwise	(+)
Institutional trust	Dummy = 1 if have trust in local administration, Farmers' Training Centre (FTC), and Farmer's Field Day (FFD); 0 otherwise	(+)
Social trust	Dummy = 1 if have trust in people (neighbours, friends, relatives, model farmers); 0 otherwise	(+)
Norms of reciprocity	Dummy = 1 if have membership in self-help groups (idir and equip) and community development groups (watershed management, and forest development); 0 otherwise	(+)
Distance	Continuous, measured in walking km to district main market	(−)
Access to information	Binary, with 1 indicating access and 0 indicating lack of access	(+)
Land tenure	Dummied as 1 if own, 0 otherwise	(±)
Location	Binary = 1 if Jere Henesa (wetter area), 0 otherwise (dry areas)	(±)
Per capita income	Continuous, aggregated value (birr) of net income from different sources divided by household size	(+)

Source: Literature review and local context, 2020

Table 3 Level of perceptions of climate change in Sidama, Ethiopia, 2020

Change category	Study locations			
	Sample (N = 315)	Abaya Zuria (n = 175)	Jere Henesa (n = 140)	χ2-test/*P* value
Increasing temperature	92	98	86	19.5***
Decreasing temperature	7.0	2.0	12	
Constant	1.0	0	2.0	
Increasing precipitation	34	31	37	8.8**
Decreasing precipitation	64.5	69	60	
Constant	1.5	0	3.0	

Source: Survey data, 2020

** and *** respectively represent significance levels at 5% and 1%

decades, respectively. In contrast, 7% and 34% perceived decreasing temperature and increasing rainfall, respectively, over this period. If we compare the perceived level of climate change by study location, a significantly larger share (98%) of farmers situated in drier areas (Abaya Zuria) perceived increasing temperature (98%) and perceived decreasing rainfall (69%) (Table 3). Studies (Deressa et al., 2009; Diggs, 1991) confirm that farmers living in drier areas are more likely to describe climate change as warmer and drier compared to wetter areas due to more exposure to climatic risks.

According to focus group discussants, the outcomes of climate changes impacts include the following: changing planting and harvesting times; increasing crop loss induced by late/early onset/offset of rainfall or too much or too little rainfall during critical times; increasing livestock/crop/human disease; drying surface water (river and springs) and underground water sources; intensely decreasing land/livestock/labour productivity; intensifying vulnerability and poverty; decreasing access to grazing resources; increasing school dropout rates induced by hunger, frequent soil erosion; and recurrent and subsequent flooding and drought followed by damaged livelihoods.

Determinants of perceptions of change in temperature and rainfall

The main goal of this section is to investigate the determinants of perceived change in rainfall and perceived change in temperature over the past one and two decades in rural districts of Sidama, Southern Ethiopia. To understand how sensitive farmers perceived climate change to livelihood assets, institutional factors and agro-ecological settings, we ran logit regression, and the results indicated strong explanatory power with a significant Wald χ2 ranging from 72 to 78 and $P < 0{\cdot}001$ (Table 4).

The results showed that farmland size seems to increase the probability that farmers perceive long-term changes in rainfall and temperature. The marginal effect confirms that the probability of farmers' perceived change in rainfall and temperature increases by 14% and 5.1%, respectively, for a unit increase in farmland size. This implies that wealthier farmers with more land are likely to recognize changes in climate, as a larger farm size allows them to practise various agricultural activities through which they can increase their practical knowledge, which is in line with Waha et al. (2018).

Natural capital represented by values of land and livestock has a negative impact on perceived change in temperature. The marginal effect confirms that the probability of perceiving a change in temperature decreases by 0.97% for a unit increase in the value of natural capital. This reflects that wealthier households with more farmland value are less likely to perceive changing temperatures probably they are situated in areas less exposed to climatic hazards and may own more fertile land that can provide adequate food and feed. Similarly, a recent study (Koirala et al., 2022) indicated an inverse relationship between farmland productivity and farmers' responsiveness to climate change.

