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A gendered analysis of adaptive capacity and food security in Makueni County, Kenya

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Climate change is expected to reduce crop and livestock productivity leading to increased hunger and food insecurity. Formulation of effective adaptation strategies can reduce the negative effects of climate change on food security. This study examined types of adaptation strategies implemented by males/male-headed households and females/female-headed households and how these influence food security. Food security was measured using Household Food Insecurity Access Prevalence (HFIAP) and probit model was used to estimate the effect of adaptation strategies on food security. Due to potential self-selection bias, this study also estimates Coarsened Exact Matching (CEM) model. Data was collected using structured questionnaires from 521 households and 1,049 adults from Makueni County, Kenya. Study findings indicated that approximately 72, 62, and 75% of households experienced reduced rainfall, less predictable rainfall and recurrent and prolonged droughts, respectively, to a large extent. The three most adopted adaptation strategies were conservation agriculture (69%), change of planting dates (49%), and planting of drought tolerant crops (47%). A higher share of male-headed households than female-headed households implemented all three adaptation strategies. Access to credit, non-farm income, types of crops grown, and weather perception variables were the important determinants of adaptation. We also found that planting drought tolerant crops and practicing conservation agriculture were associated with increased likelihood of food security but only for males/male-headed households. For female headed households, growing drought tolerant crops and changing planting dates reduced likelihood of food security while the effect of conservation agriculture was not statically significant. These findings provide evidence that adaptation to climate change provide potential for improvements in food security among males/male-headed households. This potential is however limited for female headed households. They are not only less likely to adapt but are also less likely to benefit from adaptation. These findings highlight women's vulnerability to climate change and especially female-headed households and calls for policies that build women's capacity to effectively adapt.

KEYWORDS

climate change, adaptation, food security, gender, Kenya

1 Introduction

Climate change is expected to reduce crop and livestock productivity (Zhao et al., 2017; Ortiz-Bobea et al., 2021) leading to increased hunger and food insecurity (Richardson et al., 2018; Hasegawa et al., 2021) and malnutrition (Thompson et al., 2010). Negative impacts of climate change on food security can be reduced through effective adaptation (Thompson et al., 2010; Shukla et al., 2019). Adaptation is "the process of adjustment to actual or expected climate change and its effects" (IPCC, 2014, p. 5). It entails enhancing resilience to deal with actual and expected climate and the extreme weather events associated with it (Adger et al., 2007). Adaptation can be autonomous or planned (Fankhauser et al., 1999).

Men and women play different roles with different responsibilities and socio-economic inequalities between them can cause them to face differential risks and opportunities (Rossi and Lambrou, 2008). Women are also confronted with unclear natural resources access, lack of financial resources and limited market opportunities (Djoudi and Brockhaus, 2011). Factors such as financial, social, individual, cultural and institutional also influence the ability of individuals and households to adapt (Adger et al., 2009; Mersha and Van Laerhoven, 2016) and these are not uniformly distributed between genders. How do these differences affect how men and women adapt to climate change? What is the implication of this for food security? The objective of this study is to examine types of adaptation strategies implemented by males and females in the same household and by male-headed and female-headed households and how these influence a household's food security.

This study focuses on Makueni County, a semi-arid county located in the Eastern part of Kenya. Women living in arid and semi-arid areas not only make up the highest share of the world's most poor but are also the most vulnerable to adverse effects of climate change (Yadav and Lal, 2018). In Makueni County, climate change and variability is one of the challenges confronting the agricultural sector. Approximately 57% of the population is food poor (Ministry of Agriculture, and Livestock and Fisheries, 2016).

Understanding differences in the way men and women experience and adapt to climate change is important for enabling development of policies to promote adaptive capacity of all genders which contributes toward the Sustainable Development Goal (SDG) 5 of promoting gender equality. Further, understanding how different adaptation strategies affect household food security is an important starting point for identifying effective ways to reduce food insecurity thereby contributing to the SDG goal 2 of zero hunger.

2 Literature review

We hypothesize that adaptation to climate change improves food security. According to Food and Agriculture Organization of the United Nations (2018) climate change impacts food security by affecting food availability through reduction in food production and food access by impacting food prices. Engaging in adaptation practices such as conservation agriculture, growing drought tolerant crops and changing planting calendar can help mitigate the negative effects of climate change on crop productivity leading to increased production and improved food security. We hypothesize that level and intensity of adaptation may differ between males and females and this may lead to differential effects of adaptation on food security across genders with women benefiting less.

A number of studies examine the effect of adaptation on food security within the African context (Alhassan, 2020; Diallo et al., 2020; Ndiritu and Muricho, 2021; Ogundeji, 2022; Zakari et al., 2022; Gebre et al., 2023; Madaki et al., 2024). These studies measure food security diversely. Some measure food security using household food insecurity and access scale (Diallo et al., 2020; Ogundeji, 2022; Gebre et al., 2023) while others use dietary diversity score and coping strategy index (Madaki et al., 2024) and monthly per capita food expenditure (Alhassan, 2020).

In estimating the effect of adaptation on food security, these studies account for potential self-section bias in adapting to climate change. Some of the studies use propensity score matching (Diallo et al., 2020; Ogunpaimo et al., 2021; Gebre et al., 2023; Madaki et al., 2024). Others use endogenous treatment effect models (Alhassan, 2020; Ogundeji, 2022), endogenous switching regression (Ndiritu and Muricho, 2021; Madaki et al., 2024), difference-in-difference (Ogunpaimo et al., 2021), and average treatment effect (ATE) and average treatment effect of the treated (ATET) (Zakari et al., 2022).

