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Agriculture & Food Security (2023) 12:37
https://doi.org/10.1186/s40066-023-00437-1

Agriculture & Food Security

RESEARCH

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Women empowerment in agriculture and its effect on household food security: evidence from Gamo Zone of Southern Ethiopia

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Abstract

Background Women empowerment and food security are supposed to be two mutually reinforcing goals of the 2030 Sustainable Development Agenda of the United Nations. However, the measurement of women's empowerment and its relationship with household food security in the agricultural context is too limited, especially in Ethiopia. The main objective of this study is to examine the effect of women's empowerment in agriculture on household food security in the Gamo zone of Ethiopia.

Methods Cross-sectional data were collected from 385 dual-adult households, selected through a multistage random sampling procedure from two districts—Chencha and Kucha of Gamo zone in Ethiopia. The data were collected on the sample households' demographic, socioeconomic, women empowerment, food consumption and livelihood activities—crop production, livestock holding and off-farm participation by interviewing both primary male and female decision-makers from each household. Household food security was measured using Calorie Availability, Household Food Consumption and Dietary Diversity Score, while women's empowerment in agriculture was measured using the Abbreviated Women Empowerment in Agriculture Index. Ordinary Least Square, Two-Stage Least Square, Poisson and Instrumental Variable Poisson regression were used as analytical models.

Results Our study shows that increases in women's empowerment are positively and significantly associated with all food security indicators—adult equivalent calorie availability, household-level food consumption and dietary diversity. The result also shows that food security is positively related to the proportion of adult household members, age and education of primary female, landholding size, crop diversification, food crop production, the number of dairy cows owned and off-farm participation. However, food security is negatively related to household size.

Conclusion The implication of the finding is that stakeholders should give due attention to promoting women's empowerment and eliminating the gender gap in agriculture through appropriate gender mainstreaming intervention in dual-adult households. Food security programmes could also gain from prioritizing female education and promoting agricultural diversification (crop and livestock) and off-farm income diversification strategies as valuable investments to improve household food security. This study is the first application of the Abbreviated Women's Empowerment in Agriculture Index in Ethiopia as a predictor to household food security, and contributes to the women's empowerment–household food security nexus literature in developing countries.

Keywords Women empowerment, Agriculture, Household food security, Poisson, Instrumental variable, Ethiopia

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Background of the study

Food security has been the priority development agenda for over half a century. The ongoing 2030 Sustainable Development Agenda of the United Nations identified ending hunger and achieving food and nutrition security as its second goal (SDG 2) [1]. However, food insecurity has been rising since 2015 [2], with an estimated 29.3% of the world's population being food insecure in 2021. The Global Report on Food Crises also shows that, in 2022, about 193 million people are acutely food insecure and need urgent assistance across 53 countries and territories, including Ethiopia [3]. The outbreak of the COVID-19 pandemic, climate shocks and widespread conflicts are said to have aggravated the problem [3, 4].

The sustainable development agenda rightly recognizes that increasing agricultural productivity and income of smallholder producers is essential to achieve the food security goal. The government of Ethiopia, through its ten-year development plan [5], has also acknowledged that increasing crop and livestock production and incomes are essential to improve food security and ensure food self-sufficiency.

Instrumental to enhance food production and incomes among farm households is to utilize the full human potential, including women [1]. Despite progress in addressing gender inequality in Ethiopia, women continue to be denied their full human rights and opportunities [6, 7]. Women face many marginalization and constraints, often embedded in norms and practices [8, 9]. They are discriminated against access to productive resources, such as land and livestock, and services, such as credit, household and agricultural decisions, participation in community affairs and leadership, education and productive employment [7, 9, 10].

Women empowerment is perceived to play a pivotal role in the production and ensure food security in agricultural communities [11–15]. Several pathways are possible in the framework of preference disparity between male and female decision-makers in a household [16, 17]. First, greater control over assets, such as land, helps women use it to produce varieties of crops that can enhance household dietary diversity [11, 18]. Second, women's livestock ownership, especially cows and poultry, allows them to produce livestock by-products essential to feed the family and generate income from the sale of dairy and poultry products, which they often allocate to purchase food for their family [10, 19]. Third, women's control of household income and participation in household expenditure decisions allows them to buy better quality food for household consumption [2, 11, 16]. Finally, women's membership in economic groups and access to credit enables them to diversify their income sources to off-farm activities to complement household income and improve food security [18, 20].

