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Gender differences in climate-smart adaptation practices amongst bean-producing farmers in Malawi: The case of Linthipe Extension Planning Area

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Agriculture is amongst the vulnerable sectors to climate change and its associated impacts. Most women are more vulnerable to the impacts of climate change than men. Climate Smart Agriculture ensures increased productivity thereby enabling food security, income security and wealth creation amongst the farming households. A study was carried out to understand the gender differences in access and use of climate-smart agriculture, challenges and solutions that men and women farmers use to adapt to climate change. Data was collected from 246 randomly sampled households from 14 villages at Linthipe Extension Planning in Dedza district in Malawi. The multivariate probit model was employed to understand the influence of sociodemographic, farm-level, and institutional factors in the application of climate-smart agriculture in the study area. Findings from this study indicate that there are differences in the adoption and use of climate-smart agriculture technologies in bean production amongst different gender categories. More women compared to men and youths tend to use fertilizer, use improved seeds and plant early in order to mitigate and adapt to climate change. Most men adopt and use irrigation, whilst the youth mostly adopted and used pesticides and conservation agriculture practices. The study recommends policies that would ensure the promotion of gender-responsive climate-smart agriculture technologies, improved access to inputs, and capacity building through training.

KEYWORDS

gender, climate-smart agriculture, technology, food security, differences

Introduction

Agriculture provides most of the world's food, creates employment opportunities and helps eradicate poverty. In 2018, agriculture accounted for 4% of the global Gross Domestic Product (GDP), rising significantly to about 25% of the GDP in the least developing countries (World Bank, 2022). In Sub-Saharan Africa (SSA), agriculture employs more than half of the workforce and therefore plays a critical role in poverty alleviation (OECD, 2016; Mkpado and Mkpado, 2020). However, SSA's agriculture is significantly affected by climate change resulting in prolonged dry spells, drought, heat waves, rising temperatures, cyclones, flooding, irregular rainfall patterns, and increased cases of pests and diseases, all of which affect the overall agriculture production in the region.

SSA is one of the regions worse hit by climate change as a majority of the people in the region depend on rain-fed agriculture as their primary source of income (McCullough, 2017; Giller et al., 2021). As such, a negative impact on agricultural production results in a significant drop or complete loss of income for most households. Secondly, Sub-Saharan Africa has underlying challenges, including the prevalent cases of undernourishment coupled with the relative lack of economic diversification (OECD, 2016). Undernourishment has been a problem for a long time, perpetuating uneven growth throughout the region due to its rapid population growth. The proportion of undernourished persons is still high despite a slight drop in the last two decades (McCullough, 2017; Duffy et al., 2021). Moreover, the lack of agricultural mechanization has also contributed to the delay in achieving food security due to the low yield of agricultural products. Therefore, the impact of current climatic shocks has reduced productivity, increased suffering and slowed economic growth and development.

The impact of climate change on food production in SSA is further worsened by prevailing gender disparities in access and use of climate technologies which threaten the livelihood of millions of people, especially women. Women in SSA are more vulnerable to the negative consequences of climate change than men because women make up the majority of the region's disadvantaged and vulnerable group (Duffy et al., 2021; Phiri et al., 2022). They lack equal land access and land ownership rights as men. They are proportionally more reliant on small-scale agriculture, which is negatively impacted by climate change. Women also have the least ability to react to climate shocks because of their limited access to financial capital (McCullough, 2017; Phiri et al., 2022). Their predicament is further worsened by cultural barriers that affect the decision-making capacity on-farm compared to men. Women also lack adequate access to technology, training, and extension services. As a result, they are less prepared to adapt to the effects of climate change.

Gender and socioeconomic inequality remain a persistent challenge in the global agri-food system, worsening the plight of women. There is a wide gender disparity in technology access and use, with women being the most disadvantaged. Technologies are often designed with a man as a farmer in mind, and as such the relatively low technological use by women. Due to these inequalities, women are often the most affected by climate change and experience significant challenges in their attempt to adapt. Nonetheless, women's access to agricultural resources and services can play a vital role in addressing the region's food security problem and undernourishment.

In Malawi, the impact of climate change has been felt across the country, with the most affected being smallholder farmers, especially women. There have been increased droughts, food shortages, and a significant drop in income because agriculture remains the major employer of most of the nation's population. Majority of Malawi's population lives in rural areas and rely on agriculture as their primary source of livelihood (FAO, 2018). However, the current drought remains a significant challenge resulting in increased food insecurity and malnutrition. Smallholder farmers are adapting to this reality in different ways, including planting early maturing crops. The government of Malawi also instituted a national climate change management policy in 2016 to enhance coordination and implementation of climate change activities to develop and transfer climate technologies and promote capacity building among smallholder farmers. With more women depending on agriculture as their primary source of income, climatic shocks result in increased challenges for women farmers. Women lack land ownership in most parts of the country. Existing cultural barriers discourage women in some parts of the country from owning land although 80% of the population follows the matrilineal—matrilocal land tenure inheritance system—a common pathway to land ownership (Asfaw and Maggio, 2018). As such, women live with a pre-existing disadvantage because of the lack of fundamental rights to land ownership. Additionally, cultural practices also give men the decision-making power on most issues, leaving women with less influence on household decisions. Thus, in addressing climate change, one can address gender inequality and overall economic prosperity.

