



Response to climate change in a rain-fed crop production system: insights from maize farmers of western Kenya

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Abstract

Climate change poses a threat to crop production and livelihoods of rural farming communities in Kenya, a majority of whom are mainly dependent on rain-fed agriculture. The purpose of this study was to examine farm-level adaptation responses towards climate change and their influencing factors, using a case study of western Kenya. Structured questionnaire was administered to 210 farmers in selected locations in the region where households farm maize as the main crop. Logistic and multiple linear regression models were used to ascertain the factors that influence farmers' adaptation practices. The results indicate that farmers perceived climate change as being responsible for the reduction in crop yield and production, crop failure and increase of fallow farms. The major adaptation strategies undertaken by the farmers included change in planting dates by either planting early or late during a season, diversification of crops, growing early maturing cultivars, use of drought-tolerant varieties and timely planting. The key determinants of adaptation strategies by the farmers included farm size, income and extension training. Understanding farmers' responses to climate change in rain-fed crop production systems could assist in planning adaptation strategies towards sustainable crop production.

Keywords Adaptation · Agriculture · Climate variability · Food systems · Sustainability

1 Introduction

The impacts of climate change are detrimental and have been observed to have multiple dimensions in major sectors of development in various regions of the world. As the per Fifth Assessment Report of the IPCC, the severity of climate-related impacts varies strongly with environmental, socio-economic and other factors that influence exposure,

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adaptive and coping strategies of the concerned communities (IPCC, 2014). In Africa, societal learning and collective action are used to support adaptation aimed at addressing the risks that result from climate change (IPCC, 2014). This is particularly critical in agriculture, which is considered as a key strategic sector that has been targeted by most governments to boost the economic growth and food security for the population (Calzadilla et al., 2013a, b; Diao et al., 2007). Despite the significant contribution of agriculture to the economies of many countries in Sub-Saharan Africa (SSA), the sector is challenged by climate variability which is likely to reverse the gains that have been achieved on rain-fed crop production (Barrios et al., 2008; Hansen et al., 2011; Müller et al., 2011). Therefore, the importance of supporting local and national capacity-building strategies focusing on adaptation has become more prominent, even at global policy discussion forums on the impacts of climate change over the past few decades.

Adaptation is a key option to respond to climatic risks and improve the resilience of agriculture in Africa (IPCC, 2014). However, the report identified that there was limited research on development of home-grown strategies and localizing global adaptation techniques aimed at building resilience. In addition, the factors influencing effective adaptation, including community-based adaptation, were also identified as a research gap in the report. Therefore, strategies aimed at strengthening adaptive capacities for climate change in agriculture should focus on participatory scientific research involving local farmers, improved communication on climatic risks and diversification of livelihood options. However, in Africa, adaptation to climatic change is constrained by financial barriers, inadequate access to water, low soil fertility, land fragmentation, poor road network, crop pests and diseases, lack of access to inputs, lack of information dissemination and communication, poor quality cultivars and limited knowledge on climate change (Barbier et al., 2009; Bryan et al., 2009; Nyanga et al., 2011).

Farm-level adaptation is aimed at strengthening the resilience of an agricultural system to survive the susceptibility to the negative impacts posed by climate change and variability (M. S. Alam et al., 2017a, b; Bradshaw et al., 2004; Moroda et al., 2018). Thus, given the role played by adaptation in sustaining crop production under the facets of climate change, it is undeniable that farmers' perceptions of climate change are essential for decision-making on actions necessary to tackle the challenges posed by climate change (Bryant et al., 2000; Chhogyel et al., 2020; Gandure et al., 2013; Gopalakrishnan et al., 2019; Hasan and Kumar 2019; Jianjun et al., 2015; Vogel et al., 2012). Knowledge of how climate variability is perceived by farmers and the drivers of such perceptions are important in understanding their adaptive behaviours and responses (Weber, 2010). Farmers' behaviour is influenced more by their perception of climate change and associated risks, rather than the spatial and temporal patterns determined scientifically (Adger et al., 2009). It has also been generally observed that one must first perceive the change before undertaking any adoption strategies towards climate change (Deressa et al., 2009; Hasan et al., 2018; Maddison, 2007).

Previous research has identified several socio-economic variables that may influence the access to, uptake of, effectiveness of and general capacity for adaptation. As per Pandey et al. (2018), the perceived impact of climate change on crop production is hypothesized to encourage farmer's uptake of adaptation. Among the key factors is age, which is associated with farming experience under climate change (Twongyirwe et al., 2019). The gender of the household head also influences access to financial resources and extension services on adaptation practices (Bryan et al., 2013). Other studies have shown that education level influences an individual's ability to acquire and understand information necessary for adopting new farming technologies (Pandey et al. 2018;

Mugi-Ngenga et al. 2016). According to Bryan et al. (2013), farm-level adaptation is enhanced by access to training facilities, information and farming skills.

