



Exploring effects of climate-smart agriculture innovations on women smallholders' livelihoods in Ethiopia

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Abstract

Studies do not often provide evidence as to how innovations improve women smallholders' livelihoods in male-headed households by analyzing women farmers in their own rights which is vital to develop and implement future gender responsive and transformative agricultural innovations. This study investigates if Climate Smart Agriculture (CSA) – specifically conservation agriculture (CA) and small-scale irrigation schemes (SSIS) – improve women smallholders' livelihoods. A concurrent mixed method was applied, and data was collected using survey, in-depth interviews and focus group discussions (FGDs). Descriptive and t- statistics were used to analyze quantitative data and thematic and narrative analysis methods to analyze qualitative data. Findings demonstrate that gender norms and intersectional identities and experiences of women together with the absence of gender equity and equality based structural works limit improvement in women's livelihoods. While the use of CA did not change both men and women farmers livelihoods, SSIS improved men users' financial and physical capitals. Hence, future CSA innovations should first identify the root causes of contextual gender inequalities and CSA innovations should be implemented based on women smallholders needs, experiences and realities. Building women smallholders' livelihood capitals through off-farm income-generating activities and broadening the operational scale of CSA innovations for addressing strategic gender needs are desired. Explicitly, there is a need to move to a gender transformative approach (GTA) when implementing CSA innovations as GTA challenges and transforms gender norms and intersectional problems including unequal gendered access to livelihood capitals and decision-making power, unequal gender role distributions and gendered representations and implementation processes in economic policies.

Keywords CSA · Gendered agricultural development · Determinants of women farmers livelihoods · Women in male headed households · Change in women farmers capital · Ethiopia

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1 Introduction

Climate change, precisely, drought is often beyond the capability of smallholders to respond to without access to agricultural innovations, relevant and targeted policies, and institutional support in Ethiopia (Belay et al., 2017, 2022). Climate-smart agriculture (CSA) is a strategy to address food insecurity and environmental sustainability and it is based on the principles of increasing production and income, developing resilience to climate change, and reducing greenhouse gas emissions (FAO, 2017). Conservation agriculture (CA) and small-scale irrigation schemes (SSIS) are from among the CSA technologies (Mwongera et al., 2017). The principles of CA include zero tillage (ZT), mulching, and intercropping of legumes with maize. ZT preserves organic matter in the soil and decreases soil degradation; mulching is expected to conserve soil moisture and increase infiltration; and intercropping facilitates nitrogen fixation which thereby increases yield (Giller et al., 2009; Mbanyeleye et al., 2021).

It has been verified that agricultural innovations leading to increased productivity have reduced poverty and food insecurity for the rural poor in sub-Saharan Africa (Brenya et al., 2024; Christiaensen et al., 2011; Djoumessi, 2021). CA is proven to increase food security in Zimbabwe (Marongwe et al., 2011) and increases yields in Zambia (Ngoma, 2018). The use of irrigation and improved water management enhanced poverty reduction through various pathways, such as increased production and productivity (Ahmed et al., 2022; Namara et al., 2010). SSIS also improves rural livelihood assets through increased production and productivity in Ethiopia (Bojago & Abrham, 2023). Nevertheless, agricultural innovations may not equally reach, benefit, empower or transform women smallholders' livelihoods given the many intersectional factors that shape their access to and control over livelihood capitals (Tsige, 2019). Specifically, the 'triple wins' narrative of the CSA may not be valid for the poor and marginalized (Karlsson et al., 2018). Furthermore, since increasing production through the diffusion of innovations is taken as a priority in CSA (Lipper & Zilberman, 2018), intersectional factors of production and productivity do not often win adequate consideration when agricultural innovations are implemented. As a result, CSA innovations may also produce negative effects depending on the intervention type, local contexts, and farmers' access to livelihood assets (Beuchelt, 2016).

Although women smallholders are actively engaged in sowing, weeding, and harvesting in Ethiopia (Tsige et al., 2020), they have limited access to agricultural land, and other agricultural inputs, information, and extension services (Badstue et al., 2020a; Ragasa et al., 2013). Intra-household inequality in using land is common as the head of the household is traditionally accepted as the real land "owner" and customary laws limit women farmers use of agricultural land (Badstue et al., 2020b; Tsige, 2019). Men household heads are considered as the only livestock owners and control over assets in rural Ethiopia is guided by gender norms and the household head is the one who is often accepted as the main decision-maker on productive assets (Badstue et al., 2020). Thus, agricultural innovations may not improve or transform the livelihoods of women smallholders and innovations may even produce negative consequences in contexts where women have limited access to and control over production inputs and outcomes.

