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RESEARCH

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Do gender disparities in socioeconomic status affect *Teff* productivity? A comparative analysis in Ethiopia

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Abstract

Ethiopia is one of Africa's fastest-growing economies, and the recent political and economic reforms recognize the importance of empowering women and increasing their labour force participation. The Federal Democratic Republic of Ethiopia (FDRE) constitution of 1995 recognized women's right to equality and provides intervened to enable women to compete and participate in all spheres of life and to exercise their rights on equal grounds with men. Gender empowerment and gender equality are given national priority and positioned at the centre of all policy, legal, and institutional frameworks. Research suggests that women remain overrepresented in lower-skilled jobs, while carrying out the bulk of unpaid care work. Women also face multiple forms of deprivation, gender-based discrimination, lack of access to productive resources, intimate partner violence, lack of education and training, and employment. Persistent inequalities in ownership and control over assets, such as land, houses, and oxen negatively affect their productivity and livelihoods. This paper aims at answering the question "Do gender disparities in socioeconomic status affect *Teff* productivity in Ethiopia?" Using mixed methods, the study conducted a cross-sectional household survey. Purposive sampling was used to select top *Teff*-producing regions, districts, *Kebeles*, key informants and FGD participants while a random sampling method was used to select the survey respondents. Results suggest that, although women were fully engaged in *Teff* production activities, due to a low level of ownership of productive resources such as land, labour, and oxen, there is a statistically significant difference in *Teff* production between female and male-headed households which needs the attention of the government and stakeholders. The paper contributes to understanding how gender-based disparities in socioeconomic status affect *Teff* production.

Keywords Ethiopia, Women, Teff production, Land, Labour, Oxen, Assets

Introduction

Teff (Eragrostis teff) is a cereal crop essential in the agricultural and food economy of Ethiopia. The crop has both its origin and diversity in Ethiopia, and plays a vital role in the country's overall food security but national yield levels are low (Kebebew et al. 2011). According to Getu et al. (2017), *Teff* was grown by 43 per cent of all Ethiopian farmers out of which 11 percent represent female-headed households. It is the dominant cereal crop in 83 high-potential agricultural districts, covering the highest area planted in the country. Similarly, the report of Demeke and Di Marcantonio (2013) indicated that *Teff* accounted for the largest share of the cultivated area (28.5%) in 2011.

The Central Statistics Agency (CSA 2017/18) reported that about 6.7 million smallholder farmers were engaged in *Teff* production in the 2017/18 harvest period covering

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more than 3 million ha of land and producing 52.8 million quintals of *Teff* crops. The compiled statistical report of the Central Statistical Agency (CSA) also indicates that the number of *Teff* producers increased from 5,177,125 in 2005/06 to 6,771,977 in 2017/18 with an average growth rate of 10.90% per annum. Yet, compared to the other major cereals, *Teff* yield is relatively low as 25–30% of each pre-harvest and post-harvest losses reduce the quantity available to consumers (Cannarozzi et al. 2014; Girma et al. 2014). On the consumption side, *Teff* is a daily staple food crop for more than 50 million Ethiopians (CSA 2018; Demeke and Di Marcantonio 2013, 2019; Mottaleb and Rahut 2018).

Recent studies (Assefa et al. 2022), focused on determinants of productivity and efficiency of *Teff* production while Abebe et al. (2022) assessed the factors associated with the socioeconomic status of the household. Mihiret and Tadesse (2014) also reviewed gender participation and the decision-making process of farming activities and Chalachew and Mulunesh (2020) assessed the agricultural extension training and women's participation in Ethiopia. Other studies (Markew and Mesele 2022) focused on gender differences in the adoption of agricultural technology while Pender and Gebremedhin (2007) paid attention to the determinants of agricultural and land management practices and impacts on crop production and household income. The studies focused on the productivity and efficiency of *Teff* production, socioeconomic status of the households, gender participation in decision making decision-making processes of farming activities, the adoption of technology, agricultural and land management practices and impacts on crop production and other similar issues. These researchers did not assess gender-based socioeconomic disparities in relation to *Teff* production. The objective of this paper is to answer the question "How do gender disparities in socioeconomic status affect *Teff* productivity in Ethiopia?" The paper systematically examines household-level *Teff* productivity differentials among male and female-headed households in Ethiopia which is characterized by smallholder agriculture.

This paper is divided into various sections. The paper begins with the background and methodology and then presents the findings from the analysis of *Teff* production in Ethiopia. The discussion compares the findings of our analysis against previous studies and draws out the lessons for policy and *Teff* production. The conclusion is a recapitulation of the key ideas emerging from this paper.

Literature review

The agricultural sector remains critical to local and regional economies across sub-Saharan Africa and it is the base for food security and an important source of employment, particularly for women. As agricultural gender inequalities remain strong, women farmers are particularly at risk of hunger, especially when crisis strikes (UN Women 2019). On average, rural women account for nearly half the agricultural workforce in developing countries. Despite their crucial roles in household food security, they face discrimination and limited bargaining power (Oxfam 2019). Yet, studies consistently find that female farmers have lower rates of agricultural productivity than male farmers (UN Women 2019). Patriarchal norms create disadvantages for women farmers, specifically in land rights (small plots, difficulties attaining ownership, discriminatory inheritance rights), productive resources (no access to credit, extension services or inputs), unpaid labour, insecure employment and exclusion from decision making and political representation (Oxfam 2019). In this regard, Mihiret and Tadesse (2014) highlighted that most rural women in Ethiopia did not have any role in decision-making with regard to the purchase or sale of farming implements, land preparation and determination of type and amount of chemicals (pesticides, herbicides) used.

Research undertaken in five countries (Ethiopia, Malawi, Rwanda, Uganda and the United Republic of Tanzania) shows that women are less efficient farmers as they experience inequitable access to agricultural inputs, including family labour, high-yield crops, pesticides and fertilizer (MoANR 2018). It also indicates that gender gaps in agricultural productivity are considerable, ranging from almost 11 per cent in Ethiopia to 28 per cent in Malawi. Studies using comparable methods have generated similar findings for other countries with gender gaps in agricultural productivity, ranging from 8 per cent in Kenya to more than 30 per cent in Nigeria (MoANR 2018). Similarly, Aguilar et al. (2015) argued that the gap in agricultural productivity between plots managed by men and women varies across countries and crops, but ranges from 4 to 25% when measured as the value of agricultural production per hectare across Sub-Saharan Africa. According to a policy brief by UN Women (2019), the gender gap in farm crop productivity in Ethiopia in 2015–2016 was 9.8 percent. This means that a female-managed farm plot was on average 9.8 percent less productive than a male-managed farm plot in Ethiopia. According to the UN Women Ethiopia country office, this gap is not caused by women being poorer managers of their farms, but because women have fewer resources and earn less from their resources than men who manage plots (UN Women Ethiopia Country Office 2018). The most important drivers of the gender gap in agricultural productivity in Ethiopia are the lack of household male labour, limited access to extension services, and lower use of improved seeds and fertilizers (UN Women 2019).

Women make essential contributions to the agricultural and rural economy in Ethiopia. The Federal Democratic Republic of Ethiopia (FDRE) constitution of 1995 recognized women's right to equality and intervened to empower women to compete and participate in all spheres of life as well as exercise their democratic and human rights just as men (FDRE 2019). Women participate in crops and livestock farming, food preparation, working for wages in agricultural or other rural enterprises, collecting fuel and water, engaging in trade and marketing, caring for family members and maintaining their homes (Barrett 2008; Haileselassie et al. 2011). However, as per the research output of some scholars such as Agada and Ajani (2014), argue that the underperformance of the agricultural sector is due to the severe constraints that reduce their productivity compared to men in accessing productive resources crucial in agriculture and the rural economy.

In Ethiopia, demographic factors such as family size, sociocultural circumstances, religion, level of education, age, marital status, gender, and occupation affect the economic activities (Fatima 2009). Mihiret and Tadesse (2014) show that rural women participate in critical farming activities including weeding, seed preparation, selling agricultural commodities, and harvesting. The level of their participation is limited to ploughing farmland, spreading chemicals, and crop protection activities (Mihiret and Tadesse 2014). Mulema et al. (2016) found that in comparison to men, women farmers in Ethiopia were disadvantaged because they had limited access to productive assets including irrigation water, credit, extension services, and female rural institutions which constrained their adoption of innovations. Rural women's participation in farm management decision-making was minimal. Lack of experience, illiteracy, assumptions about the role of rural women in agriculture, shortage of technical knowledge/skills, and limited extension service affected the participation of rural women in the decision-making process (Mihiret and Tadesse 2014). Chalachew and Mulunesh (2020) also found that illiteracy, poor mainstreaming of gender in the agricultural sector and priority to widowed or divorced women farmers are important factors contributing to the low participation of women farmers in the training services provided by the district. Gender disparities in farmers' productivity due to labour, resource endowment, access to information (extension) and cultural taboo constraints was discovered (Pender and Gebremedhin 2007). UN Women's country office also highlighted that about 66 per cent of gender gap is explained by gender-based differences in access to productive inputs (UN Women Ethiopia Country Office 2018). In other words, in many instances' females had lower levels of the inputs needed to undertake farming on their plots; which is explained by the lower use of pesticides, herbicides, or fungicides, the lower use of household male labour, the higher use of exchange labour, and the higher use of organic fertilizer (UN Women Ethiopia Country Office 2018). The main drivers of gender differences in returns to factors of production are the lower use of non-labour inputs, and in particular fertilizer, the higher size of households, and the higher dependency ratio, which is the numbers of non-working and elderly as a ratio of the numbers of working-age adults in the household (UN Women Ethiopia Country Office 2018). Gender differentials in the use of pesticides and fertilizer are particularly large in Ethiopia, explaining 45 per cent and 25 per cent of the total agricultural productivity gap, respectively (UN Women 2019).

In *Teff* production, researchers such as Agada and Ajani (2014) and Amentae et al. (2016) argued that male-headed households tend to have more man-hours available for *Teff* harvesting and other farming activities compared to their female counterparts who have additional tasks and household responsibilities that reduce their available time. Biologically, female farmers are not physically as strong as male farmers. In this regard, Keller and Mbewe (1991); Mussema (2006) argued that the positive contribution of females to agricultural policy needs to provide women with equal access to resources, technology, credit, and other facilities. Research outputs of Nehru and Dhareshwar (1994) also indicate that the proportion of female-headed households ranked as 'very poor' was higher than that of male-headed households. Moreover, in a study of post-harvest losses for *Teff* crops, female farmers were found to be more prone to high levels of losses than their male counterparts since *Teff* is labour-intensive (Minten et al. 2016). Gender disparities disadvantaged women in economic and access to basic services and are among the most food insecure groups in society (Cagatay 1998).

Various economic, cultural and social factors that contribute to the gender gap in *Teff* production in Ethiopia. Women in Ethiopia have limited access to resources such as land, credit, and training, which are essential for agricultural productivity. Traditional gender roles and expectations limit women's participation in decision-making in agriculture. This can lead to a lack of representation and influence for women in farming, further perpetuating the gender gap in *Teff* production.