Kenya, like many other countries in SSA, has experienced seasonal and annual variations in precipitation and temperature over the last 50 years, which is to some degree associated with climate change (Koei, 2013). For example, the country has experienced frequent occurrences of extreme weather events such as floods and prolonged droughts that have affected crop production in the past (Biamah, 2005). Future projections for Kenya also show increases in precipitation of 2 to 12% and temperature of up to 3 °C (GoK, 2016). The changes in precipitation and temperature have direct link to the state of crop water availability and the length of the growing season (Anandhi et al., 2013; Calzadilla et al., 2013a, b; Gopalakrishnan et al., 2019; Rosenzweig et al., 1995). In Kenya, this has resulted in low crop productivity, considering that agriculture is mainly rain-fed. Existing literature has mainly focussed on adaptation of crop production under climate change (Macharia et al., 2012; Roncoli et al., 2010; Ruane et al., 2013). However, there is limited information linking the socio-economic drivers with the farmers' adaptation behaviours in high potential agricultural areas, such as in western Kenya. A better understanding of the socio-economic drivers influencing farmers' adaptation behaviours would be useful in formulation of strategies to minimize the impacts of climate variability on crop production (Alam et al., 2017a, b; Deressa et al., 2009). For instance, the policy and decision makers can enhance farm-level adaptation measures by investing on the socio-economic drivers.

This study seeks to address the aforementioned limitation by analysing the on farm-level response strategies to climate change and the influencing factors using a case study of maize farmers in western Kenya. The study addresses the following questions: (i) What are the perceived impacts of climate change on rain-fed crop production? (ii) What adaptation strategies are being undertaken by farmers to sustain crop production under climate change? (iii) What household socio-economic factors are associated with farmer's adaptive response to climate change? Broadly, the study aimed to enhance the understanding of climate change response practices undertaken in SSA. The study used primary data in order to explicitly capture the perceptions of the farmers on the effects of climate change on crop production and farm-level adaptation response strategies, including their determinants. Data collection for the study was undertaken between July and August 2019 across four maize growing divisions of Kabiyet, Soy, Kiminini and Kapenguria in western Kenya.

2 Materials and methods

2.1 Study area

The survey was conducted in western Kenya, which lies between longitude 34° 00'E and 35° 30'E and latitude between 00° 00'N and about 01° 15'N (Fig. 1). The specific study locations in the region included Kabiyet, Soy, Kiminini and Kapenguria Divisions in Nandi, Uasin Gishu, Trans Nzoia and West Pokot counties respectively. These are the divisions where most farmers farm maize as the main crop. The focus of the study was on maize farming since it is the major staple food crop in Kenya (Nyoro et al., 2004). Crop production in the selected areas relies mainly on the long rainy season of March to May and moderate rains of June to August (Kogo et al., 2019a).