Climate change creates extreme weather events, such as floods, unpredictable rainfall, prolonged dry spells and droughts, which have considerably impacted Malawi's ability to realize its sustainable development goals on climate action and gender equality (SDG 13 and 5). Prolonged droughts, pests, and diseases have affected the availability of staple crops, consequently reducing food availability and making it more difficult for smallholder farmers to provide for their families (Nsanja et al., 2021; Zingwe et al., 2021). Lack of food availability adds to an already existing undernourishment and poverty problem. Climate change can potentially worsen the livelihoods of the most vulnerable smallholder farmers, notably women, if not addressed on time (Assan et al., 2018; Cipriano et al., 2022).

These climatic phenomena have a detrimental impact on the lives of resource-poor farmers. It is important to know the gaps to improve farmers' abilities to access and use climate-smart agricultural technologies and practices. Thus the aim of this paper is to understand the gender differences in access and use of Climate Smart Agriculture technologies and challenges and solutions men and women farmers use to adapt to climate changes in Dedza district in Malawi.

Conceptual framework

Climate-smart agriculture (CSA) is an approach to agricultural development that aims to transform and reorient modern agriculture in light of the new realities of climate change. The primary goal of CSA is to improve food security and economic growth by increasing sustainable productivity and improving resilience (adaptation). The success of CSA depends on the coordination of its three interdependent pillars—productivity, adaptation, and mitigation. Productivity is the first pillar of CSA and is focused on increasing agricultural productivity and income from various sources, including crops, while remaining environmentally conscious (Mwesigye et al., 2020). With increased productivity, food and nutritional security are improved. The second pillar, adaptation, aims to reduce farmers' exposure to short-term risks while increasing their resilience by improving their ability to adapt to shocks and longer-term stresses to enable them to thrive. The third and final pillar—Mitigation- is primarily concerned with lowering greenhouse gas (GHG) emissions.

Farmers' adoption of CSA impacts the outcomes of these three pillars because climate-smart technologies and practices are influenced by intersectional and contextual factors, especially among communities that are more vulnerable to the effects of climate change. The most influential contextual factors influencing the implementation of climate-smart technologies are human capital, physical capital, financial capital, and social capital (Mwesigye et al., 2020; Nsanja et al., 2021). In addition to contextual factors, intersectional factors (such as age, gender, marital status, farmers' occupation, and type of household) also influence the implementation of CSA.

Social capital is a significant resource for building adaption by farmers. It contributes to how farmers respond and adapt to climate change and helps ensure food security and the resilience of livelihoods (Zingwe et al., 2021). A high degree of social capital fosters self-organization and a capacity for learning adaptation among smallholder farmers because it can enhance information and knowledge transfer among farmers (Nsanja et al., 2021). Social capital is significantly beneficial in rural communities where people rely on cooperatives for alternative responses to climatic shocks. Different dimensions of social capital influence the choices of adaptation measures utilized by smallholder farmers, which therefore makes it crucial because farmers' adaption to climate change is created by a social component through their interaction with others, networking to gain information, sharing resources and creating collective norms to build resilience against climate change (Nsanja et al., 2021). In addition to human and financial capital, social capital remains a significant resource because climate change adaptation is a dynamic social process underpinned by socio-cultural characteristics of farmers, groups or the society that is adapting (Zingwe et al., 2021). Therefore, social capital plays a crucial role in farmers' decision-making, which consequently impact the implementation of smart climate agricultural practices among farmers in Sub-Saharan Africa.

Human capital refers to the economic value of farmers' knowledge and skills, including training, education, skills and health. Farmers with a sufficient level of education are better equipped to make informed decisions on adopting new technologies and navigate the challenges posed by climate change. A more substantial human capital base positively impacts farmers' lives because it helps them adapt to changing climatic conditions. A weak human capital base negatively impacts farmers' lives (Bassey and Bubu, 2019; Nsanja et al., 2021). For instance, household size may affect agricultural productivity, reflecting labor and skills availability. The availability of labor and skills is important in enhancing resilience to climatic shocks because it reduces the labor and skill constraints that must be overcome while introducing and implementing new CSA methods, making CSA adaptation easier. As a result, boosting investment in human capital can support a shift in productivity and resilience to climatic shocks. Climate-smart interventions that deliver multiple benefits depend on human capital to enhance climate change adaptation and mitigation for communities. Therefore, this study anticipates that human capital would significantly influence the adoption of climate-smart agriculture practices among bean farmers.

Physical capital significantly influences the adoption and use of climate-smart technologies. The availability of physical capital assets such as mobile phones, computers, farm machinery and means of transportation determine the level of production, resilience and adaption to climate shocks. Farmers with a robust physical capital base can better adapt to climate-smart agricultural practices (Nsanja et al., 2021). Mobile phones, for example, can enable farmers to share information on CSA practices and participate in online groups during training and other activities. Among rural communities in Sub-Saharan Africa, ownership of a wide range of physical capital differs by gender. It thus affects the general performance of men, youth and women in adopting climate-smart agriculture. Nonetheless, physical capital remains an important factor in climate change management.

