TYPE Original Research
PUBLISHED 03 May 2023
DOI 10.3389/fsufs.2023.1040977

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OPEN ACCESS

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RECEIVED 09 September 2022
ACCEPTED 11 April 2023
PUBLISHED 03 May 2023

CITATION
Nchanji E, Nduwarugira E, Ndabashinze B, Bararyenya A, Hakizimana MB, Nyamolo V and Lutomia C (2023) Gender norms and differences in access and use of climate-smart agricultural technology in Burundi. *Front. Sustain. Food Syst.* 7:1040977. doi: 10.3389/fsufs.2023.1040977

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Gender norms and differences in access and use of climate-smart agricultural technology in Burundi

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The adoption and use of climate-smart agricultural practices are critical for improving the productivity and sustainability of smallholder farming systems. However, the gendered dimensions of access to and use of climate-smart agriculture in common bean (*Phaseolus vulgaris* L.) production remain unexplored among smallholder farmers in Burundi. A mixed methods research design was employed to investigate gender dynamics in common bean production among smallholder common bean farmers in the communes of Kirundo, Bwambarangwe, and Muyinga in Burundi. In addition, how the adoption and use of climate-smart agricultural practices differed by gender in Burundi. A multivariate probit model was employed to evaluate how improved bean seed, pesticide use, irrigation, conservation agriculture and other factors contribute to reducing gender gaps and influencing access to and uptake of climate-smart agriculture. The results revealed existing gender gaps and differences in access to and use of climate-smart agriculture practices, with women being the most vulnerable. Disproportionate experiences of production challenges emerged as critical obstacles to gender equality in bean production. Drought affected women and young farmers more severely than men. Joint decision-making, access to information, and collective action in groups reduced gender gaps in bean production and gender differences in access to and use of climate-smart technologies.

KEYWORDS

climate-smart agriculture, gender, adaption, climate change, decision making

1. Introduction

Agriculture is an important driver of growth and poverty reduction in Sub-Saharan Africa (OECD/FAO, 2016). The sector is dominant in most countries in terms of employment, and its share in GDP formation remains significantly high (Tomšík et al., 2015; Sakho-Jimbira and Hathie, 2020). However, despite its contribution to the economies in the region, agricultural production in Sub-Saharan Africa remains relatively low compared to the rest of the world (Bjornlund et al., 2020). The low production levels are attributed to factors inherent to Africa and its people. In particular, gender norms and climate change are key contributors to the region's low agricultural production (Bjornlund et al., 2020).

Gender norms in Sub-Saharan Africa vary from one community to another. Nonetheless, there are some common similarities. For example, women have limited control over family farms, play a limited role in decision-making, perform household chores, and are restricted from venturing into new activities without the approval of their spouses. These gender norms determine socially acceptable behavior for men and women and, as a result, shape women's empowerment opportunities (Jayachandran, 2021; Bullough et al., 2022). These informal, unwritten social rules influence the gender gaps between men, women, and gender-diverse people because they determine key opportunities for women's empowerment in agriculture.

Agricultural production in Sub-Saharan Africa is also impacted by climate change, and the effects on smallholder farmers are worsened by the pre-existing vulnerabilities. Climate change is a global phenomenon that poses a wide range of challenges, especially on smallholder production systems in the developing regions of the world (Gomez-Zavaglia et al., 2020). As a result, consequences of climate change such as drought and erratic and irregular rainfall patterns exacerbate food insecurity and deny many households much needed revenue. Despite key interventions being implemented in most parts of SSA, climate change continues to pose significant challenges that could destabilize local markets, and heighten agricultural risks for smallholder farmers, particularly the women (Chilunjika and Gumede, 2021; Baptista et al., 2022).

In Burundi, the interaction between climatic shocks and gender norms slows down economic growth and development, in part because of the limited women's participation in key areas that determine agricultural production in the country (Warinda et al., 2020; Hillenbrand et al., 2022). The women, who are often a crucial resource in agriculture and the rural economy, are frequently disadvantaged by gender norms that deny them critical opportunities of empowerment such as decision-making, land ownership, and control over personal decisions. Moreover, women are expected to take care of household chores and are therefore unable to participate fully in agriculture because of time constraints. Given the crucial role of women in agriculture and the rural economy, their disadvantage due to gender norms is particularly concerning in the context of rain-fed agriculture in Burundi, which is highly vulnerable to climate change impacts.

The majority of farmers in Burundi practice rain-fed agriculture which is extremely vulnerable to climate change (Berckmoes and White, 2016; Muchiri and Nzisabira, 2020). Irregular rainfall patterns and increased cases of droughts leads to a decrease in crop production, subsequently impacting the livelihood of the majority of farmers. In the literature, smallholder farmers are often the most affected in the region by this scenario due to a wide range of reasons (Warinda et al., 2020; Hillenbrand et al., 2022). First, the impact of climate change is associated with prevalence of pests and diseases which cause a decrease in crop production (SkendŽić et al., 2021). As a result, farmers incur more losses, leading to increased food insecurity due to the decline in crop production.

Climate change has exposed farmers in Burundi, especially women to potential threats of crop failure. Severe challenges with food security also exposes women farmers to devastating economic challenges (Campbell et al., 2014; Mangheni et al., 2019; Azadi et al., 2021). The situation is worsened because of increased cases of changing weather patterns, erratic rains, and droughts (Campbell et al., 2014). As a result, agricultural production has been hampered, necessitating the need for interventions to address the problem and uplift smallholder women common bean farmers in Burundi.