Research methodology

A cross-sectional survey, with a mixed approach considering both qualitative and quantitative research methods has been used in this study. Cross-sectional research is a research approach in which the researcher investigates the situation in a population at a certain point in time.

The sampling design that matched the selected research approach was multi-stage sampling whereby both purposive (non-probability sampling) and random sampling methods were used. The purposive sampling method has been used to select top *Teff*-producing regions, districts, *Kebeles*, sub-*Kebeles*, key informants and FGD participants while the random sampling method was used to select survey respondents. Primary data were collected from multiple sources using different tools. The data collection tools used in this study include a literature /documentation review, structured questionnaire survey, focus group discussions and key informant interviews. A total of 332 survey respondents, 84 FGD participants and 25 key informants were involved in the study. The collected data were analysed both qualitatively and quantitatively. The details of the study methodology are presented hereunder.

Sampling

The unit of analysis of this study is rural heads of households who are engaged in *Teff* production in 2017/18. In the selection of rural household respondents, a multistage sampling technique was used. The regional states, districts, *Kebeles*, and sub-*Kebeles* were purposively selected. The potential *Teff* production regions at national level, information in relation to the average *Teff* cultivated area, *Teff* production by regions, average production per hectare and percentage of regional contribution to national *Teff* production were used to select the study areas. Oromiya and Amhara regional states were among the top *Teff* producer regions and suppliers to the local markets (CSA 2015). SNNPR (Southern Nation and Nationalities and Peoples Region) and Tigrai regional states were selected as having potential for *Teff* production (Gideon 2016).

In phase 2, districts were purposively selected. Lomie district was purposively selected from the East Showa zone of Oromiya regional state as it is ranked 1st in *Teff* production at Oromiya regional state as well as at the national level. Minjar Shenkora district is purposively selected from the North Shewa zone of the Amhara regional state as it is ranked 4th in *Teff* production from the Amhara region and 7th in *Teff* production at the national level. The two districts are among the seven top *Teff*-producing districts at the national level (Warner et al. 2019). Furthermore, the Halaba zone (SNNPR regional state) and Tahtai Maichew district (Tigrai regional state) were purposively selected as the top *Teff* producer districts in their respective regions (CSA 2015).

Thirdly, two *Teff*-producing *Kebeles* were purposively selected from the four districts in consultation with the Office of Agriculture and Rural Development at the district level. A total of eight *Kebeles* were purposively selected for the study at hand. In this regard, Deke Bora and Tulu Re'ee *Kebeles* were purposively selected from Lomie district, Agirat and Bolo Silassie *Kebeles* were purposively selected from Minjar Shenkora district, Andegna Hansha and Guba *Kebeles* were purposively selected from Halaba zone and Kewanit and May Brazio *Kebeles* were purposively selected from Tahtai Maichew district. The main criteria for selecting the two *Kebeles* from each district were potentially *Teff*-producing area, geographically convenient to conduct surveys, easy to find representative people from *Teff* producers and easy access to transport facilities (Fig. 1).

Sample size

Factors like available time and financial resources, discussions with stakeholders involved in *Teff* industry in Ethiopia, and the sample sizes of similar studies conducted earlier were considered in deciding upon the sample size. Likewise, determining the sample size for a survey hinge on factors like the level of precision required, the level of risk allowed, and the degree of variability in the attributes being measured. A 95% confidence level and ± 5% precision as applied by Cochrane in determining the size of the sample was applied (Cochrane 2007). For large populations, Cochrane developed a mathematical equation that yields a representative sample for proportions. The equation is:

$$n = \left(\frac{t}{d}\right)^2 p(1-p)$$

where, n = sample size,

- t = values of standard variant at 95% confidence interval (t = 1.96),
- p = the estimated proportion of an attribute that is present in the population (e.g., 35%) and,
- d = acceptable margin of error for proportion being estimated = 0.05

The Cochrane formula was considered as the most conservative estimate because it is associated with the largest sample size. Applying a sample size determination equation of Cochrane (2007) mentioned above and including a 5% reserve for non-response rate, a total of 368 sample households were chosen using systematic random sampling from the eight sub-*Kebeles*. In terms of female-headed households, though there is a difference among regions, the 2018 national percentage of 25% was considered during sample selection (RST 2018).

In identifying the potential survey respondent, a list of 1073 heads of households (268 female-headed households and 805 male-headed households as sample frame)

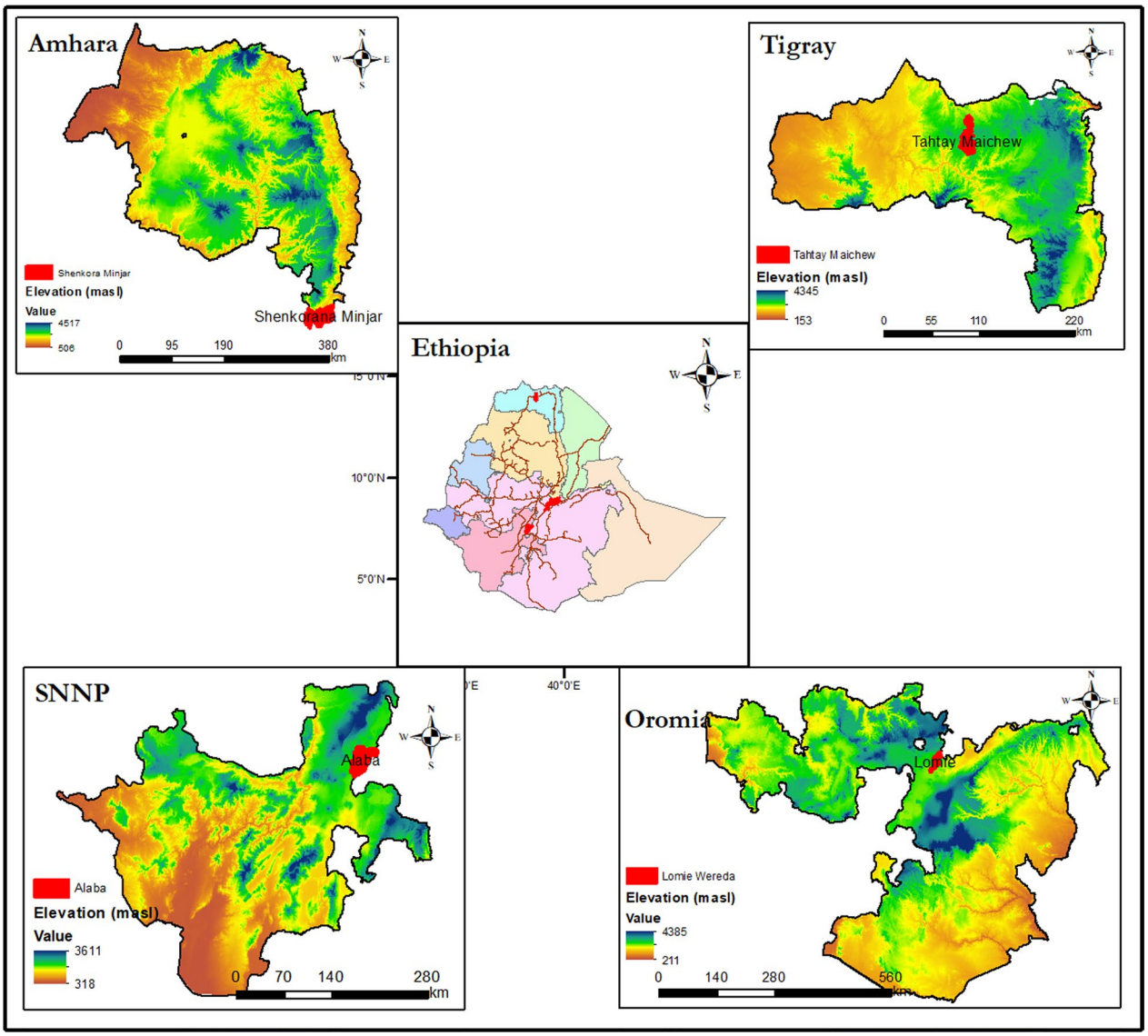

Fig. 1 Administrative map of Ethiopia and study sites. Mekelle University, GIS section, 2019

who were engaged in *Teff* production in 2017/18 and residing in the purposively selected eight *Kebeles.* The list of the sample frames was obtained from respective extension agents. Based on the planned sample size, a total of 368 (92 female-headed households and 276 male-headed households) were identified from the sample frame using systematic random sampling methods. During data collection, about 11 sample respondents were not interested in being a part of the survey and 5 respondents were not found by data collectors and thus a total of 16 respondents were replaced using systematic random sampling. After pre-testing, a survey was conducted and data were collected from a total of 368 (46 respondents from each *Kebele*) respondents. Data collection took place from August 2018 to October 2018. Due to the large sample size and time constraints, the survey was conducted with the help of trained enumerators. Five enumerators were selected, and they were trained and informed about the scope of the study, ethical issues and the importance of data collection before the survey. During data collection, a supervisor accompanied the enumerators in the field to both supervise and take part in the survey process.

Survey respondents were informed (informed consent) that they have the right to privacy, anonymity, confidentiality, voluntary participation, and the right to withdraw to ensure ethical standards (Madey 1982). The completed questionnaires were examined on the same day and those with incomplete responses or missing values

were discarded. In this regard, about 36 questionnaires were found to be incomplete and thus rejected indicating a 90.22% success rate in data collection from the survey. Only questionnaires with all responses completed were retained for data analysis, and thus a total of randomly selected 332 respondents (76 female and 256 male-headed households) were considered for the survey. Moreover, about 84 FGD participants and 25 key informants were purposively selected during the survey.

Data collection methods

The data collection tools used in this study are desk review of relevant documents, focus group discussion, key informant interview and survey.

Review of documents, focus group discussion and key informant interview

Relevant documents were reviewed to determine the national level and regional level data in relation to the involvement of smallholder farmers, farmland allocated for *Teff* production in ha and average *Teff* production per year by regions. Scholarly articles and previous worldwide studies were also assessed and reviewed. These documents were analysed to assess and develop the literature in areas for *Teff* production and the role of women in agriculture. To gain insights into the role of women and men in *Teff* production, open-ended questions were prepared for the focus group discussion and key informant interviews.

About eight focus group discussions were organised in eight *Kebeles* involving 84 participants (68 *Teff* producers, 7 Kebele administrators and 9 development agents) in four districts from August 2018 to October 2018. Four focus groups involved solely female-headed participants while four groups were male-headed participants. The reason for organizing homogeneous female focus groups was to ensure active discussions, as people from the same socio-economic backgrounds tend to freely express and share their ideas, perceptions, and experiences. Most of the participants in these focus groups also knew each other and this prompted free participation in the discussions. These discussions aimed at gaining insights into the role of women and men in *Teff* production, including their concerns associated with *Teff* production. Moreover, in-depth interviews were conducted with 25 key informants. After seeking prior consent, 23 of the interviews were electronically recorded but for 2 interviews notes were taken by the study team. Each interview on average took about 25 min. To ensure ethical standards, FGD participants and key informants were informed that they have the right to privacy, anonymity, confidentiality, voluntary participation, and the right to withdraw (Madey 1982).