Financial capital plays a significant role in mitigating challenges arising from climatic shocks because it enables farmers to use climate-smart technologies to adapt to climate change. They include transferable resources such as wages, salaries, and cash flows. The implementation of CSA practices requires additional financing. Inadequate finance has been a significant challenge in adopting climate-smart technologies, especially among smallholder farmers (Mwesigye et al., 2020; Nsanja et al., 2021). Thus, off-farm income can benefit smallholder farmers and positively influence the adoption of climate practices. However, a significant gender gap exists in access to and use of financial resources, thus reducing the performance of the youth, men and women in agricultural production in Sub-Saharan Africa. In most cases, women and youth rely on men for financial support.

Intersectional factors such as age, sex, culture, decision making and crop management, marital status, and occupation significantly influence farmers' adoption of climate-smart technologies. Age is argued to be a significant aspect that influences the adoption of new technologies and the participation of farmers in social groups. Older farmers are believed to have enormous farming knowledge and experience that they have accumulated over the years. As a result, they can evaluate new farming technologies better than young farmers. However, age has a negative influence on technology adoption and group participation. Unlike the youth, older farmers (men and women) are risk-averse and focus less on long-term farm investment (Bassey and Bubu, 2019). Future farm investment differs by gender. Unlike the youth, men and women take fewer risks in future investments. They often do not participate actively in social groups to foster the adoption and implementation of new practices. By contrast, young farmers are willing to engage in new technologies and are typically less risk-averse (Mwesigye et al., 2020). The impact of culture, marital status, and occupation on adopting climate-smart technologies also differ by gender. In most Sub-Saharan countries, men are involved in most of the decision-making process since they own the land and therefore determine the implementation of CSA practices. On the other hand, women have little influence on land use except in women-headed households. The youth also have a relatively minor impact on adopting climate-smart technologies because most youth still do not own land culturally.

Methodology

Study area

The study was conducted in Linthipe Extension Planning Area (EPA) in Dedza district in the Central region of Malawi, where the primary income source is agriculture. Malawi has a subtropical climate with strong seasonal fluctuations and relatively dry weather. The warm-wet season lasts three quarters of the year, from November to April, and accounts for 95% of yearly precipitation. The annual rainfall average ranges from 725 to 2,500 mm. The altitude has an impact on the average temperature. The country's agroecological conditions are ideal for growing staple foods like corn, beans, and rice. The recent climatic shocks and their inherent variability have significantly impacted agricultural production in Malawi during the last few decades. Climate change has already had negative impacts in many areas, with considerable reductions in agricultural output, deterioration of water quality, and loss of biodiversity among the consequences. The weather in Linthipe, Malawi, is relatively warm with an average temperature of between 24 to 27°C at different times of the year (Gwenambira-Mwika et al., 2021). The region records an average of 1168 mm of precipitation annually. However, recent droughts and prolonged dry spells have decreased precipitation levels and caused a significant rise in temperature in the region.

Sampling procedure and sample size determination

The study focused on smallholder Malawi farmers involved in common bean production. Common bean is a staple food in Malawi and a source of income for smallholder farmers. Various villages were chosen at random to improve representation. Linthipe Extension Planning Area (EPA) was purposively selected because it is one of the major bean growing areas, has high rainfall variability and it is prone to droughts and floods. The final phase involved picking households at random. Linthipe has a wide range of common bean varieties introduced in the region. The presence of various common bean farmer networks in the region makes the bean-growing population in the area heterogeneous. Therefore, the sample size for the study was calculated using the formula:

$$n = \frac{pqZ2}{E2} \quad (1)$$

where, n is the sample size of bean farmers to be determined. Z is the confidence level (alpha = 0.05), p is the population proportion. q is 1-p, and E is the precision error. Because the population of bean farmers in Linthipe was unknown, the value of p was set to 0.5. In this case, $q = 0.5$, $Z = 1.96$, and the error term was 0.05, resulting in a sample size of 384 farmers. However, the target sample size of 384 farmers was not met due to logistical challenges during the data collection period. Some of the respondents were unreachable during the survey.

Regional extension offices provided a list of farmers in the selected village. The lists were used to make a sampling frame, which was then imported into Excel, and farmers were randomly selected using the RAND function. The RAND function returns a random number that is greater than or equal to zero, but less than one. An objective sample of farmers was chosen from each village using the probability proportional to size sampling approach was used to determine unbiased samples

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from selected from each village. The sample size comprised a total of 239 respondents of which 196 were females and 50 were males.

Data collection

The study was conducted using a quantitative methodology, with data collected from bean growers in various villages across the Linthipe Extension Planning Area (EPA) in Dedza district through a questionnaire. The villages included Chioza Kalichero, Chipse, Dambo, Huwa, Kabango, Kangulu, Kutelera, Paiwe, Sefasi, Solowa, Thomas, Tumbwe, Lumwira, and Chiwaka. Trained enumerators collected data from the sampled households. The instrument was co-created by all relevant parties and subjected to preliminary testing to ensure internal consistency and validity before being administered to specific farmers. The respondent's responses were elicited in five different ways across five questionnaire sections. The first section collected data on home locations and sociodemographic factors. The second section sought information on land ownership, access, and allocation to bean production over seasons and bean production-related decision-making. In the third portion of the questionnaire, farmers were asked about the bean seed and bean varieties they planted and their bean production methods. Data on production constraints were collected in the fourth portion of the questionnaire, and farmers' access to information about bean production techniques and marketing was assessed in the fifth section. Data was collected manually and later filled in excel and SPSS for analysis.

