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Gender-differentiated perception of climate-smart agricultural practices in contrasting landscapes of the Ethiopian highlands

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Abebe Nigussie
John W. Recha
Gebremedihin Ambaw
Maren Radeny
Abonesh Tesfaye
Wuletawu Abera
Lulseged Tamene
Dawit Solomon

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Technical Report

CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Abebe Nigussie
John W. Recha
Gebremedihin Ambaw
Maren Radeny
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Contact us
CCAFS Program Management Unit, Wageningen University & Research, Lumen building, Droevendaalsesteeg 3a, 6708 PB Wageningen, the Netherlands. Email: ccafs@cgiar.org

Abstract

Climate-smart agricultural (CSA) practices have been promoted as a prominent strategy to offset the adverse effect of climate change on food production and mitigate greenhouse gas emissions. Even though several studies have shown farmers` perception on CSA practices, gender-differentiated perception has hardly been studied. The objective of this study was therefore to investigate gender-disaggregated differences in terms of: (i) experience in climate change and its negative impacts, (ii) perception towards CSA practices, and (iii) motivation and constraining factors to uptake CSA. A total of 800 farmers were interviewed from two climate-smart landscapes – which vary in terms of practices, years of implementation and degree of gender-inclusion in decision making. CSA interventions increased yield and income by two-to-threefold. Food availability and diversity also increased owing to CSA practices. Farmers who adopted CSA practices were almost twice less likely to borrow or spend money for food and other goods. A higher number of CSA non-adopters sold their assets and/or changed food consumption pattern following climate-related shocks. The gender-disaggregated data showed variation in the perception of CSA practices between female and male headed households. This difference is mainly attributed to variation in access to resources, education, information on weather forecasts and participation in decision-making. Male farmers tended to have better knowledge on the benefits of CSA practices, and the difference was more pronounced at the landscape level where women participation in decision-making is limited. Female farmers showed low preference for CSA practices which requires labour (i.e., soil bunds and green manuring) and knowledge (i.e., crop diversification). The findings demonstrate the significance of gender equality in decision-making, access to climate information and agricultural extension services for rapid uptake of CSA practices, thereby curbing the negative effects of climate change on agricultural production in Ethiopia.

Keywords

Climate change; agriculture; gender, decision-making; climate-smart agriculture.

About the authors

Abebe Nigussie is an Assistant Professor of Soil Science at Jimma University, Ethiopia. Contact: abebe.nigussie@ju.edu.et

John W. Recha is a Climate-Smart Agriculture and Policy Scientist at the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). International Livestock Research Institute (ILRI) in Nairobi, Kenya. Contact: J.Recha@cgiar.org

Gebremedihin Ambaw is a Research Associate at the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). International Livestock Research Institute (ILRI) in Addis Ababa, Ethiopia. Contact: G.Ambaw@cgiar.org

Maren Radeny is a Science Officer of the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS) East Africa. Contact: M.Radeny@cgiar.org

Abonesh Tesfaye is a consultant for the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Contact: abonesh.tesfaye@gmail.com

Wuletaw Abera is a Scientist at the International Center for Tropical Agriculture (CIAT). Wuletaw.Abera@cgiar.org

Luelseged Tamene is a scientist at the International Center for Tropical Agriculture (CIAT) – Research Program on Water, Land and Ecosystem. Contact: LT.Desta@cgiar.org

Dawit Solomon is a scientist and East Africa program leader for the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Contact: D.Solomon@cgiar.org

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Contents

Acronyms

CCAFS	Climate Change, Agriculture and Food Security
CSA	Climate-smart agriculture
CSV	Climate-Smart landscapes (Village)
FAO	Food and Agriculture Organization
USD	United States Dollar

Introduction

Climate change results to significant losses of agricultural production and is threatening food security across the globe (Lesk et al. 2016). In the last decade, for instance, the agriculture sector shares about 25 % of climate-associated disasters, and subsequently lost around 25 billion USD (FAO, 2014). Frequency and intensity of extreme weather events, including droughts, heavy rainfall and high temperature are the main climate-related problems for agricultural production. The negative effect of climate change on food security is expected to be severe in developing countries – where agricultural production entirely depends on rainfall (Recha et al. 2017; Nigussie et al. 2015). In Sub-Saharan countries, for instance, yield of maize (*Zea mays*), sorghum (*Sorghum bicolor*), and millet (*Panicum miliaceum*) are expected to reduce by 5 %, 14.5 % and 9.6 %, respectively by the end of the 21st century owing to climate change (Knox et al. 2012). Climate models have predicted that extreme weather events are to become more persistent and more extensive in the future (Dai 2013; Trenberth et al. 2014). The global food demand is expected to be doubled by 2050 (Davies et al. 2009; Tilman et al. 2011), and yield should be increased annually at the rate of 2.4 % to meet the future food demand (Ray et al. 2013). It is therefore critical to develop technologies to curb the adverse impact of climate change on food production and to realize the sustainable development goals – which are aimed to eradicate poverty and hunger by 2030 (Taddese et al. 2021; Ambaw et al. 2020).