Financial capital represented by net income over debt negatively influences the likelihood of perceived change in temperature. The marginal effect reveals that the probability of farmers' perceived change in rainfall decreases by 1% for a unit increase in financial capital. This reflects that higher income may allow wealthier households to invest in relatively more stable non-land-based alternatives.

Table 4 Results of binary logistic regression for perceptions model in Sidama, Ethiopia, 2020

Independent variable	Perceived change in rainfall	Perceived change in temperature
	Marginal effect ∂p(y = 1/x)/∂x)	Marginal effect ∂p(y = 1/x)/∂x
Age (years)	0.00037	1.03
Gender (1 = male)	0.066	−0.00083
Family size (persons)	0.019	0.0024
Cultivated land (ha)	0.14**	0.051***
Livestock (tropical livestock units)	−0.0038	−0.00035
Natural capital (value)	0.000038	−0.000097**
Physical capital (value)	−0.000018	0.000015
Financial capital (net savings)	−0.01**	−00041
Human capital (education in sch yr.)	−0.008	0.088***
Bonding social capital (BoSC)	0.088	0.12
Bridging social capital (BrSC)	0.15**	0.0023
Social trust (STSC)	0.06	0.024
Norms reciprocity (NR)	0.168***	0.042
Institutional trust (ITSC)	−0.22***	0.11
Distance to market	−0.011**	−0.019**
Access to CC information (1 = access)	0.49***	−0.0055
Land tenure (1 = own; 0 otherwise)	0.31	0.026
Location (1 = Jere Henesa)	−0.12**	−0.13***
Net per capita income (birr)	0.98	0.0047
N (sample size)	314	314
Pseudo R^2	0.72	78
Wald (X^2)(14)	$P < 0.001$	$P < 0.001$

Source: Survey data, 2020

** and *** indicate significance levels of 5% and 1%, respectively

As expected, distance has a negative impact on both perceived change in temperature and rainfall, implying that perception decreases with increasing distance from the urban market. This implies that marketplaces give farmers an opportunity to exchange mutually rewarding information with traders, relatives, friends and other farmers. The marginal effects further confirm that the probability of farmers perceiving changes in rainfall and temperature decreases by 1.1% and 6.4%, respectively, for every one km increase in distance from the urban market centre.

As per prior expectations, access to climate change information has a positive impact on perceived change in rainfall. Improved access to climate change-related information that may occur through improved access to extension services is believed to enhance farmers' perceived change in climate. The marginal effect depicts that the probability of perceiving a change in rainfall increases by 49% for a unit increase in access to climate change information.

Education seems to increase the probability that farmers perceive long-term changes in temperature. The marginal effect confirms that the likelihood of perceived change in temperature increases by 29% for a unit increase in schooling year. Thus, educated farmers are more likely to perceive local temperature as a real issue of global and immediate concern, which agrees with Debela et al. (2015).

Bridging social capital formed by connecting with people outside social norms (heterogeneous group), such as agricultural development agents (DAs) and local administrative workers, positively influenced the likelihood of perceived change in rainfall. The marginal effect further confirms that the likelihood of perceiving a change in rainfall increases by 15% for a unit increase in bridging social capital. This implies that such a network enhances perceived climate change through improved access to new ideas and resources that may emanate from private and public sectors (Howden et al., 2007; Kobayashi, 2010).

Norms of reciprocity, which refers to people's willingness to help others and generate good will to others, help farmers adopt climate change adaptation strategies by facilitating the exchange of beneficial information and resources (Cox & Orman, 2010; Putnam, 2000). The marginal effect confirms that the likelihood of perceptions of change in rainfall increases by approximately 17% for a unit increase in norms of reciprocity. People's connectedness to mutual self-help groups (idir, equip) and membership in watershed and environmental protection groups helps to construct norms of reciprocity social capital. In this regard, people respond to changing environmental conditions by changing their behaviour and norms to reduce their vulnerability to climate change (Meinzen-Dick et al., 2014).

In general, perceived changes in rainfall and temperature are more likely influenced by livelihood assets, distance, and exposure to climatic risks.