Nevertheless, some studies show that there are possibilities by which innovations can bring positive improvements in women's livelihoods. Analysis of the impacts of eight agricultural interventions that include the use of micro-irrigation treadle pumps, development and deployment of new cereal varieties and dairy value chain, in African and Asian coun-

tries, for instance, have shown positive improvements in women's control over livelihood assets and financial income through enhanced or increased food production (Johnson et al., 2016). Another study that reveals a review of current practices on women farmers and their use of innovations states that carefully implemented innovations that fit institutional arrangements with viably connected models possibly increase the economic empowerment of women farmers (Thakur, 2023). Such studies prove that there are opportunities to improve and transform the livelihood capitals of women smallholders using agricultural innovations if gender focused structural and institutional works are appropriately executed by designing innovations based on proper institutional and structural arrangements. Understanding how CSA innovations improve or transform women smallholders' livelihoods in male-headed households will help to designing and implementing future gender responsive and transformative CSA innovations. Nevertheless, this was not often investigated by making women farmers centers of analysis in Ethiopia's agri-food system. Hence, this study explores if CSA improves the livelihood capitals of women smallholders in male-headed households. This study also investigates what shapes improvement in women smallholders' livelihoods in three study contexts. Explorations under the study provided information on what is needed for implementing gender-responsive or transformative agricultural innovations.

1.1 Hypothesizing change in women CSA users' livelihoods using intersectionality and the sustainable livelihoods framework

Postmodernism constituted multiple fundamental thoughts and perspectives where social scientists agree that there is no unified and singular identity, culture and reality as there are many intersectional variables needed to be investigated for understanding social problems (Layder, 2007). In line with this theoretical assertion, postmodern feminists argue that women's lives are shaped by multiple identities, realities, and experiences within the social structures in which they are living (Bryson, 2016). The theory of intersectionality is part of this postmodern theorization movement where intersectional dynamics of social inequalities are investigated and addressed for social development outcomes (Cho et al., 2013).

Women smallholders have limited access to agricultural land, agricultural inputs, information, and extension services in Ethiopia (Badstue et al., 2020a; Ragasa et al., 2013; Tsige et al., 2020). Many gender norms and patriarchal principles limit women smallholders rights in using agricultural land (Badstue et al., 2020b; Tsige, 2019). Men household heads are assumed to be livestock owners and main decision makers on any productive assets and outcomes in rural Ethiopia (Badstue et al., 2020). Access to food, which is a primary form of human capital, is limited for female members within households (Belachew et al., 2011). Access to health care is likewise restricted for women compared to men in southern rural Ethiopia (Dercon & Krishnan, 2000). Hence, it is less likely that these intersectional variables and above-mentioned entrenched gender norms allow improvement in women smallholders livelihoods through agricultural innovations. The likelihoods of livelihoods transformation are even lower among women in male-headed households given the higher level of unequal gender power relations within male headed households in rural Ethiopia.

A livelihood includes people, their capabilities and their means of living including food, income, and assets (Chambers & Conway, 1992). This confirms that individuals together with their livelihood potentials should come at the center of any livelihood analysis. SLF

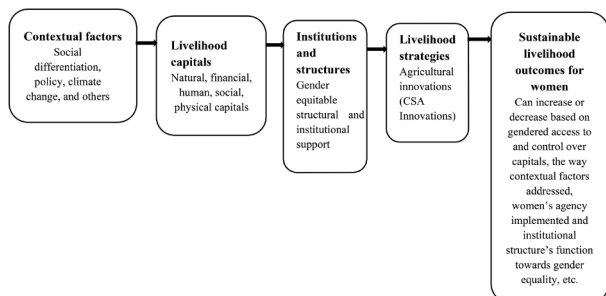
(Sustainable Livelihoods Framework), which is linked to the capability approach, is workable to investigate the gendered nature of people's livelihoods in sub-Saharan Africa. In family-based smallholder farming, livelihood security profoundly depended on the five capabilities or basic livelihood capitals (DfID, 1999; Scoones, 1998). Women's limited access to livelihood capitals in sub-Saharan Africa is the result of their limited access to and control over these five capitals. Consequently, SLF aligns with the theory of intersectionality as it has a comprehensive approach that recognizes and addresses many contextual realities (vulnerability contexts) as determinants of people's livelihoods. Intersectionality similarly focuses on contextual realities and experiences of people (individuals) as the center of any development analysis. More importantly, SLF allows individual women and men to be centers of analysis which makes the framework different from mainstream economics that tends to categorize the household as the only unit of analysis in understanding changes in agricultural livelihoods. SLF is also appropriate to investigate culturally embedded inequalities that affect improvement in women's livelihoods, and it helps to understand how transforming structures and processes positively or negatively affect improvement in women's livelihoods figure 1.

SLF further shows the extent to which access to and control over livelihood capitals and the function of transforming structures and processes determine transformation in people's livelihoods (DfID, 1999; Scoones, 1998). Furthermore, the sustainable livelihoods framework (SLF) explains the need to obtain the five livelihood capitals (natural, human, social, physical, and financial) in improving livelihoods (Scoones, 1998). These capitals are determinant in understanding how and why changes in women's livelihoods occur or do not occur through CSA innovations. The framework further shows that any livelihood strategy can affect and can be affected by individuals' possession of these capitals. Therefore, this study used the theory of intersectionality as it provides detailed understanding of the many factors that determine women's livelihoods and SLF to conceptualize women smallholders' capital possession status which is determinant in shaping their livelihood capitals. Furthermore, both intersectionality and SLF go along in many ways by which we can expose determinants of women's livelihood.

