Heliyon 7 (2021) e06789

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba South Sub-county, Kisii, Kenya

Jared O. Nyang'au [a,b,e,*], Jema H. Mohamed [c], Nelson Mango [d], Clifton Makate [b], Alex N. Wangeci [e]

[a] Department of Agroecology, Aarhus University, Blichers Allé 20, 8830, Tjele, Denmark
[b] Africa Center of Excellence for Climate Smart Agriculture and Biodiversity Conservation, Haramaya University, P.o Box 138, Dire Dawa, Ethiopia
[c] Department of Agriculture Economics, College of Agriculture and Environmental Sciences, Haramaya University, P.o Box 138, Dire Dawa, Ethiopia
[d] International Centre for Tropical Agriculture (CIAT), P. O Box MP228, Mt. Pleasant, Harare, Zimbabwe
[e] Kenya Plant Health Inspectorate Service (KEPHIS), P.O BOX 49592-00100, Nairobi, Kenya

ARTICLE INFO

Keywords:
Climate-smart agriculture
Climate variability and change
Perception
Adaptation

ABSTRACT

Many countries experience the negative impacts of climate change especially in the decline of agricultural productivity leading to decreased national and household food security. This study assessed smallholder farmers' perception of climate variability and change and their adaptation strategies in Masaba South Sub-County, Kisii County, Kenya. A multi-stage sampling technique was used to collect data from 196 smallholder farmers. Additionally, focused group discussions and key informant interviews were used. The study revealed that most farmers perceived climate changes. 88.3% of the respondents noted a decrease in rainfall, 79.1% reported poor rainfall distribution, 88.3% perceived a late onset of rainfall while 76.6% perceived an increase in temperature. The farmers' perception mirrored the actual climatic data trends for the area obtained from the meteorological department. The major climate-smart agriculture practices adopted by farmers in the area included; diversification of crops, change of planting time and crop rotation/mixed cropping. The adoption of climate-smart agriculture practices significantly correlated with the household size, monthly income, access to credit and farmers' perception of climate change. The study recommends the incorporation and prioritization of climate change in the county and government development agenda as a means of enhancing the uptake of climate-smart agricultural practices.

1. Introduction

Climate change remains a global challenge facing humans and their socio-economic activities, health, livelihood, and food security (Amjath-Babu et al., 2016). Despite the adverse impacts of climate change affecting both developed and developing countries, developing countries and poor smallholder farmers are more vulnerable as they sorely lack adequate adaptive capacity (Archer et al., 2007; Katharine, 2004). Many countries, especially in Sub-Saharan Africa (SSA) give agriculture priority, in pursuit of affordable and adequate food for their citizens, as it is a key determinant of food security. However, despite its considerable importance, agriculture is vulnerable to the potential impacts of climate variability and change and the necessary steps required to support the sector in many developing countries remain weak and fragile (Stern, 2010). Consequently, if climate variability and change are not addressed, it will potentially cause severe food insecurity, with the most tremendous effect being realized in developing countries (Kryger et al., 2010). For instance, the projected increase of temperature to 1.5 °C will expose health, livelihoods, food security, water supply, human security, and economic growth of many developing countries to climate-related risks (IPCC, 2018, 2019).

The high dependence on rain-fed agriculture by smallholder farmers' makes them vulnerable to the profound impacts of climate change. This is compounded with elevated levels of poverty, defective infrastructural and technological development (Adimassu and Kessler, 2016). In Kenya, climate change has credibly threatened food security and the economy as it is exceptionally sensitive to variations in rainfall. The effects of climate variability and change have affected the agricultural sector, which remains a crucial contributor to Kenya's economic growth. The sector contributes at least 52% of the country's GDP both directly and indirectly

* Corresponding author.
E-mail address: jaredonyango@gmail.com (J.O. Nyang'au).

https://doi.org/10.1016/j.heliyon.2021.e06789
Received 28 January 2020; Received in revised form 19 March 2020; Accepted 9 March 2021

(Government of Kenya (GoK), 2017). It accounts for 65% of total exports, provides about 75% of total employment and supports over 80% of the rural population (Government of Kenya (GoK), 2013). The productivity of the sector has, however, been compromised by evident effects of climate variability and change (Adamgbe and Ujoh, 2013).

The agricultural sector contains the potential to contribute to climate change mitigation and increasing resilience through adaptation. The sector alone contributes approximately 3.7% of greenhouse gas emissions (GHGs) globally besides being a key driver in deforestation activities, which also adds a further 7–14% of greenhouse gas emissions on a global scale (FAO, 2013). Concurrently, climate change is set to adversely affect many agricultural dependent communities especially the small scale and poor farmers. This is because they are less equipped in adapting to hostile shocks, aggravating the food insecurity and global poverty situation (Morton, 2007). Hence, both mitigating efforts in the reduction of GHGs discharges and adaptation strategies geared towards maintaining crop harvests are of global importance.

Climatic changes have negatively impacted the ecosystem, economic livelihoods and agricultural productivity (Odada et al., 2008). Therefore, they typically present a grave risk to food production sustainability and other subsistence practices in susceptible African communities such as Kenya. To address these negative impacts sufficiently, there is a need to enhance the resilience of local farmers to climatic variation. To enhance resilience, it requires adaptation of approaches that will lessen the impact on crops and subsistence while mitigating the climate change causes (Talanow et al., 2021; Traore et al., 2015). The potential vulnerability of the community depends on how they have adapted to changes in climate. In SSA, about 80% of Agriculture is managed by smallholder farmers, making this small-scale production the backbone of most SSA countries (Food and Agriculture Organization (FAO), 2012). Although the farmers have proven to be resilient, climate change is likely to outpace their current coping capabilities. Depressed levels of income and technology, coupled with social isolation from local markets and lack of institutional support, represent typical characteristics of smallholder farming systems. This makes them particularly vulnerable to changes in climate (Morton, 2007).

To achieve food security reasonably, while mitigating climatic change, it requires the preservation of essential resources and sustaining vital ecosystem services. There is a need for transiting to agricultural production methods that enable increased productivity and efficient input application. This will result in reduced variability and enhanced stability in terms of output, greater resilience to risks, shockwaves and continuing climate variability. Climate-smart agriculture (CSA) practices are recognized as the most appropriate adaptation strategies to achieve these objectives. These practices provide a "triple win" as they increase agricultural productivity, increase resilience, and reduce greenhouse gases that cause climate change (FAO, 2013).

This innovative approach of agriculture aims at strengthening subsistence and food security, more specifically that of small-scale farmers. This could be positively enhanced through effective management and use of natural resources and the successful adoption of suitable methods and technologies in producing, processing, and securing markets for agricultural produce. To achieve maximum advantage while minimizing the tradeoffs, CSA considers the context of social, economic, and environmental factors where applications are made. In adapting to the climatic changes, farmers adopt specific CSA practices as a coping strategy depending on their perception of climate variability and change. Those perceiving the changes being more likely to adopt a particular CSA practice as compared to those who do not. The farmer's choice of a CSA practice is dependent on various socio-economical characteristics, geographical characteristics, institutional and farm-related properties (Mutunga et al., 2018).

Despite the principal role farmers in the Masaba South sub-county play in the agricultural production cycle, there is limited knowledge of how they typically perceive climate variability and change. The perception affects their choice of a CSA practice to cope and/or adapt. This presents challenges regarding planning, investments and formulation of relevant policies that can enhance farmer's resilience to climate change. To seal these gaps, this study aims at sufficiently investigating farmers' perceptions of climate variability and change; and adaptation measures adopted to enhance their resilience towards climate change. The research will provide practical evidence to guide policy formulation for institutions to enhance farmers' resilience and identify practices that can be up-scaled and promoted to similar ecological zones within the study area.