Data analysis

Descriptive method

Cross-tabulation was utilized to obtain the frequencies and percentages of the farmer's replies for the categorical variables. The mean and standard deviation adequately represented the continuous numeric variables. An analysis of variance and a chi-square test of independence was used to determine the degree of variation between the distributions of continuous and categorical data.

Econometric analysis

The multivariate probit model was used to examine the influence of sociodemographic, farm-level, and institutional factors in explaining the application of climate-smart agriculture in the study area. A multivariate probit technique was chosen to analyze discrete choice data since it allows simultaneous estimation of regression equations. Five climate-smart technologies and practices (improved bean seed, pesticide, fertilizer, irrigation, and conservation agriculture) were evaluated in this scenario with no preconceptions. The listed technologies are often those propagated in the country. The simultaneous estimation of the five regression equations facilitates the exploration of climate-smart agricultural interrelationships. This is based on the study assumption that farmers will adopt agricultural innovations as a package rather than as individual activities.

This is the written form of the multivariate probit model that incorporates climate-sensitive technologies and practices as a set of binary dependent variables.

$y_m* = \beta m\ Xm + £m,\ m = 1,..., M$

$y_m = 1$ if $ym * > 1$ and 0 otherwise

Result and discussion

Descriptive results

The sociodemographic characteristics of common bean farmers in Malawi, presented in Table 1, demonstrate that most farmers (61%) are youths (18–35 years). Men and women bean farmers are 10 and 28%, respectively. A majority of the farmers (86%) stated that farming was their primary occupation. The findings show that agriculture attracts a significant number of youths compared to men and women combined, asserting that it is the main source of livelihood for rural youths in the country. Many Malawians depend on agriculture because it plays an overwhelmingly important role in Malawi's economy, accounting for about 30% of the country's GDP (Ng'ong'ola, 2020; Lindsjö et al., 2021). The results further indicate that most household heads are men (96%), thus affirming cultural narratives where men are considered the rightful heads of their families (Bassey and Bubu, 2019).

Additionally, there are more youth household heads than women at 30 and 28%, respectively. The results also demonstrated a significant difference in the age of common bean farmers in Malawi ($p < 000$). The average age of the youth was 27 years while men and women were 48 and 44 years, respectively. There were also significant differences in the education level of farmers ($p < 000$), with more youths (27%) having secondary education or higher, compared to men and women at 8 and 15%, respectively. However, on average, the majority of men, women and the youth had primary education at 71, 71, and 70%, respectively. All the men interviewed stated that farming was their primary occupation, while women and youth who identified farming as their main occupation were 81 and 90 %, respectively.

Marital status differed significantly by gender ($p < 0.028$), with a higher percentage of the respondents (81%) indicating that they were married. There were more married men (96%), women (71%) and the youth (83%). Among those who indicated being divorced, women and the youth were the

TABLE 1 Socio-demographic characteristics of respondents by gender.

Variable	Total ($N = 246$)	Youths ($n = 151$)	Women ($n = 70$)	Men ($n = 25$)	p-value
Gender of the respondent (%)		61.38	28.46	10.16	
Age of respondent (years)	34.16	27.17	44.14	48.40	0.000
	10.93	5.36	7.66	7.84	
Relation of respondent to HHH (%)	36.13	29.86	27.54	96	0.000
Education level respondent (%)					
No formal education	8.4	3.45	14.49	20.83	0.002
Primary	70.17	69.66	71.01	70.83	
Secondary or higher	21.43	26.9	14.49	8.33	
Farming as the main occupation (%)	85.77	81.38	89.86	100	0.025
Marital status (%)					
Married	81.17	83.45	71.01	96	0.028
Divorced	10.46	11.72	11.59	0	
Never married	2.51	2.07	2.9	4	
Separated	2.51	2.07	4.35	0	
Widowed	2.93	0.69	8.7	0	
Cohabiting	0.42	0	1.45	0	
Household type (%)					
Dual type	76.69	76.76	71.01	92	0.179
Woman only	11.02	9.86	17.39	0	
Woman with an absentee husband	5.51	5.63	7.25	0	
Man only	4.66	5.63	1.45	8	
Polygamy	2.12	2.11	2.9	0	

majority at 12% each. There were no divorced men among the respondents. Additionally, more men (92%) indicated being in dual households while women and the youth living in dual households were 71 and 76%, respectively. Respondents' marital status and household type show possible differences between gender vulnerabilities to climate change and respondents' adaptive capacity (Alhassan et al., 2018; Assan et al., 2018). Because of the possible gender vulnerabilities, women and the youth are more likely to find it more challenging to apply their practical agricultural knowledge than men because of socioeconomic constraints.