2 Methodology

Concurrent mixed method that integrates findings and draws inferences from both quantitative and qualitative data (Teddlie & Tashakkori, 2009), has been applied. The survey evaluates gendered differences in accessing livelihood assets and improvements in women

Fig. 1 Based on SLF, adapted from Scoones (1998)



and men CSA users' livelihood capitals. In-depth interviews and focus group discussions explore context-specific factors that affect change in women's livelihoods through CSA. This study mostly applied a feminist research approach as it uses the voice of women as the main source of knowledge. Harding (2004) explains that in standpoint feminism, women's issues should be studied from their own experiences, and they must speak for themselves. Harding (1991) argues that science can be benefited if it uses perspectives from women's lives as it provides a less distorted knowledge about women's problems in social research. This study accepted that women smallholders as individuals have distinct experiences and knowledge on changes in their livelihoods. We accepted that women could recognize, judge, decide, and provide information on whether their participation in CSA improves their livelihood capitals. As a result, individual women and men smallholders' are units of analysis and their responses in the survey are direct sources of knowledge construction as it is for interviews and FGDs in this study.

2.1 Description of study sites

Men and women smallholders practice CA and SSIS innovations in study sites as they are involved in a project called '*Research and Capacity Building in Climate Smart Agriculture in the Horn of Africa*,' that promotes CSA practices through research and capacity-building activities. The CA and SSIS interventions are aimed at increasing production and productivity for livelihoods. CA users were selected from *Loca-Abaya woreda* (smallest administrative unit above *Kebele*). The CA practices include ZT, which farmers practice after herbicide application, intercropping, which is often done using maize and haricot beans, and maize residues are used for mulching. CA in *Loca-Abaya* was introduced in 2005 with the support of the Sustainable Intensification of Maize-Legume Farming Systems for Food Security in Eastern and Southern Africa (SIMILESA) initiative.

Gravity-based SSIS users were selected from *Halaba woreda*, Ethiopia. The scheme is a community gravity based SSIS that covers 200 ha in three *kebeles* and serves 275 households. It formally started service in 2006, based on a constructed diversion weir and a regulating dam weir on *Bilate* river and it discharges 2200 m³ water per second during rainy seasons. Users of the scheme primarily produce potatoes and onions. The third case from where users were selected was a community, pump based SSIS located in *Ziway*, Ethiopia. The scheme has existed for more than 40 years. Water is taken from Lake *Ziway* using both centrally managed large pumps and individually owned small pumps. Major agricultural products include onions, tomatoes, green beans, cabbage, pepper, and maize. Currently, the scheme covers 203 ha that belonged to 470 households. Water user associations handle maintaining water canals. Rural institutions and some non-governmental organizations support the users. Small water pumps are provided by non-governmental organizations for a limited number of organized SSIS user farmer groups or cooperatives. This study investigates if the use of these agricultural technologies improves women users' livelihood capitals.

2.2 Sampling

Samples were selected using proportional stratified random sampling method. Respondents were selected from CSA users list in male-headed houses with the help of DAs (development agents). Since users list primarily incorporated only men household heads, women

users were contacted after their husbands were randomized. Fifteen *Kebeles* (smallest administrative units) were selected from three *Woredas* as they broadly practice CSA technologies compared to other *Kebeles*. Only those men and women farmers who managed to adopt at least two CA packages for three consecutive years were considered for selection. Another selection criterion was that participants had to be from male-headed households only, as we aim to investigate whether CA and SSIS improve women users' livelihood capitals in male-headed households.

Earlier studies in rural Ethiopia show that women smallholders have limited access to and control over productive assets and institutional services (Aregu et al., 2010; Buchy & Basaznew, 2005; Cohen & Lemma, 2011; Fafchamps & Quisumbing, 2005b; Ragasa et al., 2013; Tsige et al., 2020). As a result, a higher sample proportion for women users was selected and smaller for men users as a control group. Sample selection proportion of women and men users of CA and SSIS from all study areas was estimated using, $n = (Z_{\alpha/2} + Z_{\beta})^2 * (p_1(1-p_1) + p_2(1-p_2)) / (p_1 - p_2)^2$ with 80% power that means there is 80% of probability in rejecting the null hypothesis that is CSA improves women's livelihoods. Samples used per variable were calculated using G*Power 3.1.9.4 statistical software. The total sample selected to collect survey data was consisted of 223 women and 92 men CA and SSIS users. Among the 223 women, 52 were CA users and 171 are SSIS users from both irrigated areas. Among the 92 men, 30 were CA users and 62 were SSIS users from the two irrigated areas.

Data was collected using survey, in-depth interviews and focus group discussions. The marriage system is largely monogamous, but polygamy exists in both SSIS user areas. All men involved in the survey were recruited from the same households as the women respondents. Women and men users responded to questions after being told to relate their responses specifically to their user status and they responded to the survey in separate sessions. Interviewer-administered in-depth interviews were conducted with 28 women users and 18 Development Agents (DAs). Three FGDs were conducted (one in each study area) with 32 men, and women smallholders. Participants for the in-depth interviews and FGDs were purposefully selected based on their gender and user status. Informed consent was obtained from all study participants before the commencement of data collection and anonymity was applied. The first author collected data with the help of DAs. Data was collected from September 2015 to September 2016. Being smallholders, all participants owned less than two hectares of land.