2. Materials and methods

2.1. Description of the study area

This study was conducted in Masaba South Sub-County, Kisii County, Kenya. It is located in the western parts of Kenya between the latitude of 0° 30′ and 1°S and longitude 34° 38′ and 35° with 5 administrative wards (Figure 1). The headquarters of the sub-county are located in Masimba town. The Sub-County typically has a hilly landscape with many ridges and gorges and with several permanent rivers crisscrossing the landscape. The Sub-County has fertile soils that support the agricultural activities engaged in by the local community. Close to 75% of the area of study is rich in red volcanic soils. The area falls between the altitudes of 1800–2350 m above sea level. It covers 161.9 km^2 with a local population of 143,250, of which 48.82% are male, while 51.18% are females spread across 26,132 households in the sub-county (Kisii County Government, 2013).

The highland equatorial climate experienced in the area is responsible for the bimodal rainfall pattern characterized by two rainy seasons with an average annual rainfall of 1500 mm. The maximum temperatures in the area range between 21 °C–30 °C while the minimum temperatures range between 15 °C–20 °C. The area is comprised of small-scale farmers who have a high dependency on rain-fed agriculture. The sufficient rain amounts received in the region, coupled with the moderate temperatures, make the region suitable to support tea and coffee farming. Other crops typically grown in the region include maize, groundnuts, sweet potatoes, beans, bananas, and finger millet. Agriculture employs an estimated 80% of the population either directly or indirectly (Kisii County Government, 2013).

2.2. Sampling methods and data collection

A multi-stage random sampling procedure was utilized to select the target households. Data were collected by the use of pre-tested structured questionnaires entailing, primarily closed-ended and open-ended questions. The questionnaires used were pre-tested on some selected households in the area before the actual survey started. Three focused group discussions (FGDs) were held in a central place of each ward. The FGDs were comprised of church leaders, local leaders, representatives of women and youth groups. To get a deep understanding of the measures taken by various institutions to help farmers, key informant interviews were also conducted. Those interviewed included the ministry of agriculture officials, officials from the meteorological department, officials from research institutions, and agro-dealers. A total of 196 households was sampled based on Cochran's formula (Heinisch and Cochran, 1965) proportionately from the three wards based on the population. The study was conducted between April and May 2019.

2.3. Data analysis

Descriptive statistics were done by the use of SPSS software version 23. Descriptive statistics tools were used to analyze and present socio-economic characteristics, institutional characteristics, perceptions of farmers to climate variability and change, and CSA practices adopted by farmers. Factors influencing farmer perceptions were analyzed in a logistic regression model framework. The dummy variables for perceiving

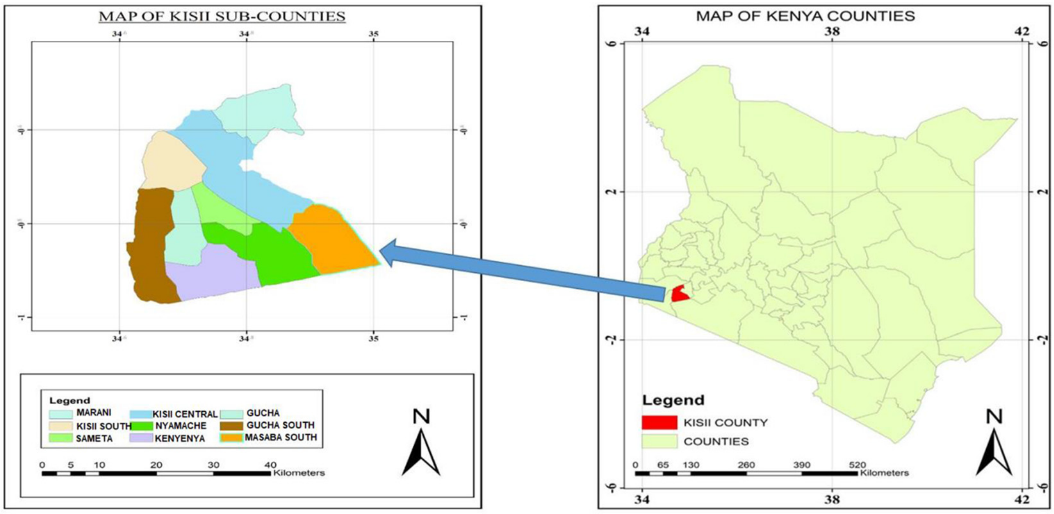

Figure 1. Map showing the study area.

climate change in general, perceiving temperature increase, and perceiving rainfall decrease were used as dependent variables. Analysis of variance, F-test, X^2 (chi-square), and mean comparison tests were run to compare adapters and non-adapters of CSA practices. Meteorological data were presented by line graphs and correlated with farmers' perception data. The reliability of the questionnaire was tested through Cronbach's alpha test in SPSS. The Cronbach's alpha value of 0.703 indicated acceptable internal consistency of the questionnaire.

2.4. Ethical considerations

Approval to conduct research and collect data from respondents was obtained from National Commission for Science, Technology, and Innovation (NACOSTI), Kenya, and a research permit issued under permit number, NACOSTI/P/19/19905/27337. Additionally, in collecting data from respondents, their interview consent was sought first.

3. Results and discussions

3.1. Demographic and Socio-economic characteristics of smallholder farmers

Out of the 196-sampled households, 40.8% were male while 59.2% were female both with an average age of 42.39 years. There was a significant difference between female and male respondents at a 5% significance level ($p = 0.010$). The considerable large number of female respondents was attributed to the fact that most men had migrated to urban areas to look for supplemental income, as the land sizes were getting smaller for agricultural production due to the land sub-divisions. This resulted in more females being involved in farming activities in the area. This is consistent with the findings of Nhemachena and Hassan (2007). They found that men more frequently seek jobs in towns, and women in South Africa do much of the agricultural work.

The average family size of the households comprised four members, with most households ranging between four and six members. The large size is an asset as it provides labour required in farm activities (Marenya and Barrett, 2007). The average farming experience was 17.57 years. The more years spent on farming influences the adoption of an adaptation strategy. The more extensive farming experience makes farmers employ adaptation measures that enhance their resilience as they can observe changes in the environment (Alhassan et al., 2019; Mwungu et al., 2018). The marital status of the respondents indicated that 81% of the respondents were married, 7.1% were single, while 11.7% were either divorced, widowed, or separated. This indicates that there is a stable marriage situation in the area. Despite the majority of the respondents being female, the males were the main decision-makers over the land use in most households. It was highlighted in the FGDs that most men are the key decision-makers over the land use and they have to be consulted during planting season on what is to be planted and where (Figure 2). This notion is true even though men stay away from home as exhibited by large percentages of females interviewed.

A high level of education is hypothesized to significantly influence the adoption of CSA practices to increase resilience against climate variability and change (Amir et al., 2020; Mutunga et al., 2018). Among the total sampled households, 55.6% had attained secondary school education level, 12.9% primary school level, 12.2% college or university education level. In comparison, 2% had never attended school, and 12.2% were school dropouts (Figure 2). The average years spent in school by the sampled respondents were 10.33. The provision of free education by the Government of Kenya attributed to the high levels of education of most respondents. A substantial proportion of the respondents who had attained high education levels were more likely to adopt CSA practices as they can receive, decode, and understand relevant information and make decisions (Ochieng et al., 2012). Additionally, relatively highly learned farmers are likely to have a higher chance of embracing technologies that will enhance adaptation as they can perceive climate changes and have access to information (Nkonya et al., 2008).