Survey

A survey was undertaken to collect data in relation to *Teff* production from respondents. In this regard, data were collected from a total of randomly selected 332 respondents (76 female-headed respondents and 256 male-headed respondents). Proper data cleaning and editing activities were also undertaken to ensure the validity of the data.

Data analysis

Descriptive statistics

Descriptive statistics such as percentages, means, standard deviations and t-test were employed to analyse survey data. In this regard, t-test (mean difference) were mainly used to see whether there is statistically verifiable difference among the variables affecting *Teff* production in relation to female-headed and male-headed *Teff* producers. Moreover, a Pearson correlation (r) was used to measure the linear association between the dependent and independent variables. In the process of examining and describing factors affecting *Teff* production and farm household characteristics of the respondents, STATA 13 software was used to analyse the quantitative data.

Econometric model

To accurately measure the difference of *Teff* productivity between male-headed households and female-headed households, farmers should be randomly assigned so that the effect of observable and unobservable characteristics is the same, and the effect is attributable entirely to gender difference. In non-experimental research with survey data, the propensity score matching (PSM) method has been widely applied to address the issue of selection bias. In this regard, the econometric model used in the study is linear regression with endogenous treatment (Carletto et al. 2013). The estimation of endogenous treatment effects is a common feature of empirical work in economics (Verbeek and Vella 1999). In this regard, we employed the treatment effects model (TEM) that allows for a specific correlation structure between the unobservable that affect the treatment and the unobservable that affect the potential outcomes.

The variables most commonly used to explain *Teff* production are related to the different forms of socioeconomic and farm characteristics. Despite the versatility of the variables, a baseline prototype measurement (though not exhaustive) believed to influence the dependent variables (*Teff* production) is taken into consideration as indicated in Table 2. In this regard, we want to measure the effect of socioeconomic variables on *Teff* production. We model *Teff* production as being determined by land ownership and cultivation, oxen ownership, investment

Table 1 Gender roles in *Teff* production by district

Districts	Role of men	Role of women
Tahtai Maichew	• Land preparation including the application of fertilizers and chemicals • Ploughing, • Sowing, • Weeding, • Harvesting, and • Threshing	• Prepare the *Teff* seeds for planting • Clearing and uprooting the remains of the previous crop • Highly engaged in breaking the bars of soil into finer pieces and removing stones to make the land suitable for the seed to grow • Weeding of *Teff* crop, and • Food preparation
Minjar Shenkora district	• Ploughing: tiles the land over and over up to four to five times to make the land very fine • Harvesting • Threshing (separating the hay from the grain)	• Weeding in the field • At the time of harvest, the women prepare food at home and take it to the men who are harvesting in the field. The women also brew *Tella* • Work on milling the *Teff* crop and engage in the whole process of baking *Injera* to feed the family
Lomie	• The main agricultural activities are done by men. These include ploughing the land, sowing, and partially participating in weeding, harvesting and threshing	• Women clean the *Teff* seed before sowing • Highly involved in the weeding activities • Preparing the land for threshing and participating in transporting and threshing the product • Store the *Teff* crop at home, get the product milled by taking the product to milling plants and then bake it into *Injera* by mixing it with other crops
Halaba zone	• Men do all the fieldwork activities including land preparation, weeding, harvesting, threshing, and transporting the product to home	• Women mainly do the food preparation and participate in weeding activities but also participate in land preparation and collection of the harvested crops

Sources: Compiled from FGD and KII, fieldwork

in inputs, investment in labour and other socioeconomic variables such as age, family size, active labour force, dependents, and education (Mesfin et al. 2022). A model with 13 independent variables were used for model specification. In the classical regression model, each estimate gives the partial effect of a coefficient with the effects of other X variables being controlled (Gebrehiwot, Azadi et al. 2018).

$$\begin{aligned} Y =& \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \\ &+ \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 \\ &+ \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} \\ &+ \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + \mathrm{u} \end{aligned}$$

Y = *Teff* production in kg (dependent variable)

α = Intercept(constant)

$\beta_{1\text{-}13}$ = a vector of estimated coefficient of the explanatory variables (regression coefficients).

$X_{1\text{-}13}$ = a vector of explanatory variables (the list of the independent variables is indicated in Table 2).

u = disturbance term.

Thematic content analysis

Thematic content analysis as developed by Creswell (1999) was also applied to analyse the qualitative data collected from farmers' focus group discussions and in-depth interviews with participants. This technique was used as it is helpful in summarizing data related to themes and contents and it involves the extraction of themes or categories from the data which enable us to explain the phenomena under investigation. Important themes relating to *Teff* production, were extracted. These ultimately led to the development of options for improving the performance of *Teff* production for sustainable development in Ethiopia.

Results

Gender roles in *Teff* production

Discussions were held with FGD participants and key informants in relation to the different roles in *Teff* farming by taking gender as a variable. We have summarized the gender roles by study areas as indicated in Table 1.

In Table 1, the major agricultural activities such as ploughing the land, sowing, harvesting using sickle, threshing using oxen and transporting the products are done by men. The roles of women include land preparation, weeding and food preparation. However, there are some unique roles for women in each district. In Tahtai Maichew and Lomie districts, women prepare the *Teff* seed to be planted by avoiding unnecessary garbage and making the *Teff* seed clean before sowing. They are also involved in breaking the bars of soil into finer pieces suitable for the seed to grow, removing stones and cleaning and uprooting the remains of the previous crop on the land. In the Minjar Shenkora district, the women prepare food and brew *Tella,* a local drink, and for the men harvesting *Teff*. The women work on milling the *Teff* crop. In the Lomie district, women prepare the land for threshing

Table 2 Two-sample t-test with equal variances: Male vs. Female, (N = 332)

Variables	Description of the variables	Mean and standard deviation			t-test
		All (N)	Male	Female	
Age (X_1)	Age of household head (in years)	44.90 ± 12.42	44.75	45.68	0.5234
Family size (X_2)	Family size in the household including adults and children (in number)	5.23 ± 1.95	5.14	5.54	0.1217
Active labour force (X_3)	Economically active labour force (18–65 years) (in number)	2.17 ± 1.32	2.17	2.07	0.9536
Dependents (X_4)	Dependents per household (children less than 18 years & old persons above 65 years)	3.07 ± 1.42	2.98	3.38	0.0290*
Education (X_5)	Years of formal schooling of the household head (in years)	3.73 ± 4.43	3.48	4.55	0.0637
Quantity of oxen ownership (X_7)	Number of oxen owned by a household (in number)	1.97 ± 1.25	2.07	1.63	0.0072**
Cost of inputs (X_8)	Amount of investment for the purchase of inputs for *Teff* production per hectare (in Birr)	2845.47 ± 3059.82	3086.94	2032.10	0.0081**
Cost of labour (X_9)	Amount of investment for hiring labour for *Teff* production per ha (in Birr)	1499.95 ± 1792.35	1475.95	1580.79	0.6550
Extension (X_{10})	Frequency of contact of the household by extension workers per year	2.78 ± 1.52	2.78	2.78	0.4979
Farmer training days (X_{11})	Number of training days a household participated in training offered by extension agent	5.87 ± 0.21	6.38	4.17	0.0000**
Teff loan (X_{12})	Borrowed amount of money allocated for Teff production	394.28 ± 82.57	469.92	139.47	0.0464*
Total available land for cultivation in ha (X_{13})	Total available area of land per household in ha (it is the summation of land owned, rented land, share-cropped land, and inherited land)	1.40 ± 0.81	1.45	1.25	0.0605
Owned land in ha (X_{14})	Owned land in ha by the household	0.89 ± 0.72	0.94	0.71	0.0132*
Teff cultivated land in ha (X_{15})	Area of land allocated for *Teff* production in ha	0.77 ± 0.42	0.79	0.67	0.0242*
Teff production in kg per hectare (Y)	*Teff* output per hectare (kg/ha)	1098.77 ± 1213.85	1171.08	855.19	0.0462*

Sources: Fieldwork survey result, 2019

and transport the threshed product. They also store the *Teff* crop. In the Halaba zone, women are involved in the collection of harvested crops.

The responsibilities of men in *Teff* production include the purchase of improved seeds, tilling the land (four to five times) to make the soil (land) fine, applying fertilizer, planting *Teff,* applying chemical treatments to *Teff* crops to prevent weeds and pests. Men do weeding, harvesting using sickles, collecting the harvested product, transporting the harvested crops to threshing ground, threshing using oxen, transporting *Teff* crops and taking the *Teff* to milling plants for grinding.

The responsibilities of women in *Teff* production include preparing the *Teff* seed for planting, removing uprooted weeds during ploughing, breaking the bars of soil into finer pieces suitable for the seed to grow, removing stones from the field, preparing food and *Tella* (beverage traditionally made of barley) for the men who work in the fields. Women participated in weeding of *Teff* crops, collecting the harvested product, harvesting, preparing the land for threshing, preparing containers to store *Teff* crops, taking the *Teff* crops to milling plants, and food preparations (making dough and baking *Injera* for household consumption economically) and feeding their families. This finding is like previous research findings of Tegegne (2012) that state that women contribute about 46% of labour to agricultural activities and rural women spend their time in productive activities such as weeding, food processing, water and fuel wood collection, assisting family farms, marketing and labour exchange for community services. This result is also similar to the findings of FAO (2019) that state in peak cropping seasons, particularly during weeding and harvesting, women and men work together with other household members. Our result is also similar to the result of Mihiret and Tadesse (2014) that showed rural women regularly engaged and participated in critical farming activities including weeding, seed preparation, selling agricultural commodities, and harvesting.

Analysing *Teff* production variables by gender

This section presents a summary of statistical results from the attributes of *Teff* producers and *Teff* production. In this regard, descriptive statistics including comparisons of *Teff* production between female-headed

households and male-headed households were done in relation to the different socio-demographic characteristics of the respondents as described in Table 2.

In our assumption, male-headed households are expected to have better ownership of productive resources and thus they produce more *Teff* crops as compared to female-headed households. From a total of 332 survey respondents who were engaged in *Teff* production in 2017/18, about 256 (77.11%) survey respondents were male-headed households while the remaining 76 (22.89%) respondents were female-headed households. Table 2 reports the descriptive statistics of the variables. The average number of household family members for the whole sample was 5.23, the smallest and the largest having 1 and 10, respectively. The average household size of 5.23 is lower than the findings of Holden and Tefera (2008) that showed average household size to be 6.8. On average, households appear to own 1.97 oxen, with 0 and 8 being the smallest and the largest number of oxen owned. The average *Teff* production for the whole sample stands at 1098.77 kg per ha with a standard deviation of 1213.85.