Climate-smart agriculture (CSA) practices have been promoted as a prominent strategy to improve farmers resilience to climate change and reduce greenhouse gases emissions (Mujeyi et al. 2021). Several studies have shown a positive impact of CSA practices on food production (i.e., availability and diversity), economic development and reduced poverty in developing countries – which are vulnerable to climate change (Ogada et al. 2019; Ouédraogo et al. 2019; Belay et al. 2017; Amare et al. 2012). For example, Taddese et al. (2021) reported that integration of different CSA practices increased crop yield 30–45 % and sequestered three to seven-fold soil carbon compared with conventional farming practices (i.e., without CSA). Similarly, both household food consumption score and household dietary diversity scores showed that farmers who adopt integrated CSA practices were 57 % and 25.44 % more food secure than the non-adopters (Belay et al. 2017). Adoption of CSA practices such as multiple stress-tolerant crops improved household income by 83 % (Ogada et al. 2019). Khatri-Chhetri et al. (2016) also revealed that CSA practices increased the net return of farmers in Indo-Gangetic plains by 93 – 210 USD ha^{-1} yr^{-1} in rice-wheat system. With this premises, the CGIAR Research Program on Climate Change Agriculture and Food Security (CCAFS) and partner organisations have tested and promoted CSA practices in diverse landscapes across different developing countries to respond to climate related risks. Specifically in Ethiopia, local communities in Doyogena (Southern Ethiopia) and Basona (Central Ethiopia) have implemented integrated CSA practices in highly degraded landscapes with the help of partners. The Inter Aide Ethiopia program spearheaded CSA activities in Doyogena and the Africa Research in Sustainable

Intensification for the Next Generation (Africa RISING) further supported the work in Doyogena and Basona. The Alliance of Bioversity International and CIAT, CGIAR Research Program on Water, Land and Ecosystems (WLE), and CCAFS partnered with the communities in capacity building, evidence generation and scaling in those sites in Ethiopia. Earlier studies have shown the positive impact of CSA practices on biophysical resources (Taddese et al. 2021; Ambaw et al. 2020) and farmers livelihood (Ogada et al. 2019), thereby suggesting the potential of CSA practices in optimizing agriculture productivity. Most of these studies however overlooked: (i) gender-disaggregated perceived effects of CSA interventions on farmers' livelihood (agricultural production, income, food security, food diversity); (ii) degree of gender participation in decision making regarding adoption and/or dis-adoption of CSA practices.

Objectives

The main objective is to undertake a comprehensive assessment on smallholder farmers` perception on the impacts of climate change and CSA practices on biophysical and socioeconomic status. The specific objectives include the following:

- To investigate gender-disaggregated experience in climate change and its negative impacts
- To investigate gender-disaggregated perception towards CSA practices
- To investigate gender-disaggregated motivation and constraints to the uptake of CSA practices.

This study was carried out based on farmers experience about the main climate shocks over the last 12 months.

Materials and methods

Description of the study sites

Two contrasting climate-smart landscapes (CSV), namely Doyogena and Basona, were included in the study. Two landscapes are compared in terms of climate change-related shocks, CSA practices and degree of farmers` participation during implementation of the CSA interventions. Table 1 illustrates the different CSA practices at the two sites. Basona CSV is located at central Ethiopia, Amhara region. The main farm activity is characterized by mixed cereal-livestock farming system. The Basona CSV is characterized by maximum and minimum temperatures of 20 °C and 6 °C respectively. The mean annual rainfall amount is ranged between 950-1100 mm. It is located geographically at an altitude of 1,980 and 3,000 m and latitude 10° 41′ 50′′ N and longitude 39° 47′ 03′′ E. Vertisols and Cambisols are the dominant soil types. About 13 % of land is under cultivation, 47 % under grazing, 9 % under forest, shrubs and bush lands and 31 % has other uses (Africa RISING, 2015). Most of the households are small-scale subsistence farmers with an average land size of less than one hectare. Seven CSA practices have been implemented at Basona CSV: Terraces (soil bunds): Terraces (soil bunds) with biological measures (*Phalaris aquatica* and *Chamaecytisus palmensis*), Trenches, Enclosures, Percolation pits, Check-dams (gabion check-dams and wood check-dams) and Gully rehabilitation.