Membership in a social group has a positive correlation to the adoption of CSA practices as it enables farmers to share and get information on climate, innovation, new crop varieties, and other relevant information that might enhance their resilience (Stefanovic et al., 2017; Washington-Ottombre and Pijanowski, 2013). Out of the sampled respondents, 44.4% belonged to a social group while 55.6% of them did not belong to any social group. The social group was either a “Chama,” or a community social group. The average household income per month for the sampled households was Ksh 6271.68, with a standard deviation of Ksh 7599.11. This indicates a significant disparity in income among households in the study area. Those households with more substantial incomes are more likely to adapt as they have the financial muscle to buy necessary agro-inputs and make investments in practices that require significant capital (Maguza-Tembo et al., 2017).

3.2. Institutional characteristics of smallholder farmers

There was a significant difference among the respondents based on the accessibility to extension service ($p < 0.000$). Those who obtained

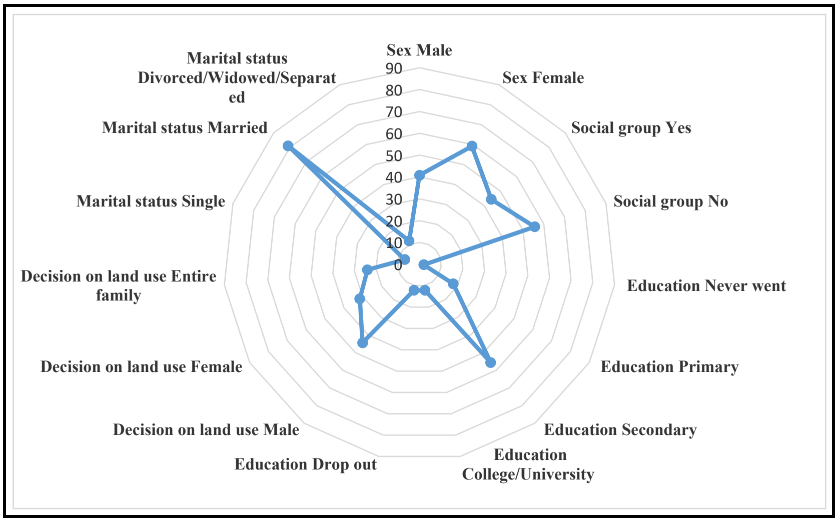

Figure 2. Demographic and Socio-economic characteristics of smallholder farmers in Masaba South Sub-County.

the services reported that they acquired them from the government institutions like the Ministry of Agriculture. The frequency of extension visits for extension recipients was about 5 visits per season (Table 1). Access to extension services influences the adoption of CSA practices, either positively or negatively. Farmers access to credit is key in supplementing their incomes to purchase agro-inputs and invest in technologies aimed at increasing agricultural productivity and carry out income-generating activities other than farming (Komba and Muchapondwa, 2015). A significant difference was reported among the local residents who had access to credit and those who did not ($p = 0.015$). The respondents from Ichuni ward enjoyed more access to credit facilities as compared to those from other wards. This is due to the proximity to Keroka town, which is one of the big towns within the sub-county. Access to credit is likely to influence the adoption of some CSA practices which require high capital investments such as soil conservation practices and irrigation (Belay et al., 2017; Mutunga et al., 2018).

Seventy-four percent of the total sampled households had access to weather and climate information from multiple sources. Of those who gained access, only 34.2% of them utilized the information in deciding on various farming activities (Table 1). This is a considerable variation among the respondents who receive the information ($p < 0.000$). The access to climate information increases farmer's awareness and knowledge of the variations in rainfall and temperature, and this informs their response strategies. The availability of weather forecasts information to farmers enables them to execute informed decisions on what crops and crop varieties to plant (Amir et al., 2020; Mutunga et al., 2018). Farmers' proximity to the market place and utilization of its services is likely to influence the adoption of appropriate CSA strategies. This is because farmers will have access to agricultural inputs such as certified planting materials and fertilizers as compared to those who are considerably away. 96.9% of the respondents had access to a market in their locality, with the average distance to the nearest market place being 2.82 km. The proximity to the market may serve as a means of sharing and exchanging information among farmers and other stakeholders, thus enhancing adoption (Maddison, 2006).

3.3. Smallholder farmers' perception of climate variability and change

To consider a proper choice of a CSA practice to adapt and increase resilience against climate change, a distinct understanding of the farmer's perception of climate changes is crucial (Gandure et al., 2013). Those who perceive changes hypothetically adopt one or more CSA practices to reduce the negative impacts associated with climate change. To determine the various adaptation strategies adopted in the study area, farmers' perception of climate variability and change needs evaluation. Farmers compared the current weather conditions with that of 20–30 years ago and identified some of the indicators of climate variability and change within their locality.

The results indicate most farmers perceived a decrease in rainfall over time with only 10.2% and 1.5% noting an increase and no change in rainfall amounts respectively (Figure 3). There was a significant difference among respondents regarding perceived changes in the amount of rainfall over time ($p < 0.000$). A significant number of households indicated that the rainfall distribution was poor, with only 2.6% who noted insignificant change within the seasons. A significant difference among the respondents reported that the onset of rainfall was late than the contrary ($p < 0.000$). The changes in the onset of rainfall resulted in the disruption of the farmers' seasonal calendar that was equally perceived to be short (Figure 3).

Table 1. Institutional characteristics of sample households.

Characteristics	Percentage of respondents		χ^2-Value
	NO (n = 196)	YES (n = 196)	
Access to extension services	82.7	17.3	83.592***
Frequency of extension contacts	0	5.1	203.643***
Access to credit facilities	58.7	41.3	5.898**
Access to weather & climate information	26	74.0	45.082***
Utilization of weather & climate information	65.8	34.2	19.612***
Access to market	3.1	96.9	172.735***
Distance to market (Km)	2.82 ± 2.30		

Note: *** significant at 1%, **significant at 5%, and * significant at 10%.

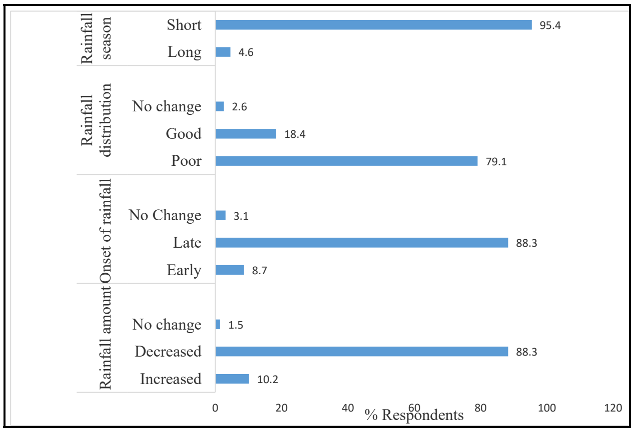

Figure 3. Farmers' perception of changes in rainfall.

Analysis of the rainfall trends from the data obtained from the meteorological department revealed that there was a declining trend in the total annual rainfall for the last 35 years. The average annual decrease was 18.47 mm of rainfall with a covariance of variation (CV) of 37.93% (Figure 4). The high CV signifies high rainfall variability within the period. This finding is in line with the majority of the farmers in the area who reported a perceived decline in rainfall over the comparable period. These findings are consistent with those of Esayas et al., (2019) who assessed farmers' perception in Southern Ethiopia. They found significant variability of rainfall with a CV of 18.75% and 25% for highland and lowland agro-ecological zones, respectively. The findings are equally consistent with those of a study in Southwestern Nigeria, where farmers' perceptions of climate change mirrored meteorological analysis (Ayanlade et al., 2017). Additionally, they are consistent with the study of Amir et al. (2020a, b) where 96% of the farmers interviewed reported to have perceived changes in climate. Furthermore, they are in line with the findings of Ochieng et al., (2017), Mutunga et al., (2017) and Belay et al., (2017) who reported that farmers had perceived a decrease in rainfall in their respective study areas within Kenya over time.