The average land holding of the respondents is about 0.89 ha which is a bit lower than the findings of Holden and Tefera (2008) which is 0.94 ha. The average land allocated for *Teff* production is 0.77 ha per household. The average expenditure for the purchase of inputs used in *Teff* production is Birr 2,845.47 per ha while that of labour expenditure is Birr 1499.95 per ha with high variability for both variables.

As indicated in Table 2, there is a statistically significant difference in the means of *Teff* production per ha (dependent variable) between female-headed households and male-headed households which indicates stronger evidence of a difference between the two groups. Similarly, there are about 7 independent variables with a statistically significant variation among female-headed households and male-headed households. These independent variables are number of dependents, ox ownership, quantity of oxen ownership, cost of inputs, farmer training days, money allocated to *Teff* production, land ownership and *Teff* cultivated land. When we compare the means of such independent variables between male-headed households and female-headed households, male-headed households are better off for the variables quantity of oxen ownership, using inputs (investment for inputs per ha), farmer's training days, money allocated to *Teff* production, land ownership and *Teff* cultivated land. Theories of agricultural production indicate that ownership of productive resources such as ox ownership, quantity of oxen ownership, use inputs, farmer training days, money allocated to *Teff* production, land ownership and cultivated land are the critical variables that positively affect agricultural production. Thus, our result shows that as male-headed households have more productive resources as compared to female-headed household, they are producing more *Teff* output. On the other side, female-headed households have a higher number of dependents and incur more labour costs as compared to male-headed households. Our findings also indicate that female-headed households are facing a shortage of labour force (due to higher number of dependents) for *Teff* production and incur more labour costs as compared to male-headed households. The details of our result for each independent variable and the findings of previous studies are described hereunder.

Teff production by gender

A comparison was made among male-headed and female-headed respondents in relation to *Teff* production per household in 2017/18. An independent t-test was also run on a sample of 332 farmers consisting of 76 female-headed households and 256 male-headed households to determine if there were statistically significant differences in *Teff* production and socioeconomic variables affecting *Teff* production. The means of the household-level independent variables affecting *Teff* productivity were also compared by gender using ANOVA. Furthermore, pairwise multiple comparisons using Bonferroni correction (t-test) were conducted and the results are presented in Table 2.

The average *Teff* production for female-headed respondents is 855.19 kg per ha while that of male-headed respondents is 1171.08 kg per ha (Table 2). As a result, the average *Teff* production of female-headed respondents is 22.17% less than the average *Teff* production for all respondents (1098.77 kg per ha). The average *Teff* production of male-headed respondents is about 6.58% greater than the average *Teff* production of all respondents (1098.77 kg ha). The survey result indicates that male-headed households produce about 315.89 kg per ha more *Teff* as compared to female-headed households. Female-managed farm plot was on average 26.97% less productive than a male-managed farm plot in Ethiopia. Our finding is similar to the findings of the UN Women Ethiopia country office that state women have fewer resources and earn less from their resources than men (UN Women Ethiopia Country Office 2018). The mean *Teff* production of male-headed households also shows a statistically significant difference as compared to female-headed households (P-value < 0.05) (Table 2). This implies that female-headed respondents do not produce *Teff* crops like the male-headed respondents. This result is like that of Biénabe et al. (2004) which state gender disparities has systematically disadvantaged women with regard to their overall

economic status as well as access to basic services and as a result woman have been considered as one of the food insecure vulnerable groups. Similarly, a public document named Ethiopia's agricultural sector policy and investment framework identified that gender disparities significantly impede women's empowerment (Chanyalew and Adenew 2010). The reasons for such differences are due to the variations in the ownership of productive resources such as land, oxen, labour, and others.

Table 2 presents the mean values of variables used in the analysis and their unconditional differences between male-headed households and female-headed households. Results show that there is a statistically significant difference with regard to *Teff* productivity in kg per household, dependents, ox ownership, quantity of oxen ownership, cost of input, cost of labour, owned land in ha, and *Teff* cultivated land in ha. This result is similar to the findings of Debela (2017) that state female-headed households own significantly fewer livestock compared with male-headed households due to the lower endowment of land area, male labour and children (aged 6–14) in female-headed households which are the observed factors causing the disparity. Conversely, no statistically significant difference is found with regard to age, family size, active labour force, education, and total land ownership in ha between male-headed households and female-headed households. For further analysis, we used the mean rank of *Teff* production. In statistics, the mean rank is the average of the ranks of all the observations in a data set. The mean rank can be used to compare two or more groups of observations. As depicted in Fig. 2 The mean rank of the male-headed household (172.96 kg) is higher than the mean rank of the female-headed households (144.73 kg). The mean rank can be used to test for statistical significance as well. For example, we used the Mann–Whitney U test to test for a difference in the medians of two groups of observations. The hypothesis test summary of the Mann–Whitney U test is "the distribution of *Teff* production kg is the same across categories of sex" with independent-samples Mann–Whitney U Test, indicating that 0.024 with a decision of rejecting the null hypothesis. This indicates that the mean rank of the male-headed households is significantly different from the mean rank of the female-headed households, and this indicates that there is a statistically significant difference in the medians of the two groups. However, since these results are only descriptive, they cannot be used to draw causal inferences and thus the variables need to be econometrically analysed to obtain more reliable results.

Age composition of the respondents and Teff production

The average age of survey respondents is 44.90 years of age with a standard deviation of 12.42. The average age of female-headed households is about 45.68, a bit higher than that of male-headed households which is 44.75 but the difference is insignificant. Measuring the strength of the linear association (correlation coefficient) using Pearson correlation between the age of the respondent and *Teff* production, the result indicates r = 0.0962, P-value of 0.080. Though weak, there is a positive relationship between the age structure of the respondents and *Teff* production. As age increases, *Teff* production shows an increasing trend, though it is not significant. Hofferth (2003) notes that the higher the age of the household head, the more stable the economy of the farm household as older people have relatively richer experiences of the social and physical environments as well as superior experience of farming activities.

Family size of the respondents and Teff production

The average family size of the whole respondents is 5.23 persons per household with a standard deviation of 1.95 with 1 and 10 being the smallest and the largest number of family size. The family size of female-headed households is about 5.54 while that of male-headed households is about 5.14, but the difference is insignificant. The strength of the linear association of *Teff* production and family size of the respondents through Pearson correlation indicate that it is positively correlated with a correlation of coefficient r = 0.0185 and P-Value of 0.738. This indicates that though it is small and insignificant, there is a positive relationship between *Teff* production and the family size of the sample respondents. This result is inconsistent with Paddy (2003) who noted there was a negative correlation between household size and food security as food requirements increase with the number of persons per household.

The availability of an active labour force within the household is an important factor expected to influence the agricultural production status of households. In this regard, the average active labour force is 2.17 persons per household while it is 2.07 for female-headed households and 2.17 for male-headed households). However, the ANOVA test for average active labour force indicates that there is no significant difference between female-headed households and male-headed households (P-value > 0.05) (please refer to Table 2 for all the ANOVA analysis). The analysis for the strength of the linear association of *Teff* production and active labour force of the respondents through Pearson correlation indicate that it is positively correlated with a correlation of coefficient r = 0.155 and P-Value of 0.005.

The average number of dependent family members was 3.07 persons per household with a standard deviation of 1.42. However, there are more dependent persons in female (3.38 dependents per household) than

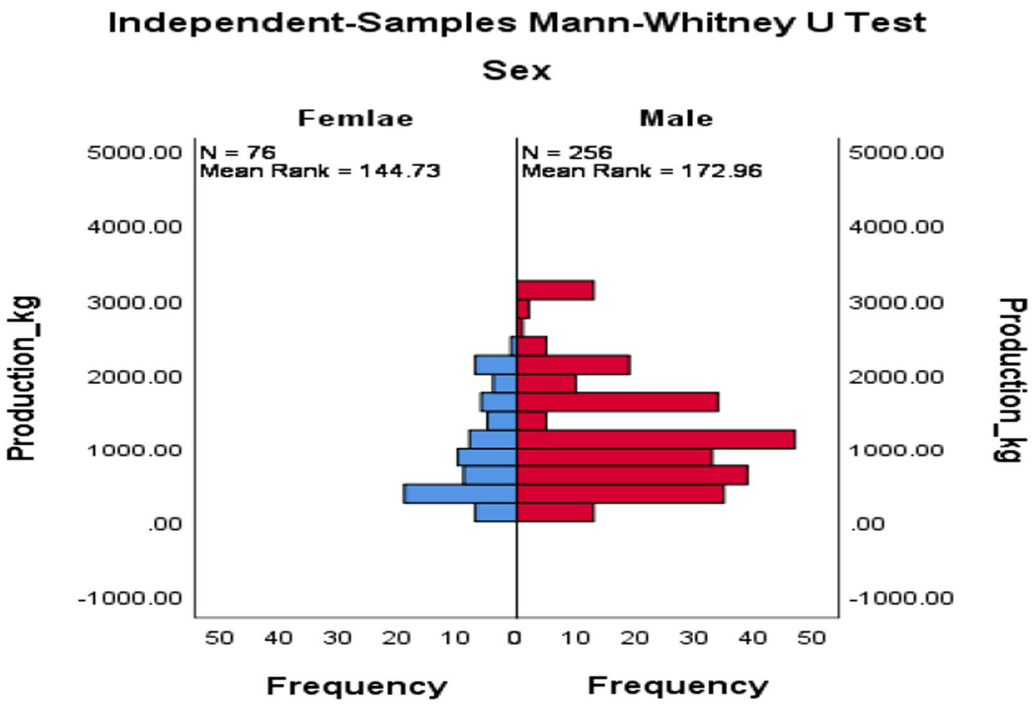

Fig. 2 Results of independent samples Mann–Whitney U test. Survey result, 2019

in male-headed households (2.98 dependents). The ANOVA test indicates that there is a significant difference ($P < 0.05$) in the number of dependents between female-headed households and male-headed households which negatively affect *Teff* production. The strength of the linear association of *Teff* production and number of dependents of the respondents through Pearson correlation indicates that it is negatively correlated with correlation of coefficient $r = -0.119$ and P-Value of 0.031. This indicates that the variable dependent has an inverse relationship with production and the number of dependents increases in a household, *Teff* productivity decreases.

Teff production is the function of labour and availability of labour force within the household and in the market, it is assumed to have a positive relationship with the volume of production. In addition to family labour, farmers are hiring additional labour force from the market especially during the weeding and harvesting of *Teff* crops. The average investment for labour was Birr 1499.95 per ha with a standard deviation of 1792.35. In labour investment by sex, female-headed households incur more costs (Birr 1580.79 per ha) as compared to that of male-headed households (Birr 1475.95 per ha). The ANOVA test for labour investment indicates that there is no statistically significant variation between male-headed households and female-headed households (P-value > 0.05). However, the Pearson correlation of *Teff* production with labour cost is about 0.222 with P-value of 0.001 which shows a significant and positive relationship between the two variables. This result is consistent with Girma and Endrias (2015) that showed availability of labour positively affects *Teff* production.