Specific adoptions to climate change

This section focuses on various adjustments made by farming activities if farmers perceived change in the climate. Limited land size, lack of active labour, lack of savings or credit, high cost of inputs, and lack of awareness about appropriate adaptation measures were cited by 161 (51%) nonadopters (Table 5) as their main barriers to adaptation. Gbetibouo (2009) adds that failure by farmers to adopt adaptive measures may also be attributed to failure to isolate climatic stimuli from other stimuli that they face in the real world, as well as their high level of concern about responding to short-term climatic variability rather than long-term climatic changes.

Effects of perceived change in rainfall and temperature on specific adaptation measures

The study employed a logit model to analyse the factors determining the likelihood of adopting specific adaptive measures. Pseudo R^2 ranging from 0.28 to 0.64 with $P < 0{\cdot}001$ shows strong explanatory power of the model.

Farmers' responses to perceived changes in temperature and rainfall are likely different (Table 6), in line with Gbetibouo (2009). Perceived change in rainfall significantly influenced the likelihood of adopting irrigation, high-yielding varieties, herd diversification, income diversification, and changing planting date strategies. On the other hand, perceived change in temperature significantly influenced the probability of adopting soil and water conservation measures, herd diversification, high yielding drought tolerant variety, changing planting dates, seasonal mobility and rotational grazing. This confirms that adaptation to climate change is a necessary precondition to guide effective land-based adoption (Gbetibouo, 2009; Maddison, 2006).

As the main strategy to adapt to decreasing rainfall, 170 (55%) respondents adopted irrigation. Gbetibouo, (2009) noted that building water harvesting schemes (ponds, diverting rivers) is a popular adaptation strategy for those experiencing decreasing rainfall. The marginal effect confirms that the probability

Table 5 Reported adoption strategies in Sidama, Ethiopia, 2020

Adopted strategies	Adopters	Nonadopters	Index
1. Soil and water conservation (SWC)	43 (133)	57 (177)	0.43
2. Irrigation agriculture (Irr)	55 (170)	45 (141)	0.55
3. High yielding variety (HYV)	64 (198)	36 (112)	0.64
4. Herd diversification (HD) (≥ 2 livestock species)	68 (201)	32 (110)	0.68
5. Crop diversification (≥ 2 crop types	28 (85)	72 (216)	0.27
6. Off/nonfarm income diversification	13 (41)	87 (270)	0.13
7. Change in planting date (CPD)	50 (154)	50 (152)	0.50
8. Seasonal mobility (SM)	51 (154)	49 (152)	0.50
9. Rotational grazing (RG)	64 (198)	36 (111)	0.64
Sample mean	49 (154)	51 (161)	0.49

Source: Survey data, 2020

Table 6 Factors affecting the adoption of specific adaptation strategies in Sidama, Ethiopia