The temperature was perceived to have increased over the years by 76.6% of the respondents. A significant difference between those who observed an increase in temperature and those who perceived either a decrease or no change was noted (Figure 5). The smallholder farmers claimed the increase in temperature had resulted in the drying of some crops in some seasons. The findings on the perceived temperature and rainfall properties are consistent with those of Ochieng et al., (2017) who found that 74.9% of the respondents sampled from various zones of Kenya perceived an increase in temperature and 46.5% believed the rainfall has decreased over 30 years. They are equally consistent with

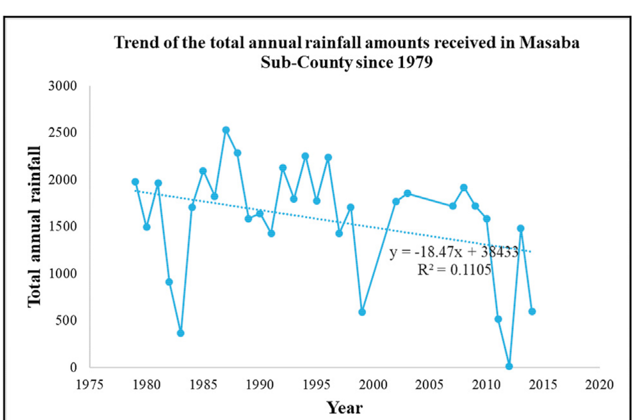

Figure 4. Trend of the total annual rainfall amounts received in Masaba Sub-county.

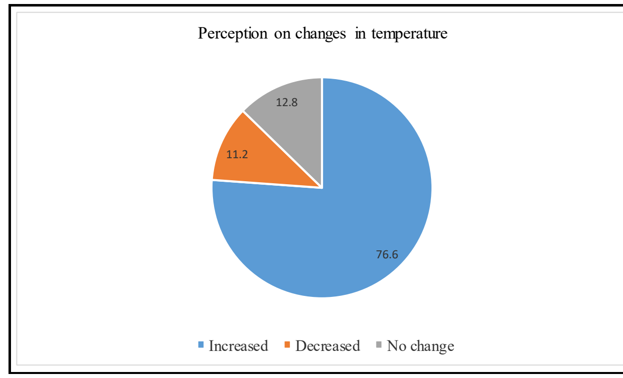

Figure 5. Perception of the changes in temperature.

those of Mutunga et al., (2017) who reported that 97 % to 100% of the respondents had identified a decrease in the amount of rainfall received over time.

The findings were moreover in support of other studies within the Eastern African region, as reported by Zizinga et al., (2017) in South Western Uganda and Belay et al., (2017) in the Central Rift Valley of Ethiopia who reported that farmers' had spotted an increase in temperature. In the study area, 87.8% of the respondents had perceived changes in climate.

Farmers' perception of the increased temperatures mirrored the factual climatic data obtained from the Kisii meteorological department. The data indicated both a gradual increase in the minimum and maximum average temperatures. The trend line indicates precisely the average annual maximum temperature increased approximately by a factor of 0.0184, while that of minimum temperature increased by a factor of 0.0164 (Figure 6). The CV for maximum temperature was 1.24%, while that of the minimum temperature was 1.98%. This result indicates that despite the increase recorded, there is little variability in both maximum and minimum temperatures over the years.

As reported by Moyo et al., (2012) the residents of Masaba South Sub-County possessed distinct perceptions of the climate changes. This is attributed to the varying cognitive and context-specific biases (Below et al., 2015). Their perception differed based on their farming experience, level of education, access to extension services, among other factors.

In accessing indicators of climate variability and change, most farmers noted a continuous decrease in the number of major food crops from their farms. They experienced a change in livelihood patterns, loss of some plant species, the soaring cost of food products and increased incidences of the pest and diseases. This was partly attributed to climate change and prolonged drought. In the FGDs, farmers confirmed that since the 1980s, there had been a rise in temperatures and a decrease in rainfall amounts. This supported the findings from the scheduled interviews. They noted these changes negatively affected agricultural productivity,

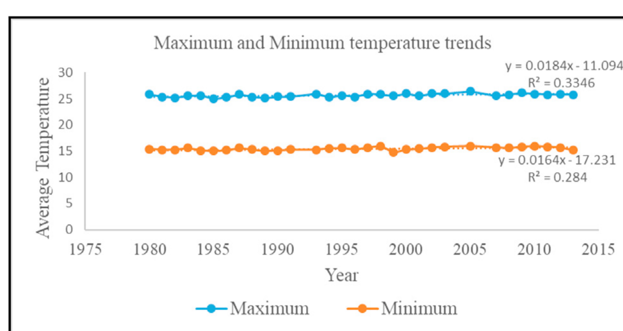

Figure 6. Maximum and minimum temperature trends in Masaba South Sub-county.

causing some of them to be food insecure at most times of the year as the production has greatly reduced. They noted the seasonal planting calendar had changed from December–January and July–August to March–May and September–November, respectively. They claimed the elevated temperatures have even affected tea production, a major cash crop, making it harder for them to educate their children. The perceived changes and indicators of climate change noted by farmers can be used to trigger changes in farming practices to enhance farmers' resilience against climate change, increase productivity and reduce greenhouse gases (Kalungu et al., 2013).

Key informants' interviews with representatives from various institutions similarly confirmed a decrease in rainfall amounts and an increase in temperature in the area. The agricultural officers interviewed noted some of the farmers are aware of the climatic changes through the periodic training and awareness creation seasons carried out by them. They also noted some farmers voluntarily practiced mulching as a water conservation measure and agroforestry for the trees to provide shade to crops as adaptation strategies. The sampled households seemed not to recognize the contributors to climate variability and change despite adversely affected. 12.2% of the respondents who were aware of the possible causes attributed the changes to deforestation and environmental pollution. In addressing the challenges of decreased agricultural production due to the prolonged drought, the sampled households identified a few institutions/organizations that came to address their problems. The institutions identified include a One-acre fund, a Young farmer's association, the Ministry of Agriculture, and a Local administrative/political class. Their kind of intervention involved training of farmers on the new ways of farming, provision of food aid, provision of credit facilities, and provision of agro-inputs.

3.4. Factors influencing smallholder farmers' perception of climate variability and change

The determinants influencing farmers' perception of climate variability and change were estimated by the logit regression model, and results are presented in Table 2. Household demographic, socio-economic, institutional and biophysical characteristics were evaluated to predict how they influence the perception of climate variability and change. The level of education, access to weather and climate information, and access to the agricultural extension positively and significantly influenced perceptions in changes in climate variability and change. Having attained higher education level increases the likelihood of perceiving general climate change, a decrease in rainfall and an increase in temperature by 1.66, 1.33, and 2.70 odds respectively. Learned farmers can receive, decode, recognize changes in the environment and comprehend information relevant to making correct decisions regarding climate change (Amir et al., 2020; Kimani and Bhardwaj, 2015; Mutunga et al., 2018) which could explain our findings.

Farmers' access to climate and weather information increases their awareness and knowledge of the variations in rainfall and temperature. This aids them to execute an informed decision on the relevant adaptation strategy to enhance their resilience (Maguza-Tembo et al., 2017). Access to weather and climate information increases the likelihood of perceiving climate changes, a decrease in rainfall and an increase in temperature by 3.50, 3.17, and 3.15 odds. Access to extension services enhances farmers 'perception and adoption of CSA practices as they are informed about climate and weather changes. The provision of extension services increases farmers' knowledge, skills, and awareness towards innovations of which some might be adopted or not based on their perceptions (Yesuf et al., 2008). Access to agricultural extension services increases the likelihood of perceiving changes in rainfall by 3.68 odds.