From discussions with key informants and FGD, the participants believe that the cultivation of *Teff* crops demands more effort and more labour force as compared to other crops. In this regard, a study participant from Minjar Shenkora district stated the following.

> *"Farming in Ethiopia is basically done using family labour. However, Teff is very laborious starting from its land preparation where farmers go through it up to six times as compared to other crop types that only need two to three times. It also needs more labour for weeding and threshing." (Minjar Shenkora_4).*

Rural–urban migration, and migration to other countries, lack of interest in farming by the youth, the labour-intensity of *Teff* cultivation and the cost of labour were cited as challenges at Lomie district:

> *"Even though family labour is contributing a lot in the cultivation and harvesting activities, nowadays, youngsters don't want to do these activities. Alternatively, they are migrating to the cities, and thus, those farmers who afford to pay can hire labour from the market. In this regard, Teff pro-*

duction shows a decreasing trend from time to time due to lack of interest to work on such tedious farming activities of the youngsters and their migration to cities and other countries." (Lomie_6).

In Lomie, government intervention and technology were cited as possible solutions to the perennial labour challenge. Through innovative technology, the labour-intensive activities in *Teff* production, such as weeding, harvesting and threshing would be resolved. Another study participant from Lomie district also said the following in relation the possible solution to the problem of labour.

"Farmers are moving out to cities and thus labour is getting too expensive in the market. All our profit goes to labour, and it is our big challenge. The government should resolve this problem of labour through the provision of technology that simplifies the high demand of labour especially for weeding, harvesting and threshing activities" (Lomie_9).

Labour scarcity meant it was costly to engage the labour of people outside the household. During the labour-intensive months household members had to contribute to *Teff* production. The cost of labour was highest during harvesting where it reached Birr 200.00 per day. Lack of interest by the youth to participate in farming, the rural–urban migration of the economically active labour force to towns and labour costs takes essential labour away from *Teff* cultivation. The production of *Teff* is labour-intensive and with limited access to technology, there are no large-scale *Teff* producers in the country (Berhe 2009; FAO 2015). Farmers suggested that government intervention and relevant technology were critical to dealing with the high demand for labour during weeding, harvesting and threshing of *Teff*.

Education and Teff production

Education broadens farmers' skills and techniques of modern farming enabling them to perform farming activities wisely and efficiently. Educational attainment by the household could lead to the awareness of the possible advantages of modernizing agriculture using technological inputs and enable them to read instructions on fertilizer packs (Girma and Endrias 2015). When we calculate the average number of years of formal schooling of the household heads in years it is about 3.73 with a standard deviation of 4.43 that shows a higher variability. The female-headed households' formal schooling seems better with an average year of 4.55 than that of male-headed households which is 3.48 but it was not statistically significant (P-value > 0.05). If we see the strength of the linear association (correlation coefficient) between *Teff* production and level of the education of the sample respondents with Pearson's coefficient correlation, it is negatively correlated by − 0.189 with P-Value = 0.001, (correlation is significant at the 0.01 level (2-tailed). There was a significant but negative relationship between education and *Teff* production. The result goes against our assumption and the findings of Hailu et al. (2015) which showed that education level increases steadily with the yield. The finding might be explained by households that possess more resources such as land holding, cultivated land and oxen despite the education level.

Quantity of oxen ownership and Teff production

Oxen serve as a source of traction in many developing countries and thereby significantly affect households' crop production. The previous research result of Jayne et al. (2010) states animal traction power enables households to cultivate greater areas of land and to execute agricultural operations timely. Households with high numbers of oxen may produce more *Teff* and a positive relationship is expected between *Teff* production and ox ownership. About 89% of the respondents own at least one ox while the remaining 11% of the respondents do not own an ox. About 21% of female-headed households and 8% of male-headed households did not have oxen. The average ox ownership per household for all respondents is 1.97 with a standard deviation of 1.25; with 0 and 8 being the smallest and the largest number of oxen per household (Table 2). The Pearson correlation of ox ownership and *Teff* production is positive with r and P-value of 0.178 with P-Value = 0.001 and the Pearson correlation of quantity of oxen ownership with *Teff* production is about r = 0.037 and P-Value of 0.506. Correlation results indicate that there is a positive and strong relationship between the oxen ownership and quantity of oxen ownership to that of *Teff* production and the correlation is statistically significant. We also examined ox ownership and gender using Pearson Chi square test and found the result of Pearson's chi-squared test revealed a statistically significant relationship between gender and ox ownership is ($\chi 2(1) = 9.7710$, $p = 0.002$). This means that there is a very small probability (0.002) of obtaining a chi-squared statistic as large as 9.7710, assuming that the null hypothesis is true. Therefore, we reject the null hypothesis and conclude that there is a statistically significant relationship between the two variables (gender and ox ownership). In other words, the data is very unlikely to have occurred by chance, and there is a strong relationship between the two variables.

When we see the average ox ownership by sex, it is about 2.07 per household for male-headed households and 1.63 per household for female-headed households. This result is similar to the findings of FAO (2019) that

indicates 14.9% of female-headed households own only one ox, about 27.2% more than one ox and about 12.3% own two or more oxen while 21.5% of male-headed households owned one ox, 52.2% had more than one ox and 30.7% owned two or more oxen. The ANOVA test for the average ox ownership of the farmers indicates that there are statistically significant variations between male-headed households and female-headed households (P-value < 0.05). As male-headed households own more oxen than female-headed households, they produce more *Teff* crops. Our research finding is similar to the results of Getu et al. (2015) that state the number of oxen per household tends to have a statistically significant impact on yield.

Investment in inputs and Teff production

Fertilization of farmland can boost agricultural production and influence the food security status of a household. In this regard, researchers such as Roseberg et al. (2005) and Funk and Brown (2009) found that fertilization of farmland can boost agricultural production and influence the food security status of a household. When we see the average investment for inputs for all respondents it is Birr 2,925.54 per household with a standard deviation of 1,854.39. The Pearson correlation of *Teff* production with investment for inputs is r = 0.068 and the P-Value of 0. 218. Consistent with previous studies (Crawford et al 2003; Chauvin and Mulangu 2012) this paper indicates that there is a strong and significant relationship between the investment for inputs and *Teff* production. Household investment in inputs contributes to increased *Teff* production.

The average investment for inputs by sex, is Birr 3086.94 per ha for male-headed households while it is Birr 2032.10 per ha for female-headed households. The ANOVA test for the average investment inputs between female-headed households and male-headed households indicates that there are statistically significant variations (P-value < 0.05). This indicates that male-headed households invest more money on fertilizer and chemicals for *Teff* production as compared to female-headed households and such variation is significant.

Despite the value of inputs for improved *Teff* production, the key informants and farmers were also aware of the impact of chemical fertilizers on their land. The farmers were concerned that the chemical fertilizers diminished the fertility of the soil.

> *"First, we as farmers, were using compost for our land. Now, there is enough fertilizer and chemical supply, even though the chemical is somehow making our land less fertile from time to time. I think that there is nothing that can be better than compost, but the farmers these days are getting tired of collecting the ingredients to make compost like dried leaves and cattle dang and simply apply a chemical fertilizer, which eventually harms the land even though the product is easily obtained. Nevertheless, we are supplied with fertilizer without a delay whenever we need it" (Lomie_7).*

The views from the Lomie key informant represent perspectives that are common among the farmers and officials in the region. Another study participant from the Halaba zone stated the following in relation to the problems of inputs.

> *"We do get enough supply of fertilizer, but the problem is with seed and chemical supply. The price of fertilizer has also increased tremendously. Two years ago, the price for DAP was Birr 6.00 per kg but now it is Birr 13 per kg. Seed supply is available in small quantities and still, it is expensive. Anti-pest is not available mostly and if we want to buy in town, it is on the market, but its effectiveness is not good, and its cost is high" (Halaba_zone_5).*

Being in a marginal region, the participant argued that farmers were also concerned about the chemical fertilizers sold to farmers, the increasing price of fertilizers, the decline in availability of fertilizers and pesticides that are ineffective. The participants noted that the distribution of fertilizer is good in all districts and farmers are convinced that the inputs can boost *Teff* production. As a result, farmers made requests for inputs to local authorities. However, there are inconsistencies in the supply of some improved seeds and chemicals especially in the Halaba zone and in remote areas. Organic fertilizers are rarely used by farmers to enhance soil fertility.

Teff farmers' concerns included, the rising costs of farm inputs, poor quality of the inputs and chemicals, use of uniform chemical fertilizers for all types of land, improper use of inputs and pesticides. There was a decline in the use of manure or composite which resulted in the decline in soil fertility.

The rising costs of seeds and fertilizers were also a concern. The costs were related to the liberalization of fertilizer prices and removal of subsidies between 1997 and 98 (Spielman et al. 2010). Ethiopia also imports fertilizers and chemicals, and the price increase of fertilizer is due to the international rising prices for inputs, bureaucratic procedures for imports and currency fluctuations. The price instability is due to the limited participation of the private sector in fertilizer markets. The rising costs of improved seeds is due to the limited capacity of agricultural research centres, seed producers and

seed distribution challenges in Ethiopia. The best policy for maintaining the price stability of seeds and fertilizers will vary depending on the specific circumstances of each region/district. Effective approaches for maintaining the price stability of seeds and fertilizers include the following.

- Providing subsidies or tax incentives to farmers to help offset the cost of inputs such as fertilizers, pesticides, and seeds. The governments can procure seeds and fertilizers at a low price and distribute them to farmers at a subsidized price. This can help to keep prices stable and make these inputs more affordable for farmers.
- Investing in research and development to develop new, more affordable seeds and inputs that are tailored to local conditions.
- Encouraging the use of organic and natural farming methods that rely less on expensive inputs.
- Promoting the use of precision farming techniques that can help farmers optimize their use of inputs and reduce waste.
- Supporting farmer cooperatives and associations that can help farmers pool their resources and negotiate better prices for inputs.
- Developing an efficient input marketing and rural financial system: Governments can provide credit to farmers to help them purchase seeds and fertilizers. This can help farmers to afford these inputs and also reduce their risk of price fluctuations.
- Strengthening market research and information: Governments can collect and disseminate market research and information on seed and fertilizer prices. This can help farmers make informed decisions about when to purchase these inputs and can also help to stabilize prices.

By addressing these factors, governments can help to stabilize the prices of seeds and fertilizers and make inputs affordable for farmers. This can help to improve agricultural productivity and food security in Ethiopia. By developing and implementing policies and strategies, the federal and regional governments can help farmers reduce their input costs and improve their productivity, while also promoting sustainable farming practices that protect the environment and support rural livelihoods.