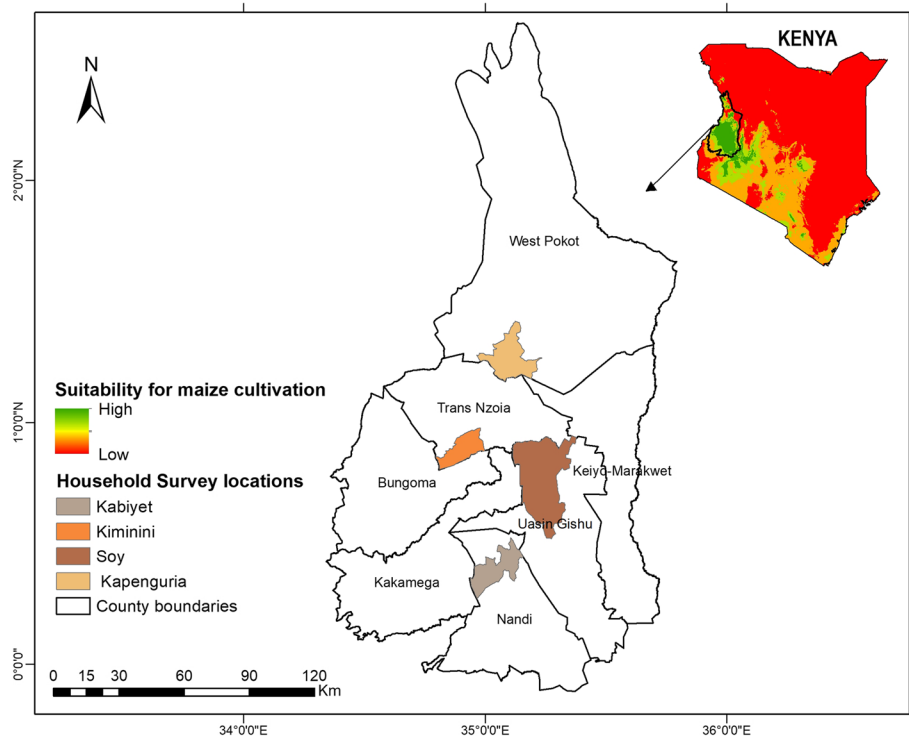


Fig. 1 Map showing the study locations in western Kenya. The inset map shows the country's climatic suitability for maize production derived by Kogo et al. (2019b)

2.2 Sampling of households for interviews

Initially, the target was to randomly interview 60 farmers from a list maize farmers registered with the agricultural extension officers in each of the maize producing locations. However, due to challenges such as unavailability of respondents and rainy weather, the percentage of registered farmers interviewed was 77%, 100%, 93% and 80% in Kibiyet, Soy, Kiminini and Kapenguria, respectively, giving a sample size representing 88% of the targeted population of farming households. A pre-tested structured questionnaire was used to undertake face-to-face interviews with farmers in order to collect information on: (a) perceived impacts of climate change on crop production, yields, input costs, land suitability for usual crops and food availability; (b) household socio-economic characteristics; and (c) the agricultural response strategies used by farmers to cope with climate change on crop production. The adaptation measures examined were those that were being practiced by farmers in the study area. These included change of planting date, crop diversification, planting of short-duration crops, use of drought-tolerant cultivars, on-farm rainwater harvesting for irrigation, timely planting and agroforestry practices. In addition, the questionnaire collected information on access to early warning and agricultural extension services on farming and adaptation to climate change.

2.3 Data analysis

The study employed both descriptive and inferential statistical approaches for data analysis. For the first research question, the perceived impacts of climate change on crop production were ranked based on average impact scores assigned as 3, 2, 1 and 0 to represent high, medium, low and no impact, respectively. The second research question entailed analysing the number of farmers practicing the various adoption strategies. In this case, adaptation was considered farm-level management strategies that were undertaken in response to adverse climatic conditions on crop production. The farmers were also grouped into adopter categories based on the number of farm-level adaptation measures they implemented. For instance, the farmers who implemented less than 2 adaptations were grouped as low adopters, those that implement 3 to 4 adaptations as moderate adopters and those that implement more than 4 adaptations as high adopters.

As for the third research question, the factors that influence farmers to implement the various adaptation strategies were analysed individually using the logistic regression model (LRM) and together using with multiple linear regression (MLR). To identify the key factors that influence farmers to undertake adaptation measures, an identical set of socio-economic variables (independent variables) was entered in the LRM and MLR models in the statistical software RStudio-version 1.2.5033 (<https://www.rstudio.com/>). LRM was used to specifically analyse the factors that influence farmers to implement each of the eight adaptation options. According to Bewick et al. (2005), LRM is computed as:

$$\log\left(\frac{P_i}{1 - P_i}\right) = \log(P_i) = \beta_0 + \beta_i X_i$$

where P_i is the probability of perceiving a given adaptation, X_i is an independent variable, β_0 is a constant and β_i provides the logistic regression coefficients.

The MLR model was used to analyse the key factors that influence the overall status of adoption by farmers. MLR works by synchronically analysing the relationship between dependent and independent variables (Uyanik and Güler 2013). MLR analysis is formulated as follows:

$$y = \beta_0 + \beta_1 x_1 + \dots + \beta_n x_n + \varepsilon$$

where y is the dependent variable, x_1 is the independent variable, β_1 is the parameter and ε is the error of measurement.

The outputs of the two models were regression coefficients that show the independent variables as being either positively or negatively correlated to adaptation strategies.