Second, the majority of the farmers are not wellconversant with emerging climate-smart technologies and therefore suffer from prolonged drought, irregular rainfall, and rising temperatures, which affect agricultural output and consequently livelihoods of households that depend on rain-fed agriculture as the primary source of income (Arbuckle et al., 2015; Kalele et al., 2021). While challenges associated with climate change affect nearly all farmers, women farmers in Burundi are more vulnerable to climate shocks due to pre-existing conditions and gender norms that hinder their agricultural production efforts (Maja and Ayano, 2021; Theodory, 2021). For example, women farmers in Burundi face low economic endowment, which limits their ability to invest in farming inputs and technologies that could improve their yields (Maja and Ayano, 2021). Women also face challenges with land rights, which restrict their access to land and reduce their ability to produce food.

Additionally, women have inadequate access to information and resources, including extension services, market information, and financial services (Maja and Ayano, 2021; Theodory, 2021). These socio-economic challenges are unique to specific regions, exacerbating the difficulties faced by women farmers. Addressing these pre-existing challenges is crucial to improving the resilience of women farmers in Burundi and reducing the negative impacts of climate change on their livelihoods. In the literature, the roles of the majority of women in Burundi, are limited to domestic chores while the men participate in commercial activities, resulting in unequal financial endowment between men and women. This scenario leads unequal access to education, economic empowerment, and wider gender gaps (Katungi et al., 2020).

Nonetheless, women constitute a significant labor force in agriculture in Burundi, making them major players in agricultural production in the region despite facing a myriad of challenges such as low access to markets, weak institutional policy, low technology adoption, inadequate government support, and poverty, which are among the most common challenges across SSA (Mizik, 2021; Theodory, 2021; Bedeke, 2022). Due to these pre-existing vulnerabilities, women farmers are often unable to adjust and respond effectively to the impacts of climate change and weather variability, which in turn leads to poor crop production (Bunce et al., 2010; Bedeke, 2022; Murken and Gornott, 2022). Consequently, food security becomes a challenge, causing most women to rely on government support, which often does not address all the farmers' needs.

Climatic shocks and gender norms have created unfavorable economic environment for small holder farmers in Burundi, and the most affected are smallholder women farmers (Batungwanayo et al., 2023). In response to the prevailing challenges posed by climate change in the country various interventions have been introduced to address the situation, especially among bean farmers. However, there is limited literature on the success of these interventions in helping close existing gender gaps in bean production. Disaggregating the bean production challenges by gender to better understand the plight of smallholder bean farmers in Burundi. This study explores gendered differences in access and use of climate smart agriculture among bean farmers in Burundi to understand how climate smart agricultural interventions are transforming gender norms and practices, building sustainable food systems that support women as equal partners in agriculture.

2. Materials and methods

2.1. Study area

The study was conducted in the communes of Kirundo and Bwambarangwe in Kirundo province (1,703.34 km^2) and in the commune of Muyinga in Muyinga province (1,836.26 km^2) (Figure 1). The commune of Muyinga has an area of 379.94 km^2, accounting for 20.6% of the area of Muyinga province, while the communes of Kirundo and Bwambarangwe have an area of 207.29 km^2 and 193 km^2 respectively. According to ISTEEBU (2019), the population of Muyinga province is estimated to be 945,771 people with 460,640 males and 485,131 females while the population of Kirundo province is estimated to be 939,560 people, comprising 454,321 males and 485,239 females. These two provinces were chosen for the study because common bean cultivation is widely practiced. Moreover, various climate smart interventions, including climate information services, soil and water conservation, and early warning system, have also been introduced in these two regions. However, it is not clear whether the gender gaps have been closed or how these interventions are helping transform gender norms to close the gender gap in agricultural production. Therefore, undertaking a study in these two provinces helped understand the role climate-smart technology in transforming gender norms and promoting gender equality in agricultural production in Burundi.

2.2. Sampling procedure and sample determination

A survey was conducted in two provinces, Kirundo and Muyinga. In Kirundo province two communes were chosen: Kirundo and Bwambarangwe, while in Muyinga province only the commune of Muyinga was selected. The choice to work in only two provinces and three communes was made due to budget constraints, while the choice of collines within the communes was motivated by the presence or absence of a bean seed producer, who is a partner to ISABU (Institut des Sciences Agronomiques du Burundi). In total, four collines were studied, namely Rambo in Kirundo commune, Bugorora in Bwambarangwe commune, and Rugari and Bwica in Muyinga commune.

The sample size was calculated using the following formula.

$$n = \frac{pqZ2}{E2},$$

where n is the sample size to be determined. Z is the confidence level with an alpha equal to 0.05. The p is the population proportion in the region that is identified to possess the characteristics of interest for this study. $Q = 1\text{-}p$, while the E is the precision error. The actual population of the bean farmers in the three communes was unknown and so the p value was set to 0.05. Therefore, given that $q = 0.05$, error set to 0.05 and Z = 1.96, the sample determined from this formula was 384.

The study employed a combination of purposive sampling to select participants with specific characteristics (common bean farmers) and random sampling to ensure representativeness of the larger population of common bean farmers in Burundi. This combination of sampling techniques helped achieve a balance between selecting participants with relevant characteristics and ensuring that the study's findings can be generalized to the larger population. A list of farmers provided by local extension officer in the different collines formed the sampling frame from which survey participants were randomly selected. The sampling frame was coded in Excel, where the farmers were randomly selected using the RAND function. The application of this procedure resulted in a sample size of 170 respondents, which is ∼42 households per colline for the four targeted collines in the study.

2.3. Data collection

The study used a quantitative research design to collect data from common bean farmers across the four collines. All stakeholders jointly developed and piloted the tool to ensure internal consistency and validity before administering it to the selected farmers. The stakeholders involved in the study, included farmers, researchers, and extension workers who provided input in the development of the questionnaire. They were consulted during the design process to ensure that the questions were relevant and could capture the needed information accurately. The questionnaire was developed based on a conceptual framework that included factors influencing common bean production and adoption of climate-smart interventions. The framework included variables such as household characteristics, access to information and resources, production practices, and decision-making.