Doyogena CSV is located at Kembata-Tembaro zone, South Ethiopia. The Doyogena CSV is located at an altitude of 2420 to 2740 m and latitude 7◦170 – 7◦190 N latitude and 37◦450 – 37◦470 E longitude. The mean annual rainfall ranges from 1,000 to 1,400 mm. The Basona CSV is characterized by maximum and minimum temperatures of 12 °C to 20 °C, respectively. The farm activity is characterized by Enset (*Ensete ventricosum*) based mixed cereal-livestock farming system. Most of the households are small-scale subsistence farmers with an average land size of less than 0.5 ha (Table 2). Wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), and faba bean (*Vicia faba*) are the main cereals and pulses grown in the area. In addition, vegetables such as potatoes (*Solanum tuberosum*), carrots (*Daucus carota*), and Ethiopian mustard (*Brassica carinata*) are grown commonly in the area. Eleven CSA practices were implemented at Doyogena CSV since 2011 including, Terraces with Desho grass (*Pennisetum pedicellatum*) a soil and water conservation measure; Controlled grazing; improved wheat seeds (high yielding, disease resistant & early maturing); improved bean seeds (high yielding); improved potato seeds (high yielding, bigger tuber size); Cereal/potato-legume crop rotation (N fixing & non-N fixing); residue incorporation of wheat or barley; green manure: vetch and/or lupin during off-season (N fixing in time); improved breeds for small ruminants; agroforestry (woody perennials and crops) and cut - and - carry for animal feed.

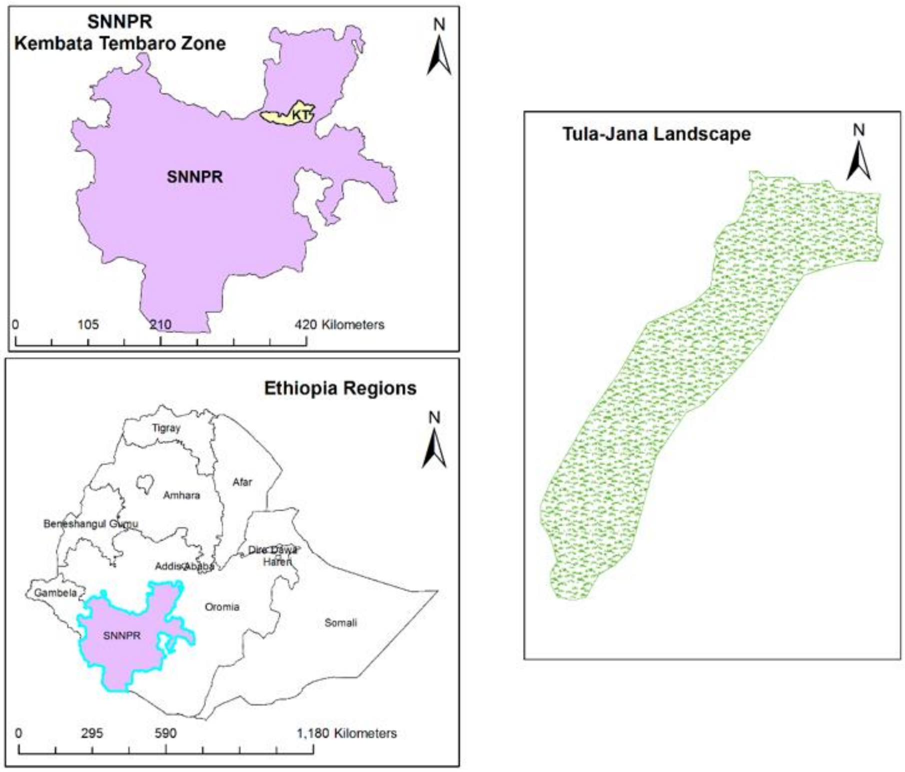


Figure 1. Map of the study areas (a) Tula-Jana landscape (i.e., Doyogena CSV); and (b) Basona CSV.

Survey tools and sampling techniques

The field study was conducted between December 2020 and February 2021. The Geofarmer tool was used to collect the data and summarize the outputs. The Geofarmer tool was used because previous studies by the authors have shown the suitability of the tool to: (i) monitor the impact of CSA practices on biophysical resources, (ii) identify climate shocks over the last twelve months, (iii) assess the farmers resilience for climate shocks, and (iv) investigate gender-disaggregated perceived effects of CSA interventions. In each CSV, 400 farmers were selected. Of these, 200 households were the treatment group - who are practicing the CSA practices, and 200 households were the control group - who are not practicing CSA interventions. The control groups were selected from the nearby areas to avoid the biophysical variation between the treatment and control groups. The indicators used to assess the effects of CSA practices include food security, productivity, income and resilience of farmers to climate shocks.

Table 1. Gender-disaggregated adoption of the different CSA practices.