The studies generally find that adaptation to climate is associated with improved food security. Alhassan (2020) found that both on-farm and off-farm adaptation to flooding were associated with improved food security in Upper East region of Ghana. Madaki et al. (2024) found that adoption of climate risk adaptation strategies increased dietary diversity score and reduced food security coping strategy index among farming households in Nigeria. Also using Nigerian data, Ogunpaimo et al. (2021) found that adapting to climate change was associated with 9% increase in food security status.

In Mali, Diallo et al. (2020) found that maize farmers adapted by changing planting dates, using organic fertilizers and by growing short duration maize varieties. They further found that growing of short duration maize varieties and use of organic fertilizers were associated with increased maize yields and reduced food insecurity. Using data for rural Niger, Zakari et al. (2022) found that majority of the farmers adapted using crop diversification (73%), income diversification (68%) and change of planting dates (55%). They found that households who adapted were 7–9% more likely to be food secure than those households who did not adapt.

In Kenya, Gebre et al. (2023) found that majority of farmers adapted by planting drought tolerant crops (55%), growing diversified crops (34%), growing early maturing crops (22%), and diversifying sources of household income (18%). They found that farmers who adapted to climate change had higher food security status and that the effect of adaptation of food security was higher the higher the number of adaptation strategies implemented. Focusing on pastoralist living in semi-arid areas of Kenya, Ndiritu and Muricho (2021) found that adaptation to climate change was associated with increased food security.

These studies do not however consider gendered differences in effect of climate change adaptation on food security. Some previous studies examine gendered differences in climate change adaptation (Ngigi et al., 2017; Adzawla et al., 2019; Nchanji et al., 2022; Acheampong et al., 2023). Ngigi et al. (2017) found that roles and responsibilities of men and women, social norms, perceptions of risks and resource access shape adaptation to climate change options. That women mostly adapted using crop-related strategies while men used livestock and agro-forestry related strategies.

Adzawla et al. (2019) found that climate change impacts were severer for female-headed households than for male-headed households and male-headed households had higher levels and intensity of adaptation than female-headed households. These studies do not however consider how these differences affect food security. This study builds on these studies to consider the effects of gendered differences in adaptation to climate change on food security.

3 Materials and methods

3.1 Assessment of food security

Food security was assessed by household food insecurity and access scale (HFIAS). Following (Coates et al., 2007), we constructed food insecurity categories from 9 sets of questions. The questions were related to (1) household members worried they would not have enough food, (2) household members not being able to eat the kinds of foods they preferred, (3) household members eating limited varieties of food, (4) household members eating food they did not want to eat, (5) household members eating smaller meals than they felt they needed, (6) household members eating fewer meals (7) absence of food of any kind to eat in the household, (8) household members going to sleep at night hungry and (9) any household member going the whole day and night without eating anything. Sub-sections were added to the main questions to divide the questions further into (a) and (b) so that we have 1a and 1b, 2a, and 2b and so forth. Responses to the (a) questions were (0) No and (1) Yes. Those who respond (1) Yes to (a) go to (b) to give the extent. Responses to the (b) questions were (1) rarely (2) sometimes and (3) often. Those who respond 0 (No) to (a) go to the next question.

Following Coates et al. (2007) we computed the Household Food Insecurity Access Prevalence (HFIAP) which is a categorical variable. The indicator categorizes households into four levels: food secure, mildly, moderately and severely food insecure. Households were categorized as food secure if they did not experience any of the food insecurity conditions mentioned above or they just experienced worry but rarely. Households were categorized as mildly food insecure if they sometimes or often worried about not having enough food and/or were not able to eat the preferred food and/or ate monotonous diets than what they would desire and/or ate some foods considered not desirable though only rarely. Moderately food insecure households were those who sometimes or often ate monotonous diets that were not desirable and/or reduced the number of meals or size of meals rarely or sometimes. Severely food insecure households often reduced size of meals and number of meals, and/or ran out of food, went to bed hungry or went the whole day and night without eating.

The four categories were calculated as follows. Food secure (1) if [(Q1a = 0 or Q1a = 1) and Q2 = 0 and Q3 = 0 and Q4 = 0 and Q5 = 0 and Q6 = 0 and Q7 = 0 and Q8 = 0 and Q9 = 0], mildly food insecure (2) if [(Q1a = 2 or Q1a = 3 or Q2a = 1 or Q2a = 2 or Q2a = 3 or Q3a = 1 or Q4a = 1) and Q5 = 0 and Q6 = 0 and Q7 = 0 and Q8 = 0 and Q9 = 0], moderately food insecure (3) if [(Q3a = 2 or Q3a = 3 or Q4a = 2 or Q4a = 3 or Q5a = 1 or Q5a = 2 or Q6a = 1 or Q6a = 2) and Q7 = 0 and Q8 = 0 and Q9 = 0] and severely food insecure (4) if [Q5a = 3 or Q6a = 3 or Q7a = 1 or Q7a = 2 or Q7a = 3 or Q8a = 1 or Q8a = 2 or Q8a = 3 or Q9a = 1 or Q9a = 2 or Q9a = 3].