3 Results

3.1 Socio-economic characteristics of the respondent farmers

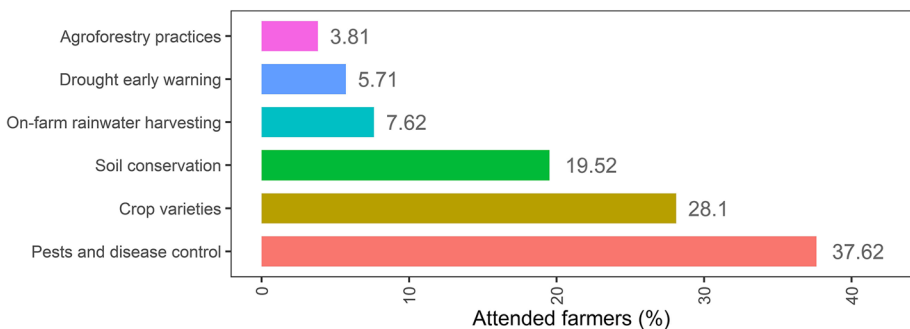
Table 1 presents a summary of descriptive statistics of respondent farmers' demographic profiles. The mean age of the respondent farmers was 46.2 years, with a range of 21–76 years. In terms of gender, 62.9% and 37.1% were males and females respectively. Household headship was dominated by males (81.4%). Across the four counties,

Table 1 Descriptive statistics of farmer characteristics

Characteristics	Units	Mean or categories	SD or percentage
Age	Years	46.2	12.14
Sex	Nominal	Male	62.9%
		Female	37.1%
Household head	Nominal	Male	81.4%
		Female	18.6%
Education	Years of schooling	10.5	4.4
Employed family member	Number	0.9	1.1
Family size	Number	6.2	2.2
Highest education	Years of schooling	13.5	3.4
Farm size	Acres	5.4	7.7
Income from crops	Thousand USD	5.0	35.5
Membership in farmers' association	Nominal	Yes	34.8%
		No	65.2%
Risk perception	Score	15.3	2.7
Training received	Number	1	0.9
Impact perception	Score	12.6	2.4

the mean family size was 6.2. The average farm size was 5.4 acres (SD = 7.7 acres) and the mean annual income from crops being 5169 USD (ranging from farmers who do not earn any income to those who earn a maximum of 37,500 USD from crop sale). Of the respondents, only 34.8% confirmed to be members of farming associations. With respect to agricultural extension trainings on farming and adaptation to climate change, the mean was one training (range 0–4 trainings) among the farmers.

In terms of extension training, the survey revealed that the farmers had received a number of trainings related to farming practices and adaptation to climate change (Fig. 2). The most common trainings were on pests and disease control (37.6%), crop varieties (28.1%) and soil conservation (19.5%).

**Fig. 2** Proportion of farmers trained on various farm practices and adaptation strategies

3.2 Perceived impacts of climate change

Average perception scores of respondents on farming risks and impact of climate change were 15.3 (SD=2.7) and 12.6 (SD=2.4), respectively (Table 2), against a possible range of 0 to 54 and 0 to 18. Figure 3 presents the perceived impacts of climate change by the sampled maize farmers in western Kenya. The results show that the major climatic impacts perceived by the farmers were mainly crop failure ($n=210$), decrease in yield ($n=210$), food shortage ($n=193$) and decreased production ($n=188$). However, the four impacts were perceived to be of medium risk to crop production (average score greater than 2). The impacts that were perceived to be of low risk (average score less than 1) were increase in cost of production ($n=74$) and change in land suitability for crop production ($n=55$).

3.3 Adaptation strategies

Farmers' adaptation to climate change typically involves many response strategies. For instance, the results show that the majority (78.7%) of the farmers in western Kenya practiced early/delayed planting as a major adaptation strategy to combat the negative impacts of climate change (Fig. 4a). Likewise, 63.3% of the farmers practiced crop diversification by planting an average of two crops on their farm with a common combination being intercropping of maize and beans in a given planting season. Other strategies implemented were cultivation of short-duration crops, timely planting and use of drought-tolerant varieties. However, these adaptation strategies were perceived to have low impact on crop production (average impact score of between 0.05 and 1.56). Further analysis to examine the adopter categories shows that a greater number of farmers were moderate adopters (57.6%) implementing between 3 and 4 adaptation strategies at farm level, whereas those who undertook more than four practices were few (4.8%) (Fig. 4b).

3.4 Factors influencing farmers' adaptation options

The results of the regression analysis of the factors that influence adaptation options undertaken by farmers to cope with the impacts of climate change in crop production are presented in Table 2. The results show that three predictors had significant correlation to the planting time. Male farmers were more likely to alter planting time than the female farmers. Farmers with larger farm sizes adopted this practice more than those with smaller farms. Surprisingly, agricultural extension trainings were negatively correlated with the probability of adopting alteration of planting time. Adaptation of drought-tolerant varieties was likely to be positively influenced by education and extension trainings. On the contrary, younger farmers were more likely to use drought-tolerant varieties than the older farmers. Farmers with larger number of family members were likely to plant early maturing crop varieties more than those with few members. Likewise, extension trainings were positively correlated with the probability of the farmers to use early maturing varieties. Planting of diversified crops was positively correlated with the age of the farmer. On the contrary, female farmers were more likely to diversify cropping than male farmers. The use of soil and water conservation was positively affected by farmers' income and extension trainings. The two factors that were positively correlated with practicing on-farm rainwater harvesting for irrigation of crops were extension trainings and impact perception.