The farming characteristics of common bean farmers as reported by men, women, and the youth are presented in Table 2. The results demonstrate a statistically significant difference in land ownership among common bean farmers. On average, Men own more land (2.14 acres) compared to women (1.64 acres) and youths (1.13 acres). Lindsjö et al. (2021) found that even though men and women did not farm all the land due to physical labor, they tended to withhold their pieces of land, which explains why youths have access to the least acres of land compared to men and women. Additionally, men have access to more land (2.73 acres) compared to women youths at 2.3 and 1.60 acres, respectively. Culturally the land is considered to belong to the man, which explains why more land is owned and accessed by more men than women and youth (Mwesigye et al., 2020).

In Sub-Saharan Africa, women have fewer property rights. They are less likely to be named on ownership documents such as titles, despite many households claiming that the husband and wife jointly own the land (Chigbu, 2019; Bhatasara, 2021). A sole focus on land ownership ignores a significant aspect of the realities of land tenure. This omission can harm women's land rights in particular and their overall participation in agricultural production. According to the National Census of Agriculture and livestock (NACAL) 2006/2007, 4.9 million parcels (gardens) representing 64.03% were from male-headed households, and 2.8 million parcels (35.97) were from female-headed households. According to IHS4 on average, male-headed households had bigger land, and cultivated 1.7 acres compared to their female counterparts who cultivated 1.2 acres. Furthermore, IHS4 findings indicate that the proportion of female-headed households cultivating less than an acre of land is higher (57%) than their male counterparts, (41%). On the other hand, the proportion of male-headed agricultural households who cultivated more than one but less than two acres of land (32%) is higher than the female-headed households (29%).

TABLE 2 Common bean farming characteristics.

Variable	Total (*N* = 239)	Youth (*n* = 145)	Women (*n* = 69)	Men (*n* = 25)	*p*-value
Average acres of land owned	1.38	1.13	1.64	2.14	0.000
Average acres of land accessed	1.92	1.60	2.30	2.73	0.000
Average acres of land rented-borrowed	0.54	0.47	0.66	0.59	0.330
	[0.25]	[0.25]	[0.25]	[0.5]	
	(0.90)	(0.76)	(1.19)	0.64	
Who owns land (%)					
Man	18.83	18.62	11.59	40.00	0.002
Woman	46.44	49.66	52.17	12.00	
Both man and woman	34.73	31.72	36.23	48.00	
Who has access to land (%)					
Man	2.09	2.07	2.9	0	0.019
Woman	20.08	18.62	30.43	0	
Both man and woman	76.57	78.62	63.77	100	
Other relative	1.26	0.69	2.9	0	
Who manages the bean crop (%)					
Man	17.57	15.17	18.84	28.00	0.010
Woman	36.4	36.55	46.38	8.00	
Both man and woman	48.28	34.78	64	46.03	
Main purpose of growing beans (%)					
Food	9.24	9.03	10.14	8	0.954
Sale	2.52	2.78	1.45	4	
Both	88.24	88.19	88.41	88	
Decision on income from bean sales (%)					
Man	30.51	32.39	24.64	36	0.088
Woman	19.92	18.31	28.99	4	
Both man and woman	49.58	49.3	46.38	60	

Common bean production constraints

Table 3 common bean production is affected by various production constraints arising from climatic shocks like pests, diseases, and droughts. Post-harvest constraints are linked to storage pests and excessive rains at harvest. Market constraints like fluctuating prices, unstandardized scales and distant markets make it difficult for women to access better prices due to mobility.

In response to the production constraints common bean farmers face, some of the changes implemented comprised the use of pesticides, conservation agriculture, fertilizer, and a combination of other changes, as demonstrated in Table 4. A majority of the women and youth used pesticides compared to men. By contrast, more men and youth used conservation agriculture compared to women. On average, more women used fertilizer than men and youth. Common bean farmers incorporated other changes, including irrigation, improved seeds, and early or timely planting.

Decisions on changes to protect bean production against production constraints significantly differed by gender ($p < 0.005$) as shown in Figure 1. More men (48%) than women (13.43%) and the youth (18.66%) indicated that men made decisions in response to common bean production constraints. However, more youths and women (27 and 22%, respectively) indicated that both men and women—as partners in a household (jointly)—made decisions on the changes to common bean production constraints. The joint decision-making could result from gender training for farmers during bean demonstrations and field days with bean farmers' households. Acosta et al. (2020) posit that over the years, there has been significant progress in decision-making among smallholder farmers in Sub-Saharan Africa from the conventional male-dominated decision-making to a more gender-balanced decision-making approach to agricultural production. Since no qualitative data

TABLE 3 Production, post-harvest, and market constraints experienced by farmers by gender.