3.5. Climate-smart agriculture adoption by smallholder farmers

Coping strategies and enhanced adaptive capacity of farmers are crucial in addressing climate variability and change. The perceived climatic changes can shape the promotion and adoption of appropriate CSA practices. Enhanced adoption of CSA practices will increase farmers' resilience to climate change, increase productivity and reduce greenhouse gases emission. Following the continuous decrease in the quantity of farm produce as reported by the sampled households, farmers adopted out of necessity various strategies to enhance their resilience. The study revealed that 84.2% of the sampled households reported a decrease in the quantity of the major food crop grown compared to the previous harvest with 15.8% reporting the losses as severe (Figure 7). This decrease in the quantity of farm produce would be attributed to low rainfall amounts received in the area and higher temperatures. These findings are consistent with those of Kalungu et al., (2013) where 80% of the farmers sampled perceived changes in productivity for the past 30 years. Moreover, they are consistent with those of and Ayanlade et al., (2017) where farmers noted that some crop yields are lower in recent years compared to the past 30 years.

The decision by farmers on what coping or adaptation strategy to use to overcome the impacts of climate change and variability is influenced by opportunities and constraints available to farmers. These are in turn shaped by various factors beyond the farm household-scale at the community, landscape and regional levels (Tittonell, 2014). The adopted CSA practices in the study area by smallholder farmers can be divided into five categories as per Smit & Skinner (2002). The categories represent changes in farm production practices, changes in the land use, water management practices, changing land topography to address moisture deficiencies and change in timing of farming activities. From FGDs, the adoption of CSA practices is explicitly done to increase agricultural productivity and increase resilience to climate variability and change.

Farm production adaptation strategies: Strategies evaluated under this category include; planting of different crop varieties, diversification of crops, manure application, and change in the rate of fertilizer application. The findings indicate that 64.3% of the respondents have changed the varieties of crops they grow to cope with the changing climate (Table 3). Some of them use retained maize as planting seeds from the previous harvest as they believe that they are more resistant than hybrid seeds from seed merchants. From one of the key informant interviews, some of the seed merchants have started promoting drought-resistant seeds like SC Simba, Punda Millia 529, and SY594. These are earlier maturing seeds to help farmers to cope with climate change. A greater number of smallholder farmers diversified the kind of crops to grow, with some of them planting drought-resistant crops and other crops never grown in the area before such as sorghum, cowpeas, finger millet, green grams, and flowers for export (Table 3). These findings are in line with findings reported among farmers in semi-arid and sub-humid regions of Kenya where they stopped growing some crops due to low yields associated with low rainfall and opted for early maturing and drought-resistant crop varieties (Kalungu et al., 2013). The findings are equally consistent with a study in Ghana where farmers switched to drought-tolerant crop species with others growing different crops suited to the new climate they face (Antwi-Agyei and Nyantakyi-Frimpong, 2021). The respondents applied manure to their farms as an adaptation strategy to increase soil fertility and conserve soil moisture. The high proportional use of manure was attributed to the fact that the cost of fertilizers is high, and their continuous use has not proven to increase yield.

Change of planting time adaptation practices: Farmers change the timing of their farming activities to address the shifting spells of growing plants and related changes in temperature and moisture. In this study, 79.1% of the respondents changed planting time due to changes in temperature and precipitation. Most of the farmers shifted to planting crops after the onset of rainfall when they were sure there was enough moisture in the soil to support growth. During the key informant interviews and FGDs, farmers highlighted having been planting between December to February before the onset of the long rainfall season. With the late-onset, they have shifted planting between March and May. In the short rainfall season, in which they used to plant in July/August, they

Table 2. Logit regression model for factors influencing climate change perceptions among smallholder farmers.

Variables	(1)		(2)		(3)	
	Climate has changed		Rainfall decreased		Temperature increased	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Farmer is female (1 = yes)	1.14	[0.55,2.37]	1.24	[0.61,2.53]	1.33	[0.67,2.66]
Age of farmers in years	0.96	[0.81,1.14]	0.88	[0.75,1.04]	1.00	[0.86,1.17]
Age of farmer squared	1.00	[1.00,1.00]	1.00	[1.00,1.00]	1.00	[1.00,1.00]
Farmer is married (1 = yes)	0.75	[0.28,2.03]	0.62	[0.24,1.56]	0.88	[0.37,2.11]
Level of education attained is lower than secondary (1 = yes)	0.80*	[0.30,2.13]	0.60*	[0.23,1.56]	0.72*	[0.30,1.73]
Level of education attained is higher than secondary (1 = yes)	1.66*	[0.69,4.02]	1.33*	[0.57,3.09]	2.70*	[1.19,6.14]
Household size	0.63	[0.24,1.67]	1.17	[0.47,2.92]	0.84	[0.36,1.96]
Not a member of any social group (1 = yes)	2.32*	[1.10,4.88]	3.24**	[1.57,6.70]	2.03*	[1.05,3.93]
Land size in acres (log transformed)	2.17	[0.99,4.78]	2.10	[0.98,4.49]	1.74	[0.86,3.52]
Access to agricultural extension (1 = yes)	2.98	[0.97,9.16]	3.68*	[1.29,10.51]	2.16	[0.85,5.48]
Access to weather and Climate information (1 = yes)	3.50**	[1.57,7.77]	3.17**	[1.42,7.07]	3.15**	[1.41,7.05]
Access to credit facilities (1 = yes)	0.50	[0.22,1.16]	0.40*	[0.18,0.92]	0.46	[0.21,1.01]
Approximate monthly income in Ksh (log transformed)	0.66*	[0.47,0.93]	0.66*	[0.47,0.93]	0.95	[0.70,1.30]
Number of livestock owned	1.10	[0.98,1.23]	1.04	[0.99,1.09]	1.04	[1.00,1.08]
Distance to the nearest market (log transformed)	1.84	[0.69,4.91]	4.37**	[1.63,11.75]	0.99	[0.46,2.15]
Worked with formal institutions in the recent past (1 = yes)	0.62	[0.17,2.23]	0.86	[0.25,2.96]	0.24*	[0.07,0.83]
Ichuni ward	0.67	[0.26,1.69]	1.22	[0.48,3.06]	0.65	[0.27,1.57]
Gesusu Ward	1.97	[0.77,5.06]	2.73*	[1.09,6.85]	1.08	[0.47,2.48]
Number of observations	196		196		196	

Notes: ***Significant at 1% level; **significant at 5% level; *significant at 10% level; Reference categories are as follows ward = Masimba, education = secondary education. Dependent variables are dummy variables measuring climate change perceptions 1(climate change in general), 2(rainfall decreased), and 3(temperature increased), In parenthesis, are 95% Confidence Intervals (CI) for the odds ratios.

have shifted to planting as from September when the rainfall onset. These findings were consistent with those of Kahsay et al., (2019), who found that 83.60 % and 86% of farmers in Hawzen and Irob, respectively, in Northern Ethiopia adopted a change of planting time as an adaptation strategy. The results are equally consistent with other studies that report adjustments in the planting calendar (Amir et al., 2020; Antwi-Agyei and Nyantakyi-Frimpong, 2021; Talanow et al., 2021).

Water management and change of land topography adaptation practices: Water harvesting was among the least adopted adaptation strategies in the region. About 18.4% of those who adopted water-harvesting technology did so by collecting rainwater from the roofs and storing them in water tanks or shallow wells near the roads. They mainly used the collected water to irrigate vegetables in their gardens and for their cows. The collected water would be used to irrigate crops during dry spells to increase yield stability or for planting off-season to increase household income. This practice is adopted by a few people as it requires investment costs and knowledge which restrict widespread uptake by smallholder farmers (Fox et al., 2005).