Table 2 Determinants of farmers' adaptation options

Predictors	LRM coefficients					MLR coefficients			
	Early/delayed planting	Drought-tolerant varieties	Early maturing varieties	Crop diversification	Soil water conservation	On-farm rainwater harvesting	Timely planting	Agroforestry	Overall strategies
Age	0.018	-0.043**	-0.010	0.025*	0.008	-0.026	0.008	0.021	0.004
Gender (male)	0.977**	-0.464	0.002	-0.794**	-0.164	-0.002	0.033	0.396	-0.003
Head (male)	-0.624	-0.650	-0.068	-0.334	-0.084	-0.214	0.484	-2.713	-0.523
Education	0.017	0.126**	0.030	0.046	-0.020	-0.050	0.064*	0.371	0.006
Employed	-0.190	0.059	-0.144	-0.006	0.193	0.129	-0.012	-3.550	-0.209*
Family size	0.006	-0.009	0.276***	0.046	-0.093	-0.125	-0.047	-0.408	0.049
Farm size	0.247*	-0.139	-0.243***	-0.040	0.051	-0.128	-0.001	0.530	-0.053**
Income	0.800	-0.160	-0.050	0.016	0.154*	-0.049	0.011	-0.121	0.013**
Membership in farmers' association	0.188	0.285	-0.535	-0.322	-0.210	0.101	0.011	2.462	-0.153
Number of trainings	-0.555**	1.846***	0.410**	-0.182	1.595***	1.347***	-0.160	0.730	1.073***
Risk perception	0.026	-0.008	-0.021	0.093	-0.119	-0.039	-0.012	0.014	0.012
Impact perception	0.146	-0.060	-0.013	0.085	0.021	0.246*	0.039	-0.951	0.054
Null deviance (df 209)	218	251	288	276	202	113	269	47.3	F(12, 197) = 5.723***
Residual deviance (df 197)	166	158	234	254	136	90.6	259	19.0	
McFadden R ²	0.238	0.371	0.187	0.080	0.327	0.200	0.037	0.598	R ² = 0.259

Note 1: *, ** and *** denote significance at 0.10, 0.05 and 0.01 level of probability, respectively

Note 2: LRM, logistic regression model; MLR, multiple linear regression model

Fig. 3 Perceived impacts of climate change on crop production

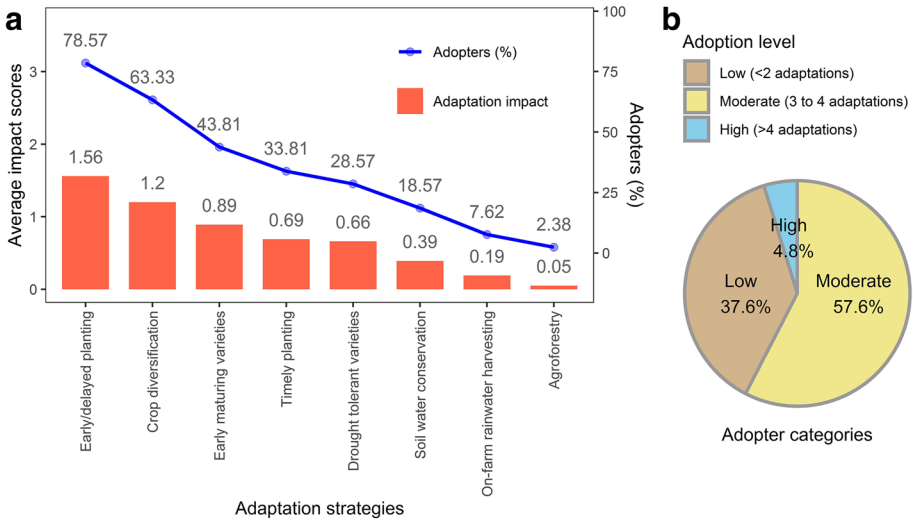
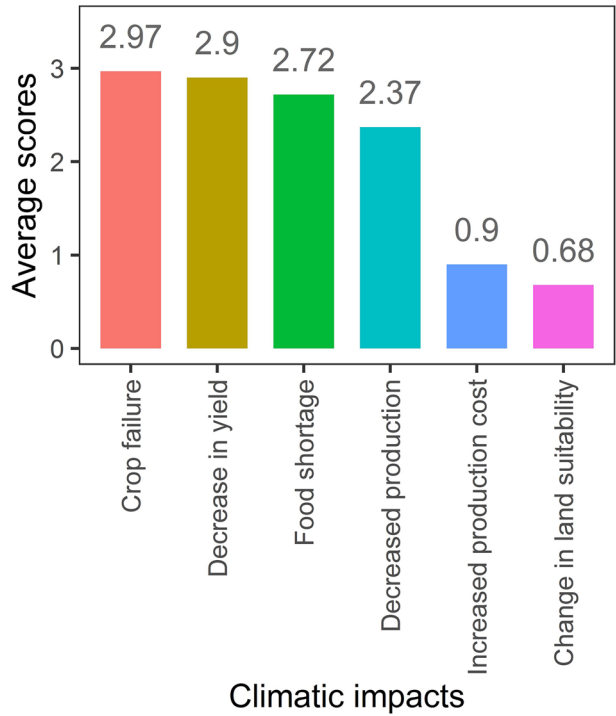