Independent variable	Results of logistic regression (marginal effect = ∂p(y = 1/x)/∂x)								
	SWC	IRR	HYV	HD	CD	NFS	CPD	SM	RG
Age (years)	1.010	−0.0037	−.0029	−0.0013	−00047	−0.00004	0.0029	0.0022	0.000805
Gender (1 = male)	0.013	2.01	1.400	0.83	1.400	0.620	1.180	0.420	0.530
Household size (persons)	0.039**	0.0035	0.025	0.0073	.0023	−0.00980	0.83	−0.005	0.015
Perceived change To ($C^{0)}$	0.22***	0.160	0.35***	0.310***	−0.240	0.990	0.69***	0.350***	0.400***
Perceived change rainfall (mm)	0.110	0.19***	0.25***	0.230***	−0.100	0.120***	−0.160***	0.110	−0.032
Cultivated land (ha)	−0.0054	−0.0015	0.011	0.107**	−.033	−0.030	0.12**	−0.068	−0.031
Livestock (TLU	−0.0045	−0.0049	−0.0024	−0.013	−.0050	0.0043	0.0016	0.0035	0.100**
Natural capital (value)	−0.0002	0.230	0.0051	−.1300	0.2900	−0.0005	−0.104	0.120	−0.160
Physical capital (value)	−0.0001	−0.017	0.057**	0.0016	.051**	0.990	0.0062	0.0074	0.110
Financial capital (net saving)	−0.0018	1.010	0.950	0.990	1.010	−0.0004	−0.037**	0.990	−0.0018
Human capital (sch.yr)	0.00021	0.0054	−0.0012	−0.016	0.016	0.0094	0.032***	0.980	0.0066
Bonding social capital (BSC)	−0.078	0.072	0.012	0.220***	−0.130*	−0.018	0.019	−0.089	−0.011
Bridging social capital (BrSC)	0.42***	0.120*	−0.040	0.130**	−0.095	0.055	−0.048	−0.110	0.150**
Intuitional trust	0.06**	−0.180**	0.077	−0.017	0.073	−0.019	0.108**	−0.16**	0.029
Social trust	0.17***	0.28***	−0.133	0.055	−0.005	−0.081	0.40***	−0.14**	−0.081
Norms of reciprocity	0.099	0.14*	0.20***	−0.022	0.0045	0.059	−0.18	0.042	0.026
Distance to market (hr)	1.020	−0.013**	−0.016**	−0.067	−0.023**	−0.0041	−0.019***	−0.013**	−0.014***
Access to CC info (1 = yes)	0.040	0.750	0.860	2.830	0.110	0.960	6.20***	0.730	6.960
Land tenure (1 = own)	0.980	0.460	0.740	0.800	1.170	0.650	0.890	0.780	0.660
Location (1 = Jere.H)	0.070	0.890	0.540	0.0021	2.490	2.300	0.201***	0.380	−0.008***
Per capita income (birr)	0.980	0.0014	−0.0018	0.890	0.0023	0.980	0.0036	−.009***	0.960
Sample size (N)	314	314	314	314	314	314	314	314	314
Wald $\chi 2$ (10)	13.96	1`2.16	18.76	11.11	23.55	9.15	44.31	23.09	20.54
Pseudo R^2	0.42	0.54	0.60	0.27	0.28	0.76	0.75	0.48	0.64
Loglikelihood	−208.83	−209.48	−206.99	−201	−171	−115	−167	−210.85	−202.72

Source: Survey data, 2020. ** and *** indicate the 5% and 1% significance levels, respectively. abbreviated adaptation strategies

Adaptation strategies in Table 6 are abbreviated as follows: *SWC* soil and water conservation, *IRR* irrigation, *HYV* high-yielding varieties, *HD* herd diversification, *CD* crop diversification, *NFS* non/off-farm strategies, *CPD* changes in planting date, *SM* seasonal mobility, and *RG* rotational grazing

of adopting irrigation strategies increases by 19% for a unit increase in perceived decrease in rainfall. This implies that irrigation is perceived as protection during drought and famine and can improve farm productivity (Dowgert, 2010).

Those respondents who perceived both increasing temperature and decreasing rainfall adopted high-yielding drought-tolerant varieties (HYV) as a strategy to protect harvest and reduce losses in times of intense drought (Alamgir et al., 2021; Paul, 1998). The marginal effects confirm that the probability of adopting high-yielding variety increases by 25% and 35% for a unit increase in the likelihood of perceived change in rainfall and temperature, respectively, reflecting that farmers' response may vary depending on the extent of riskiness of climatic factors.

A significantly larger share (68%) of respondents adopted herd diversification as a strategy to adapt to perceived changes in rainfall and temperature. The marginal effect confirms that the probability of adopting herd diversification increases by 23% and 31% in response to a unit increase in perceived change in rainfall and in temperature, respectively. Studies (Martin et al., 2020; Tichit et al., 2004) argue that keeping a mix of livestock species enables farmers to exploit possible synergies and complementarities between species due to differences in their behaviour, feed requirements, susceptibility to disease and parasites, seasonality and duration of production cycles and products.