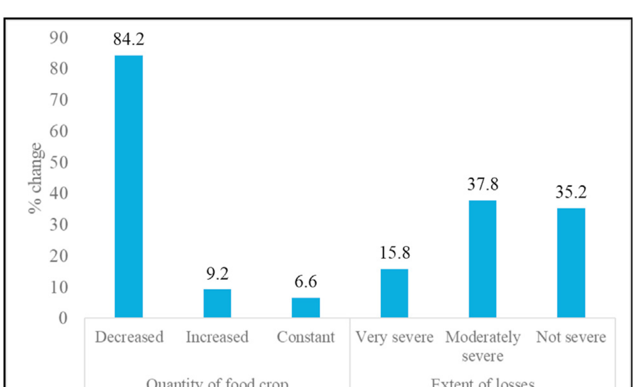

Figure 7. Changes in the crop production patterns among smallholder farmers.

Change in land topography adaptation practices: 56.1% of the respondents adopted other soil conservation practices such as mulching and terraces in their farms. They adopted the practices to retain water for a prolonged period to support the growth of crops (Table 3). The adoption of the soil conservation practices was highest in Masimba and Ichuni wards. This was attributed to the fact that these two regions are on slightly steep hills as compared to most farms in the Gesusu ward.

Change in land use adaptation strategies: These adaptation strategies aim at shifting crop and livestock rearing sites and /or application of the alternative fallow and tillage practices. Land use decisions on agricultural production are the major contributors to greenhouse gases emission in the agriculture sector. Deforestation and soil erosion were identified as major agricultural practices that contribute to climate change. This upshot is consistent with the findings of a review by Oladipo for the case of Nigeria (Oladipo, 2010). They identified some legislation to address issues of erosion and deforestation linked to climate change. To enhance farmers' resilience and mitigate climate change, farmers need to make better land-use decisions. 77.6% of the farmers practised either crop rotation or mixed cropping to increase productivity. Farmers in the FGDs highlighted that mixed cropping allows them to grow more than one crop at a time to cushion themselves in case of one crop failure.

The major food crop grown under mixed cropping was mainly identified as maize and beans, while crop rotation was mostly done with maize, beans, or finger millet. Mixed cropping has the advantage of allowing greater production from the same land, while not causing additional degradation to the soil. This is because different crops require different nutrients which can be mutually beneficial to each other (Katharine et al., 2013). With diminishing land due to sub-division, 36.2% of the respondents increased their land under cultivation through either leasing or purchasing an extra piece of land (Table 3). Members of the FGDs noted that some of the farmers in the region go as nearby Narok County to lease land for agricultural activity. Since the majority of the farmers in the area and Kenya at large depend on maize as a staple crop, it was found that it is only 9.7% of the respondents completely switched from crop growing to livestock keeping. This is in

Table 3. Households' adoption of climate-smart agriculture practices.

Climate Smart Agriculture Practice	% Non-adapters N = 196	% Adapters N = 196
Crop Diversification	16.3	83.7
Change of planting time	20.9	79.1
Crop rotation and mixed cropping	22.4	77.6
Use of manure	31.1	68.9
Change of crop varieties	35.7	64.3
Soil conservation/mulching/terraces	43.9	56.1
Livelihood diversification	48	52
Enhancing animal rearing practice	51	49
Increase land under farming/cultivation	63.8	36.2
Use of Integrated Pest Management	75	25
Change to Irrigation/Water harvesting	81.6	18.4
Reducing the land under cultivation	88.8	11.2
Switch from crop farming to livestock	90.3	9.7

line with studies carried out by Bernier et al., (2015). To reduce practices that continue to emit the greenhouse gas among smallholder farmers, there is a need to formulate and implement relevant policies to protect the environment from degradation as this will ultimately enhance farmers' adaptive capacity (Oladipo, 2010).

As the climate changes and exacerbates the already existing problems of food insecurity, some of the respondents (52%) have diversified their source of income. The diversification was either through doing a part-time job, a full time, a business, or through self-employment. This is consistent with other studies (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Mekuyie and Mulu, 2021). During the FGDs, it was noted that most women were involved in assisting other people in farm duties like weeding and tea picking to earn extra income. An increasing number of youths were involved in the motorbike business, with some taking loans to buy them. Some reported having started poultry farming as the product is more reliable, predictable, and running costs are low. Some of these livelihood diversification strategies were similar to those reported by Alhassan et al., (2019) in the Northern part of Ghana.

The relationship between farmers' characteristics and the adoption of CSA practices was tested using correlation analysis. The adoption of most CSA practices was positively significantly correlated with household size, monthly income, access to credit, and farmers' perception of climate change (Table 4). Large household size increases the likelihood of adaptation as it is associated with labour-intensive agricultural practices (Marenya and Barrett, 2007). Practices like soil conservation, mixed cropping, and application of manure are labour-intensive; hence large family size positively and significantly influences adoption. Households generating better income and having adequate assets are better placed to adopt new farming practices to enhance their resilience (Maguza-Tembo et al., 2017). Soil conservation practices and proper use of manure require capital investments. Wealthier farmers, because of their financial endowment, are likely to adopt these practices than the less endowed in the community. Accessibility to credit is an important factor in narrowing the financial gap of the farmers. This can help farmers purchase the required farm inputs and useful technologies in adaptation to climate change. Farming experience correlated negatively and statistically significantly with the adoption of CSA practices (Table 4). This upshot is contrary to the findings that report more experienced farmers as more informed about climate changes and are more likely to employ adaptation measures to enhance resilience (Deressa et al., 2008; Mwungu et al., 2018).

As a short-term coping strategy, farmers reported they purchase maize and other major food crops during the dry seasons. This is to ensure a continuous supply of food in the homestead. Most men in the households had moved to urban areas in search of an additional source of income to cope with hard conditions. Scientists working in research institutions within the study area noted there is ongoing research to develop drought-resistant crops specific to the region. Despite the positive move, they noted they faced financial constraints and legal challenges, especially on the long period required to release a new variety. It was also pointed out that the efforts to increase resilience through the adoption of these strategies is limited by factors such as; lack of capital, shortage of land, low level of infrastructure and technologies, lack of weather and climatic information. To minimize the vulnerability of the farmers, relevant government and non-governmental organizations need to increase their adaptive capacity through training and provision of critical inputs such as certified seeds that are tolerant to diseases and drought.

The key adaptation strategies adopted by farmers were consistent with studies of Kichamu et al., (2018) in Matungulu Sub-County, Eastern Kenya, Wamalwa et al. (2016) in three Sub-counties in Kisii county, Ochieng et al., (2017) in various agro-ecological zones in Kenya, Mburu et al., (2015) in Yatta District, Kenya. They identified change of crop varieties, change of planting time, crop diversification and soil and water conservation practices as the most adopted strategies to cope with changing climate. This study revealed livelihood diversification as a coping strategy adopted by almost half of the respondents, findings not highlighted by other studies. They did this as a way of increasing their

Table 4. Correlation of the farmers' characteristics and adoption of some CSA Practices.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Household size	1	-.060	.176*	-.014	.089	-.107	-.137	.021	.143*	-.236**	.028	.171*	-.095	.297**	.211**
2	Education level	-.060	1	-.286**	.002	.098	-.019	.168*	.085	-.089	.004	-.156*	.092	.047	.205**	.114
3	Farming experience	.176*	-.286**	1	-.027	-.160*	-.071	.031	-.297**	.061	.090	.057	-.186**	-.134	-.190**	-.234**
4	Social group	-.014	.002	-.027	1	.058	.030	.079	.166*	.105	.148*	.078	.110	.045	-.113	-.004
5	Monthly income	.089	.098	-.160*	.058	1	-.084	-.202**	.214**	-.055	-.127	.000	.096	.092	.314**	.354**
6	Agric. extension	-.107	-.019	-.071	.030	-.084	1	.057	.108	.089	.145*	-.053	-.109	.004	-.158*	-.138
7	Weather & climate	-.137	.168*	.031	.079	-.202**	.057	1	-.022	-.115	.286**	-.042	.015	.009	-.147*	-.173*
8	Access to credit	.021	.085	-.297**	.166*	.214**	.108	-.022	1	.029	-.153*	.090	.228**	.279**	.251**	.429**
9	Perception in C.C	.143*	-.089	.061	.105	-.055	.089	-.115	.029	1	-.084	.046	.135	-.039	.220**	.172*
10	crop varieties	-.236**	.004	.090	.148*	-.127	.145*	.286**	-.153*	-.084	1	.132	-.069	.009	-.340**	-.359**
11	Crop diversification	.028	-.156*	.057	.078	.000	-.053	-.042	.090	.046	.132	1	.060	.078	-.118	.082
12	Mixed cropping	.171*	.092	-.186**	.110	.096	-.109	.015	.228**	.135	-.069	.060	1	.144*	.299**	.264**
13	Planting time	-.095	.047	-.134	.045	.092	.004	.009	.279**	-.039	.009	.078	.144*	1	.061	.127
14	Use of Manure	.297**	.205**	-.190**	-.113	.314**	-.158*	-.147*	.251**	.220**	-.340**	-.118	.299**	.061	1	.560**
15	Soil conservation	.211**	.114	-.234**	-.004	.354**	-.138	-.173	.429**	.172*	-.359	0.082	.264**	.127	.560**	1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