	Total ($N = 239$)	Youth ($n = 145$)	Women ($n = 69$)	Men ($n = 25$)
Production constraint				
Diseases and pests	42.79	42.96	45.45	34.69
Drought/dry spell	17.74	18.15	15.15	22.45
Excess rains/floods	8.87	10	6.82	8.16
Access to quality seed	7.32	7.78	6.06	8.16
Poor soils	5.76	5.56	5.3	8.16
Access to inputs	4.43	5.19	3.03	4.08
Theft	3.99	3.7	5.3	2.04
Labor constraints	2	1.11	3.79	2.04
Access to production finance	1.77	0.37	3.79	4.08
Weeds	1.55	1.85	1.52	
Access to knowledge and information	1.33	1.11	2.27	
Others specify	1.33	1.11	0.76	4.08
Increased input price	0.67	0.74	0.76	
Vermin i.e., wild harmful animals	0.44	0.37		2.04
Post-harvest constraints (%)				
Storage pests	48.4	46.67	52.04	47.06
Excessive rains at harvest	20.83	23.89	16.33	17.65
Lack of knowledge on appropriate storage practices	12.5	10.56	16.33	11.76
Labor constraints	7.69	7.22	7.14	11.76
Storage space	4.81	3.89	5.1	8.82
Access to post-harvest handling equipment	3.85	5.56	1.02	2.94
Other specify	1.92	2.22	2.04	
Marketing constraints (%)				
Fluctuating prices	49.33	50	50.89	42.22
Unstandardized weighing scale	27.2	25.69	28.57	31.11
Distant market	12.27	12.39	12.5	11.11
Poor means of transport	9.6	10.55	6.25	13.33
Illiteracy	0.8	0.46	0.89	2.22
Others specify	0.53		0.89	
Bad roads	0.27	0.46		

TABLE 4 Changes made in response to common bean production constraints by gender.

Change made	Total	Youths	Women	Men
Pesticide	28.03	29.32	26.37	25.00
Conservation agriculture	20.70	21.99	17.58	21.88
Other	18.79	18.85	17.58	21.88
Fertilizer	12.10	11.52	15.38	9.38
Irrigation	7.01	6.81	7.69	9.38
Improved seed	7.01	6.81	7.69	6.25
Early/Timely Planting	6.37	5.24	7.69	6.25

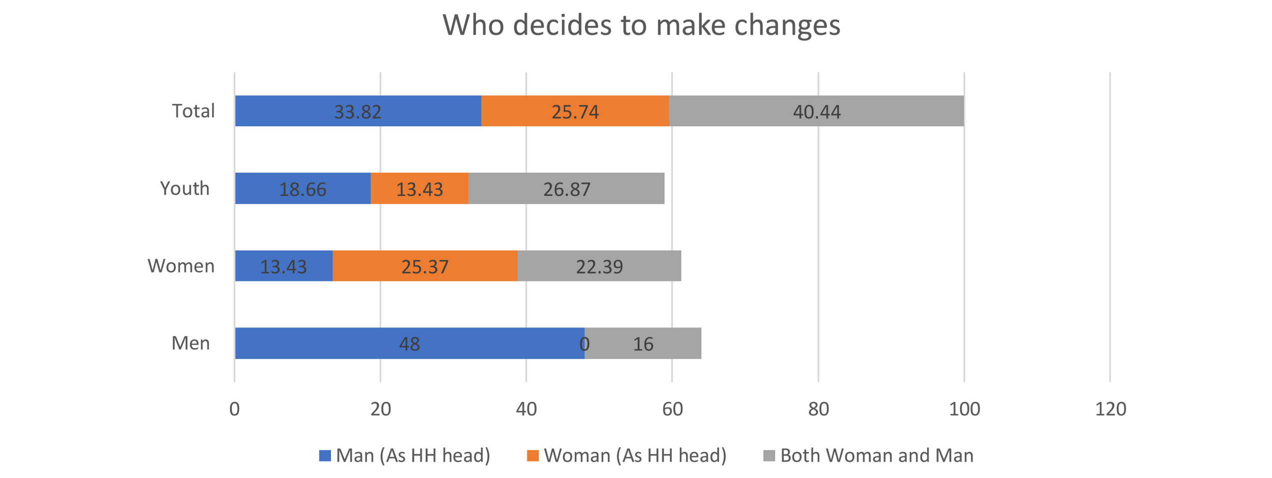

FIGURE 1
Decision-maker about changes to protect bean production against production constraints by gender.

was collected, it is difficult to determine what joint decision-making entails for men and women farmers. Do women contribute or decide?

Climate-smart agriculture is important and has been identified as one of the most critical approaches to strengthening climate resilience across all the four dimensions of food security, including food availability, access, stability, and utilization. It promotes precision agriculture to enhance climate resilience. Some of the climate-smart agriculture practices common bean farmers have implemented in their farms are; agroforestry, manure application, conservation agriculture, drought tolerate crops, early maturing crops, fertilizer, and irrigation shown in Table 5. Among these, manure application was the most common among men, women and the youth. Irrigation and conservation agriculture were the second and third most preferred by men, women and youth.

Nonetheless, more women (19%) used early maturing crops compared to men (16%) and the youth (8%). Men mostly preferred the use of conservation agriculture compared to women and youth. Conservation agriculture is less labor-intensive, especially where herbicides are used, as less labor is required for land preparation and weed control as compared to the conventional tillage method (Ngwira et al., 2012; Thierfelder et al., 2017; Kassam et al., 2019; Shrestha et al., 2020). Moreover, it is less costly to implement and also less labor intensive.

Institutional and support services

Institutional, social and technical support services received by common bean farmers are presented in Table 6. The information presented demonstrates no significant gender difference between men, women and youth regarding their access to bean farming training and membership in local groups and associations. However, there were remarkable statistically significant gender differences in access to bean production information and the distance to the nearest agro dealer. More youth than men and women received bean production information. Moreover, youth and women covered a long distance to the nearest agro dealer (∼6 km) compared to men, who covered <5 km to the nearest agro dealer.