2.3 Data analysis

Livelihood studies are often conducted based on the income and consumption levels of households and often fall short of exposing the real picture of gendered livelihoods at the individual level (Ellis, 2000). Such studies often obscure the nature of gendered livelihoods within male-headed households where most women live (Deere & Twyman, 2012). To address this issue, this study made individual women and men units of analysis and the direct responses of men and women users were used to construct knowledge. Quantitative and qualitative data were concurrently collected, and the analysis section compared if there are differences and similarities between the two data sets. Quantitative data were analyzed using descriptive and t-statistics. Thematic analysis was used to analyze qualitative data after transcribing, coding, and categorizing concepts and by sorting out ideas that contribute

to emerging themes (Strauss & Corbin, 1990). Narrative analysis is also used to catch the real nuances and perspectives of participants.

Qualitative concepts and quantitative variables were constructed using the SLF indicators and intersectional variables that shape women smallholders' livelihoods. Changes in livelihood capitals were investigated using indicator variables (Table, 1). Access refers to the ability to benefit from resources while control in the analysis means having decision-making power over resources. Improvement in the natural capitals was not investigated since land and forest are currently under the control of the state in Ethiopia.

3 Results

3.1 Socio-demographic background

Most of the women respondents (77.1%) are in monogamous marriages, while 22.9% are in polygamous marriages. Polygamous marriages exist in the two irrigated study areas. In-depth interviews show that women living in polygamous marriages have limited control over livelihood capitals compared to women in monogamous marriages. In-depth interviews further show that the class and social status of the men and women in descending order are wealthy old men, adult men, poor men, old women, adult women, and poor women. The lower class and social status of women affect their ability to develop livelihood capitals. For instance, only old and adult men are allowed to take part in traditional community gatherings, which is vital for developing social capital. FGD findings confirm that patriarchal ideologies govern asset distribution and control over assets within the household. Who sells what and who decides on productive assets are all decided by patriarchal norms and are often in favor of men. Most women CSA users are at their younger age compared to men, which affects women's decision-making ability within the household as older age is culturally respected. Among the 223 women CA and SSIS users, the majority (62.3%) cannot read or write. The proportion of women respondents who can read and write without having attended formal education is 20.2% and 11.7% of them received elementary education, and only 5.8% received junior education. In comparison, of the 92 men CA and SSIS users, only 14.1% cannot read or write; while 27.2% can read and write, 28.3% of them received elementary education, and 30.4% attended junior school. Thus, women participants have lower education status compared to men (0.000*** Table 2), which confirms that women

Table 1 Indicators used to evaluate changes in the livelihood capitals of women

Capital categories adopted from the SLF (DfID, 1999; Scoones, 1998)

Capital categories	Specific variables	Indicators in the survey
Human capitals	Food, education, and healthcare	Improvement in women's access to food, education, and healthcare
Social capitals	Social support, network, and information	Improvement in women's social network, information, and social support.
Financial capital	Income	Women's access or use rights to cash income.
Physical capitals	Cattle and house	Improvement in women's ability to buy and sell cattle, houses, motor pumps, etc.

Table 2 Access to and control over livelihoods capitals among women and men CSA users

Variables	WUMHHs	MUs	<i>p</i> -value
Age	1.24 (0.42)	1.53 (0.50)	0.000
Education status	1.17 (0.38)	1.61 (0.49)	0.000
Access to land	0.69 (0.46)	0.98 (0.10)	0.000
Access to forest	0.39 (0.48)	0.41 (0.49)	0.764
Control over water	0.62 (0.48)	0.81 (0.39)	0.055
Off-farm income	0.16 (0.37)	0.10 (0.31)	0.165
Access to credit	0.37 (0.48)	0.82 (0.38)	0.000
Access to collateral	0.45 (0.49)	0.64 (0.48)	0.002
Access to healthcare by a doctor	0.07 (0.25)	0.16 (0.37)	0.033
Access to improve vocational or adult education	0.05 (0.22)	0.15 (0.36)	0.017
Access to information on how to use innovations and product prices from people in your networks	0.37 (0.48)	0.95 (0.20)	0.000
Access to urban markets	0.77 (0.42)	0.97 (0.14)	0.000
Membership in cooperatives and WUAs	0.11 (0.31)	0.81 (0.39)	0.000
Access to extensions	0.20 (0.40)	0.83 (0.37)	0.000
Access to skill trainings	0.05 (0.23)	0.86 (0.33)	0.000

Value=Dummy equals 1 if yes and 0 otherwise. Table has means. Numbers in parentheses are standard deviations. Test statistics are t-statistics for unequal variances. *p*-values refer to difference between men and women CSA users. Women users in male-headed households (WUMHHs)=223. Men users (MUs)=92. *N*=315. ****p*<0.001, ***p*<0.01, **p*<0.05. Source Fieldwork

have lower human capital compared to men which could negatively affect development in their livelihood capitals.