A semi-structured questionnaire that was designed based on review of literature and consultation with experts was used to collect quantitative data. The data was collected through face-to-face interviews with selected farmers. The questionnaire gathered data on household socio-demographic details, including age, sex, education, household headship, occupation, and climate-smart interventions adopted by farmers, such as irrigation, use of improved seed, pesticides use, and conservation agriculture (CA). The survey tool also collected information on land ownership, access, and allocation to bean production across seasons, as well as decision-making about bean production. Data on seed and bean varieties planted by farmers and bean production practices were also collected. The questionnaire also collected data on production constraints and farmers' access to information about bean production, technology, and marketing. The study instrument was programmed in ODK and administered to farmers by trained enumerators from ISABU. The data collection process involved.

The enumerators underwent a 2-day training that covered the study's objectives, questionnaire administration, and ethical considerations in data collection. The training also included a role-play session to help the enumerators practice administering the questionnaire and handling any issues that might arise during data collection. One of the main challenges encountered during data collection was the language barrier between the enumerators and some farmers. The study team addressed this challenge by hiring local assistants who could speak the local language to assist in translation during the interviews.

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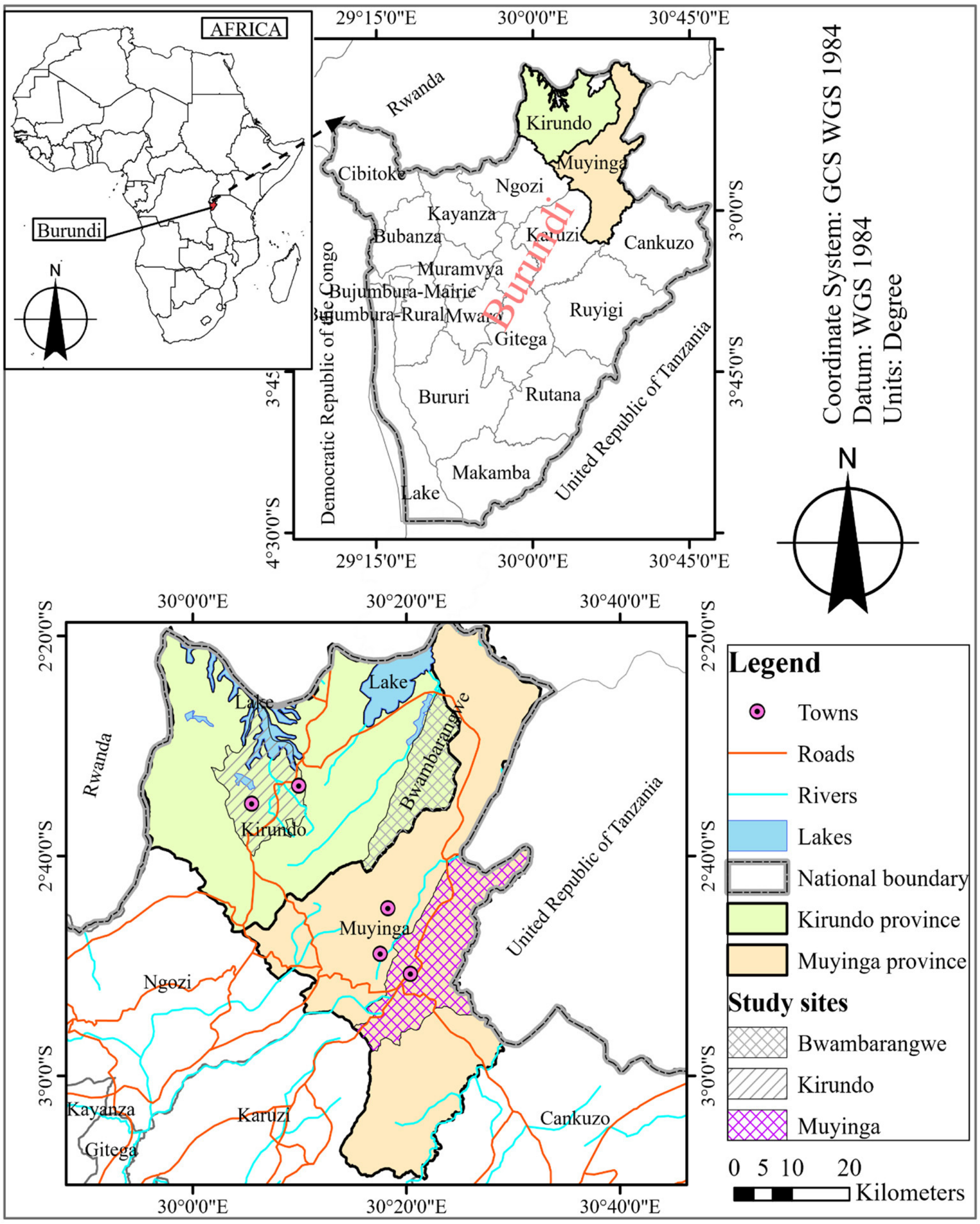

FIGURE 1
Map of the study area.

2.4. Data analysis

2.4.1. Descriptive method

The frequencies and percentages of farmers' responses were obtained through cross-tabulation of categorical variables. Means and standard deviations were also used to describe numeric continuous variables in the data set. Additionally, Analysis of Variance (ANOVA) and chi-square test of independence were consequently performed to test for existence of systematic differences in the distribution of continuous and categorical variables, respectively.