3.2 Model specification

The estimated equation is given by:

$$FS = \alpha_0 + \alpha_1 A_i + \alpha_2 x + \mu \quad (1)$$

Where A_i measures various adaptation strategies implemented, x is a vector of the control variables and μ is the error term. Adaptation strategies adopted by households and individuals was the key independent variable and was measured as a dummy variable taking value 1 if a given adaptation strategy was implemented by a household/individual and 0 otherwise. The control variables considered were age, gender, household size, education, land size, access to credit, livestock ownership, non-farm income, crops growth and climate perception variables.

Interest is on the effect of specific adaptation strategies on food security. We wanted to know whether implementation of a given adaptation strategy improved food security. To do this, we ensured that households that implemented the strategy and those that did not were comparable. The better off households may be the ones that actually implement the adaptation strategies and in this case the two groups will not be comparable due to self-selection. In this case observed differences in food security between the households that implement the adaptation strategy and those that do not may be attributed to pre-existing factors rather than as a result of implementing the adaptation strategy. Results obtained in this case would be biased. Different econometric techniques exist to address this self-selection problem, but the lack of panel and experimental data limits options here. The majority of previous studies control for sample selection using matching methods such as propensity score matching (Diallo et al., 2020; Ogunpaimo et al., 2021; Gebre et al., 2023; Madaki et al., 2024) and average treatment effects and average treatment effects of the treated (Zakari et al., 2022).

In line with previous studies, this study used matching techniques. Matching techniques create more suitable comparison groups, thereby reducing possible bias due to self-selection (Blackwell et al., 2009). We used the Coarsened Exact Matching (CEM) technique, a matching method recently used in development economics (Green et al., 2015; Nilsson, 2017; Bertoni et al., 2020). This technique deals with some of the weaknesses of earlier matching techniques such as reduced sample size. This approach involves recoding each one of the control variables such that values that are similar are grouped together and assigned the same value. That is, we generate discrete representations known as bins. This is referred to as "coarsening" of the variables (Blackwell et al., 2009). We then create a set of strata such that each strata contains similar coarsened values of the control variables. Then strata that contain at least 1 control and 1 treatment observation are kept while those that only contain treated units or control units are dropped (Lacus et al., 2012). In the last step, the weight for each stratum is computed based on relative proportion. This is used to estimate the effect of the treatment variable (Sidney et al., 2015).

3.3 Data

Data used in this study was collected from Makueni County, Kenya. Makueni County is one of the semi-arid counties found in the eastern region of Kenya. Agricultural sector employs 78% of the population in this county (Ministry of Agriculture, and Livestock and Fisheries, 2016). Climate change and variability is one of the challenges confronting the agricultural sector in this area. Climatic hazards characterizing the county include drought, temperature increases, increased preheat and moisture stress and increases precipitation (Ministry of Agriculture, and Livestock and Fisheries, 2016). The county mainly relies on long rains which contribute to about 60–70% of annual crop production. Approximately 57% of the population in this county is food poor (Ministry of Agriculture, and Livestock and Fisheries, 2016).

Multi-stage sampling was used to select a representative sample. Makueni County has 3 livelihood zones which represent different climatic and agro-ecological livelihood characteristics. We first stratified the county into the three livelihood zones and randomly selected one sub-county in each livelihood zone. The list of sub-counties in Makueni County was our sampling frame. We then randomly selected one ward from each selected sub-county. The list of wards was our sampling frame. Then 1 village was randomly selected in each ward. The list of villages in each selected ward was our sampling frame. We then used systematic sampling to select 200 households from each village bringing the total to 600 households.

In each household, we interviewed a male and a female household member (the household head and the spouse in male-headed households). We skipped households that the head was not present and was not going to be present for the period we were collecting data. In polygamous households, we traced and interviewed all the wives that lived in the same village. In female-headed households, we interviewed the female head and the older son if present. If the older son was not present, we interviewed any adult male child. In cases where there was no adult male child in the household, we just interviewed the female household head. We interviewed 521 households and 1,049 individuals. We only interviewed individuals 18 years and above.

A structured questionnaire was used to collect data. Information collected included demographic characteristics, food consumption, expenditure on food and non-food items, adaptation strategies implemented, asset ownership, incomes and income sources, sources of water, and distances to water sources, access to credit, and access to social support among others.

4 Results and discussion

4.1 Descriptive statistics

We interviewed 521 households and 1,049 individuals. Household and individual characteristics are presented in Table 1. About 27% of households in our sample were female-headed. Approximately 50% of female heads had no formal education compared to 22% of male heads. Conversely, more male heads (5.82%) had attained college education compared to 1.44% of female heads. Majority of the female-headed households (80%) were widowed and 4% were divorced/separated. For male-headed households, majority were married monogamous (93%).

The average household size was 5, a slightly lower average household size of 4 is reported for female-headed households. The average farm size was 3 acres. The average was slightly lower for female-headed households at 2 compared to 3 for male-headed households. In terms of accessing credit, approximately 16% of the households had accessed credit. Slightly more female-headed households, 17% than male-headed households 16% accessed credit. A higher proportion of male-headed households (17%) engaged in non-farm work than female-headed households (9%). Six percent of households were cash crop farmers (6%) with a higher share of male-headed households engaging in cash crop farming (6%) than female-headed households (4%). Approximately 75% of male-headed households owned cattle, sheep and goats compared to 71% of female-headed households.