Econometric results

Estimates of the multivariate probit coefficients of the factors that influenced common bean farmers' adoption of climate-smart technologies and practices in Malawi are presented in Table 7. The results of the Wild Chi-square test for overall model fit to demonstrate that the independent variables included in the model are significantly different from zero. This implies that CSA practices are influenced by at least one of the variables in the model. The five equations are interdependent, with some error terms being negative and others positive.

Land tenure and land size has a influence on the use of conservation agriculture and irrigation. Farmers are more likely to invest in technologies including conservation agriculture and irrigation if they have larger land size (Kamwamba-Mtethiwa et al., 2012; Ngwira et al., 2014; Makate et al., 2019; Mulimbi et al., 2019; Chichonsgue et al., 2020). Secured access to land also enables farmers to invest in implementing new practices to enhance production. Farmers are generally willing to invest in irrigation and implement conservation agriculture when they have land and are guaranteed to earn from their investment, unlike when their access to land is controlled or when they are constantly exposed to the risk of losing their investment

TABLE 5 Use of climate-smart agricultural technologies/practices by gender.

Practice	Total	Youths	Women	Men
Agroforestry	2.11	2.78	1.47	0.00
Manure application	43.03	43.06	42.64	44.00
Conservation agriculture	8.44	7.64	8.82	12.00
Drought tolerant crops	2.53	2.78	1.47	4.00
Early maturing crops	11.81	7.64	19.12	16.00
Fertilizer use	7.59	9.03	5.88	4.00
Water harvesting / Irrigation	14.35	15.97	10.29	14.35
Others	10.13	11.11	10.29	4.00

TABLE 6 Common bean farmers have access to institutional, technical, and social support services by gender.

Variable	Total	Youths	Women	Men	*p*-value
Average distance to agro-dealer (km)	5.9	6	6.07	4.84	
Percent owning mobile phone	75.42	71.33	78.26	91.67	0.082
Percent received bean production information					
Not always	7.98	6.25	7.25	20.00	
Sometimes	68.49	72.92	65.22	52.00	
Not at all	22.69	20.83	24.64	28.00	0.058
Percent received agricultural training	77.31	79.17	75.36	72.00	0.659
Membership to local groups/associations (%)	59.66	55.56	62.32	76.00	0.136

when that access is limited or altogether denied (Cipriano et al., 2022; Lee and Gambiza, 2022). Besides increasing food production, conversation agriculture and irrigation also help restore ecological balance.

Joint bean management by men and women has a significant positive influence on the use of conservation agriculture as a climate-smart practice than men or women solely. Conservation agriculture is 20 to 50% less labor-intensive FAO (2022). As such, it is often a preferred CSA practice because it brings down farming labor demands, reduces crop production costs and increases household income and food security (Wekesah et al., 2019). This reveals that conservation agriculture aligns with most household goals hence its preference for use in jointly managed bean crops. The influence of joint crop management on the use of conservation agriculture reveals a significant transformation in household gender relations in terms of crop management practices. Wekesah et al. (2019) reported that women's decision-making capacity expanded because of engagement in conservation agriculture. This finding corresponds with a study by Hove and Gweme (2018), which reported that in nearly half of households practiced conservation agriculture in Zimbabwe, women were the primary crop managers or co-managers, contrary to the widely held belief that women were merely providers of labor. This suggests that women bean farmers in Malawi also considerably influence bean crop management.

The result demonstrates that the likelihood of farmers using improved seeds increased by a factor of 0.47, as a direct result of increased access to information about climate change and agricultural technologies designed to mitigate the consequences of climatic shocks. This can be explained by the increased use of mobile technologies for information transmission (Abegunde et al., 2019; Anuga et al., 2019). Most farmers have access to mobile phones, which possibly enables them to access digital information, thus influencing their use of improved seeds. Mendes et al. (2020) observed that mobile phones determine who has access to specific agricultural technologies, and farmers with access to mobile phones are better suited to access digital information and can adapt to changing conditions (Chavas and Nauges, 2020). As such, access to information promotes the adoption of climate-smart technologies that will boost bean yield. Takahashi et al. (2020) further observed that farmers with relatively high access to information-sharing technology have a more optimistic view of technology, which helps to explain why access to information positively correlates with the use of improved seed.

Group membership positively and significantly influenced farmers' probability of using irrigation by 0.52. Additionally,

TABLE 7 Multivariate probit coefficient estimates of determinants of farmers' use of climate-smart technologies and practices.