2.4.2. Econometric analysis

A multivariate probit model was used to estimate the role of institutional, farm, and sociodemographic factors in influencing access to and uptake of climate smart agriculture by common bean farmers in Burundi. A multivariate probit model was preferred in this case because of because of the need to run simultaneous estimation of regression equations which included improved bean seed, conservation agriculture, irrigation pesticide use. Simultaneous estimation of the four regression equations was critical to allow for comprehensive exploitation of the interrelationships that exist between the climate smart practices/technologies based on the assumption that common bean

TABLE 1 Sociodemographic characteristics of respondents by gender.

Variable	Total ($N = 170$)	Youths ($n = 84$)	Women ($n = 33$)	Men ($n = 53$)	p-value
Gender of respondent (%)		49.41	19.41	31.18	
Age of respondent (years)	38.48	29.00	47.03	48.17	0.000
Relation of respondent to HHH (%)	62.35	48.81	36.36	100	0.000
Education level respondent (%)					
No formal education	15.88	8.33	30.3	18.87	0.003
Primary	54.12	50	54.55	60.38	
Secondary or higher	30	41.67	15.15	20.75	
Farming as the main occupation (%)	90.59	90.48	100	84.91	0.050
Marital status—Married (%)	90.59	95.24	66.67	98.11	0.000
Household type (%)					
Dual type	83.53	86.9	51.52	98.11	0.000
Woman only	1.18	1.19	3.03	0	
Man only	6.47	2.38	27.27	0	
Woman with absentee husband	8.82	9.52	18.18	1.89	

farmers could adopt the CSA practices/technologies as a bundle and not as isolated practices.

The equation for the multivariate probit model for use of climate smart technologies is as follows:

$$y^*_m = \beta'_m X_m + \varepsilon_m, m = 1, \ldots, M$$
$$y_m = 1 \text{if} y^*_m > 0 \text{ and } 0 \text{ otherwise}$$

ε_m, m = 1, ..., M are the error terms that are distributed as multivariate normal. Each of them has a mean of zero, and variance-covariance matrix V, where the V has values of 1 on the leading diagonal and correlation pjk=pkj as off-diagonal elements. In this case the M refers to the number of climate smart technologies observed (in this case they are four equations). The Xm is the p explanatory variables which consists of sociodemographic variable (age, gender, education, marital status, occupation, and relation to household head), farm characteristics (acres under beans, land accessed, and bean manager), institutional support (group membership and distance to agro dealer), technology (mobile phone ownership and social media membership). Beta β are the parameters that are estimated in the model, and E is the distribution term. The latent Y^*m denotes decision to use climate smart agriculture which captures unobservable preferences.

3. Results and discussions

3.1. Descriptive results

Table 1 presents the socio-demographic characteristics of the farmers who participated in the study disaggregated by gender: men, women, and youths. According to the Charter (2006), youths are individuals between 18 and 35 years old and include both male and female. Women refer to adult females above the age of 35, while men refer to adult males above the age of 35. Youths were not disaggregated into male and female categories because of the small sample size. Disaggregating the data would have made it impossible to conduct any regression analysis. ANOVA tests results for continuous variables are presented in the probability value (p-value) column for the age of the respondents. For the categorical variables (gender, relationship to household head, education, occupation, marital status, and household type) the chi-square tests are presented.

The demographic results show that young farmers were the majority (49%), compared to men (31%) and women (19%). The average age of farmers differed significantly by gender ($p < 0.000$)—young farmers 29 years, women 47 years and men 48 years respectively. There were statistically significant gender differences in relation to household head. All the men were household head, while only 36% of the women and 48% of the young farmers indicated being household heads. The results are consistent with the prevailing gender norms in SSA, where more men are household heads. And so, unlike women, male headship captures socio-economic conditions for most men. Women only assume household headship on rare occasions, such as upon the demise of their spouses (Dungumaro, 2008). These results further confirm that the culture of common bean (*Phaseolus vulgaris* L.) farmers in Burundi is deeply rooted in strong patriarchal culture (Kwizera and Base, 2017). Patriarchal cultures are known to dictate gender roles and consequently place restrictions on women's decision-making abilities, workforce participation, and social mobility (Tamale, 2008; Adisa et al., 2019).

When most households in society follow these norms, households headed by women are viewed as outliers and may be side-lined in socio-economic activities. This could, in turn, adversely affect the women's participation in agriculture as well as their overall wellbeing. These societal norms also add obstacles to women's participation in agriculture. For women headed households, this means added time constraints because of the

TABLE 2 Farm and bean farming characteristics.

Variable	Total (*N* = 170)	Youths (*n* = 84)	Women (*n* = 33)	Men (*n* = 53)	*p*-value
Average acres of land owned	1.855272	1.124033	3.98351	1.689087	0.000
Average acres of land accessed	1.187361	1.031528	1.77416	1.068975	0.001
Who owns land (%)					
Man	34.12	35.71	24.24	37.74	0.000
Woman	11.76	7.14	39.39	1.89	
Both man and woman	54.12	57.14	36.36	60.38	0.000
Bean crop manager (%)					0.000
Female spouse/ wife	44.71	42.86	60.61	37.74	
Male Spouse/ husband	22.94	27.38	15.15	20.75	
Both man and woman head	32.35	29.76	24.24	41.51	
Food	58.82	57.14	51.52	66.04	0.516
Sale	6.47	8.33	3.03	5.66	
Both Food and Sales	34.71	34.52	45.45	28.3	
Decision maker on purpose to grow bean (%)					0.000
Man	21.76	25	21.21	16.98	
Woman	13.53	9.52	36.36	5.66	
Both man and woman	64.71	65.48	42.42	77.36	

increased burden of working on the farms, maintaining the household, and caring for dependants (Sachs, 2018). Moreover, the result also revealed that education statistically significantly differed by gender ($p < 0.00$). There were more women (30%) without formal education, compared to men at 18% and young farmers at 8%. These findings can be attributed to the high levels of poverty in most parts of the country which is detrimental to the education of the girls in Burundi (Berckmoes and White, 2016; Muchiri and Nzisabira, 2020; Bedeke, 2022). The results further demonstrate that agriculture is the main occupation for majority of bean farmers in Burundi and attracts all people of working age. 90% of the farmers indicating that agriculture was their primary occupation, with all the women stating that agriculture was their main occupation while men were 85% and the youth 90%.