In terms of crops cultivated, a higher share of male-headed households reported growing all the crops considered. More than 90% of the households grew maize and beans. Only 13% of female-headed households grew green gram compared to 36% of male-headed households. Similarly, 60% of male-headed households grew cowpeas and pigeon peas compared to 40% of female-headed households. Only 4% of female-headed households grew millet compared to 11% of male-headed households and approximately 50 and 45% of male and female-headed households grew vegetables, respectively.

At the individual level, data indicates that 54% of the interviewed individuals were females. The average age of the study population was 51 years. Approximately 24% of the respondents had attained no formal education (less than primary education). Only 5 and 0.67% attained college and university education, respectively. Slightly more males (6%) than females (4%) attained college level education. Most respondents were married monogamous (76%) while 3% were married polygamous. 22% of women were widowed compared to 3% of men. In terms of access to credit, approximately 15% of the individuals had accessed credit and this remains same for both males and females. Approximately 14% of the individuals reported having non-farm income. Slightly more males (16%) than females (12%) reported to have non-farm income. Only 5% of the study population reported engaging in cash crop farming while 73% reported to own cattle, sheep or goats.

4.2 Differences in how female/female-headed households and male/male-headed households experience climate stressors

Table 2 presents the share of households that reported experiencing various weather events. Eighty six percent of the households and 84% of individuals experienced at least one extreme weather event. Approximately 44, 20, and 51% of households experienced reduced rainfall, less predictable rainfall and recurrent and prolonged droughts to a large extent. The differences by gender were generally statistically insignificant except differences in proportion reporting less predictable rainfall and recurring and prolonged drought at household level.

Table 3 presents the self-reported effects of extreme weather events on crop production. Approximately 84% of the households reported that these events caused crop failure, 88% reported that they caused reduced crop yields and 45% reported that they caused some crops not to be planted. At individual level, similar trends were observed with 82% of individuals reporting experiencing crop failure and 87 and 50% reporting experiencing reduced yield and not being able to plant some crops, respectively. A slightly higher share of males/male-headed households than female/female-headed households reported negative effects of extreme weather events on crop production. However the differences were only statistically significant for some types of crops not grown.

TABLE 1 Household and individual characteristics by gender.

	Household level				Individual level			
	All	Female headed	Male headed	Diff	All	Female	Male	Diff
Gender (%) (Female = 1, Male = 0)	26.9				53.5			
Age in years	58.6	66.5	55.7	10.8***	51.4	51.8	51	0.8
Education (%)								
No formal	29.6	49.6	22.2	27.4***	24	28.4	19	9.4***
Primary	46.2	43.2	47.4	−4.2	50.5	53.7	46.8	6.9**
Secondary	19	5.8	23.8	−18***	19.8	13.8	26.6	−12.8***
College	4.6	1.4	5.8	−4.4**	5.1	4	6.39	−2.39*
University	0.7	0	0.8	−0.8	0.7	0.2	1.24	−1.04**
Marital status (%)				0				0
Married monogamous	71.2	12.2	92.9	−80.7***	76	72.4	80.2	−7.8**
Married polygamous	2.5	1.4	2.9	−1.5	3.1	3.1	3.1	0
Separated/divorced	1.6	4.3	0.5	3.8***	1.3	1.1	1.4	−0.3
Widowed	24.2	79.9	3.7	76.2***	13.2	22.1	2.9	19.2***
Never married	0.6	2.2	0	2.2***	6.5	1.4	12.4	−11***
Number of household members	5	4.2	5.3	−1.1***	5.1	5.2	5.1	0.1
Assets and resources (%)				0				0
Land in hectares	2.5	1.7	2.9	−1.2***	2.2	2.1	2.4	−0.3
Access to credit	15.9	16.6	15.6	1	15	14.9	15.1	−0.2
Non-farm income	14.9	9.4	16.9	−7.5**	13.8	11.9	16.1	−4.2**
Cash-crop farming	5.6	4.3	6.1	−1.8	5.4	5.6	5.2	0.4
Livestock ownership	73.9	70.5	75.1	−4.6	73.1	73.1	73.2	−0.1
Crops (%)				0				0
Maize	96.7	94.2	97.6	−3.4*	95.7	95.3	96.1	−0.8
Beans	95.9	95	96.3	−1.3	94.9	94.4	95.5	−1.1
Green grams	29.6	12.2	36	−23.8***	29.3	29.6	28.9	0.7
Cow pies	55.1	41	60.3	−19.3***	54.4	54.8	54	0.8
Millet	8.7	3.6	10.6	−7**	8.7	9.2	8.3	0.9
Vegetables	48.6	44.6	50	−5.4	49.7	50.6	48.7	1.9
Pigeon peas	54.9	40.3	60.3	−20***	52.5	52.4	52.6	−0.2
N	517	139	378		1,049	562	487	517

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

TABLE 2 Proportion of households experiencing various weather events.