3.2 Contextual factors

Lack of rainfall is shown as major livelihood stressor in all study areas where 77.2% of women users and 81.5% men users say that shortage of rainfall is the primary stressor affecting agricultural livelihoods. CA users told that the El Nino that has stricken Ethiopia has decreased production. Similarly, the amount of water in the *Bilate* river and Lake *Ziway*, which are the water sources for SSIS in study areas, has significantly decreased due to the drought that has persisted for three consecutive years. Interviews with CA and gravity based SSIS users indicated that many farmers are forced to sell their cattle to buy food. Recurrent drought has also been specified as contributing to the decline of cattle price, as people cannot buy and feed cattle in a situation of drought. Although drought seems to have similar effect on men and women smallholders, women are differently affected by drought. We have identified from FGD discussions that more women users are forced to be involved in canal deepening works at times of drought in both irrigated areas that means drought increases women's labor. Expensive input costs and decline in vegetables price at times of harvesting owing to the lack of storage facilities were indicated as major livelihood stressors among both men and women users in both irrigated areas.

3.3 The livelihood capital status of men and women users of CA and SSIS

Access or user rights to land among men and women users are investigated by presenting indicators. It is investigated whether users have rights on what to sow, how to sow, and

how to collect and use crops from the land. Results show that men have significantly better access or user rights to land compared to women (0.000*** Table 2). In-depth interviews and FGDs demonstrate that men are customarily accepted as the main landowners as they inherit land from their fathers, while women marry without having any rights to inherited land. Interviewed women stated that although they are registered on a land certificate, which is provided to improve “ownership security,” the registration does not provide any different user rights to women. Furthermore, agricultural land is currently owned by the state that makes gendered land ownership even more complicated. Men have better control over irrigation water (0.05* Table 2). Interviewed women SSIS users indicated that they encounter challenges in accessing water from irrigation schemes due to fierce competition for water during dry seasons and owing to unequal power relations between scheme users. In both irrigated areas, many first wives from polygamous households are forced to give away or rent out their land to other men farmers due to their restricted control over irrigation water. Interviews and FGDs show that water user committees are dominated by men and men are managing the maintenance of canals while women are contributing labor. Men committee members better control irrigation water and group-owned large pumps compared to women SSIS users and even compared to other men farmers.

Access to credit (0.000*** Table 2), collateral (0.002** Table 2), health care by a doctor (0.033* Table 2), access to education (0.000*** Table 2), information about how to use agricultural innovations and product prices (0.000*** Table 2), access to urban market (0.000*** Table 2) are all better for men CSA users compared to women users which demonstrate that women smallholders livelihood capitals status is lower which thereby limits improvement in their livelihoods.

3.4 The status of livelihood improving structures and processes

Men are significantly better in accessing agricultural extension (0.000*** Table 2), skills trainings (0.000*** Table 2), and membership in cooperatives (0.000*** Table 2) compared to women (Table 2) and these findings show that men have relatively better served by rural livelihood improving structures and institutions compared to women farmers. Interviews with DAs revealed general problems in accessing credit and agricultural extension related skills training for all smallholders. Nevertheless, interviews and FGD findings conducted with women and men users show that institutional services provided to farmers focus on men household heads. For women to access credit, they need to get the consent of their husbands; and institutions often do not trust women’s ability to pay back credit unless they apply together with their husbands. Interviewed women users specify that some NGOs provide small motor-pumps to some women only groups. However, support is often short-term and less transformative. Access to facilities to improve vocational or adult education was also lower among women smallholders compared to men (0.017* Table 2). Although access to health care by a doctor is low in all study areas, men have better access to health care by a doctor (0.033* Table 2). Access to urban markets and information on how to use innovations and prices are significantly more limited for women compared to men (0.000* Table 2). Interviews also reveal that women are usually limited to small local markets, rather than large markets situated further from their homes and women’s involvement in social networks is constrained by time-consuming household chores.

Table 3 Descriptive data on attributed livelihood changes women versus men CA and SSIS users

Variables	WUMHHs		MUs	
	Yes	No	Yes	No
Does CA improve access to food	76.9	23.1	90	10
Do SSIS improve access to food	91.2	8.8	96.8	3.2
Does CA improve ability to afford healthcare	7.7	92.3	30	70
Do SSIS increases ability to afford healthcare	26.9	73.1	56.5	43.5
If CA increases access to education	1.9	98.1	10	90
If SSIS increases access to education	6	94	9.7	90.3
If CA raises financial capital	11.5	88.5	23.3	76.7
If SSIS raises financial capital	50.3	49.7	91.9	8.1
If CA increases ownership of physical capital? (house, cattle, etc.)	11.5	88.5	13.3	86.7
If SSIS increases ownership of physical capitals?	28.1	71.9	80.6	19.4
If CA enhances social capital? (Being listened by the society, participation in traditional community meetings, local social networks etc.).	0	100	0	100
If SSIS enhances social capital (Being listened by the society, participation in traditional community meetings, local social networks etc.).	0	100	17.7	82.3

Women users in male-headed households (WUMHHs), Men users (MUs), Numbers are percent, Women CA users=52, Men CA users=30, Women SSIS users=171, Men SSIS users=62 $N=315$

Table 4 Livelihood capitals improvements attributed to the use of CA. Men versus women