CSA practices	Gender-disaggregated adoption			
	Total	Male	Female	p-value
Basona CSV				
Soil bund	100	100	100	NS
Soil bund and Trees/shrubs	76.67	55.08	31.87	***
Trench	27.62	19.25	12.09	NS
Area enclosure	33.81	20.32	18.13	NS
Percolation pit	7.14	3.74	0	NS
Check dams	17.62	13.37	6.59	NS
Gully rehabilitation	27.62	18.18	13.19	NS
Doyogena CSV				
Terrace and Desho grass	100	100	100	NS
Control grazing	94.92	54.89	46.24	NS
Improved wheat seed	78.17	44.02	39.25	NS
Improved bean seed	11.17	9.24	2.69	NS
Improved potato seed	57.36	34.78	26.34	NS
Legume rotation	35.03	25.00	12.37	**
Residue incorporation	53.30	33.15	23.66	NS
Green manuring	27.92	21.20	8.60	*
Improved animal breed	13.71	8.70	5.91	NS
Agroforestry	31.47	20.11	13.44	NS
Cut and carry	84.77	43.48	46.77	NS

*, **, and *** - represent significant at $p < 0.1$, $p < 0.05$, $p < 0.01$, respectively; NS – represents non-significant at $p < 0.1$

Data analysis

The demographic and socioeconomic data were summarized and presented using descriptive statistics. In addition, non-parametric test (i.e., Kruskal-Wallis) for continuous variable and Chi-square test for categorical variables were used to test for significant differences between the different farmers groups (i.e., the adopters and non-adopters) and gender-disaggregated data. All statistical analysis were performed using the R software version 3.6.0.

Key results and findings

Socioeconomic characteristics

The socioeconomic characteristics of farmers included in this study is presented in Table 2. All the respondents practiced rain-fed and subsistence crop-livestock mixed production systems. Irrespective of the study area, farmers who adopted CSA practices had a higher average gross annual income ($p < 0.001$); savings from agricultural activities ($p < 0.01$); and access to climate change information ($p < 0.001$) as compared to the non-adopters. In general, the variation between the adopters and the non-adopters was more noticeable at Doyogena. Implementation of CSA practices was gender inclusive at Doyogena and has been practiced for more than a decade and hence the more pronounced effect of CSA practices on the social economy is plausible at Doyogena compared to Basona. Nearly 80-90 % of gross annual income was originated from farming activities. Off-farm activities contributed for 15-20 % of the total income for the adopters, but income from the off-farm activities was decreased to ~6 % for the non-adopters at Basona. Even though many farmers were recipient of aid and/or gifts at Doyogena, adoption of CSA practices helped farmers to be less dependent on aid ($p < 0.001$). Even though many farmers were illiterate (> 46 %) at Basona, the adopters had relatively a higher educational status compared with the non-adopters. In contrast, less than 30 % of the respondents were illiterate at Doyogena, and no difference was observed in educational status between the adopters and the non-adopters. The farm size was almost twice higher at Basona as compared with Doyogena. The adopters had a bigger land size (0.82 ha) than the non-adopters (0.64 ha) at Doyogena ($p < 0.001$), but the difference between the adopters and non-adopters was marginal ($p > 0.05$) at Basona. Gender disaggregated socioeconomic data are presented in Appendix Table 2. There was no variation between male and female in terms of socioeconomic status except educational status ($p < 0.01$); age ($p < 0.001$); savings from agricultural activities ($p < 0.001$). In general, male headed household had a higher educational status and tended to gain more income from agricultural activities. In agreement with our findings, Asrat and Simane (2018) and Nyang'au et al. (2021) reported higher livelihood assets, including human, financial, physical, natural and social capitals for farmers who adopt CSA practices. The higher access for the different livelihood capitals helps farmers to have access for new technologies and resilience against various shocks, including climate change (Yang et al. 2018).

Table 2. Socioeconomic characteristics of the household (HH) heads included in the study.

Socioeconomic variables	Basona CSV			Doyogena CSV		
	Beneficiary	Control	p -value	Beneficiary	Control	p -value
No (%) household	182 (48%)	199 (52%)		186 (50%)	186 (50%)	
Male headed HH	76.37%	79.90%	0.48ns	84.41%	78.49%	0.18ns
Education	0.67	0.52	0.019**	1.03	1.02	0.68ns
Age (year)	57.41	54.74	0.025**	45.30	45.61	0.81ns
Household size	2.84	3.10	0.12ns	3.86	2.77	<0.001***
Area (ha)	1.30	1.26	0.63ns	0.82	0.64	0.08*
Owned land (%)	85.00	88.9	0.34ns	91.40	96.23	0.09*
Savings from farm (%)	75.90	60.80	0.003***	91.67	84.75	0.062*
Access to credit (%)	10.44	6.12	0.18ns	9.14	10.22	0.84ns
Access to weather forecast (%)	56.45	24.73	<0.001***	65.38	48.46	<0.001***
Aid recipients (%)	12.09	8.04	0.25ns	8.06	16.13	0.03**
Farm income (USD year $^{-1}$)	2293.02	981.92	<0.001***	993.24	320.89	<0.001***
Off-farm income (USD year $^{-1}$)	418.94	70.57	<0.001***	287.16	92.27	0.015**
Total income (USD year -1)	2711.96	1052.49	<0.001***	1280.40	413.16	<0.001***