	Household level				Individual level			
	Full sample	Male headed	Female headed	Diff	Full sample	Male	Female	Diff
Reduced rainfall (%)	44	42.9	46.8	−3.9	43.6	43.5	43.6	−0.1
Less predictable rainfall (%)	19.6	21.1	15.6	5.5*	18.4	19.3	17.6	1.7
Recurring and prolonged drought (%)	50.9	52.6	46.1	6.5*	49.5	49.5	49.5	0
Extreme rainfall (%)	0.6	0.8	0	0.8	0.7	1	0.5	0.5
Experienced at least 1 event (%)	85.4	86.6	82.3	4.3	83.4	84.2	82.7	1.5
N	521	380	141	239		1,049	487	562

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

TABLE 3 Self-reported effect of extreme weather events on crops production.

	Household level				Individual level			
	All	Female headed	Male headed	Diff	All	Female	Male	Diff
Crop failure	84.1	84.5	83	1.5	81.7	82.3	81.1	1.2
Reduced crop yields	87.9	88.9	85.1	3.8	86.2	87.2	85.2	2
Some crops not planted	44.7	48.4	34.8	13.6***	45.2	50	43.4	6.6*
	521	380	141		1,049	487	562	

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

TABLE 4 Adaptation strategies implemented by gender.

	Household				Individual			
	Total	Male headed	Female headed	Diff	Total	Male	Female	Diff
Changing planting dates	48.9	52.4	39.6	12.8***	49.5	50.1	48.9	1.2
Planting drought tolerant crops	47.2	50.5	38.1	12.4**	46.5	45.4	47.5	−2.1
Conservation agriculture	59.7	61.8	54.0	7.8*	58.6	59.1	58.2	1.0
N	521	382	139		1,049	487	562	

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

4.3 Differences in types of adaptation strategies implemented by female/female-headed households and by male/male-headed households

Table 4 presents adaptation strategies implemented by study participants to mitigate the negative effects of climate change. The most used adaptation strategy was conservation agriculture (mulching, crop rotation, minimum tillage, and strip cropping) with 69% of households using this strategy. This was followed by change in planting dates at 49% and planting of drought tolerant crops at 47%. In terms of gender, there were statistically significant differences in proportion of males and females that implemented the three types of adaptation strategies at household level but not at individual level.

Table 4 shows that 52% of male-headed households adapted by changing planting dates compared to 40% of female-headed households. The difference was statically significant at 10% level of significance. Similarly, 51% male-headed households planted drought tolerant crops compared to 38% of female-headed households and this a statistically significant difference at 5% level of significance. Also, 62% of male-headed households practiced conservation agriculture compared to 54% of female-headed households again a difference that was statistically significant at 10% level of significance.

4.4 Effects of different adaptation strategies on food security

4.4.1 Assessment of food security

Table 5 presents the Household Food Insecurity Access categories by gender and for periods of normal rainfall and period of extreme weather. There were large differences in food security between periods of normal rainfall and periods of extreme weather. The share of households that were severely food insecure rose from 51% during periods of normal weather to 79% during periods of extreme weather. Similarly, while 22% of households were food secure during periods of normal weather, only 3% were food secure during period of extreme weather. These statistics majorly remained the same by gender both at household and at individual level. The differences by gender were not statistically significant.

4.4.2 Determinants of adaptation

Tables 6, 7 present the determinants of adoption of various adaptation strategies both at individual and household level. The two tables present marginal effects from multinomial probit models. Access to credit increased likelihood of farmers adopting all the three adaptation strategies. Access to credit increased likelihood of households changing planting dates, growing drought tolerant crops and practicing conservation agriculture by 8, 11, and 21 percentage points, respectively. Access to credit provides the much needed resources that can support and facilitate adaptation. Previous studies report similar findings. Access to credit increased likelihood of changing planting dates (Diallo et al., 2020; Madaki et al., 2024) and of growing drought tolerant crops (Zakari et al., 2022; Madaki et al., 2024).

Households that had non-farm income were more likely to practice conservation agriculture than those who did not have non-farm income. Household who had non-farm income were 14 percentage points more likely to practice conservation agriculture than those who did not. Diallo et al. (2020) also reported similar findings that off-farm employment was associated with increased likelihood of farmers changing planting dates, using organic fertilizers and growing short duration crops.

In terms of weather perception variables, in general, those who expected changes in weather patterns were more likely to adapt to climate change. Households who expected reduced rainfall were more likely to change planting dates. Households who expected reduced rainfall were 6 percentage points more likely to change planting dates.

TABLE 5 Food security by gender.

	Household level				Individual level			
	Total	Male headed	Female headed	Diff	Total	Male	Female	Diff
Normal period								
Food secure (%)	22.7	21.2	26.9	−5.7	21.6	22.1	21.1	1.9
Mildly food insecure (%)	5.7	6.4	3.7	2.6	6.8	6.7	6.9	−0.3
Moderately food insecure (%)	20.4	21.2	17.9	3.3	21.2	20.2	22.0	−1.8
Severely food insecure (%)	51.3	51.2	51.5	−0.3	50.4	51.0	49.9	1.1
Period of extreme weather								
Food secure (%)	3.1	2.9	3.7	−0.8	3.1	3.5	2.7	0.8
Mildly food insecure (%)	2.4	2.1	3.0	−0.9	2.2	1.9	2.6	−0.7
Moderately food insecure (%)	15.3	15.7	14.2	1.47	16.9	15.83	17.9	−2.0
Severely food insecure (%)	79.3	79.3	79.1	0.2	77.8	78.75	76.9	1.9
N	511	377	134		1,029	480	549	

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

TABLE 6 Determinants of adaptation strategies—household level analysis (multinomial probit marginal effects).