source of income to improve their living standards in the face of climate change. These findings would be attributed to the fact that the land sizes are small, and the effects of climate variability and change are severe on their farm produce.

4. Conclusions

We can make a few conclusions from this study. First, the adoption of CSA is affected by farmers' perception of climate variability and change at the farm level. Further, the adoption of CSA is also influenced by farmers' attitudes and knowledge of climate change. Second, farmers' perceptions about climate change in the studied area accurately mirrored the climatic data. Farmers' perception of increased temperature and decreased amount of rainfall over time, matched climatic data trends from the meteorological station.

Third, education and access to information are essential for farmers to perceive climate change accurately. Results show farmers' perceptions are significantly influenced by the farmers' level of education, access to weather and climate information, and access to agriculture extension services. Fourth, farmers' agricultural activities adjust to their climate perceptions. Smallholder farmers adopted crop diversification, change of planting time, crop rotation/mixed cropping, use of manure and change of crop varieties as the major adaptation strategies. They explicitly adopted the practices to enhance their resilience against climate variability and change.

Lastly, farmer socioeconomic conditions significantly explain adaptation decisions. The adoption of the CSA practices was significantly correlated with the household size, monthly income of the household, access to credit, and farmers' perception of climate variability and change.

To increase the effectiveness and sustainability of adaptation interventions in the study area, we recommend climate change knowledge and adaptation capacity of farmers be part of the local development agenda. Local governments need to prioritize climate change awareness and allocate sufficient resources towards the same cause. Such actions can go a long way in enhancing awareness and promote informed climate change adaptation actions.

National and County governments need to incorporate the climate change knowledge of the people and shape farmers' understanding of climate change. Having useful linkages between farmers and relevant stakeholders (e.g., researchers, extension office and meteorologists) strengthened is one way of improving and synchronizing farmer knowledge with their farming activities.

Declarations

Author contribution statement

Jared O. Nyang'au: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Jema H. Mohamed; Nelson Mango: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Clifton Makate; Alex N. Wangeci: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Funding statement

Jared O. Nyang'au was supported by the World Bank through the Africa Centre of Excellence for Climate Smart Agriculture and Biodiversity Conservation. The Centre is hosted at Haramaya University, Ethiopia.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at https://doi.org/10.1016/j.heliyon.2021.e06789.

References

Adamgbe, E.M., Ujoh, F., 2013. Effect of variability in rainfall characteristics on maize yield in Gboko, Nigeria. J. Environ. Protect. 4, 881–887.

Adimassu, Z., Kessler, A., 2016. Factors affecting farmers' coping and adaptation strategies to perceived trends of declining rainfall and crop productivity in the central Rift valley of Ethiopia. Environ. Syst. Res. 5, 1–13.

Alhassan, H., Kwaka, P.A., Adzawla, W., 2019. Farmers choice of adaptation strategies to climate change and variability in arid region of Ghana. Rev. Agric. Appl. Econ. (RAAE) 22 (1), 32–40.

Amir, S., Saqib, Z., Khan, M.I., Ali, A., Khan, M.A., Bokhari, S.A., Zaman ul Haq, 2020a. Determinants of farmers' adaptation to climate change in rain-fed agriculture of Pakistan. Arab. J. Geosci. 13 (19).

Amir, S., Saqib, Z., Khan, M.I., Khan, M.A., Bokhari, S.A., Zaman-Ul-haq, M., Majid, A., 2020b. Farmers' perceptions and adaptation practices to climate change in rain-fed area: a case study from district chakwal, Pakistan. Pakistan J. Agric. Sci. 57 (2), 465–475.

Amjath-Babu, T.S., Krupnik, T.J., Aravindakshan, S., Arshad, M., Kaechele, H., 2016. Climate change and indicators of probable shifts in the consumption portfolios of dryland farmers in Sub-Saharan Africa: implications for policy. Ecol. Indicat. 67, 830–838.

Antwi-Agyei, P., Nyantakyi-Frimpong, H., 2021. Evidence of climate change coping and adaptation practices by smallholder farmers in northern Ghana. Sustainability.

Archer, E., Mukhala, E., Walker, S., Dilley, M., Masamvu, K., 2007. Sustaining agricultural production and food security in Southern Africa: an improved role for climate prediction? Climatic Change 83 (3), 287–300.

Ayanlade, A., Radeny, M., Morton, J.F., 2017. Comparing smallholder farmers' perception of climate change with meteorological data: a case study from southwestern Nigeria. Weather Clim. Extr. 15 (September 2016), 24–33.

Belay, A., Recha, J.W., Woldeamanuel, T., Morton, J.F., 2017. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agric. Food Secur. 6 (1).

Below, T.B., Schmid, J.C., Sieber, S., 2015. Farmers' knowledge and perception of climatic risks and options for climate change adaptation: a case study from two Tanzanian villages. Reg. Environ. Change 15 (7), 1169–1180.

Bernier, Q., Meinzen-Dick, R., Kristjanson, P., Haglund, E., Kovarik, C., Bryan, E., Ringler, C., Silvestri, S., 2015. Gender and Institutional Aspects of Climate-Smart Agricultural Practices: Evidence from Kenya. CCAFS Working Paper.

Deressa, T., Hassan, R.M., Alemu, T., Yesuf, M., Ringler, C., 2008. Analyzing the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile Basin of Ethiopia. In: IFPRI Discussion Paper (Paper 007981).

Esayas, B., Simane, B., Teferi, E., Ongoma, V., Tefera, N., 2019. Climate variability and farmers' perception in southern Ethiopia. Adv. Meteorol.

FAO, 2013. Climate-smart agriculture sourcebook. Food and agriculture organization of the United Nations. In: Sourcebook on Climate-Smart Agriculture, Forestry and Fisheries.

Food and Agriculture Organization FAO, 2012. Smallholders and family farmers. In: Sustainability Pathways.

Fox, P., Rockström, J., Barron, J., 2005. Risk analysis and economic viability of water harvesting for supplemental irrigation in semi-arid Burkina Faso and Kenya. Agric. Syst.

Gandure, S., Walker, S., Botha, J.J., 2013. Farmers' perceptions of adaptation to climate change and water stress in a South African rural community. Environ. Develop. 5, 39–53.

Government of Kenya GoK, 2013. Adaptation Technical Analysis Report for the National Climate Change Action Plan. https://environmentalmigration.iom.int/government-kenya-adaptation-technical-analysis-report.

Government of Kenya GoK, 2017. Kenya Climate Smart Agriculture Strategy 2017-2026.

Heinisch, O., Cochran, W.G., 1965. Sampling Techniques, 2. Aufl. John Wiley and Sons, New York, London, 1963. Preis s. Biometrische Zeitschrift.