HH – household; *, **, and *** - represent significant at *p < 0.1*, *p < 0.05*, *p < 0.01*, respectively; NS – represents non-significant at *p < 0.1*

Farmers` perception on climate change and coping strategies

Figure 2 shows the farmers` perception on climate change related shocks along the different climate smart landscapes (i.e., Basona and Doyogena) and farmers groups (i.e., the adopters and the non-adopters). The results showed that 80-90 % of the respondents perceived weather variability (i.e., unexpected heavy rainfall, frost, early or late set of rainy seasons) and associated reduction in crop and livestock production (Table 3). Irrespective of the CSV and farmers groups, heavy rainfall was identified as the major climate change related event which reduced agricultural production in the study area (Fig. 2). Similarly, over 85 % of farmers identified irregular rainfall amount as the main challenges for agricultural production in the country (Asrat and Simane, 2018; Alemayehu and Bewket, 2017; Belay et al. 2017). Over 54 % of the respondents at Basona also experienced frost as the major climate shock. At Doyogena, in contrast, disappearance of the short rainfall seasons (40 % of the respondents) and low temperature (35 % of the respondents) were also identified as the major climate change events. Climate models projected that the temperature in Ethiopia is increasing at the rate of 0.46 - 0.49 °C per decade (USAID, 2015). Unlike the expectation, however, only less than 15 % of the respondents experienced the change in temperature as the major climate related shocks. This finding was also in contrast with earlier studies (Belay et al. 2017) who reported that 69 % of the farmers experienced increase in temperature at the central Rift Valley of Ethiopia. The difference between the studies implied the diversity of climate-related shocks in the country, and the call for designing site-specific CSA practices to boost agricultural production in Ethiopia in a changing climate. Farmers` perception on climate change events significantly varied ($p < 0.001$) between the CSA practices adopters and non-adopters, particularly at Doyogena where farmers have better access to weather forecast (Table 2). In general, farmers who adopted CSA practices had more experience on weather variability than non-adopters (Fig. 2). Gender disaggregated perception on climate change related events was evaluated in this study (Appendix 1), but the difference was marginal ($p > 0.05$).

Climate information services and sources of information varied between the different farmer groups (i.e., adopters and non-adopters), gender and climate smart landscapes (Table 2; Appendix 2). The adopters had more access for climate information services than non-adaptors ($p < 0.001$). Radio/ television was the main source of information which was followed by formal communication. The contribution of extension services and governmental and/or non-governmental organizations to provide weather information is generally limited in the study area, suggesting the call for participation of different stakeholders to equip smallholder farmers with weather information and improve their resilience to climate change. In Ethiopia – where the agricultural production is the mainstay of the economy – participation of policymakers and stakeholders is crucial to secure the country`s economy and social well-being in the face of climate change (Admassie et al. 2008).