	(1)	(2)	(3)
	Changing planting dates	Planting drought tolerant crops	Practicing conservation agriculture
Age of household head	−0.000303	−0.000644	0.000431
Gender of household head	−0.0291	−0.0144	−0.0360
Household size	0.000177	0.00519	0.0156**
Head has above secondary level of education	0.0210	0.0173	−0.0719
Size of land	−0.0136	−0.00756	0.0111*
Access to credit	0.0832***	0.106***	0.209***
Owns livestock	0.0237	0.0301	0.0288
Has non-farm income	−0.0269	−0.0642	0.137***
Crops grown			
Beans	−0.0464	−0.0748	−0.0454
Green grams	−0.0333	0.0166	−0.0276
Cow pies	−0.0142	0.0749*	0.00757
Millet	0.0265	0.0468	0.146**
Vegetables	0.0483*	0.00110	0.121***
Pigeon peas	−0.104**	0.0487	0.0589
Climate perception variables			
Reduced rainfall	0.0625**	0.0473	0.0101
Less predictable rainfall	0.0265	−0.0291	0.128***
Recurring and prolonged drought	0.0152	0.00838	0.218***
N	517	517	517

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

Those who expected less predictable rainfall and recurring and prolonged drought were 13 and 22 percentage points more likely to practice conservation agriculture, respectively. Obsi Gemeda et al. (2023) also found climate change perception variables to be positively correlated with adaptation.

Household size and land size were also associated with increased likelihood of a household practicing conservation agriculture. A 1 unit increase in size of land and household size were associated with 1 and 1.5 percentage point increase in likelihood of household practicing conservation agriculture. Previous studies also report a positive

TABLE 7 Determinants of adaptation strategies-individual level analysis (multinomial probit marginal effects).

	(1) Changing planting dates	(2) Planting drought tolerant crops	(3) Practicing conservation agriculture
Age of household head	−0.000480	−0.0000451	0.000479
Gender of household head	−0.00400	0.00162	0.00360
Household size	0.00610	0.00655*	0.00849
Head has above secondary level of education	−0.000810	0.0120	0.000326
Size of land	−0.00633	−0.00453	0.00816**
Access to credit	0.101***	0.0871***	0.262***
Owns livestock	0.0181	0.0118	0.00889
Has non-farm income	−0.0115	−0.0590**	0.187***
Crops grown			
Beans	0.0312	−0.0822**	0.0105
Green grams	−0.0292	0.0399*	−0.00147
Cow pies	−0.0193	0.0850***	0.0211
Millet	0.0817*	0.0311	0.0543
Vegetables	0.0170	0.0170	0.108***
Pigeon peas	−0.107***	0.0264	0.0919**
Climate perception variables			
Reduced rainfall	0.0368*	0.0500**	−0.0104
Less predictable rainfall	0.000856	0.00345	0.0700**
Recurring and prolonged drought	0.000730	0.0198	0.170***
N	1,042	1,042	1,042

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

association between household size and adaptation to climate change (Diallo et al., 2020; Gebre et al., 2023) while others report mixed findings depending on type of adaptation strategy (Zakari et al., 2022).

Type of crops grown determined adaptation strategy undertaken. Households who grew millet were 15 percentage points more likely to practice conservation agriculture while those who grew vegetables were 5 and 12 percentage points more likely to change planting calendar and to practice conservation agriculture, respectively. Households who grew cow peas were 7 percentage points more likely to plant drought tolerant crop varieties.

4.4.3 Adaptation and food security

Tables 8–11 present results of the effect of adaptation strategies on food insecurity. Tables 8, 9 present probit results while Tables 10–13 present CEM results. Since the CEM results control for potential selection bias among households/individuals who engage in adaptation, our interpretations are based on CEM results. The results indicate that adapting by growing drought tolerant crops and practicing conservation agriculture have positive and statistically significant effects on food security of males/male-headed households. For female-headed households, changing planting calendar and planting drought tolerant crops have negative and statistically significant effects on food security while practicing conservation agriculture has insignificant effect. For females, mixed results are observed. The effect of adapting by growing drought tolerant crops is positive and statistically insignificant. The effect of conservation agriculture is positive and statistically significant while the effect of change in planting dates is negative and also statistically significant.

Households who planted drought tolerant crops and practiced conservation agriculture were 10 and 21 percentage points, respectively, more likely to be food secure. Individuals who planted drought tolerant crops and practiced conservation agriculture were 19 and 24 percentage points, respectively, more likely to be food secure. Previous studies also report positive effects of adaptation to climate change on food security. Focusing also on Kenya, Gebre et al. (2023) and Ndiritu and Muricho (2021) found that farmers who adapted to climate change had higher food security status. Alhassan (2020), Ogunpaimo et al. (2021), Ogundeji (2022), Ogundeji (2022), and Diallo et al. (2020) also found adaptation to climate change to promote food security. Madaki et al. (2024) found that adoption of climate risk adaptation strategies increased dietary diversity score and reduced food security coping strategy index. Amare and Simane (2018) found that households that adopted any adaptation strategy had higher food calorie intake per adult equivalent.