Variables	WUMHHs			MUs			p-value
	Mean	SD	SE mean	Mean	SD	SE mean	
Access to food	1.23	0.42	0.05	01.10	0.30	0.05	0.111
Social capital	2.00	0.00	0.00	1.96	1.18	0.03	0.326
Ownership of physical capital	1.86	0.32	0.04	1.86	0.34	0.06	0.817
Access to vocational and adult education	1.88	0.32	0.04	1.96	0.18	0.03	0.145
Financial capital	1.88	0.32	0.04	1.76	0.43	0.07	0.198
Ability to afford health care	1.92	0.26	0.03	1.70	0.46	0.08	0.007

Value=Dummy equals 1 if yes and 0 otherwise. Table has means. SD refers to standard deviations, SE is standard error. Test statistics are t-statistics for unequal variances. p-values refer to difference in responses between men and women CA users. Women users in male-headed households (WUMHHs)=52. Men users (MUs)=30. $N=82$. *** $p<0.001$, ** $p<0.01$, * $p<0.05$. Source Fieldwork

3.5 Changes in women CA users' human and social capitals

A significant difference was not identified between men and women CA users concerning access to food (Tables 3 and 4). Most women and men (76.9% and 90% respectively) responded that CA has improved access to food at the family level in relative terms compared to their earlier worse-off status during dry seasons, particularly, in the three years where El Nino caused drought. However, access to food within the household is determined by gender norms. FGD findings identified examples of gender norm-based explanations that restrict women's access to nutritious food, for example, "husbands must be served first,"

“women are resistant to hunger,” and pregnant women are recommended not to eat nutritious food as “it may enlarge the baby in the womb and create labor complications.”

A difference was not identified between men and women as to whether the use of CA improves access to education (Table 4). The social capital of both women and men was not improved by CA. Men users indicated improved access to health care from the use of CA compared to women (Tables 3 and 4). – this is the only relative difference identified between men and women CA users in terms of whether the use of CA improves gendered livelihood capitals. Interviewed DAs said that the success of CA is limited, and it is not improving livelihood assets as much as expected. The lack of access to herbicides and other required inputs is the major problem indicated by interviewed DAs and women farmers. A meaningful change in women’s and men’s physical and financial capital has not been identified from CA (Tables 3 and 4), except that CA improves men farmers ability to afford health care (0.007** Table 4). Gender or patriarchal norms determine who sells what including women and men’s involvement in the sale of livestock and crops. Women are not counted as owners of livestock and are not primary decision-makers on the sale and purchase of livestock. Women often sell items that have little economic value, while men sell items for higher returns.

A woman CA user reflected on who sells what, as follows: “*I am selling only butter, milk, chicken, and coffee and it is prohibited for a woman to sell cattle if her husband is alive* (Women, 42 years age, *Locabaya*). Another woman CA user reflected on who sells what as follows: “*I decide on the sale of butter, eggs, hens, and small kilos of women’s coffee [coffee residue women collect from a coffee tree after men take the first batch of coffee]*. Another woman CA user states that “*After he leaves some maize in the storage, he sells all the rest. He is also the one selling cattle. In our society, a woman has no right to sell cattle, if she does, she is considered as unethical, and people would say, she won over her husband, which is a serious taboo.*” (Women, 30 years age, *Locabaya*). Patriarchal ideologies shape gender norms and restrict what women and men may and may not sell. A woman CA user commented: “*It is he who is providing money for the household. I do not ask him how much he gets from the sale of products. What choice do I have then? I must feed my children.*” (Women, 35 years age, *Locabaya*). These contextual realities and experiences of women limit their control over production assets or capital needed to improve physical and financial capitals through CA innovations.

3.6 Changes in women SSIS users’ human and social capitals

Most women and men (91.2% and 96.8%) responded that SSIS improves access to food (Tables 3 and 5). Men’s response on improved access to food owing to SSIS is better compared to women (Tables 3 and 5). In-depth interviews and FGDs prove that the income source for buying food is mainly from SSIS, which enables farmers to sell vegetables and buy other foods. Interviews and FGDs confirm that gender norms guide access to food within the household (as is the case with CA users). Women are culturally expected to serve the husband and other household members first. Men indicated improved access to health care owing to SSIS compared to women (0.000 *** Table 5). The use of SSIS has improved men’s social capital (social networks and social supports) (0.001 *** Table 5), unlike for women farmers. The education status of both men and women was not improved owing to the use of SSIS (Tables 3 and 5).

Table 5 Livelihood capitals improvements attributed to the use of SSIS. Men versus women

Variables	WUMHHs			MUs			p-value
	Mean	SD	SE	Mean	SD	SE	
Access to food	1.08	0.28	0.02	1.03	0.17	0.02	0.079
Social capital	2.00	0.00	0.00	1.82	0.38	0.04	0.001
Ownership to physical capital	1.71	0.45	0.03	1.16	0.41	0.05	0.000
Access to vocational or adult education	1.99	0.76	0.00	1.91	0.27	0.03	0.038
Financial capital	1.49	0.50	0.03	1.08	0.27	0.03	0.000
Ability to afford health care	1.70	0.48	0.03	1.40	0.52	0.06	0.000

Value=Dummy equals 1 if yes and 0 otherwise. Table has means. SD refers to standard deviations, SE is standard error. Test statistics are t-statistics for unequal variances. p-values refer to difference in responses between men and women CA users. Women users in male-headed households (WUMHHs)=171. Men users (MUs)=62. $N=233$. *** $p<0.001$, ** $p<0.01$, * $p<0.05$. Source Fieldwork