Fig. 4 **a** Perceived impact of adaptation strategies and percentage of farmers using the adaptation strategies. **b** Adopter categories based on the number of adaptation strategies used

4 Discussion

Climate change is projected to have a significant impact on the agricultural sector in many SSA countries (IPCC, 2014). Considering that the full potential for minimizing the impacts of climate change on crop production has not been adequately achieved, farm-level response in most countries has been through adaptation of farm management practices. In SSA, adaptation is critical due to the large uncertainties as a result of climate change and variability. Therefore, this study was designed to document the adaptation strategies and their influencing factors using a case study of maize farmers of western Kenya. A total of 210 respondents were interviewed and the data were analysed using both descriptive and inferential statistical approaches to evaluate the adaptation strategies, the adopter categories and the household socio-economic factors that influence the farmers to adopt. The outcome of the survey is discussed in the following sections:

4.1 Adaptation strategies

4.1.1 (i) Early/delayed planting

It is notable from the results in Fig. 3 that the key adaptation strategy by the farmers in the western region of Kenya was a change of planting decision by either planting early or delaying planting date. This supports the findings of a review study by Kogo et al. (2019c) which established that change of planting dates was one of the major agro-adaptation options towards mitigating the impacts of climate change on crop production. According to Lv et al. (2020), adjusting of planting date is one of the strategies used by farmers to maintain or increase crop yields under climate change. However, the major constraint to the shift of planting time is the lack of accurate information on climate forecast to complement indigenous knowledge (Fisher et al., 2015). The adoption of this practice by the farmers is perceived to have low impact on crop production. The factors that positively influence farmers to undertake early or delayed planting were gender of household head and farm size (Table 2). In this case, the heads of households, who were mostly males, were more likely to influence decision on planting time of crops since they are responsible for most of the farm activities and have better understanding of various on-farm crop production practices. In addition, male farmers are more of risk-takers and are likely to adjust their farming practices and adapt to new technologies (Dang et al., 2019).

The influence of farm size on farmers' decision to plant early before the rains or delay planting can be seen from two perspectives: the first being the fact that farmers with large farms may be forced to plant early so as not to be overwhelmed by planting during the rains, and the other perspective being delayed planting as per early warning information on weather patterns and fear of crop failure in case of planting before reliable rains.

4.1.2 (ii) Crop diversification

Crop diversification is one of the management options in rain-fed systems that can mitigate against the impacts of climate change and market shocks (Birtchal and Hazrana 2019). According to Lin (2011), crop diversification can increase production and improve resilience by reducing vulnerability to pest outbreaks, disease transmission and buffering crop

from effects of climate variability and extreme weather events. The use of multiple cropping systems can also influence ground cover, soil erosion, soil chemical properties, pest infestation and potential for carbon sequestration (Waha et al., 2013).

Approximately 63.3% of the farmers interviewed in this study confirmed to be undertaking crop diversification on their farms. The most common diversification strategy (undertaken by 57.6% of the farmers) was intercropping of maize and beans. In the study area, the farmers confirmed that crop diversification was likely to have low effect on crop production under climate change. Age was a variable that positively and significantly influenced farmers to undertake crop diversification. The implication of this is that more elderly household heads were more likely to have high level of experience on the benefits of crop diversification.