The gender disaggregated results show that planting drought tolerant crops increased likelihood of males/male-headed households being food secure by 35 and 22 percentage points, respectively. The effects are even higher at 42 percentage points for males living in female-headed households compared to 34 percentage for males living in male-headed households. Males/male-headed households who

TABLE 8 Effect of adaptation on food security-Household level analysis (Probit marginal effects).

	(1) Full sample	(2) Female -headed	(3) Male-headed
Adaptation strategies			
Change of planting dates	−0.139***	−0.127	−0.0957*
Conservation agriculture	0.194***	0.148	0.201***
Drought tolerant crops	0.221***	−0.153	0.291***
Household and individual characteristics			
Age	−0.0008	0.007**	−0.002*
Gender	0.0841*		
Household size	−0.0107	−0.0006	−0.0193**
Above secondary education level	0.0457	−0.0067	0.0502
Wealth status (Base: Low)			
Middle wealth status	0.187***	0.127	0.220***
High wealth status	0.250***	0.220**	0.240***
Land in acres	0.0018	0.0572**	0.0005
credit	0.139**	0.283***	0.0793
livestock	0.0282	0.165**	−0.0323
Non-farm income	0.187***	0.267**	0.162***
Plant cash crops	0.307***	0.272	0.302**
Community level			
Distance to water source	−0.028**	0.026	−0.047***
N	508	135	373

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

practiced conservation agriculture were 25 and 23 percentage points more likely to be food secure than those who did not. Females who practiced conservation agriculture were also 24 percentage points more likely to be food secure. Females/female headed households who changed planting dates were 13 and 29 percentage points less likely to be food secure. Similarly, female-headed household who grew drought tolerant crops were 33 percentage points less likely to be food secure.

These gendered findings indicate that even when they adapt to climate change, women benefit less from such strategies compared to men. Female-headed households are especially the most disadvantaged. For them, there is a negative association between adapting to climate change and food security. According to Yadav and Lal (2018), women living in arid and semi-arid areas make up the highest share of the world's most poor. Women are also generally confronted with unclear natural resources access, lack of financial resources and limited market opportunities (Djoudi and Brockhaus, 2011). Adzawla et al. (2019) found that male-headed households had higher levels and intensity of adaptation than female-headed households. In this study, adaptation to climate change was measured as dummy variable taking value 1 if a household/individual implemented a particular adaptation strategy and 0 if otherwise. We did not consider the intensity of adaption. If women's intensity of adaptation is lower than that of men, then this may explain why we find negative association between adaptation and food security for female headed households.

On other determinants of food security, Tables 8, 9 indicate that female-headed households were 8 percentage points more likely to be food secure. The effect was however only statistically significant at 10% level of significance. Ndiritu and Muricho (2021) also report similar results that male-household heads were more likely to be food secure than female-headed households. Larger household sizes were associated with reduced likelihood of food security. This effect was especially significant for female-headed households. Female-headed households with large household members were 2 percentage points less likely to be food secure. This maybe because a large household size means many people to feed and therefore a higher chance of food insecurity. Similar findings were reported by Tambe et al. (2023) and Wudil et al. (2023). These findings however contradict those of Worku (2023).

As expected, higher wealth status was associated with increased likelihood of food security. Households in high wealth quintile were 25 percentage points more likely to be food secure than those from the lower wealth quintile. Ndiritu and Muricho (2021) and Tambe et al. (2023) also found positive association between wealth status/household income and food security. Larger farm size was associated with increased likelihood of food security. This effect was only significant for female-headed households. Female-headed households with larger farm sizes were 6 percentage points more likely to be food secure. Wudil et al. (2023) also found a positive association between farm size and food security.

Access to credit was also an important determinant of food security. Households that reported accessing credit were more likely to be food secure. The effect of credit on food security was especially large for female-headed households. Access to credit increased the likelihood of

TABLE 9 Effect of adaptation on food security-Individual level analysis (Probit marginal effects).

	(1) Full sample	(2) Female	(3) Male
Adaptation strategies			
Change of planting dates	−0.110***	−0.115**	−0.110**
Conservation agriculture	0.183***	0.144***	0.224***
Drought tolerant crops	0.170***	0.100*	0.260***
Household and individual characteristics			
Age	−0.0010	−0.001	−0.002
Gender	0.0277		
Household size	−0.0212***	−0.018**	−0.023***
Above secondary education level	−0.0017	−0.059	0.051
Wealth status (Base: Low)			
Middle wealth status	0.209***	0.177***	0.237***
High wealth status	0.286***	0.283***	0.260***
Land in acres	0.000779	0.011	−0.009
credit	0.159***	0.197***	0.099*
livestock	0.0154	0.021	0.007
Non-farm income	0.145***	0.098	0.205***
Plant cash crops	0.208***	0.122	0.293**
Community level			
Distance to water source	−0.00587*	−0.00446	−0.0299**
N	943	502	441

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

TABLE 10 CEM results on effects of adaptation on food security-household level analysis.

	(1) Full	(2) Female	(3) Male	(4) Full	(5) Female	(6) Male	(7) Full	(8) Female	(9) Male
Change of planting dates	−0.06	−0.286***	0.0266						
Conservation agriculture				0.207***	0.106	0.234***			
Drought tolerant crops							0.104*	−0.333***	0.219***
N	243	67	176	344	88	256	294	66	228

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

TABLE 11 CEM results on effects of adaptation on food security-individual level analysis.