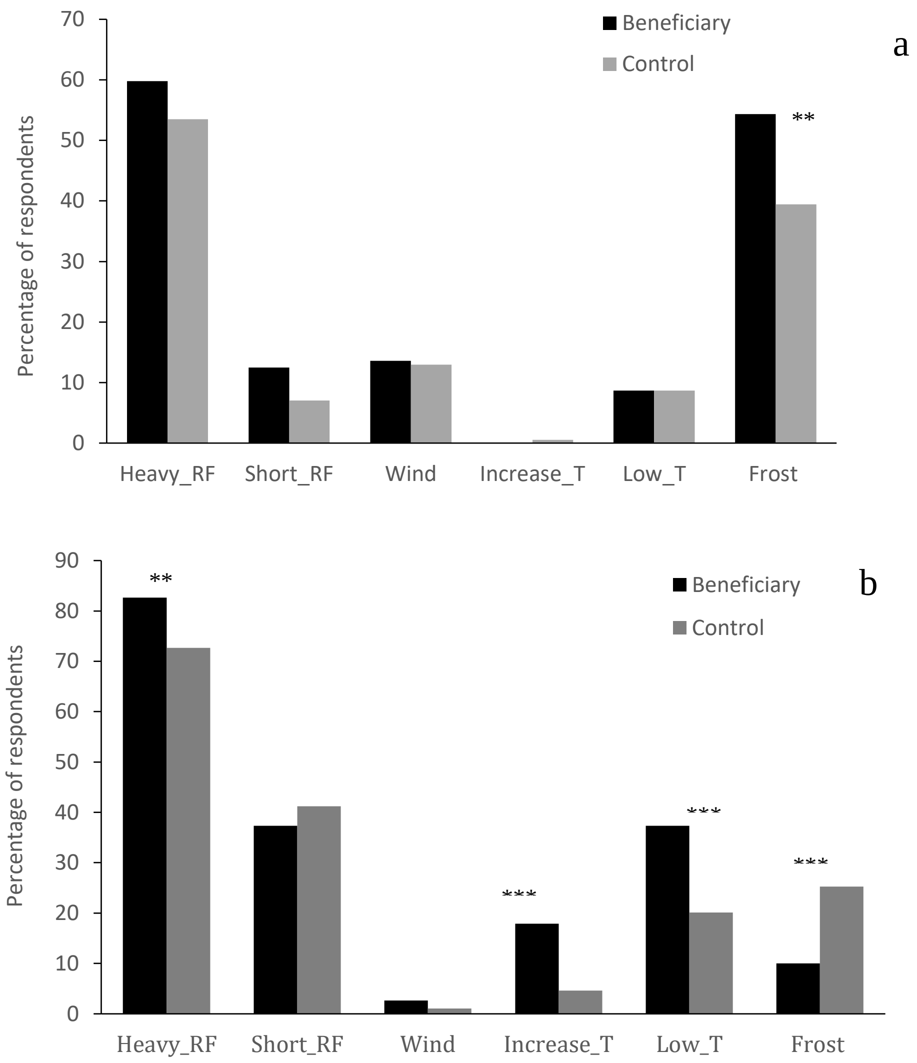


Figure. 2. Farmers` experience on climate related events affecting agricultural production. (a) Basona CSV; and (b) Doyogena CSV.

Where: Heavy_RF represents heavy rainfall; Short_RF represents disappearance of short rainfall; Increase_T represents increase in temperature; Low_T represents decrease in temperature; *** represents significant at $p < 0.001$

Table 3. Impact of climate change (CC) related events on agricultural production and coping strategies among the different farmers group.

	Basona CSV			Doyogena CSV		
	Beneficiary	Control	p-value	Beneficiary	Control	p-value
Experience of CC related events	88.11%	79.89%	0.04**	97.31%	88.94%	0.003**
Yield reduction due to CC	87.57%	80.43%	0.08*	96.77%	87.89%	0.003**
Change in cropping activities due to CC	30.39%	19.13%	0.02**	58.06%	46.32%	0.03**
Change in animal husbandry due to CC	14.34%	10.93%	0.24ns	32.26%	32.11%	NS
Borrowing money due to CC impact	7.14%	2.73%	0.09*	13.16%	26.88%	0.003***
Spent more money due to CC impact	89.01%	76.50%	0.003**	26.32%	38.71%	0.03**

Many farmers in the study (i.e., > 80 %) observed yield reduction in the last 12 months owing to climate change (Table 3). Higher number of the adopters indicated yield reduction owing to climate change compared with the non-adaptors. At Basona, for instance, 88 % of the adopters and 80 % of the non-adopters found yield reduction due to climate change. Similarly, 97 % of the adopters and 88 % non-adopters observed yield reduction in the last 12 months due to climate change. To combat the negative impact of climate change on agricultural production, farmers practiced various strategies (Table 3). At both sites, change in planting dates, introduction of new crop varieties and diversification were the most common crop-based climate change coping strategy. In addition, livestock-based climate change coping strategy include (i) feed management, (ii) improved breeds, and (iii) change in heard size. Similarly, changing in crop pattern, planting date and decrease the herd size were identified as adaptation strategies in many parts of the county (Alemayehu and Bewket, 2017). At Doyogena – where the diverse CSA practices were implemented for decades – non-adopters spent more money and/or borrow money; selling assets (i.e., livestock), change food consumption pattern to cope with the negative impact of climate change. At Basona – where only soil conservation practices were implemented – the effect of CSA practices was non-significant.

Farmers perception on CSA practices

Gender-disaggregated perceived effects of CSA practices is presented in Table 4. The perceived effect of CSA practices on agricultural production and income was varied between the different gender groups. At Basona CSV, more male respondents identified the benefits of CSA practices compared with female respondents ($p < 0.001$). However, the farmers` perception didn't vary between the gender groups at Doyogena CSV. Men-dominated decision-making is evident in many developing countries (Macharia et al. 2014; Mwaura et al. 2021). Similarly, equal participation of male and female in decision-making was limited in the study areas, particularly at Basona CSV. For example, 90 % male but only 60 % female respondents were involved in the decision-making process when CSA practices were implemented at Basona (Appendix Table 4). At Doyogena, more than 75 % of female and 90 % of male respondents decided the CSA practices implemented on their farmlands. The observed gender-disaggregated variation is therefore attributed mainly from the limited access of female in decision-making during the implementation phase of the CSA practices. Limited access to education (Appendix 2) might also influence the female farmers perception on CSA practices. In line with this finding, Murage et al. (2015) and Ndeke et al. (2021) reported that more male-headed households adopted CSA practices than female-headed households. This finding implies the importance of women participation and their access for resources to ease the adoption of CSA practices (Ndeke et al. 2021).