Landholding and Teff production

In Ethiopia, land is public property that has been administered by the government for more than four decades. According to Najafi (2003), under subsistence agriculture, landholding size is expected to play a significant role in influencing farm households' food security. In this study, the actual total size of land ownership for each respondent was obtained by summing up the fragments plots of land including owned farmland, cash renting land, sharecropping land, and inherited land (Desiere and Jolliffe 2017). It is measured in *Tsimad* (0.25 hectare) and converted to hectares. Farm households who own and cultivate large acreage of land are expected to produce more *Teff* crops. The total available land for cultivation in ha (owned land, rented land, sharecropped land, and inherited land) of all the respondents is 1.40 ha per household with a standard deviation of 0.81 with high variability, 0.125 ha being the smallest and 3.75 ha being the highest. When we see the total available land for cultivation in ha by sex, it is about 1.45 ha per household for male-headed households and 1.25 ha per household for female-headed households. However, the ANOVA test indicates that there is no statistically significant difference in the total available land for cultivation between male-headed and female-headed respondents. From the total available land for cultivation, on average about 0.77 ha (53.1% of the land) is allocated for *Teff* production with a standard deviation of 0.42. Female-headed households on average allocate 0.67 ha for *Teff* production while male-headed households allocate about 0.79 ha for *Teff* production. The ANOVA test for both the average ownership of land and *Teff* cultivated land between female-headed households and male-headed households indicates that there are statistically significant variations between male-headed and female-headed respondents (P-value < 0.05). The Pearson correlation of *Teff* production with available land for cultivation in ha, land ownership in ha, *Teff* cultivated land in ha is about 0.529 (P-Value < 0.001), 0.328 (P-value < 0.001) and 0.858 (P-value < 0.001), respectively. This indicates that there is a positive and strong relationship especially between the total available land for cultivation and *Teff* cultivated land with *Teff* production.

When we see the average *Teff* productivity of land per ha, Ceteris Paribus (all other things being constant), the average production for all respondents is 1433.35 kg per ha (total *Teff* production of all respondents in kg divided by total *Teff* cultivated land in ha) which is a much less than the national average (1748 kg per ha) in 2017/18 harvest period (CSA 2017/18). However, male-headed household respondents on average produce more *Teff* crop (1,482.38 kg per ha) as compared to women-headed respondents (1,276.40 kg per ha). This indicates that women-headed respondents produce about 10.95% below the average production of all the respondents. This implies that the productivity of male-headed respondents is better as compared to female-headed respondents. Male-headed household

respondents produce more *Teff* crop (205.98 kg per ha) as compared to female-headed household respondents.

Discussions were undertaken with key informants and FGD in relation to access to land and a study participant from the Tahtai Maichew district noted the following about the scarcity of land.

> *"He said that land was very scarce in his area and the young couldn't have their own land and they are dependent on the land of their families. He added the land was inadequate" (Tahtai_Maichew_10).*

Similarly, a study participant from the Halaba zone said the following.

> *"She said that due to the increasing trend of population, there was a big problem of accessing land and as a result, the young generation got the small sized pieces of land either from their parents or the government. Only parents did have land. The land was further divided into all the children and the portion of land was getting lesser and lesser due to such division of the existing farmland to the children" (Halaba_zone_1).*

A key informant from Tahtai Maichew also mentioned the following in relation to the demand for land and land provisions for youngsters.

> *"He said that the needs of human beings were unlimited and the land around them was scarce and it had been already divided among the farmers some years back. There would obviously be new demand from the youngsters. There was a provision of land for young farmers and land was given to the youth in forms of group for those who want to work on beekeeping, dairy, or fattening projects. However, the access to land is still a big challenge especially for the youth" (KII_Tahtai_Maichew_1).*

In the discussions with key informants and FGD, we have come to understand that land is a scarce resource in all the districts, especially for the youth due to population increase while the land is limited. Only parents have land. The land is further divided among children and the land size is getting smaller due to the sub-divisions. The youth couldn't get farmland unless it was allocated to them by their families. Compared to the needs of the farmers, the land is inadequate in most of the cases. Although farmers have an interest in growing *Teff* crops, the inadequacy of land restrains them from planting their land with varied crop types and thus they wait for another year through crop rotation. In some cases (such as Tahtai Maichew district) land is provided to youngsters who are interested in working in groups on beekeeping, dairy or fattening projects. This requires the introduction of agricultural policy and strategies that consider the underlying factors shaping gender productivity gaps rather than focusing solely on agricultural production factors. In this regard, a support system for farmers within a holistic gender-sensitive framework is needed.

Access to extension services and Teff production

Extension programs can provide farmers with the appropriate technology and skills. Farmers who have frequent contact with development agents have better access to knowledge and increased output. Mussema (2006) showed that visits by an extension agent had a significant and positive effect on the quantity of pepper produced and supplied to the market. Thus, in this study, frequent contact with extension workers is expected to have a positive effect on Teff production. About 317 (95.48%) respondents had contact with extension workers within the 2017/18 harvest period. In this study, the average frequency of contact with extension agents was 2.78 with a standard deviation of 1.52 and there is no significant variation among female and male-headed households.

When we measure the strength of the linear association between frequency of contact with extension agents and *Teff* production through Pearson's correlation, it is positive with a correlation of 0.453** (correlation is significant at the 0.01 level (2-tailed)) and the correlation is statistically significant. There is a positive and significant relationship between the frequency of contact with the extension workers and *Teff* production. These findings are consistent with Rehima et al. (2013) and Girma and Endrias (2015) that showed visits by extension agents had a significant and positive effect on the quantity of agricultural commodities produced and supplied to the market.

Access to training and Teff production

Becoming a farmer generally does not require formal training or credentials (Yihdego et al. 2015). However, knowledge and expertise in agricultural production are essential to success for prospective farmers. Whether gained through experience or formal education, farmers need enough technical knowledge of crops, growing conditions and plant diseases to make sound decisions (Abrha 2015; Yihdego et al. 2015). Despite having a farming background, a person considering farming would benefit from the training offered by development agents and different development partners (Sah et al. 2007). Therefore, a direct and positive relationship is expected between access to training and *Teff* production.

As part and parcel of capacity-building programs for farmers, different short-term training programs are given to farmers through extension workers. The objectives of such training are to introduce better farming practices to the farmers and provide proper utilization of inputs

that enable farmers to improve their agricultural production. When we see the access to training for survey respondents, about 324 (97.59%) respondents received training at least once in agriculture-related fields and the remaining 8 (2.41%) did not have access to training in 2010 (2018/19) harvest period. The average training days per respondent is 5.87 with a standard deviation of 3.75. When we see the participation of farmers in training programs offered by extension agents and district-level experts by gender, it is about 4.17 days for female-headed households and 6. 38 for male-headed households.

When we measure the strength of the linear association between training days with Teff production through Pearson correlation, it is negative with the correlation of r = 0.469** (correlation is significant at the 0.01 level (2-tailed)) and the correlation is statistically significant. This indicates that there is a positive relationship which implies that farmers' training contributes to increasing Teff production of households. This result is like the findings of some researchers such as Rahman et al. (2018) that state training of farmers essentially contributes to human resource development in agriculture.

Access to credit and Teff production

The survey result indicates that only 86 (25.90%) respondents claimed loans for their agricultural activities in 2010 (2017/18) and the remaining 246 (56.05%) respondents did not claim any loan in the same period. The average amount of borrowed money is Birr 1,730.74 per household (1537.22 for female-headed households and 1788.19 for male-headed households) with a standard deviation of 3951.37 which shows higher variability among survey participants. From this loan amount, on average about Birr 394.28 (22.78%) (139.47 for female-headed households and 469.92 for male-headed households) is allocated for *Teff* production with a standard deviation of 1504.43 which also shows higher variability among the survey respondents. The ANOVA test for both the loan amount allocated to *Teff* production between female-headed households and male-headed households indicates that there are statistically significant variations (P-value < 0.05).

When we measure the strength of the linear association between the amount of money accessed through credit and allocated to *Teff* production and *Teff* production through Pearson correlation, it is positive with a correlation of r = 0.087, p = 0.115. This indicates that there is a positive relationship. However, it is very weak and insignificant. This implies that the strength of the association between the two variables is not strong, which is like some authors such as Carswell (2000) that state inflexible credit repayment procedures are widely reported as hindering smallholders' interest in farm credit.

Econometric results

Table 3 presents the results of the treatment effects model for all the survey participants. To ensure the normality of the data for the dependent variable (*Teff* production per ha), different options of transformations were considered, and the logarithm was the best option for linearity of the data, and it is considered to determine how well a regression model fits the data. Thus, the interpretation of the coefficient parameter estimates of the factors refers to the transformed response *Teff* production variable.

The Wald test reported in the footer indicates that we can reject the null hypothesis of no correlation between the treatment-assignment errors and the outcome errors. Wald test (Wald chi2(13) = 3605.69) tell us that the correlation coefficient between the dependent variables and independent variables is statistically significant. The p-value for the Wald test (Prob > chi2 = 0.0001) is very small, which means that the null hypothesis can be rejected with very high confidence. This means that the parameter estimate is statistically significant and that the null hypothesis, which is that the parameter estimate is equal to 0, is not likely to be true. The term "Prob > chi2" is a statistical term that refers to the probability of obtaining the chi-square statistic given that the null hypothesis is true. A Prob > chi2 = 0.0000 means that the probability of obtaining the observed chi-square statistic by chance is less than 0.0001. This is a very small probability, so it is very unlikely that the observed difference between the groups is due to chance and thus the null hypothesis can be rejected with very high confidence. This suggests that the independent variables in the model are jointly statistically significant in explaining the variation in the dependent variable. In other words, if the Wald chi-squared test is significant, then we can conclude that the linear regression model is a good fit to the data. This implies that the overall effect of the explanatory variables is statistically significant.