3.7 Changes in women SSIS users physical and financial capitals

Men SSIS users indicated improvement in their physical capital compared to women (0.000*** Table 5). Interviewed women explained that SSIS has enabled families to buy motor pumps and build other houses. However, motor pumps are men's property and women have limited decision-making power or agency on the use of motor pumps which could further affect their control over production outcomes. Men users indicated that they have improved their financial capital due to the use of SSIS compared to women (0.000*** Table 5). Interview results show that men are the main sellers of production, and they control the income from the sale of vegetables; women often collect leftover vegetables to sell or use within the household. Interviewed women explained that since men bring the land from their inheritance, they have the right to control and decide on the income from the sale of production. Many patriarchal explanations are used as a pretext to deny women's rights to developing financial capital. A gravity-based woman SSIS user said: "It is believed that husbands are better at controlling family income and women waste money." (Women, 50 years of age, Halaba).

4 Discussion

In this study, we have investigated the effects of CSA innovations on Ethiopian women smallholders' livelihoods in three study contexts. Although the primary aim of CSA is indiscriminately enhancing positive changes in smallholders' household food security and livelihoods, findings identified that there are differentiated outcomes in livelihood changes between men and women CSA users. We found that despite women and men share similar climate related vulnerability contexts such as drought and irrigated water scarcity, women users face problems emanated from patriarchal norms and intersectional contextual factors. It is identified that women's limited access to and control over resources, which is primarily produced by unequal gender power relations limit success in women smallholders livelihood capitals which is similar with a finding by (Tsige, 2019). We identified that women smallholders have limited access to credit, collateral, agricultural extension, skills trainings, and membership in cooperatives, compared to men and these findings are similar with many earlier studies (Aregu et al., 2010; Buchy & Basaznew, 2005; Cohen & Lemma, 2011;

Fafchamps & Quisumbing, 2005b; Ragasa et al., 2013; Tsige et al., 2020). These findings prove that livelihood improving structures and processes placed women as subordinate, and women smallholders have limited access to agriculture-related institutional services. All our findings confirm that assets needed to improve people's livelihood capitals and the functioning of transforming institutions and structures explained in the SLF (DfID, 1999; Scoones, 1998) are lower for women compared to men CSA users. Findings in this study further supported that deprivation of elementary capitals inevitability results in livelihood insecurity (Sen, 1981, 1999).

In this study, we have also confirmed what has been conceptualized in postmodern feminism and the theory of intersectionality that is women's economic success is shaped by their multiple identities, contextual realities, and experiences within the social structures they are living (Bryson, 2016; Cho et al., 2013). Our findings show that improvement in women's livelihood capitals is constrained by their gender identity that functions in accordance with patriarchal norms, their married status, gender norms that keep producing women's limited access to and control over productive resources, their age, education status, their exclusion from rural institutional services. All these findings confirm feminists' intersectionality theorizations.

This study identified intra-household inequalities in accessing agricultural land which is similar with other studies (Fafchamps & Quisumbing, 2005a; Holmes & Jones, 2013; Tsige, 2019). Customary law allows husbands to inherit land from their fathers all over Ethiopia but mainly in the southern section of Ethiopia. The fact that women join the husband's family without bringing inherited land affects their decision-making ability on the land certificate for accessing credit and financial institutions demand land certificate as collateral to providing credit. Ethiopia had launched a land certification program in 2005 that aimed at enhancing tenure security among smallholders. At the national level, 38.8% of the land is registered on the land certificate in the name of the husband, 51.86% in the names of both, and only 11.2% is in the name of a wife or unmarried woman (Makki, 2012). Our finding shows that this joint land registration action does not improve women's decision making power over agricultural land. It is only through the consent of the husband that women could use land certificate as collateral primarily due to customary patriarchal norms that practically guide the use of agricultural land. Women's limited access to credit, caused by their limited control over agricultural land, thereby limits their ability to buy agricultural inputs needed for the successful use of agricultural innovations.

Although an enhanced off-farm economy would broaden the ability to afford agricultural inputs for using innovations (Maindi et al., 2020), we found that off-farm income is almost absent in study areas. Farmers only have access to a small (-prearranged) amount of credit from rural financial institutions and these institutions do not often provide credit for women unless they obtain the consent of the husband which is a similar finding with a study by (Alemu et al., 2022). Restricted access to rural institutional services and access to urban markets by women users have been investigated and these findings are similar with a study by (Tsige et al., 2020) and these all are structural restraints that limit women's ability to improve and transform their livelihoods through agricultural innovations.

The use of CA does not improve physical and financial capital neither for men nor for women. It does not significantly increase production that could enable increased income and the purchase of physical assets. On few occasions where farmers sell produce, gender norms dictate that women sell items with small and men with better returns as the head of

the household is the main decision maker over financial and physical capitals. This is a similar finding with an earlier study by (Fafchamps & Quisumbing, 2002). Therefore, the limited rights of women in controlling physical and financial capitals inhibit them from improving these capitals through CA. This study also finds that the household head sells production outcomes from the use of SSIS and controls the financial returns from the sale of vegetable production, which is a similar finding with, (Tsige, 2019) and motor pumps are owned by men, meaning that they have more rights to operate motor pumps and these gendered problems resulted into the limited improvement of physical and financial capitals of women SSIS users.