The association between marital status and gender was analyzed using a chi-square test, which revealed a statistically significant difference ($p < 0.000$). The results showed that the distribution of marital status significantly differed by gender. Specifically, a higher proportion of men (98%) and youths (95%) were married compared to women (67%). The results are consistent with available literature which asserts that women are. Women in sub-Saharan Africa are more likely to be widowed, separated, or divorced than men because of gender inequality, cultural norms and practices, and poverty (World Bank, 2017; Moodley et al., 2019; Wanjala, 2021). In most settings in SSA, especially in patriarchal cultures, widows and divorcees may be shunned, dispossessed, and even ostracized (Anyanwu, 2014; Ortega-Díaz, 2020). As a result, divorcees are likely to suffer other forms of disadvantage because of the social norms in the society. The percentage of dual household types was statistically significantly ($p < 0.000$) higher than the percentages of women-only households (1%), men-only households (6%) and women with absentee husbands (9%). The findings in the in marital status and household type of bean farmers reveal a possible difference in the gender vulnerabilities to climate change and adaptation.

Table 2 presents farm characteristic disaggregated by gender. The *p*-values are presented for land accessed and land under beans. For categorical variables, chi-square tests are presented. On average, women reported that their households owned 4 acres of land. However, more men (38%) than women (24%) and youth (36%) owned land. This finding confirms common narrative that outline some of the existing gender disparities in land ownership and access in Sub-Saharan Africa brought about by prevailing gender norms. These disparities explain the cultural biases that tend to disparage the youth and women while favoring men.

Most land holdings in Burundi are acquired under customary law. Whereas the nation's statutory law upholds gender equality in land ownership, customary law in Burundi discriminates against the women (Saiget, 2016; Tchatchoua-Djomo, 2018). Customary law devolves land to male members of the paternal line under intestate succession, while women can have tenure after a will is written documenting their ownership of particular property, such a situation is rare (Saiget, 2016; Tchatchoua-Djomo et al., 2020). Moreover, there is no law on inheritance.

3.2. Bean production constraints

Table 3 presents production constraints as reported by bean farmers. Climate change is a major challenge posing significant

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

Constraints	Total	Youth	Women	Men	*p*-value
Production constraint (%)					0.000
Drought	25.96	24.84	31.67	24.24	
Floods	16.03	15.69	16.67	16.16	
Diseases& pests	14.1	11.76	10	20.2	
Access to fertilizers and agro-chemicals	8.65	9.15	3.33	11.11	
Other	8.33	7.19	15	6.06	
Poor soils	5.45	5.88	5	5.05	
Access to quality seed	3.53	5.88		2.02	
Access to knowledge and information	1.6	0.65	1.67	3.03	
Access to production finance	0.96	1.31		1.01	
Vermin	0.64	0.65		1.01	
Theft	0.64	0.65	1.67		
Labor constraints	0.64			2.02	
Increase the input prices				1.01	
None	13.14	16.34	15	7.07	
Post-harvest constraints (%)					**0.000**
Storage pests	19.21	17.7	15.91	23.61	
Excessive rain during post-harvest handling	7.42	7.96	11.36	4.17	
Lack of knowledge on appropriate storage practices	5.24	3.54	4.55	8.33	
Lack/access to PHH facilities/equipment	4.37	5.31	2.27	4.17	
Other	4.37	3.54	9.09	2.78	
Storage space	3.49	4.42	2.27	2.78	
Labor constraints	1.31	0.88	2.27	1.39	
None	54.59	56.64	52.27	52.78	
Market constraints (%)					**0.000**
Fluctuating prices	24.79	23.68	12.82	32.1	
Other	5.13	6.14	7.69	2.47	
Poor means of transport	2.99	3.51	2.56	2.47	
Distant market	2.99	6.14			
Unstandardized weighing scale	2.14	2.63		2.47	
Bad debt	0.85	1.75			
Bad roads	0.43			1.23	
Illiteracy (can't read and write)	0.43	0.88			
Delayed payment	0.43			1.23	
None	59.83	55.26	76.92	58.02	

threats to agricultural productions. Its impact is widely felt in various sectors of the food value chain. Some of the prevalent production challenges identified by farmers in this study comprised droughts, flood, pests and diseases, and access to fertilizers and agro chemicals. The production constraints differed significantly by gender ($p < 0.000$). 25% of the youth, 24% of the men and 31% of the women indicated that drought was a major challenge which majorly affected their bean production. The results show that women were the most affected by drought. Additionally, 15% of the youth, 17% of the women and 16% of the men also indicated that flood was a major problem.

More men (20%) than youth (11%) and women (10%) mentioned that pests and diseases hindered bean production. The results show that climate change has disrupted the normal climatic conditions of the regions. Kirundo, Muyinga, and Bwambarangwe are known to exhibit varying degrees of precipitation patterns. The annual average rainfall for Kirundo and Bwambarangwe stands at ∼1,200 mm, while that of Muyinga is around 900 mm. The wettest months for these regions are typically observed between February to May, while the driest months tend to fall between June to August (Minani et al., 2013). Moreover, the climate in these areas is humid. However, with the impact of climate change, there have been significant changes in the ecological conditions in the region.