4.1.3 (iii) Use of early maturing cultivars

Cultivation of early maturing cultivars is among the key adaptation strategies being undertaken by 43.8% of the farmers. The factors that were likely to positively influence farmers' decision to cultivate early maturing crops were family size and extension trainings. The rationale is that households with large number of members were more likely to grow early maturing crop varieties in more than one season in a year in order to offset production deficit. Additionally, most farming households rely on family labour; thus, with more family members, there is a possibility for adequate labour availability, which can in turn allow completion of farming tasks without hire of labour that increases the production cost during peak seasons. As per Van et al. (2015), household size positively influences adaptive behaviours and uptake of farming technologies. Likewise, extension trainings play an important role in enlightening the farmers on early maturing crop varieties that can be planted during short rainy season. On the other hand, farm size was negatively correlated to cultivation of early maturing crops. This suggests that households with large farm size are not likely to plant early maturing cultivars since they could have sufficient production in one season of the year. On the contrary, farmers with small farm size are more likely to plant early maturing varieties in two seasons of the year under the same plot in order to have adequate produce for their families. This is in agreement with other studies, such as those by Salasya et al. (2007), who noted that late maturing cultivars were likely to extend to more than one season, making it impossible to plant a crop in two seasons on the same piece of land.

4.1.4 (iv) Timely planting

Timely planting is a farm management practice aimed at getting the crop planted at optimum planting dates that is largely driven by the prevailing weather conditions (Doerge et al., 2015). As per Sacks et al. (2010), timing of rainfall onset is a key factor that influences planting date. In western Kenya, the onset of long rains ranges from early March to end of April (Mugalavai et al., 2008). This is the period in which the farmers plant maize in order to pollinate and mature between June and August when rains are reliable and avoid the drought stress in September, which can affect grain-filling and overall yields. Approximately 33.8% of the farmers interviewed undertake timely planting as one of the adaptation strategies towards maize production under climate change. However, timely planting was confirmed to have low impact on crop production (average impact score of about 0.69). This is likely to result from poor timing of optimum planting time and possibility of

changing weather patterns during crop development that affect overall yields. The regression results show that education level positively influenced farmers' decision to undertake early planting. This may imply that educated farmers were more observant and better informed than less educated ones about the weather patterns and ultimately, timed rainfall onset as an adaptation decision for optimal crop production under rain-fed conditions.

4.1.5 (v) Drought-tolerant varieties

The use of drought-tolerant varieties was also confirmed to be one of the adaptation options by 28.6% of the respondents. Such varieties are bred to tolerate environmental stresses, including water deficit conditions during seasons of low rainfall (Westengen and Brysting 2014). As per Fisher et al. (2015), the barriers that may influence farmers to use drought-tolerant varieties as an adaptation to climate change were inadequate information, financial constraints, high seed price and limited access to seed. Extension trainings and education level of the household head were positive predictors of adaptation level of the farmer using drought-tolerant varieties. This implies that the farmers that had received extension training and are more educated were more likely to adapt their farming systems to climate variability by use of drought-tolerant varieties. This corroborates a study by Opiyo et al. (2016) that concluded that educated household heads were likely to have better understanding and access to information on adaptation to climate change. On the contrary, households that were headed by elderly persons were more likely to have low-level adaptation to climate variability through the use of drought-tolerant varieties. This is likely because most elderly farmers may be less informed on improved crop varieties and may not be willing to change their conventional cropping systems.

4.1.6 (vi) Soil water conservation

Soil water conservation is one of the farm management practices meant to minimize loss of water through run-off by increasing infiltration rates of the soil surface (Adimassu et al., 2017). This strategy, which is aimed at achieving high rain-use efficiency in crop farming, is among the adaptation measures practiced by 18.6% of the farmers in the study area. The common methods used by farmers to undertake soil water conservation is application of farmyard manure and organic mulching. However, the farmers perceived that the practice had low impact on crop production (average impact score of about 0.39). This implies that full potential of this practice has not been achieved due to other reported constraints such as soil nutrient depletion (Wanyama et al., 2010). Income levels and agricultural extension trainings were the key factors that positively influenced the farmers to undertake soil water conservation. This suggests that wealthier households were likely to have sufficient financial resources to implement soil water conservation measures to improve crop production on their farms. Similarly, farmers who had received extension trainings were likely to understand the need for soil water conservation and would have the knowledge on how to undertake the practice at farm level.

4.1.7 (vii) On-farm rainwater harvesting for irrigation

On-farm rainwater harvesting is one of the climate change adaptation strategies whose aim is to collect surface run-off that can be used for supplemental irrigation to mitigate against water deficit during crop growth stages (Odhiambo et al., 2021). In the study area, 7.6% of

the farmers interviewed confirmed to be undertaking on-farm rainwater harvesting. However, they reported low impact (impact score of about 0.19) on crop production. This suggests that the households may not be adequately utilizing the harvested rainwater to bridge intra-seasonal dry spells that occur due to unreliable rainfall, and thus were more likely to perceive low benefits in crop production. Extension training and impact perception were some of the factors influencing farmers to undertake rainwater harvesting for irrigation. It is therefore advisable that extension training considers sensitizing farmers on the need to utilize harvested water to irrigate the crops in order to reduce risk of water stress and benefit from improved crop production during rainfall-deficient seasons.