This paper evaluated the perception of the adopters and non-adopters towards the effects of CSA practices. As compared with the non-adopters, the adopters experienced the benefits of various CSA practices, including increase in agricultural production, income and food availability and/or diversity (Table 4). In addition, CSA practices prevent farmers to sell their assets and/or change their food consumption patterns amid climate shocks – which is comparable with the Alemayehu and Bewket (2017). The CSA activities have been practiced at Doyogena for more than a decade and hence the effect of CSA practices was more pronounced at this site as compared to Basona. For instance, 97 % of the respondents at Doyogena identified the benefits of CSA practices on food diversity and/or availability. This value was however decreased to 85 % at Basona. Table 5 shows the challenges and motivations to adopt the CSA practices at Doyogena and Basona CSV. Irrespective of the landscape and gender group, the major motivations to adopt the CSA practices were either to adapt to climate change or to respond to climate change. Irrespective of the study area, the major constraints to practice the CSA interventions include: (i) lack of information, (ii) limited technical skill, (iii) lack of farmers participation in decision making, and (ii) consumption of labour and time during implementation. Specifically, 44 % – 51 % of the female respondents identified the lack of participation in decision making as a challenge to practice CSA interventions.

Table 4. Chi-square values for the perceived effects of CSA practices on agricultural production, income, food security and food diversity.

Perceived effects of CSA practices	Treatment effect (adopters vs non-adopters)		Gender dis-aggregated perception	
	Basona	**Doyogena**	**Basona**	**Doyogena**
Increase production	18.90***	4.79**	22.62***	0.74ns
Increase income	0.76ns	62.18***	9.42**	2.86*
Increase in food availability	2.41ns	54.61***	0.16ns	0.24ns
Increase in food diversity	3.30*	163.23***	<0.001ns	0.97ns

Table 5. Challenges and motivations to adopt CSA practices.

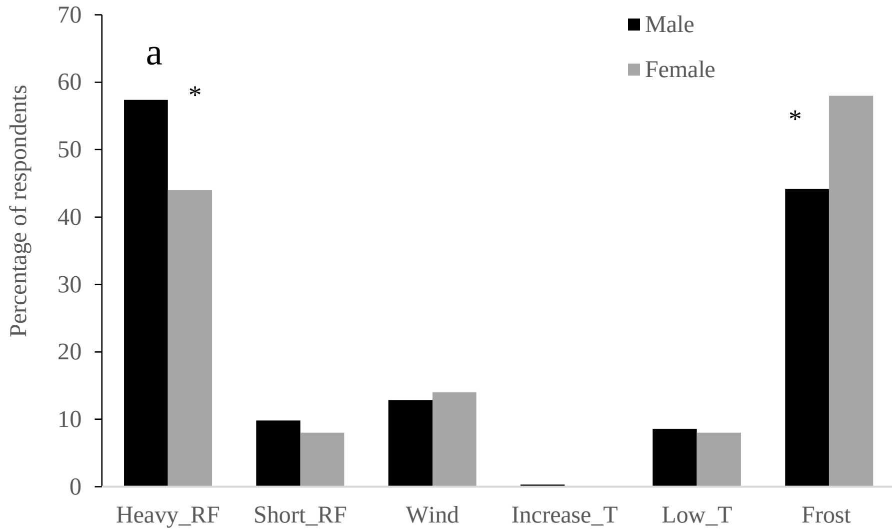
	-------------------- Location -----------------			------------- Gender disaggregated ----------					
	Total respondents			Basona CSV			Doyogena CSV		
	Basona	**Doyogena**	**p-value**	**Male**	**Female**	**p-value**	**Male**	**Female**	**p-value**
Motivation									
Adapt to CC (%)	31.79	61.20	15.75***	31.91	23.50	2.28ns	60.85	57.67	0.08ns
Response to CC (%)	76.23	65.57	1.97ns	75.00	57.92	5.75**	76.72	50.26	14.58***
Market-oriented (%)	9.57	7.92	0.06ns	10.64	6.01	1.03ns	9.52	5.82	0.61ns
Challenges									
Decision making (%)	50.64	32.51	0.02**	17.55	44.81	<0.01***	22.22	51.32	<0.01***
Time consumption (%)	36.00	38.80	0.88ns	13.66	25.00	0.07*	28.57	46.56	0.013**