Interpretation of results

The treatment-effects model with endogenous treatment shows that variables like *Teff* land ($p < 0.01$), active labour force ($p < 0.01$), input cost per ha ($p < 0.01$) and training days ($p < 0.05$) have statistically significant positive effect on *Teff* productivity. On the other side, family size ($p < 0.01$) has a negative effect on *Teff* productivity. This means that while higher *Teff* land, active labour force, investment on inputs and training days tend to boost productivity, higher family size turns out to reduce

Table 3 Treatment-effects model with endogenous treatment

	Coef	Std. Err	z	P>|z|	[95% Conf. Interval]	
Ln production ha						
Ln owned land	− .0279632	.0806022	− 0.35	0.729	− .1859407	.1300142
Ln *Teff* land	2.28607	.2371467	9.64	0.000	1.821271	2.750869
Ln active labour	.2152342	.0690897	3.12	0.002	.079821	.3506475
Ln oxen quantity	− .0248417	.0935901	− 0.27	0.791	− .2082749	.1585916
Ln input cost ha	.6087759	.0402645	15.12	0.000	.5298589	.687693
Ln labour cost ha	− .0078871	.0076436	− 1.03	0.302	− .0228684	.0070941
Ox ownership	− .0391128	.2253821	− 0.17	0.862	− .4808535	.4026279
Training days	.0157188	.0066934	2.35	0.019	.0026	.0288376
Contact extension	.0312347	.0164159	1.90	0.057	− .0009397	.0634092
Teff loan	.0000225	.000015	1.50	0.134	− 6.93e-06	.0000518
Education	.0025704	.0055391	0.46	0.643	− .0082861	.013427
Family size	− .0487607	.017322	− 2.81	0.005	− .0827113	− .0148102
Age	.0010142	.0020468	0.50	0.620	− .0029974	.0050259
_cons	.5060346	.2647517	1.91	0.056	− .0128692	1.024938
Ox ownership						
Dependents	.2003733	.0777809	2.58	0.010	.0479255	.352821
_cons	.6506084	.2292722	2.84	0.005	.201243	1.099974
/athrho	*.0721147*	*.2544977*	*0.28*	*0.777*	*− .4266917*	*.5709212*
/lnsigma	*− .9139786*	*.0393947*	*− 23.20*	*0.000*	*− .9911908*	*− .8367663*
rho	*.07199*	*.2531788*			*− .4025528*	*.5160355*
sigma	*.4009259*	*.0157944*			*.3711345*	*.4331088*
lambda	*.0288627*	*.1017081*			*− .1704815*	*.2282068*

Linear regression with endogenous treatment Number of obs = 332

Estimator: maximum likelihood Wald chi2(12) = 3605.69

Log likelihood = − 279.65015 Prob > chi2 = 0.0000

LR test of indep. eqns. (rho = 0): chi2(1) = 0.08 Prob > chi2 = 0.7818

Table 4 The predicted value of treatment effects: ATE

Production in ha	Coef	AI Robust Std. Err	z	P>|z|	[95% Conf. Interval]	
ATE						
Sex						
(Male vs Female)	235.6863	117.5132	2.01	0.045	5.364761	466.0079

Treatment-effects estimation Number of obs = 332

Estimator: propensity-score matching Matches: requested = 76

Outcome model: matching min = 76

Treatment model: logit max = 76

Sources: Survey result, 2019

productivity. Variables such as quantity of oxen, investment on labour, *Teff* loan, education and age have no significant effect at all.

Our findings indicate that *Teff* land has a statistically significant and positive effect on *Teff* productivity and 1% increase of land increases *Teff* productivity by 229%. This result is similar to the findings of Efa et al. (2016) that state farm size allocated for *Teff* production positively and significantly affects the extent of marketed surplus at 1% significance level. It is also similar to the results of Dule and Tazeze (2020) who stated allocating one additional hectare of land to *Teff* production would increase the probability of being market participant by 15.7% and quantity of *Teff* marketed by 6.33 quintal and this in turn show that larger area allocated to production increases the quantity of produce available for sale.

The variable active labour force has also a statistically significant and positive effect on *Teff* productivity. 1% increase of active labour force increases *Teff* productivity by 21.52%. Our finding is consistent with the result of Kidane et al. (2005) that state the availability of labour is an important determinant of household production and food security, especially in subsistence-oriented households given the necessary landholding and rainfall.

Investment in input (input cost per ha) has also a statistically significant and positive effect on *Teff* productivity. 1% increase of investment on inputs increases *Teff* productivity by 60.88%. This result is similar to the finding of Bart et al. (2013) that state modern inputs are increasingly adopted in *Teff* production and increasing availability of improved varieties and chemical fertilizer and an improved extension system in rural areas are increasing downstream demand for commercial *Teff* driven by growing incomes, urbanization, and high-income elasticities for *Teff* (Bart et al. 2013).

Farmers' training days has also a statistically significant and positive effect on *Teff* productivity. One day increase in farmers' training day increases *Teff* productivity by 1.57% at 5% significance level. Our result is consistent with the findings of Sah et al. (2007) that state a person considering farming would benefit from the training offered by development agents and different development partners.

Family size has a statistically significant but negative effect on *Teff* productivity. An increase of one person in a family decreases *Teff* productivity by 4.88% and this result is similar to the findings of Paddy (2003) that argued there is a negative correlation between household size and food security as food requirements increase in relation to the number of persons in a household. Dule and Tazeze (2020) also stated family size had significant and negative effect on *Teff* market. This result could be due to the fact that about 58.7% of the family size are dependents. 3.07 persons in a family are dependents in a family size of 5.23 persons (Table 2).

Some consistencies are apparent from a comparison of the unconditional (Table 2) and conditional (Table 3) results. The unconditional (no other variables controlled for) results show there is a statistically significant difference in the *Teff* productivity between male-headed households and female-headed households, the treatment effects results (ATE) also show that male-headed households produce more *Teff* crops as compared to female-headed households. However, there are some variations in the results when we compare the naive comparison and econometric results for women-headed households and male-headed households. For example, quantity of oxen ownership and owned land come to be significant in naive results while in econometric results they are negative and insignificant. On the other side, family size is significant in the econometric result while and it is not significant in naïve results. Without doubt naive results are less reliable as it is unconditional.

Using simulated data, we can argue that the value of ATE shows the true difference in *Teff* productivity between male-headed households and female-headed households which is 235.69 (Table 4). This information provides an estimate that is close to the true value. If we estimated by ignoring the endogeneity, the estimate would have been 315.89. The values are close to each other, indicating that the average predicted outcome is almost similar to the average predicted outcome for the whole population. However, the estimate using the propensity-score matching gives us the results considering the endogeneity. In magnitude, the estimated ATE is less than that of the estimate that allows for endogenous treatment assignment. Disregarding endogeneity overestimates the effect of *Teff's* productivity difference.

Conclusion

This study analyses the effect of gender disparities in socioeconomic status on *Teff* productivity of smallholder households in Ethiopia. The study employed a cross-sectional survey design with a mixed approach. A purposive sampling method was used to select top *Teff*-producing regions, districts, *Kebeles*, key informants and FGD participants. Moreover, a random sampling method was used to select survey respondents. To this end, cross-sectional data from 76 female-headed households and 256 male-headed households were analysed using linear regression with endogenous treatment, which accounts for both observed and unobserved sources of selection bias. The result shows that active labour force, investment in inputs, *Teff* cultivated land ha and farmers' training days have a statistically significant positive effect on *Teff* productivity while family size has a statistically significant negative effect on *Teff* productivity. Moreover, the study result indicates that there is a significant difference in the ownership of productive resources between female and male-headed households. While women are fully engaged in *Teff* production activities, due to low the level of ownership of productive resources such as land, labour, and oxen, the average *Teff* production for female-headed respondents is much lower than that of male-headed households.

The constitution of the country has recognized women's right to affirmative action and provides special attention to enable women to compete and participate in all spheres of life as well as exercise their democratic and human rights on equal grounds with men. Women's empowerment is a national priority mainstreamed in all

policies, legal, and institutional frameworks. Though not uniformly implemented, women's empowerment initiatives target women but inequalities between female and male-headed households persist and these that can be explained by statistically significant differences in the ownership of productive resources at the grassroots level. A comparison between male and female-headed households suggests that male-headed households are better off for variables such as ox ownership, quantity of oxen ownership, use of inputs (investment in inputs), farmer's training, money allocated to *Teff* production, land ownership and *Teff* cultivated land. Intervention by government and all stakeholders is required to develop relevant strategies and action plans to address persistent gender disparities in the ownership and control over assets, such as land, labour, and oxen affect *Teff* productivity and livelihoods.

Strategies for minimizing gender disparities in the ownership of assets will vary depending on the circumstances of each region/district. By developing and implementing policies and strategies, the federal and regional governments can help farmers reduce the gender gap for ownership of assets between female and male-headed households. Implementing these strategies, can empower women farmers and improve their productivity, to benefit their families, communities, and Ethiopia. Some of the recommended approaches for minimizing the gender gap are described hereunder.

- Addressing the root causes of gender inequality will create an enabling environment for women to thrive in agriculture.
- Design of gender-responsive national agricultural policies and strategies that reflect the factors shaping gender productivity gaps rather than gender-blind agricultural production factors should be considered.
- Design of an action plan to minimize gender productivity gaps to support farmers within a holistic gender-responsive framework.
- Promoting women's access to credit and financial services will help women invest in assets such as livestock, and farm inputs.
- Provision of appropriate technology to female-headed households will cater for the labour-intensive *Teff* farming activities.
- Increasing women's participation in training and extension programs will help women learn about new agricultural technologies and practices to improve *Teff* productivity. It is recommended that empowering of female household heads by proving a continuous and practical training on *Teff* production.

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Author contributions
Nahusenay designed the study and Catherine participated in the conception of the study. Nahusenay managed developing instruments, data collection, and conducted the thematic content and statistical analyses, interpreted the data and wrote the first draft. Catherine Ndinda revised it to make the final manuscript. All authors have approved the final manuscript.

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Availability of data and materials
The datasets generated during and/or analyzed during this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participants
This study is based on a research project approved by Ethics Committee of UNISA and Mekelle University. In this regard, before conducting the field research, an ethical clearance with reference number 2017_DEVSTUD_Student_31 was obtained from the University of South Africa (UNISA), Department of Development Studies, Research Ethics Review Committee. Moreover, notifications of expedited approval with reference number 1107/2017 was obtained from Mekelle University, College of Health Science, Health Research Ethics Review Committee. All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable. Written Informed Consent was obtained from all subjects.

Consent of publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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References

Abebe F, Zuo A, Wheeler SA, Bjornlund H, Chilundo M, Kissoly L, Dube T. The influences on farmers' planned and actual farm adaptation decisions: evidence from small-scale irrigation schemes in South-Eastern Africa. Ecol Econ. 2022;202:107594.
Abrha BK. Factors affecting agricultural production in Tigrai region, northern Ethiopia. PhD dissertation. Pretoria: UNISA; 2015.
Agada M, Ajani EN. Constraints to increasing agricultural production and productivity among women farmers in sub-Saharan Africa: implications for agricultural transformation agenda. Int J Agric Sci Res Technol Ext Educ Syst (IJASRT in EES). 2014;4(3):143–50.
Aguilar A, Goldstein M, Kilic T, Oseni G. Decomposition of gender differentials in agricultural productivity in Ethiopia. Agric Econ. 2015;46(3):311–34.
Amentae TK, Tura EG, et al. "Exploring value chain and post-harvest losses of Teff in Bacho and Dawo districts of central Ethiopia."2016.