The results on post-harvest constraints faced by farmers significantly differed by gender (p 0.000). Post-harvest challenges, including storage pests, excessive rain during post-harvest, and lack of knowledge on appropriate storage practice, were identified as the most common challenges. The results significantly differed by gender with more men 24% than young farmers (18%) and women (16%) stating that storage pests were a major challenge. Among the major market constraints experienced by farmers include fluctuating market prices, poor means of transport, and distance to markets.

Table 4 presents changes made by farmers in response to the consequence of climate change that affected their crop production. Majority of the farmers affected by production challenges stated that they used conservation agriculture, manure, and pesticides as the most common interventions to address bean production challenges. Other responses to bean production challenges were conservation agriculture (minimum tillage) and manure. Farmers also used fertilizers, practiced early planting, changed bean varieties planted, and implemented crop diversification in response to production constraints.

Regarding decision making on changes to protect bean production by gender, more youths 65% and men 77% indicated that bean production was handled jointly between the man and the woman (Figure 2). By contrast, more women than men and youths combined stated that decision making on changes to protect bean production was made by women. The high percentage of joint decision-making, as demonstrated in the results, can be attributed to the role of agriculture as a major source of income for most smallholder farmers in Burundi.

To address the impact of climate change on bean production, farmers implemented different climate smart practices. The top three practices that farmers implemented were fertilizer use (95%), improved seed (77%), and conservation agriculture (Table 5). Farmers also used pesticides (50%) and irrigation (41%) using water mainly obtained from local streams. Except for pesticide use, there were no significant gender differences in the practices implemented by the farmers.

3.3. Institutional and support services

Institutional, technical, and social support services received by farmers are presented in Table 6. The result showed that there

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

Change made	Total	Youth	Women	Men
Soil conservation	24.79	27.66	38.46	14.58
Manure	18.18	21.28	11.54	18.75
Pesticide	16.53	12.77	19.23	18.75
Timely planting	10.74	12.77	3.85	12.5
Change seed	10.74	6.38	3.85	18.75
Fertilizer	7.44	6.38	11.54	6.25
Agroforestry	4.96	6.38	3.85	4.17
Crop diversification	2.48	2.13	3.85	2.08
Crop rotation	2.48	2.13		4.17
Irrigation	1.65	2.13	3.85	

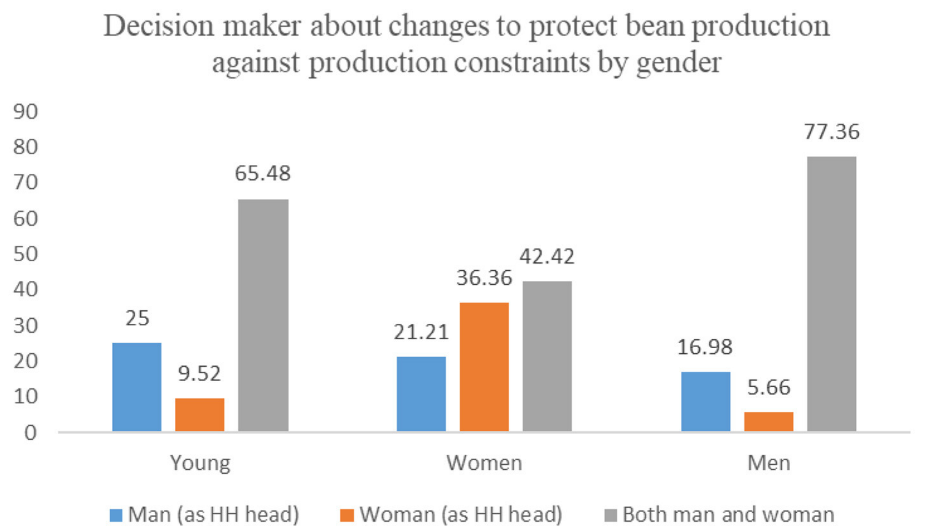

FIGURE 2
Decision maker about changes to protect bean production against production constraints by gender.

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

Practice	Total	Youths	Women	Men	*p*-value
Conservation agriculture	60	60.71	63.64	56.6	0.797
Pesticide use (biopesticides)	50	40.48	48.48	66.04	0.014
Fertilizer use (organic)	94.71	94.05	93.94	96.23	0.819
Use of improved seed	77.06	75	84.85	75.47	0.494
Irrigation	41.18	39.29	39.39	45.28	0.765

TABLE 6 Institutional, technical, and social support received by farmers.

Variable	Total	Youth	Women	Men	*p*-value
Average distance to agro-dealer (km)	3.08	3.46	3.69	2.12	0.06
Percent owning mobile phone	118	62	18	38	0.115
Percent receiving information on mobile phone	82	40	16	26	0.986
Presence on agriculture social media platform (%)	21	8	5	8	0.541
Percent received bean production information					0.487
Not at all	38.82	45.24	36.36	30.19	
Sometimes	53.53	47.62	57.58	60.38	
Always	7.65	7.14	6.06	9.43	
Percent received agricultural training	100	46	21	33	0.202
Membership to local groups/associations (%)	100	49	20	31	0.232

was no significant gender difference in distance to the nearest agro-dealers. The average distance covered by the farmers to reach the nearest agro-dealer was 3.1 kilometers. The result also showed that young farmers had a higher access information via their phones than men and women. Additionally, more youth 46% than men (33%) and women (21%) received training on bean production. The number of farmers on social media platforms was relatively low—youth (8%), women (5%) and men (8%). Nonetheless, more youths (79%) indicated being members of local farmer groups.