Although some agricultural projects improve women's livelihoods by improving women's control over physical assets such as cattle, goats, and poultry in Africa and South Asia (Johnson et al., 2016), we found a contrary result in Ethiopia except that CSA improves access to food, compared to smallholders' earlier status. A study by Belachew et al. (2011) in south-west Ethiopia shows that female household members are more food-insecure than other household members. Same study similarly found that access to food is culturally determined as women are prohibited from eating nutritious food within male headed households which thereby limits improvement in women's human capital. In a feminist food sovereignty analysis, Sachs (2013) asserts that it is less likely that women in developing economies have equitable access to food within the same household. CA does not improve women's access to health care, while men users show better ability to afford health care owing to the use of CA. Men SSIS users' indicated improvement in their access to health care as women have restricted control over financial capitals obtained from the sale of vegetables. These findings confirm those of Dercon and Krishnan (2000) who explained that women in the southern part of Ethiopia have less access to health care compared to men due to their limited control over household income. Education and social capitals did not improve for either men or women smallholders due to SSIS that illustrated the extent to which transforming structures and institutions are less functional in the study contexts.

5 Conclusions and policy implications

This study investigated whether CSA innovations improve or transform women smallholders' livelihoods by assuming improvement or transformation in four livelihood capitals (human, social, financial, and physical). Increased production is assumed as a pathway for the livelihoods change. Empirical data was obtained from the direct responses of men and women CSA users in male-headed households in three study areas in rural Ethiopia. The sustainable livelihoods and the intersectionality frameworks have been used to conceptualize and analyze changes in men and women CSA users' livelihoods as individual farmers.

Findings confirm that women users of CA and SSIS in male-headed households have insufficient access to and control over basic livelihood capitals and thus despite labor contribution, their access to income, health care, education, and social capitals have not been improved due to their CSA user status. CA was not found influential in improving rural livelihoods either for women or men except that it improved farmers' access to food only in relative terms compared to their earlier status. SSIS improves men users' financial and physical capital, compared to women farmers as men are primarily controlling production outcomes.

Improvement or transformation in women smallholders' livelihoods through CSA innovations has been limited by intersectional barriers that includes women smallholders gender identity that forces them to operate in line with restrictive patriarchal norms, gender norms that are producing women's limited access to and control over productive resources, women's married status and their age, their educational status, and women smallholders' exclusion from rural institutional services. This study provides empirical evidence for those managing agricultural innovations and recommends that existing and new innovations need to be designed and implemented in ways that transform women smallholders' livelihoods by considering and implementing the following policy implications.

- To enable gendered livelihoods transformation, rural institutions that are expected to work as “transforming” structures must identify and address contextual gendered and other intersectional challenges that limit transformation in women's livelihoods among innovation users.
- Since any development scheme should be designed by considering the question of how to equitably benefit its participants, agricultural interventions should identify and address women smallholders locally specific needs in their planning, implementation, monitoring, and evaluation processes.
- Collecting reliable periodic intra-household data on the livelihood status of individual men and women is an essential strategy to identify and address both practical and strategic gender needs.
- Rural institutions and projects working to improve rural livelihoods should assist women to become involved in off-farm income-generating activities as this is useful to build their productive and adaptive abilities in using agricultural technologies. Specifically, the income from off-farm income generating activities by women smallholders can strengthen women's ability to buy agricultural inputs for using innovations in a way they can transform gendered livelihoods.
- Changing the land ownership law that currently makes land the state property in Ethiopia would improve expansion of off-farm income-generating activities and development of small scale manufacturings where women smallholders can be involved and improve or transform their production assets.
- Enlarging the operational scale of agricultural innovations for sustainable and gender equitable implementations can help to address strategic gender needs such as eradicating gender norms and other contextual persistent intersectional problems that are limiting women smallholders' control over livelihood capitals and transformations in their gendered livelihoods.
- There should be a collective understanding and allied actions among all institutions working for rural livelihoods that is improving or transforming women smallholders' livelihoods demand positive changes on gender norms and intersectional factors at multiple levels in various social, economic, and political conceptualizations that are entrenched in different institutions, structures, and policies.
- Women smallholders restricted access to and control over resources, unequal gender role distribution within households, their limited decision-making power over production capitals and outcomes, their limited involvement in social and economic institutions, their absence from policies and policy implementation processes should be addressed through executing a gender transformative approach (GTA) when implement-

ing agricultural innovations. This is because GTA executes activities and methods that transform unequal gender power relations, intersectional and contextual barriers and unfavourable structures (Hillenbrand et al., 2015) through exploring, identifying and transforming the root causes of gender inequalities embedded in norms, structures, policies and institutions using different contextual methodologies (FAO, IFAD, & WFP, 2022).

- Since improvement or transformation in women smallholders' livelihoods is primarily hindered by the lack of a suitable approach that considers the diverse experiences and needs of smallholder women CSA users, a GTA framework should be designed by considering and addressing context-specific intersectional factors when implementing future CSA innovations.

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Data availability Data is available.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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