As a strategy to protect their families against the loss of income/yield from their primary activity (Doğan et al., 2020), only 41 (13%) respondents adopted an income diversification strategy. This may reflect scanty access or high entry barriers to remunerative activities away from their own farm. The likelihood of adopting this strategy increases by 12% for a unit increase in perceived change in rainfall, as confirmed by the marginal effect.

Farmers (50%) who perceived increasing temperature adopted changing planting dates to skip yield loss or crop failure. Sakurai et al. (2018) indicated that the global average crop yield could potentially be increased by approximately 30% through optimal selection of the planting date. Most likely, this group of farmers also adopted soil and water conservation strategies to support herd diversification, high-yielding varieties, and rotational grazing, implying that land-based adoptions are likely complementary. For instance, the marginal effect confirms that the probability of adopting a soil and water conservation strategy increases by 22% for a unit increase in perceived change in temperature, and the probability of adopting a high-yielding variety, herd diversification, and rotational grazing increases by 35%, 31%, and 40%, respectively, for a unit increase in perceived change in temperature.

However, if farmers perceive further decreasing rainfall and have limited access to technologies that improve water and soil moisture, they assume that dropping changing planting dates reduces the cost of crop failure or yield loss. This reflects that farming households are more likely to reduce the risk of increasing temperature by improving soil moisture and/or access to irrigation or to drop strategies more sensitive to moisture stress to reduce risks associated with decreasing rainfall. The marginal effect confirms that the probability of adopting changing planting dates decreases by 16% for a unit increase in perceived fall in rainfall.

On the other hand, farmers tend to adopt seasonal migration strategies to adapt to increasing temperatures to spread risks associated to feed shortage over space, in contrast to rotational grazing intended to spread risk of feed shortage over time. Van et al. (2018) argue that seasonal migration is an ecological necessity in areas with severe climates and highly variable environmental conditions. Undersander et al. (2002) suggest that rotational grazing increases soil fertility, forage production, forage quality and biomass and reduces forage waste.

The effect of institutional variables and agro-ecological settings

Institutional factors often considered in the literature to influence the adoption of new technologies are access to information through extension services, land tenure (Gbetibouo, 2009) and distance to market (Maddison, 2006).

A longer distance is expected to negatively influence the probability of adopting an adaptive measure to climate change as it decreases access to information and technology (Bryan et al., 2009). The marginal effect confirms that a unit increase in distance from the farm to the urban market centre decreases the probability of adopting irrigation, high-yielding varieties, crop diversification, changing planting dates, seasonal migration and rotational grazing by 1.3%, 1.6%, 2.3%, 1.9%, 1.3% and 1.4%, respectively (see Table 6). This reflects that a longer distance increases the cost of information and inputs and transportation, thereby reducing the efficient use of farm inputs and effective price farmers receive for outputs (Maddison, 2007).

Access to climate change information, which is inversely related to distance positively influenced the probability of adopting changing planting dates by 62% implying that better access to climate change information given other factors enhances farm-level adoptions. In this connection, farm location closer to urban markets (Jere Henesa) increases the probability of adopting changing planting dates (CPDs) by 21% implying that reduced distance to urban markets reduces cost of adopting adaptive measures by reducing the cost of information and inputs. Nevertheless, the probability of adopting some strategies increases with increasing distance or marginality. For instance, the marginal effect of farm location confirms that the probability of adopting rotational grazing strategy increases by 0.8% as distance increases by a unit. This implies that marginal areas offer better access to land to adopt the rotational grazing strategy to reduce risks of feed shortage over time.

The effect of the five capital assets on specific adaptation

Individuals attempt to turn livelihood capital/assets into reasonable livelihood outcomes, thus enabling the adoption of adaptive measures that reduce mainly climate change-based risks. The marginal effect confirms that the probability of adopting herd diversification and changing planting dates increases by 10.7% and 12%, respectively, for a unit increase in land size. Evidence (Jalón et al., 2018) shows that improved access to livelihood assets such as land enhances farm-level adoption. This reflects that large-scale land holdings improve access to grazing resources, thus enabling farmers to exploit livestock species diversity and reduce stress under thermal trends while also planting crops during optimum planting dates to reduce climate change-related risks during critical developmental phases and ultimately prevent decreases in the productivity of agronomic crops (Abbas et al., 2019, in line with Gbetibouo, 2009).