Assefa A, Meded A, Alemayehu O, Mulubrihan B, Ibrahim A, Abduselam F. Determinants of Productivity and Efficiency of Teff Production in Southwestern Ethiopia. East Afr J Sci. 2022;16(1):1–14.
Barrett CB. Smallholder market participation: concepts and evidence from eastern and southern Africa. Food Policy. 2008;33(4):299–317.
Bart M, Seneshaw T, Ermias E, Tadesse K. Ethiopia's value chains on the move: the case of Teff Ethiopia strategy support programme. Addis Ababa: Ethiopia Strategy Support Program II. ESSP working paper 52. 2013.
Berhe T. "Recent Development in Teff, Ethiopia's most important cereal and gift to the world." http://www.slideshare.net2009: 2010. 2009.
Biénabe E, Coronel C, et al. "Linking smallholder farmers to markets: lessons learned from literature review and analytical review of selected projects."2004.
Cagatay N. Gender and poverty. New York: UNDP Social development and poverty elimination division; 1998.
Cannarozzi G, Plaza-Wüthrich S, et al. Genome and transcriptome sequencing identifies breeding targets in the orphan crop tef (Eragrostis tef). BMC Genomics. 2014;15(1):581.
Carletto C, Savastano S, Zezza A. Fact or Artefact: the impact of measurement errors on the farm size-productivity relationship. J Dev Econ. 2013;103:254–61.
Chalachew T, Mulunesh D. Agricultural extension training and women's participation in Ethiopia: insights from district level services. Ethiopian J Soc Sci. 2020;6(1).
Chanyalew D, Adenew B, et al. Ethiopia's agriculture sector policy and investment framework (PIF): ten year road map (2010–2020). Addis Ababa: Ministry of Agriculture and Rural Development; 2010.
Chauvin N, Mulangu F, et al. Food production and consumption trends in sub-Saharan Africa: prospects for the transformation of the agricultural sector. New York: UNDP Regional Bureau for Africa; 2012.
Cochrane WG. Sampling techniques. Wiley; 2007.
Crawford E, Kelly V, et al. Input use and market development in Sub-Saharan Africa: an overview. Food Policy. 2003;28(4):277–92.
Creswell JW. Mixed-method research: introduction and application. Handbook of educational policy. Cambridge: Academic Press; 1999. p. 455–72.
CSA. "The federal democratic republic of ethiopia central statistical agency agricultural sample survey: area and production of major crops, Addis Ababa, Ethiopia". 2015.
CSA. "Agricultural sample survey. Report on area and production of major crops (private peasant holding, *Meher* season." Statistical bulletin 586. 2017.
CSA. The federal democratic republic of ethiopia central statistical agency, Agricultural sample survey (2010 E.C), volume I, report on area and production of major crops (private peasant holding, Meher season). Statistical bulletin 586, Addis Ababa, Ethiopia. 2018.
Debela B. Factors affecting differences in livestock asset ownership between male- and female-headed households in Northern Ethiopia. Eur J Dev Res. 2016;29:328–47. https://doi.org/10.1057/ejdr.2016.9.
Demeke M. Di Marcantonio F. "Analysis of incentives and disincentives for wheat in Ethiopia." Gates Open Res. 2019;3.
Desiere S, Jolliffe D. Land productivity and plot size: is measurement error driving the inverse relationship? Washington, DC: The World Bank; 2017.
Di DemekeMarcantonio MF. Analysis of incentives and disincentives for teff in Ethiopia. Rome: Technical notes series, MAFAP, FAO; 2013.
Dule KK, Tazeze A. Determinants of market participation and intensity of participation of Teff producers in West Arsi Zone of Oromia Ethiopia. Food Sci Quality Manag. 2020;101:2020.
Efa G, Degye G, Tinsae D, Tadesse K. Determinants of market participation and intensity of marketed surplus of Teff producers in Bacho and Dawo districts of Oromia State, Ethiopia. J Agric Econ Develop. 2016;5(2):020–32.
FAO. Analysis of price incentives for Teff in Ethiopia. Rome: Technical notes series, MAFAP; 2015.
FAO. National gender profile of agriculture and rural livelihoods—Ethiopia. Addis Ababa: Country Gender Assessment Series; 2019. p. 84.
Fatima A. Socio-economic constraints to demand for borrowing among rural females of Pakistan. Int J Soc Econ. 2009;36(11):2009.
FDRE. "Beijing+25 Report ETHIOPIA—2019: Fifth National Report on Progress made in the Implementation of the Beijing Declaration and Platform for Action (Beijing +25)."2019.
Funk CC, Brown ME. Declining global per capita agricultural production and warming oceans threaten food security. Food Secur. 2009;1(3):271–89.
Gebrehiwot NT, Azadi H, et al. How participation in vegetables market affects livelihoods: empirical evidence from Northern Ethiopia. J Int Food Agribus Market. 2018;30(2):107–31.
Getu H, Alfons W, Bart M. Determinants of the productivity of Teff in Ethiopia. Eur J Develop Res. 2017;29:866–92.
Getu H, Alfons W, Bart M. Rural organizations, agricultural technologies and production efficiency of Teff in Ethiopia. International Conference on Agricultural Economics. 2015.
Gideon EO. "Platform for agricultural risk management: managing risks to improve farmers' livelihoods, agricultural risk assessment study."2016.
Girma D, Assefa K, Chanyalew S, Cannarozzi G, Kuhlemeier C, Tadele Z. The origins and progress of genomics research on Tef (Eragrostis tef). Plant Biotechnol J. 2014;12:534–40.
Girma A, Endrias G. Market performance and determinants of marketed surplus of Tef in Bacho Woreda of South West Shewa Zone, Oromia National Regional State. 2015.
Haileselassie B, Stomph T-J, et al. Feed marketing in Ethiopia feed marketing in Ethiopia, 2009. Soil Sci Plant Nut. 2011;57(4):587–96.
Hailu G, Weersink A, Minten BJ. Rural organizations, agricultural technologies and production efficiency of teff in Ethiopia. 2015.
Hofferth S. Persistence and change in food security of families with children, 1997–1999. Department of family studies. College Park: University of Maryland; 2003.
Holden S, Tefera T. From being property of men to becoming equal owners? Early impacts of land registration and certification on women in Southern Ethiopia. Final research report prepared for UNHABITAT, Shelter Branch, Land Tenure and Property Administration Section. 2008.
Jayne TS, Mather D, Mghenyi E. Principal challenges confronting smallholder agriculture in sub-Saharan Africa. World dev. 2010;38(10):1384-1398.
Kebebew A, Sherif A, Getachew B, Gizaw M, Hailu T, Mark E. Quncho: the first popular tef variety in Ethiopia. Int J Agric Sustain. 2011;9(1):25–34.
Keller B, Mbewe DC. Policy and planning for the empowerment of Zambia's women farmers. Canadian J Develop Studies/revue Canadienne D'études Du Développement. 1991;12(1):75–88.
Kidane H, Alemu ZG, et al. Causes of household food insecurity in koredegaga peasant association, Oromia Zone, Ethiopia. Agrekon. 2005;44(4):543–60.
Madey DL. Some benefits of integrating qualitative and quantitative methods in program evaluation, with illustrations. Educ Eval Policy Anal. 1982;4(2):223–36.
Markew M, Mesele B. Gender differences in the adoption of agricultural technology in North Shewa Zone, Amhara Regional State, Ethiopia. Cogent Soc Sci. 2022;8:1.
Mesfin E, Abebe A, Seid A. "Ordinal logistic regression analysis in determining factors associated with socioeconomic status of household in Tepi Town, Southwest Ethiopia." Sci World J. 2022;9.
Mihiret M, Tadesse A. Gender, participation and decision-making process in farming activities: the case of Yilman Densa District, Amhara Region, Ethiopia. J Econ Sustain Develop. 2014;5(1):2014.
Ministry of Agriculture and Natural Resources (MoANR). UN Women and UNDP—UNEP PEI (United Nations Development Programme—United Nations Environment Programme Poverty Environment Initiative). The cost of the gender gap in agricultural productivity in Ethiopia. Addis Ababa: Ministry of agriculture and natural resources, UN Women, UNDP and UNEP. 2018.
Minten B, Tamru S, et al. Feeding Africa's cities: The case of the supply chain of teff to Addis Ababa. Econ Dev Cult Change. 2016;64(2):265–97.
Mottaleb KA, Rahut DB. Household production and consumption patterns of Teff in Ethiopia. Agribusiness. 2018;34(3):668–84.
Mulema AA, Farnworth CR, Colverson KE. Gender-based constraints and opportunities to women's participation in the small ruminant value chain in Ethiopia: a community capitals analysis. Community Dev. 2016;48(3):351–69.
Mussema R. Analysis of red pepper marketing: the case of Alaba and Siltie in SNNPR of Ethiopia. Haramaya: Haramaya University; 2006.
Najafi B. An overview of current land utilization systems and their contribution to agricultural productivity. Report of the APO Seminar on impact of land utilization systems on agricultural productivity. Productivity Organization, Islamic Republic of Iran Asian. 2003.
Nehru V, Dhareshwar A. New estimates of total factor productivity growth for developing and industrial countries. Washington, D.C.: The World Bank; 1994.

Oxfam. Gender inequalities and food insecurity: ten years after the food price crisis, why are women farmers still food-insecure? Briefing Paper. 2019.
Paddy F. Gender differentials in land ownership and their impact on household food security: a case study of Masaka district. Master of Science Thesis. Uganda. 2003.
Pender J, Gebremedhin B. Determinants of agricultural and land management practices and impacts on crop production and household income in the highlands of Tigray, Ethiopia. J Afr Econ. 2007;17(3):395–450.
Rahman MS, Khatun M, Rahman ML, Haque SR. Assessment of training needs on crop production for farmers in some selected areas of Bangladesh. Bangladesh J Agril Res. 2018;43(4):669–90. https://doi.org/10.3329/bjar.v43i4.39165.
Rehima M, Belay K, et al. Factors affecting farmers' crops diversification: evidence from SNNPR, Ethiopia. Int J Agric Sci. 2013;3(6):558–65.
RST. Socio-Economic Baseline Survey Report of Tigrai Regional State. Mekelle: Tigrai Regional State; 2018.
Roseberg RJ, Norberg S, et al. "Yield and quality of teff forage as a function of varying rates of applied irrigation and nitrogen." Klamath Experiment Station Annual Report. 2005.
Sah U, Kumar S. et al. "Need perception of tribal farmers with regard to recommended potato production practices in Meghalaya." Potato J. 2007;34(3–4).
Spielman DJ, Kelemwork D, Alemu D. Seed, fertilizer, and agricultural extension in Ethiopia. Development strategy and governance division, international food policy research institute—Ethiopia strategy support program II, Ethiopia. 2010.
Tegegne M. An assessment on the role of women in agriculture in Southern Nation Nationality People's Region: the case of Halaba Special Woreda. Ethiopia: Indira Gandhi National Open University; 2012.
UN Women Ethiopia Country Office. Engendering agricultural productivity in Ethiopia: The Cost of the Gender Gap. Policy Brief. 2018.
UN Women. The gender gap in agricultural productivity in sub-Saharan Africa: causes, costs and solutions. Policy brief. 2019;11.
Verbeek F, Vella M. Estimating and interpreting models with endogenous treatment effects. J Bus Econ Stat. 1999;17(4):473–8.
Warner J, Stehulak T, et al. Woreda-level crop production rankings in Ethiopia: a pooled data approach. Gates Open Res. 2019;3:316.
Yihdego AG, Gebru AA, et al. The impact of small-scale irrigation on income of rural farm households: evidence from Ahferom Woreda in Tigrai, Ethiopia. Int J Bus Econ Res. 2015;4(4):217–28.

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