3.4. Econometrics results

The multivariate probit coefficient estimates of factors that influenced bean farmers use of climate smart agriculture practices are presented in Table 7. The Wald chi-square test for overall model fit is significant at 1%. This test indicates that the explanatory variables included in the model were jointly significantly different from zero, suggesting that at least one of them had significant influence on the use of climate-smart agriculture. Second, the likelihood ratio test was significant, meaning that the multivariate probit model was appropriate in estimating the influence of socio-economic and institutional factors on use of climate smart agriculture. Five out of six correlations coefficients were positive, implying that the various climate-smart practices are complementary practices. The correlation coefficient between conservation agriculture and irrigation was negative, suggesting that farmers tended to substitute the two practices.

The results showed that men and young farmers were less likely to use certified seeds than women farmers. In most countries in Sub Saharan Africa, common bean is considered a women's crop, especially among smallholder farmers because of the number of women involved in its production (Nakazi et al., 2017). As such, most common bean interventions in the past have targeted women farmers. Therefore, it is probable that women are more informed on various climate smart intervention such as the use of improved seeds that can be used to improve bean production in Burundi compared to men and young farmers. In this regard, therefore, certified seed stands out as a key intervention that positively contributes to closing gender gaps in agriculture.

A study by Ochieng (2014) explored women farmers' participation in farm management in Burundi, Rwanda and Democratic Republic of Congo and found that farms managed by women were less intensive because of women's inability to acquire technological inputs such as fertilizer and improved seed. As a result of these findings most interventions targeted women bean farmers. Furthermore, available reviews on gender in seed systems hint toward two major factors that promote women's access to seed—their roles as seed users and as seed producers (et al., 2021). Thus, gender responsive seed systems have a significant benefit to women farmers because it recognizes their interests and preferences, consequently helping women overcome barriers to seed access (Mausch et al., 2021).

Acreage under common beans had a significant positive influence on farmers use of certified seeds and pesticides. An increase in land area under beans by one acre increased the likelihood of farmers using of certified seeds and pesticides by 0.1 and 0.2 respectively. In Burundi, bean crop is grown for food and commercial purposes (Table 2). As such, based on economies of scale, farmers with large acres of land under beans earn more when

TABLE 7 Estimates of multivariate probit coefficients of determinants of farmer's use of climate-smart technologies and practices.

Variable	Certified seed Coef.	Certified seed Std. Err.	Pesticide Coef.	Pesticide Std. Err.	Irrigation Coef.	Irrigation Std. Err.	CA Coef.	CA Std. Err.
Youth	−0.794*	0.435	−0.333	0.405	−0.031	0.364	0.265	0.403
Men	−0.751*	0.407	0.077	0.400	0.440	0.365	0.002	0.375
Age	−0.011	0.015	0.005	0.014	−0.019	0.014	0.017	0.015
Marital	0.206	0.465	0.333	0.469	0.025	0.460	−0.343	0.379
Relationship (head)	0.372	0.288	0.557**	0.275	0.047	0.264	−0.179	0.267
Primary education level	−0.051	0.308	−0.233	0.325	−0.010	0.302	−0.003	0.296
Secondary and higher education	0.301	0.408	−0.106	0.407	−0.270	0.371	0.186	0.366
Occupation	−0.151	0.510	0.136	0.410	0.490	0.358	0.449	0.387
Acres under bean production	0.100*	0.053	0.203*	0.109	0.008	0.029	0.050	0.042
Land owner (man)	0.148	0.342	0.2089	0.363	−0.639*	0.332	0.587*	0.330
Managers (joint)	−0.007	0.251	0.449*	0.237	−0.117	0.227	−0.772***	0.223
Distance to agro-dealer	−0.011	0.031	0.011	0.028	−0.040	0.027	0.014	0.030
Ownership of mobile phone	0.134	0.272	0.289	0.273	0.109	0.266	−0.211	0.270
Groups membership	−0.089	0.391	1.484***	0.440	0.128	0.398	−0.493	0.445
Constant	1.298	1.183	−2.767	1.114	0.438	0.993	−0.312	1.059
Wald chi2(56)	106.72***							
Likelihood ratio test	22.548***							
rho21	0.156							
rho31	0.146							
rho41	0.372							
rho32	0.146							
rho42	0.342							
rho43	−0.238							

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

they use pesticides and improved seeds compared to those with less acres of land. Majority of small holder farmers thus increase their household earnings through use of certified seeds and pesticides, especially when they have access to more land (Okonya et al., 2019; Megerle and Niragira, 2020). For instance (Langyintuo, 2020), argues enhanced availability and accessibility of seed and other inputs through formal and informal sources boosts smallholder farmers' revenue, making economic sense to expand land area under crop production.

Whereas land ownership had a significant negative influence on the probability of farmers practicing irrigation, it positively and significantly influenced farmers' use of conservation agriculture. The results reveal that it that land ownership plays a crucial role in influencing farmers' decisions to practice conservation agriculture and irrigation as climate-smart practices. The positive correlation between land ownership and conservation agriculture indicates that land ownership enhances adoption of conservation practices, while farmers who do not own land are more inclined to using irrigation. Pertaining to conservation agriculture, possessing land can provide farmers, notably women, with a feeling of stability, encouraging them to invest in long-term conservation agriculture initiatives. In contrast, land lease arrangements may motivate non-landowning farmers, predominantly women, to concentrate on irrigation to optimize crop production and revenue. Earlier studies have also demonstrated mixed outcomes regarding the relationship between land ownership and adoption of climate-smart practices. For instance, some studies have identified a positive relationship between land tenure security and climate smart practices (Liversage, 2021), whereas others have reported no significant association or even negative correlations (Nkomoki et al., 2018).