Physical capital consists of tangible, human-made goods (farm tools and equipment) that assist in the creation of products or services (Haines & Sharif, 2006). The marginal effect confirms that the probability of adopting high-yielding variety and crop diversification strategies increases by 5.5% and 5.1%, respectively, for a unit increase in the value of physical assets. Sargani et al., (2022) in this connection noted that the quality and quantity of physical assets sustainably enhance farm production and productivity, which also reflect farmers' means of living conditions and determine farmers' land use decisions (Nguyen et al., 2017; Sargani et al., 2022).

Financial capital, which refers to net income over debt, credit, and other forms of funding, is necessary to acquire or purchase physical capital for the production of goods and services and undertake adaptive measures (King & Plosser, 1984). Nevertheless, the marginal effect confirms that a unit increase in financial capital and net per capita income decreases the likelihood of adopting changing planting dates and seasonal migration by 3.7% and 0.9%, respectively. This may reflect that increasing farm financial wealth encourages farm households to invest in livelihood methods, especially agri-enterprises that enable farm families to accumulate more wealth with more assets (cattle and production assets) (Sargani et al., 2022).

The marginal effect of human capital represented by formal education confirms that the probability of adopting changing planting dates increases by 3.2% for a one-year increase in schooling. Evidence (Dunn & Kennedy, 2019; Gbetibouo, 2009) shows that education increases one's ability to receive, decode and understand information for innovative decisions. Sargani et al. (2022) add that human capital/assets, including education, are generally acknowledged as critical aspects of farm households to implement various informed livelihood/adaptive investment decisions.

The marginal effect confirms that the probability of adopting a soil and water conservation strategy (SWS) increases by 3.9% for a unit increase in household size. Gbetibouo (2009) noted that a larger household is more likely to adopt labour-intensive strategies such as SWSs. Croppenstedt et al. (2003) suggest that a larger household size enables farm households to accomplish various agricultural tasks, especially during peak seasons.

We observe that social capital (bonding, bridging, institutional trust, social trust and norms of reciprocity) that emerges from networks of relationships among people is strongly associated with the likelihood of adopting several land-based adoptions. Social capital enables society to function effectively and is essential for any agrarian society in particular to cope with and adapt to climatic risks (Lee & Foo, 2020). These social networks are often measured using an indicator or combinations of indicators (Belay & Fekadu, 2021).

The marginal effect confirms that the probability of adopting a herd diversification strategy increases by 22% for a unit increase in bonding social capital, ceteris paribus for a unit increase in bonding social capital, formed by connectedness to relatives, friends and neighbours. Strong norms of trust, reputation, and monitoring behaviour of the membership with close ties are the probable reasons that an opportunity to share emotional and material support facilitates adaptations to climate change (Hamilton & Lubell, 2019).

In contrast, bridging social capital with weak ties formed by connectedness with far-reaching people such as development agents and local administrative workers (Adger, 2003; Adger et al., 2005) is believed to facilitate adaptation to climate change. This is because of the fact innovative supports from diverse actors beyond social norms would enable farmers to learn new ideas and more effectively adapt to climate change. The marginal effect confirms that the probability of adopting soil and water conservation, herd diversification and rotational grazing strategy increases by 42%, 13% and 15%, respectively, for a unit increase in bridging social capital.

Institutional trust refers to the belief or expectation that the government will do the right thing under normative standards (Hetherington, 2005; Norris, 2017). The positive marginal effect confirms that the likelihood of adopting soil and water conservation and changing planting dates increases by 6% and 10.8% for a unit increase in institutional trust. This implies that reliance on local administrative workers, farmers' training centre (FTC), and farmer's field day (FFD) as indicators of institutional trust may have assisted local farmers to adopt adaptive strategies primarily induced by government. On another hand, the marginal effect confirms that the probability of adopting irrigation and seasonal migration strategies decreases by 18% and 16%, respectively, for a unit increase in institutional trust. This implies that adopting irrigation strategy is likely constrained by access to capital, technology and skilled labour, whereas that of seasonal migration is most likely discouraged by Ethiopian government and emerging conflicts over water and grazing pasture.