IPCC, 2018. An IPCC Special Report on the Impacts of Global Warming of 1.5°C. *Intergovernmental Panel on Climate Change*.

IPCC, 2019. Special Report on Climate Change and Land. Ipcc.

Kahsay, H.T., Guta, D.D., Birhanu, B.S., Gidey, T.G., Routray, J.K., 2019. Farmers' perceptions of climate change trends and adaptation strategies in semiarid highlands of Eastern Tigray, northern Ethiopia. Adv. Meteorol.

Kalungu, J., Filho, W.L., Harris, D., 2013. Smallholder farmers' perception of the impacts of climate change and variability on rain-fed agricultural practices in semi-arid and sub-humid regions of Kenya. J. Environ. Earth Sci. 3 (7), 129–141. http://iiste.org/Journals/index.php/JEES/article/view/6379.

Katharine, V., 2004. Creating an index of social vulnerability to climate change for Africa. Tyndall Centr. Clim. Change Res. 56 (41).

Katharine, V., Cull, T., Chanika, D., Hamazakaza, P., Joubert, A., Macome, E., Mutonhodza-Davies, C., 2013. Farmers' responses to climate variability and change in southern Africa - is it coping or adaptation? Clim. Dev. 5 (3), 194–205.

Kichamu, E.A., Ziro, J.S., Palaniappan, G., Ross, H., 2018. Climate change perceptions and adaptations of smallholder farmers in Eastern Kenya. Environ. Dev. Sustain. 20 (6), 2663–2680.

Kimani, N.C., Bhardwaj, S.K., 2015. Assessment of people's perceptions and adaptations to climate change and variability in mid-hills of Himachal Pradesh, India. Int. J. Curr. Microbiol. Appl. Sci. 4 (8), 47–60.

Kisii County Government, 2013. The First County Integrated Development Plan 2013-2017.

Komba, C., Muchapondwa, E., 2015. Environment for Development Centers Adaptation to Climate Change by Smallholder Farmers in Tanzania. Environment for Development. http://www.rff.org/files/sharepoint/WorkImages/Download/EfD-DP-15-12.pdf.

Kryger, K.N., Thomsen, K.A., And, M.A.W., Dissingtion, M., 2010. Smallholder poultry production – livelihoods, food security and sociocultural significance. Smallhold. Poult. Prod.

Maddison, D., 2006. The perception of and adaptation to climate change in Africa. In: CEEPA Discussion Paper.

Maguza-Tembo, F., Edriss, A.-K., Mangisoni, J., 2017. Determinants of climate smart agriculture technology adoption in the drought prone districts of Malawi using a multivariate probit analysis. Asian J. Agric. Extens. Econ. Sociol.

Marenya, P.P., Barrett, C.B., 2007. Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. Food Pol. 32, 515–536.

Mburu, B.K., Rsquo u, J.B.K., Muriuki, J.N., 2015. Climate change adaptation strategies by small-scale farmers in Yatta District, Kenya. Afr. J. Environ. Sci. Technol. 3 (2), 19–27.

Mekuyie, M., Mulu, D., 2021. Perception of impacts of climate variability on pastoralists and their adaptation/coping strategies in fentale district of Oromia region, Ethiopia. Environ. Syst. Res.

Morton, J.F., 2007. The impact of climate change on smallholder and subsistence agriculture. Proc. Natl. Acad. Sci. U.S.A. 19680–19685.

Moyo, M., Mvumi, B., Kunzekweguta, M., Mazvimavi, K., Craufurd, P.Q., Dorward, P., 2012. African crop science journal. Afr. Crop Sci. J. 20 (2), 317–335. https://hdl.handle.net/10568/42025.

Mutunga, E., Ndungu, C., Muendo, P., 2017. Smallholder farmers perceptions and adaptations to climate change and variability in kitui county, Kenya. J. Earth Sci. Climatic Change 8 (3), 1–7.

Mutunga, E., Ndungu, C., Muendo, Patricia., 2018. Factors influencing smallholder farmers' adaptation to climate variability in kitui county, Kenya. Int. J. Environ. Sci. Nat. Res. 8 (5), 155–161.

Mwungu, C.M., Mwongera, C., Shikuku, K.M., Acosta, M., Läderach, P., 2018. Determinants of adoption of climate-smart agriculture technologies at farm plot level: an assessment from southern Tanzania. In: Handbook of Climate Change Resilience.

Nhemachena, C., Hassan, R., 2007. Micro-level analysis of farmers adaption to climate change in southern Africa. booksgooglecom.

Nkonya, E., Pender, J., Kaizzi, K.C., Kato, E., Mugarura, S., Ssali, H., Muwonge, J., 2008. Linkages between land management, land degradation, and poverty in sub-Saharan Africa: the case of Uganda. Res. Rep. Int. Food Pol. Res. Inst. 159, 1–122.

Ochieng, J., Kirimi, L., Makau, J., 2017. Adapting to climate variability and change in rural Kenya: farmer perceptions, strategies and climate trends. Nat. Resour. Forum 41, 195–208.

Ochieng, J., Owuor, G., Bebe, B.O., 2012. Determinants of adoption of management interventions in indigenous chicken production in Kenya. Afr. J. Agric. Res. Econ. 7 (1), 39–50.

Odada, E.O., Scholes, R.J., Noone, K., Mbow, C., Ochola, W.O., 2008. A Strategy for Global Environmental Change Research in Africa: Science Plan and Implementation Strategy.

Oladipo, E., 2010. Towards Enhancing the Adaptive Capacity of Nigeria: a Review of the Country's State of Preparedness for Climate Change Adaptation. Heinrich Böll Foundation Nigeria, September, pp. 1–44.

Smit, B., Skinner, M.W., 2002. Adaptation options in agriculture to climate change: a typology. Mitig. Adapt. Strategies Glob. Change 7, 85–114.

Stefanovic, J.O., Yang, H., Zhou, Y., Kamali, B., Ogalleh, S.A., 2017. Adaption to climate change: a case study of two agricultural systems from Kenya. Clim. Dev.

Stern, N., 2010. Climate: what You Need to Know. New York Review of Books (June 24,20).

Talanow, K., Topp, E.N., Loos, J., Martín-López, B., 2021. Farmers' perceptions of climate change and adaptation strategies in South Africa's Western Cape. J. Rural Stud.

Tittonell, P., 2014. Livelihood strategies, resilience and transformability in African agroecosystems. Agric. Syst. 126, 3–14.

Traore, B., Van Wijk, M.T., Descheemaeker, K., Corbeels, M., Rufino, M.C., Giller, K.E., 2015. Climate variability and change in southern Mali: learning from farmer perceptions and on-farm trials. Exp. Agric. 51, 615–634.

Wamalwa, I.W., Mburu, B.K., Mang'uriu, D.G., 2016. Perception of climate change effects and its influence on uptake of climate smart practices among small scale farmers of Kisii County, Kenya. Int. J. Inf. Retr. Res. 3 (5), 2409–2417.

Washington-Ottombre, C., Pijanowski, B.C., 2013. Rural organizations and adaptation to climate change and variability in rural Kenya. Reg. Environ. Change.

Yesuf, M., di Falco, S., Deressa, T., Ringler, C., Kohlin, G., 2008. The impact of climate change and adaptation on food production in low-income countries: evidence from the Nile Basin, Ethiopia. In: IFPRI Discussion Paper (24). http://www.ifpri.org/publication/impact-climate-change-and-adaptation-food-production-low-income-countries.

Zizinga, A., Kangalawe, R.Y.M., Ainslie, A., Tenywa, M.M., Majaliwa, J., Saronga, N.J., Amoako, E.E., 2017. Analysis of farmer's choices for climate change adaptation practices in south-western Uganda, 1980-2009. Climate 5 (89), 1–15.