Joint bean crop management had a positive and negative significant influence on the use of pesticides and conservation agriculture, respectively. Because of joint management the man and the woman can observe the impact of pests and diseases and therefore jointly agree on the solution. In Table 3, pests and diseases was identified as the most prevalent bean production challenge and hence it could have influenced the joint decision of both man and woman on the use of pesticides as a climate-smart technology. Additionally, relationship to household head had a significant positive influence of farmers use of pesticides. The finding in Table 3 revealed that pests and diseases was a major obstacle to crop production which widens the gender gap between men and women. Therefore, use of pesticides could have a positive impact in the overall bean production per household, consequently leading to an increase in household income and reduction in gender gaps in bean production.

Membership to agricultural groups had a significant positive influence on farmers use of pesticides. The result is an indication of significant role of groups influencing farmers to practice climate-smart agriculture. For instance, farmers can get access to critical information on the use on climate-smart practices via groups. In a nutshell, farmer groups in the study area may have been important in enabling farmers to access pesticides or learn application of the chemicals. Examining the findings through gender lens shows that groups may have offered women farmers interaction and with knowledge sharing platforms. Furthermore, farmer groups may have played a significant role in boosting the social capital and capacity of farmers by supporting learning about climate-smart agriculture (Aidoo and Fromm, 2015).

4. Conclusion

The study focused on evaluating disparities among bean farmers in Burundi in relation to access and utilization of climate-smart agricultural technologies and practices, and the impact of these interventions on closing the gender gap in bean production. Adaptation to climate change among men, women, and young farmers was also examined.

Findings highlighted differences in land ownership and access based on gender. Men generally owned and accessed more land than women and young farmers. For women, lack of land ownership was a considerable barrier to bean production. However, the use of certified seeds promoted women's involvement in bean production and contributed to joint decision-making within households. Most bean farmers, regardless of gender, participated in joint decision-making on bean production. Furthermore, men and young farmers were less inclined to use certified seeds compared to women.

Although women and youth experienced more vulnerability to bean production constraints than men, responses to climatic shocks were similar across genders. Having access to more land increased the probability of using pesticides, with men using them more often than women and youth. Women demonstrated a preference for conservation agriculture over irrigation, likely due to limited land access and ownership affecting their ability to secure financial capital for irrigation activities.

Pests and diseases were the primary confronting bean farmers in Burundi. Joining agricultural groups proved to be significantly beneficial for smallholder farmers, providing access to essential bean production information and climate practices that improved crop yield. Membership in these groups also strengthened social capital and fostered learning in agricultural systems resilience. Disparities in mobile phone ownership and participation in social media based on gender impacted access to agricultural information. Men and young farmers were more likely to own phones and access information compared to women. Factors such as land under beans, joint decision-making, land ownership, and group membership enhanced the use of climate-smart agricultural technologies and practices, promoting positive climate change adaptation. Nonetheless, adoption and implementation of climate-smart agricultural technologies were limited by factors such as marital status and distance from an agro-dealer.

To increase farming resilience and close gender gaps through the promotion of climate-smart technologies and practices, it is crucial to address gender disparities in land access, digital technology, and land ownership, as well as to support women's literacy via higher education and agricultural extension. Establishing an inclusive land tenure system that removes biases in land systems is necessary to close gender gaps in agricultural production by raising land ownership among women and youth. Enhancing land tenure rights, security, and incorporating digital technologies for sharing climate information are vital for increasing awareness and adoption of climate-smart agriculture.

The study acknowledges the influence of various gendered differences on technology adoption, depending on factors such as family dynamics, local context, interventions, and education. Future research should concentrate on addressing these gendered differences to improve bean crop production in Sub-Saharan Africa. Moreover, future investigations should differentiate youth into young men and women to better understand gender gaps in bean production and access to climate-smart technologies.

5. Policy implications

First, the study highlights the need to address gender disparities in land access and ownership to promote the use of climate-smart technologies and practices among all smallholder farmers. Specifically, policy interventions that promote an inclusive land tenure system that eliminates biases in land systems and increases the amount of land owned by women and youth should be implemented. Second, the study emphasizes the importance education, particularly for women farmers, to enhance their awareness and adoption of climate-smart agriculture.

Third, the study underscores the importance of promoting membership in agricultural groups and improving social capital to enhance access to information on bean production and climate-smart technologies. Additionally, policy interventions that encourage the use of certified seeds, which have been shown to increase women's participation in bean production and joint decision-making, should be promoted. Fourth, the study highlights the need to address the prevalent challenges of pests and diseases affecting smallholder bean farmers. Furthermore, policy interventions that promote the use of conservation agriculture as an alternative to irrigation for smallholder women farmers who lack access to capital-intensive climate-smart practices should be implemented.

Finally, the study recommends that future research should focus on addressing the current gendered differences to enhance bean crop production in SSA. It also highlights the need for future research to explore and understand the gender gaps in bean production between young men, young women, men and women farmers, and access and use of climate-smart technologies.

Overall, the policy implications of this study are significant and should be considered by policymakers, development practitioners, and other stakeholders to promote gender equality in agricultural production, enhance the resilience dimension of farming, and close gender gaps in the use of climate-smart technologies and practices among smallholder farmers in Burundi and other similar contexts.

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 that does not need an IRB. The patients/participants provided their written informed consent to participate in this study.

Author contributions

ENc: conceptualization. BN, ENd, AB, and MH: data curation. CL and VN: formal analysis. AB and ENd: investigation. VN and ENd: writing-original draft. ENc, ENd, BN, AB, MH, VN, and CL: writing—review and editing. All authors contributed to the article and approved the submitted version.

Funding

Global Affairs Canada and the Swiss Agency for Development and Cooperation funded the research, and Bill and Melinda Gates Foundation funded the publication of this work under the Accelerated Varietal Improvement, and seed delivery of legumes and cereals in Africa (AVISA) Grant Number INV-009649/OPP1198373.

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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