4.1.8 (viii) Agroforestry

Agroforestry is one of the climate smart adaptation strategies that involve growing of trees in a cropping system (Aperi et al., 2018; Ram et al., 2017; Thorlakson and Neufeldt 2012). From this study, it emerged that agroforestry was one of the adaptation practices undertaken by the least number (2.4%) of farmers interviewed. The farmers also perceived agroforestry to present the lowest impact on crop production. This could also be justified by the low number (3.8%) of farmers that confirmed to have received extension training on agroforestry. Despite the low uptake of this adaptation practice, it is worth noting that some of the ecological benefits associated with agroforestry include improvement of soil and water conservation, soil physical properties and resilience to uncertain windstorm through microclimate buffering (Ajayi et al., 2011; Nguyen et al., 2013; Sileshi et al., 2011; Waha et al., 2013). According to Ram et al. (2017), agroforestry can also serve as a source or sink of reactive nitrogen that can improve soil fertility and subsequently crop performance. In the study, it emerged from regression analysis that there were no noticeable factors that influenced farmers to practice agroforestry. Therefore, considering the enormous benefits of agroforestry practice, it is advisable that the extension service providers consider upscaling awareness of farmers on this practice.

4.2 Key factors influencing farmer's adaptation measures

The results of multiple linear regression analysis (Table 2) show that a limited number of socio-economic and demographic factors influenced uptake of adaptation practices in response to climate change in a rain-fed agricultural system. These included income, employment, farm size and extension trainings that seemed interconnected. Household income influences the farmers' adaptive behaviour and the ability to undertake adaptation measures that require sufficient resources for their implementation. In this case, wealthier households were more likely to undertake soil water conservation, rainwater harvesting, plant new crop varieties and irrigate crops during rainfall deficit seasons. Extension training was also found to positively influence the farmers to undertake adaptation measures. Training provides farmers with an opportunity to acquire a range of skills on farming practices, improved technologies and access to information on adaptation to impacts of climate change. On the contrary, employment was negatively correlated with farmers' adoption strategies. This implies that farmers that had off-farm employment were less likely to adapt to climate-related risks, possibly because they may have money to purchase household food in case of insufficient farm produce. Similarly, households with large farm sizes may find it expensive to undertake adaptation strategies due to increased production costs, whereas the

households with small farms were likely to embrace adaptation to maximize on production from their croplands.

5 Conclusion

The aim of this study was to assess farm-level adaptation strategies being undertaken by maize farmers in western Kenya to reduce the potential impacts of climate change, including their determinants and impacts on crop production. A total of 210 maize farmers were interviewed using structured questionnaire. Results indicate that the key adaptation measures undertaken in the region to adapt crop production to climate change were early/delayed planting, crop diversification, use of early maturing cultivars, timely planting, use of drought-tolerant varieties and farm management practices through soil water conservation, on-farm rainwater harvesting for irrigation and agroforestry.

The household socio-economic factors that were likely to influence adaptation decisions by the farmers were income, extension trainings, employment and farm size. From the study findings, it can be argued that, while relatively many farmers had embraced adaptation, they still perceived low benefits on crop production. This shows that the full adaptation potential may not have been achieved at farm level. Thus, extension trainings, which emerged as a dominant factor influencing farmers to undertake most of the adaptation decisions, should be up-scaled as a key strategic action to strengthen adaptation planning at the national, regional and farm level to ensure sustainable crop productivity. Generally, the outcome of such a research offers an opportunity to better understand adaptation response strategies and the influencing factors, which could assist in planning sustainable crop production in rain-fed farming under climate change, not only in western Kenya, but also in other tropical countries with related challenges. Future research could explore questions related to the different combinations of adaptation strategies in order to provide greater insights into the observed dynamics.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval All procedures performed in this study which involved human participants was in accordance with the ethical standards of the Human Research Ethics Committee of the Ethics Office, Research Development & Integrity, Research Division, University of New England, Armidale, New South Wales 2351, Australia (ethics approval number HE18-274).

Research involving human participants Ethical clearance for this research was granted by the University of New England (approval no. HE18-274). Approval for the field research was sought from Kenya's National Council of Science and Technology.

Competing interests The authors declare no competing interests.

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