	(1) Full	(2) Female	(3) Male	(4) Full	(5) Female	(6) Male	(7) Full	(8) Female	(9) Male
Change of planting dates	−0.023	−0.133**	0.102						
Conservation agriculture				0.244***	0.246***	0.241***			
Drought tolerant crops							0.185***	0.029	0.351***
N	517	277	240	535	285	250	476	258	218

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

TABLE 12 CEM results on effects of adaptation on food security-individual living in male headed households.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Full	Female	Male	Full	Female	Male	Full	Female	Male
Change of planting dates	−0.00489	−0.105	0.0814						
Conservation agriculture				0.241***	0.268***	0.217***			
Drought tolerant crops							0.200***	0.0276	0.344***
N	359	168	191	389	179	210	354	169	185

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

TABLE 13 CEM results on effects of adaptation on food security-individual living in female headed households.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Full	Female	Male	Full	Female	Male	Full	Female	Male
Change of planting dates	−0.0773	−0.292***	0.315***						
Conservation agriculture				0.284***	0.155	0			
Drought tolerant crops							−0.0281	−0.190	0.418**
N	109	73	36	105	75	24	91	64	27

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

female-headed households being food secure by 28 percentage points compared to only 8 percentage points for male-headed households and the later effect was not statistically significant. A similar pattern was observed at individual level with the effect of accessing credit being stronger for females than males. Previous studies also report positive effects of access to credit on food security status (see Acheampong et al., 2022; Wudil et al., 2023).

Having livestock (cattle, goat and sheep) increased likelihood of food security especially for female-headed households. Female-headed households who owned livestock were 17 percentage points more likely to be food secure than those who did not own livestock. Ndiritu and Muricho (2021) reported similar findings that households with more livestock were more food secure than those with less livestock.

Non-farm income was also associated with increased likelihood of food security. Households who had non-farm income were 19 percentage points more likely to be food secure. The effect of non-farm income was stronger for female-headed households. Female-headed households with non-farm income were 27 percentage points more likely to be food secure compared to 16 percentage points for male-headed households. At individual level, the effect of non-farm income on food security was stronger for males and was even insignificant for females. Non-farm income can be used to purchase more food and also to purchase inputs to produce more food. Worku (2023) also found that households with non-labor income were more likely to be food secure.

Households who engaged in cash crop farming were more likely to be food secure. Households who grew cash crops were 31 percentage points more likely to be food secure than those who did not. The effect was only significant for male headed households. Male headed households who grew cash crops were 30 percentage points more likely to be food secure than those who did not. A similar pattern was observed at individual level analysis where males who grew cash crops were more likely to be food secure. The effect of cash crops on food security for females at individual level was not statistically significant. Similar findings were also reported by Rubhara et al. (2020) and Hashmiu et al. (2022).

5 Conclusion

This study examined types of adaptation strategies implemented by males/male-headed households and females/female-headed households and how these influence food security. Data was collected using structured questionnaires from 521 households and 1,049 adults from Makueni County, Kenya. Study findings indicate that approximately 72, 62 and 75% of households experienced reduced rainfall, less predictable rainfall and recurrent and prolonged droughts, respectively, to a large extent. About 86% of the households experienced at least one extreme weather event. The three most adopted adaptation strategies were conservation agriculture (69%), change of planting dates (49%) and planting of drought tolerant crops (47%). A higher share of male-headed households than female-headed households implemented all three adaptation strategies. Access to credit, non-farm income, types of crops grown, and weather perception variables were the important determinants of adaptation.

Food security was measured using Household Food Insecurity Access Prevalence (HFIAP). We used probit model to estimate the effect of adaptation strategies on food security. Coarsened Exact Matching (CEM) was used to control for potential self-selection of farmers into adoption of adaptation strategies. We found that planting drought tolerant crops and practicing conservation agriculture were associated with increased likelihood experiencing food security but only for males/male-headed households. For female headed households, growing drought tolerant crops reduced likelihood of food security while the effect of conservation agriculture was not statically significant. Change in planting dates was associated with reduced likelihood of food security among females/female headed households.

These findings provide evidence that in Makueni County of Kenya, adaptation to climate change provide potential for improvements in food security among male-headed households. This potential is however limited for female-headed households. They are not only less likely to adapt but are also less likely to benefit from adaptation to climate change. This study highlight women's vulnerability to climate change and especially for female-headed households and calls for policies to build women's capacity to effectively adapt to climate change. Women often face multiple challenges including poverty and limited access to productive resources including land. They also disproportionately bear the burden of unpaid domestic and care work. Intersection of these may not only affect the likelihood but also the intensity of adaptation to climate change.

A limitation of this study is that we measured adaptation strategies as dummy variables taking value 1 if a household/individual adopted a particular adaptation strategy and 0 otherwise. This way, we did not capture the intensity of adaptation and this may affect how adaptation affects food security. Future studies can build on this study to understand how intensity of adaptation affects outcomes such as food security with view of shedding more light on why women are less likely to benefit from adaptation to climate change including understanding how they adapt.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

PM: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. SS: Conceptualization, Methodology, Supervision, Writing – review & editing. BW: Conceptualization, Methodology, Supervision, Writing – review & editing. AM: Conceptualization, Methodology, Supervision, Writing – review & editing. KD: Conceptualization, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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