The marginal effects confirm that the probability of adopting soil and water conservation, irrigation and changing planting dates increases by 17%, 28%, and 40%, respectively for a unit increase in social trust. This implies that social trust/belief that others are generally honest, fair, diligent and good may be a vital means to share critical resources and acquire information knowledge during the agricultural peak season, and sustained cooperation primarily for poor people (Adger, 2003; Taylor et al., 2007). Nevertheless, the marginal effect confirms that the probability of adopting seasonal migration decreases by 14% for a unit increase in social trust. Probably this reflects that rural wealthier households with more number of livestock are less likely to trust or rely on others to acquire resources and/or information to make such a risky adaptive decision but their own background experience and entrepreneurial skill to calculate opportunity cost of a given adaptive strategy such seasonal migration.

Norms of reciprocity is a social norm that obliges people to return favors or benefits that they have received from others is an another means to facilitate taking up of measures to reduce vulnerability to climate change. For instance, the marginal effect confirms that the probability of adopting high-yielding varieties and irrigation increases by 20% and 14%, respectively, for a unit increase in norms of reciprocity. This probable reflects that nonmarket exchange of beneficial information and resources among people willing to help others and generate good will to others influences human behaviour and relationships that enhances adaptation to climate change through increased sharing of resource, information and new ideas (Bates, 1995).

We observe that some strategies, such as soil and water conservation, are labour intensive, while others, such as irrigation, are both capital and labour intensive. On another side, strategies such as seasonal mobility and rotational grazing, are mainly driven by distress factors, such as feed scarcity/shortage induced by climate change.

Conclusions and policy recommendations

In this study, we set out to investigate three questions:

1. Which farm household-specific factors influence perceptions of climate change?
2. Do perceptions of climate change significantly influence the adoption of a set of specific measures?
3. Finally, which farm household-specific factors influence the adoption of specific land-related strategies?

This study used binary logistic regressions to investigate factors influencing perceived changes in climate (temperature and rainfall) and factors influencing the probability of adopting specific adaptation strategies.

Indeed, most farmers in the study areas recognize that temperatures have increased and that there has been a reduction in the volume of rainfall over the recent past one to two decades. Findings suggest that the perceived change in climate is influenced by different factors. For instance, livelihood assets such as farmland size positively influenced both perceived change in rainfall and temperature; human capital and natural capital positively influenced perceived change in temperature; and financial capital and social capital (institutional trust) negatively influenced perceived change in rainfall. On the other hand, institutional variables such as distance negatively influenced perceived changes in both rainfall and temperature, while access to climate change information, which is a function of distance, positively influenced perceived changes in rainfall. Meanwhile, location variables negatively influenced both perceived changes in rainfall and temperature.

Thus, understanding the way in which various factors are associated with perceived change in climate and the likelihood of adopting an adaptive measure are vital to designing effective land-based adoption.

Our results suggest that the probability of adopting a specific adaptation strategy is significantly influenced by perceived changes in climate, reflecting that perceptions of climate change are necessary preconditions to make informed adaptive decisions. For instance, farmers who perceive decreasing rainfall are more likely to adopt irrigation and off/non-farm activities but are less likely to adopt changing planting dates. On the other hand, farmers who perceive increasing temperatures are more likely to adopt soil and water conservation, changing planting dates, seasonal migration, and rotational grazing strategies. Meanwhile, farmers who perceive both decreasing rainfall and increasing temperature are more likely to adopt high-yielding varieties and herd diversification. This implies that the probability of adopting an adaptive measure is likely guided by farmers' perceived change in specific climatic elements. Moreover, the complementarity between rural adaptation strategies is also important in influencing farmers' adaptive decisions.