	Ca		Improved Seed		Irrigation		Pesticide		Fertilizer	
	Coeff.	Std Err.	Coeff.	Std Err.	Coeff.	Std Err.	Coeff.	Std Err.	Coeff.	Std Err.
Men	0.084	0.371	0.374	0.387	−0.127	0.397	−0.160	0.388	0.339	0.489
Youth	0.354	0.317	−0.249	0.307	−0.071	0.326	0.178	0.316	0.027	0.360
Age	0.003	0.014	−0.009	0.014	−0.025	0.014	0.011	0.015	−0.002	0.016
Relation	0.154	0.236	−0.272	0.229	0.415	0.238	−0.149	0.237	−0.230	0.266
Education (1 = S and Above	−0.219	0.234	0.094	0.230	−0.096	0.236	0.084	0.240	0.091	0.264
Occupation (1 = Farming)	0.446	0.297	−0.278	0.265	−0.197	0.300	−0.583	0.308	−0.251	0.283
Land accessed	0.160*	0.078	−0.034	0.070	0.280**	0.091	−0.036	0.072	0.066	0.085
Land owner (1 = Both)	0.155	0.207	−0.060	0.201	−0.123	0.210	−0.300	0.213	−0.064	0.230
Managing crop (1 = Both)	0.441*	0.185	0.018	0.185	0.055	0.190	−0.182	0.201	0.193	0.215
Distance	−0.001	0.026	−0.010	0.026	−0.023	0.026	−0.006	0.027	0.069*	0.030
Mobile	−0.220	0.217	−0.082	0.218	0.112	0.228	0.233	0.229	0.272	0.243
Group	−0.002	0.206	0.211	0.202	0.520*	0.206	0.067	0.215	−0.147	0.229
Information	0.225	0.213	0.471*	0.222	0.182	0.222	0.422	0.244	−0.308	0.250
Training	0.104	0.211	0.329	0.209	0.337	0.212	0.829***	0.223	0.140	0.233
Constant	−1.273	0.714	0.221	0.696	0.032	0.741	−0.875	0.790	0.786	0.792
Wald chi2(10)	145.41***									
Likelihood ratio test	19.8959**									
rho21 −0.161										
rho31 −0.056										
rho41 −0.255*										
rho51 0.030										
rho32 0.162										
rho42 0.240*										
rho52 0.057										
rho43 0.242*										
rho53 −0.117										
rho54 0.095										

*Significant at 10.
**Significant at 5.
***Significant at 1.

farmers' training also positively and significantly increased the probability of farmers using pesticides by a factor of 0.829. Group membership is likely to have influenced the adoption of irrigation because it gave farmers access to climate change information, helped introduce new irrigation technologies to bean farmers, and encouraged monitoring farmers' progress in implementing this practice. On the other hand, farmers' training also enhanced their adoption of the use of pesticides. Training increases farmers' awareness and information on the benefits of pesticides in increasing food production.

The correlation between pesticides and conservation agriculture is negative and statistically significant, indicating that these two were never used side by side but one over the other. Farmers who used pesticides did not use conservation agriculture as a CSA practice to increase production. However, some of the practices complemented each other and were used by farmers alongside the other. The correlation between pesticides and improved seed and between pesticides and irrigation were all positive and statistically significant, suggesting that these CSA practices were complementary and thus were used by farmers alongside each other.

Conclusion

The study investigated the influence of contextual and intersection factors on the access and use of climate-smart agricultural technologies/practices among common bean farmers in Malawi. Bean crop management remained a joint activity between men and women in dual households. Land ownership and access differed by gender, with men owning and having greater access to land than women and youths. Women and young farmers were more vulnerable to climatic shocks than men. Farmers responded to production constraints in a relatively the same way. Men, women and youth responded similarly by using fertilizer, improved seed, irrigation, conservation agriculture, and pesticides. Most farmers (men, women, and the youth) lacked enough institutional, technical, and social support, making using climate-smart technologies and practices difficult.

The study also revealed significant gender differences in mobile phone ownership, with more men-owned mobile phones than women and youths. However, more youth sometimes indicated receiving bean production information than men and women. Furthermore, more youth received agricultural training than men and women. More men were members of local groups than women and the youth. Gender disparities influenced the adoption of climate-smart agriculture and practices. Young farmers were more likely than older farmers to use climate-smart agriculture technologies because of their increased access to information. Increased education, joint crop management, farming as a primary occupation, land ownership and access, group participation and mobile phone ownership all contributed to an increased usage of climate-smart agricultural technologies and practices. However, adopting climate-smart agriculture technology was hindered by other factors such as household leadership, marital status, and distance from an agro-dealer.

The findings in this study demonstrate that addressing gender disparities in land ownership and access, ownership of digital technology, participation in agricultural groups and associations, and training are likely to promote equal opportunities for women and youth and men to enhance their resilience to climatic shocks. Inclusive gender participation in training, gender-balanced access and ownership of land through an inclusive land tenure system and enhanced ownership of digital technology by men, youth and women can eliminate existing gender biases and consequently promote bean production.

This study did not disaggregate youth into young men and women to facilitate understanding of the gaps to improve young men and women farmers' ability to access and use climate smart agriculture technologies and practices. This is a crucial limitation that should be the focus of future research to understand gender differences in access and use of climate smart technologies and the solutions young men and women use to adapt to climate change in Dedza district in Malawi.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the government institution does not need an ethics approval to carry out any research studies. The patients/participants provided their written informed consent to participate in this study.

Author contributions

EN and HK: Conceptualization. HK, LC, and VN: Data curation. LC, VN, VC, and AM: Formal analysis. VC and AM: Investigation. VN and EN: Writing—original draft. EN, HK, VN, and LC: Writing—review and editing. All authors contributed to the article and approved the submitted version.

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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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