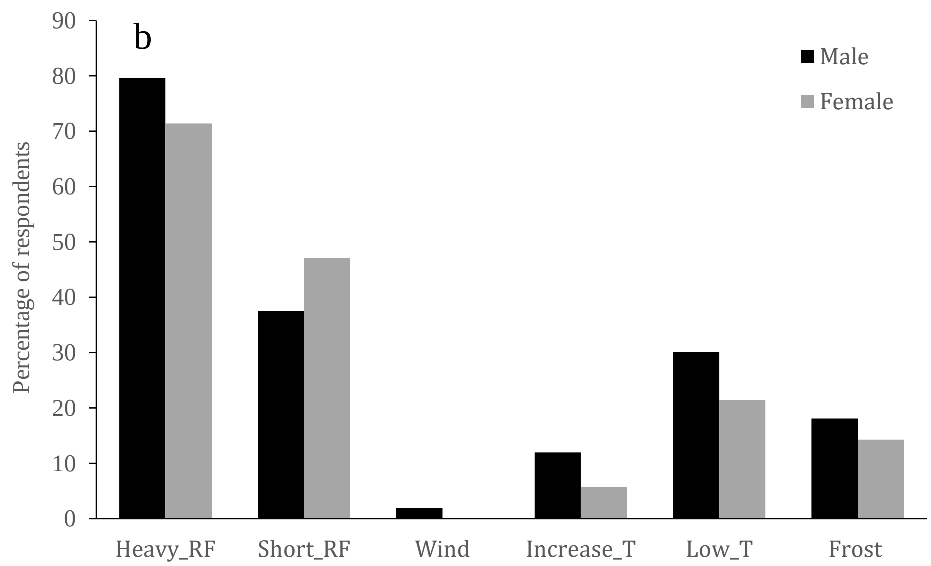
Conclusion and recommendations

This paper evaluated the perception of different farmers groups towards the effects of CSA practices on agriculture production, income, and food security – using two contrasting CSV in Ethiopia as a case study. Many farmers have identified the negative effects of climate change on agricultural production (i.e., both crop and livestock production). Heavy rainfall, disappearance of short rainfall seasons, unpredictable rainfall pattern, frost and change in temperature were identified as the major climate-related challenges. Gender-disaggregation results showed non-significance difference between male and female farmers in the perception of climate change and its impact on agriculture. Even though farmers practiced different CSA technologies, the adoption of these technologies was lower among female-headed households, particularly for technologies which require labour (i.e., soil bund and green manuring) and/or knowledge (i.e., crop diversification). As compared with the non-adopters, farmers who adopt CSA practices had higher yield, income and able to ensure food security in the household despite a changing climate. In addition, the farmers who adopt CSA practices were less likely to borrow or spend money for food or other goods compared with the non-adopters. Gender-disaggregation results showed that male farmers have better knowledge on the benefits of CSA practices more than female farmers, and this difference was more pronounced at Basona landscape – where equal participation of gender in decision-making is very limited. At Doyogena, integrated and gender-participated CSA practices have been practiced for a decade. At Basona, in contrast, only soil and water conservation practices have been implemented for few years through top-down campaign approach. Hence, farmers at Doyogena had better knowledge on: (i) climate change and its negative impacts on agriculture and (ii) the benefits of CSA practices compared to farmers at Basona landscape. Gender equality in decision-making, access to climate information and extension and shortage of labour were identified as the major challenges to adopt CSA practices. The findings imply the need to involve female-headed households during implementation of the CSA practices. Furthermore, access to climate information and extension services, and integrating the different CSA practices are crucial to curb the negative effect of climate change on agricultural production.

Appendices

Appendix 1. Supplementary Figure





Appendix Figure 1. Climate related events affecting agricultural production along different gender. (a) Basona CSV; and (b) Doyogena CSV.

Heavy_RF represents heavy rainfall; Short_RF represents disappearance of short rainfall; Increase_T represents increase in temperature; Low_T represents decrease in temperature; *** represents significant at $p < 0.001$

Appendix 2. Supplementary Tables

Appendix Table 1. Source of information for weather forecast across different climate smart landscapes and farmers groups.

Source of weather information	Basona climate smart landscape		Doyogena climate smart landscape	
	Beneficiary	Control	Beneficiary	Control
Radio/TV	66.13%	52.61%	43.99%	21.76%
Media	2.88%	0.33%	0	0
Internet	0.64%	0.65%	3.28%	0
Personal	28.11%	14.05%	28.14%	15.15%

Appendix Table 2. Gender-disaggregated socioeconomic characteristics of farmers.

Socioeconomic variables	Basona CSV			Doyogena CSV		
	Male	Female	p -value	Male	Female	p -value
Education	0.69	0.57	**	1.97	0.70	***
Age (year)	47.04	41.07	***	42.11	39.33	***
Household size (number)	3.03	3.04	NS	3.39	3.26	NS
Owned land (%)	85.08	87.01	NS	91.58	91.34	NS
Saving from farm (%)	69.36	61.70	***	89.40	85.50	NS
Access for forecast (%)	56.35	55.15	NS	39.58	36.15	NS
Aid recipients (%)	10.69	12.74	NS	13.03	10.50	NS

***, ** - significant at p<0.01, and p<0.001, respectively; NS – non-significant

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Glossary

Climate-smart agriculture (CSA): as an approach for transforming and reorienting agricultural development under the new realities of climate change. In other word, it is sustainable agricultural practices that increases productivity, enhances resilience, reduces/removes greenhouse gas emissions, and enhances achievement of national food security and development goals

Climate-smart landscapes/ villages (CSV): benchmark landscapes – where a portfolio of climate-smart agricultural interventions are implemented to increase production in a changing climate, ensure farmers` resilience to climate change and/or reduce greenhouse gas emissions.