Distance, which is an institutional variable, negatively influenced the probability of adopting irrigation, high-yielding varieties, crop diversification, changing planting dates, seasonal migration and rotational grazing, implying that distance increases the cost of taking up adaptive measures. The implication for the positive association between access to climate change information and the probability of adopting planting dates is that improved access to climate change information induced by a reduced distance to urban market centre facilitates informed adaptive decisions. This further implies that marginal locations need to receive policy attention to reduce the costs associated with acquiring critical inputs, information and technologies.

Moreover, the probability of adopting specific adaptation strategies is more likely influenced by livelihood assets. For example, the positive correlation between the probability of adopting changing planting dates and the marginal effect of human capital (education) and farmland, the probability of adopting crop diversification and the marginal effect of physical assets, and the probability of adopting rotational grazing and the marginal effect of livestock reflects that wealthier households are more likely to adopt strategies to reduce their potential vulnerability to climate change. This further reflects that wealth, which refers to past achievement and the ability to bear risk in the past, enhances land-based adaptation to climate change, in line with Gbetibouo (2009).

Nevertheless, the negative association between the marginal effect of financial capital and net income and the probability of adopting changing planting dates and seasonal migration strategies reflects that rural wealthier households with more liquid assets are less likely to invest in land-based adaptive strategies; rather, they invest in livelihood assets to accumulate wealth to invest in the future given other factors.

More generally, we observed that typologies of rural land-based adoptions are more likely influenced by the type of livelihood capita/assets owned or accessed. For instance, land size induced wealthier households to adopt changing planting dates, while the number of livestock induced wealthier households to adopt seasonal mobility.

In terms of social capital, our results confirm that elements of social capital are vital to facilitate land-based adaptation to climate change by reducing the costs associated with adaptation to climate change. For instance, bonding social capital positively influenced herd diversification; bridging social capital positively influenced soil and water conservation, herd diversification, and rotational grazing; institutional trust positively influenced soil and water conservation and changing planting dates; social trust positively influenced soil and water conservation, irrigation, and changing planting dates; and finally, norms of reciprocity positively influenced the probability of adopting irrigation and high-yielding varieties.

Thus, we further believe that investing in small- and large-scale irrigation, improving access to and productivity of livelihood assets and empowering and acknowledging local social networks would be critical to enhance land-based effective adaptive measures given heavy reliance on rain-fed small-scale agriculture with very low productivity.

Acknowledgements The authors are grateful to the Collaborative Cooperation between Norwegian University of Life Science (NMBU) and Hawassa University (HU) (NMBU-HU ICOP IV) for providing financial support and local admmintrative bodies, data enumerators, development agents, experts at various level and the respondents for their side contribution. The authors also thank the AJE language edititing services.

Author contributions The first author (WE) generated the idea, designed the study, designed data collection instruments, carried out the data collection and analyzed the data, and wrote the manuscript. The second author (PV) participated in the study design, shaped the data collection instruments, technically supported the data analysis process, and revised the draft manuscript. Both authors read and approved the final manuscript.

Funding Open access funding provided by Norwegian University of Life Sciences. The authors are grateful to the Collaborative Cooperation between NMBU and Hawassa University (NMBU-HU ICOP IV) for funding.

Data availability Not applicable to this article as there is no data were created.

Declarations

Conflict of interest The authors declare that they have no competing interest.

Ethical approval Ethical clearance to undertake study was sought from the Norwegian University of Life Science under the faulty of International Environment and Developmnt Studies, department of Noragric. In the study area, the permission of gatekeepers (chiefs, individuals from relevant agencies or organizations, assembly men and others in authority) was sought before commencing this study.

Informed consent Before proceeding with interview all respondents were informed of the nature of the study to get their consent. Besides, research participants were not exposed any risk of physical and psychological threat. Participation in the research process was voluntary and respondents had full freedom to participate or not. They could even quit in the middle of participation without providing a justification for their actions. In this study, however, none of the respondents declined from participation. Participants in the study were assured that the data would be used for academic research purposes only and would be handled properly to guarantee their safety and confidentiality.

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