Empirical evidence [2, 7, 12, 18, 21–23] also suggests that gender equality and women empowerment (SDG 5) is essential not only in its own right to women but also is linked with other SDGs such as eliminating poverty (SDG 1), achieving food and nutrition security (SDG 2), as well as good health and well-being for women and children (SDG 3). The implication is that achieving women's empowerment and gender equality should be pursued a priori to attain the other goals of the 2030 development agenda, including food and nutrition security.

Several empirical studies underscored that the redistribution of household assets and decision-making power between men and women in a manner that enhances the bargaining power of women has the potential to improve food security among agricultural communities. For instance, in Nigeria [14], female empowerment was found to reduce the severity of food insecurity among smallholder farmers. Similarly, a study from pastoral communities in Tanzania [11] indicated that female control over assets and income is positively associated with dietary diversity by increasing their ability to produce and purchase more diverse and nutritious foods. A study from Bangladesh [12] also revealed that women empowerment increases calorie availability and household dietary diversity. Moreover, women empowerment was found to improve the dietary diversity of both women and their children in Ethiopia [18] and Timor-Leste [24].

Although several studies have been conducted on the women's empowerment-food security nexus in developing countries [10–12, 14, 18, 19, 21, 22, 24–28], only a handful of them [12, 14, 18, 24, 27, 28] uses the Abbreviated Women Empowerment in Agriculture Index (A-WEAI). It is a survey-based index designed to measure women's empowerment in agriculture [13] with a focus on the agency dimension of empowerment, which is less studied relative to resources, such as income, and achievement, such as education [12]. It captures the role and extent of females participation in agriculture in five domains: (1) production, (2) resource, (3) control over income, (4) leadership, and (5) time allocation. The A-WEAI is an aggregate index measured based on the individual-level data on men and women within dual-adult households from which two indices: (1) the five domains women's empowerment (5DE) score and (2) the Gender Parity Index (GPI) are derived. The data collected from dual-adult households allows the computation of the 5DE scores for the principal male and principal female, which in turn is used to compare the agricultural empowerment of male and female decision-makers living in the same household. It is an innovative approach that helps to assess the state of women empowerment in agriculture and identify areas, i.e., domains in which empowerment needs improvement, and consequently, it has become a popular method.

It is also pertinent to note that except [18], all the aforementioned studies were done outside Ethiopia. The Ethiopian study [18] also focuses on analysing the effect of empowerment on maternal and children nutrition though it delivers interesting insight that female empowerment is essential for maternal and children nutrition outcomes. Moreover, some of the existing studies [11, 19, 21, 22, 25, 27] fail to account for potential endogeneity of women empowerment as it could be determined by the same factors that affect HFS to induce a bias.

On the other hand, much of the research in Ethiopia [29–36] analyses the factors that affect HFS without linking it to intra-household resource allocation and women empowerment. Although these studies are helpful, empirical works that establish the causal relationship between women's empowerment in agriculture and food security at the household level in the context of developing countries, in general, and Ethiopia, in particular, is of significance to guide gender mainstreaming in agriculture-related intervention.

In an attempt to fill these research gaps, using cross-sectional survey data from dual-adult households in Ethiopia as a case study, this paper examined the effect of women's empowerment in agriculture on HFS. We measure the HFS using three complementary measures: Calorie Availability, Household Food Consumption and Dietary Diversity Score.

The study contributes to the literature analysing women's empowerment-HFS nexus in developing countries' agricultural context in several ways. First, it measures women empowerment using the A-WEAI. Second, it provides empirical evidence on the effect of empowering women as measured by achievement in the 5DE score, gender parity and women's asset ownership—a key indicator in the A-WEAI, on HFS in Ethiopia. Third, it provides evidence on how socio-economic factors affect HFS among rural households in Ethiopia. Ordinary Least Square, Two-Stage Least Square, Poisson and Instrumental Variable Poisson regression were used as analytical models, with endogeneity concerns addressed.

The next section provides a review of the empirical literature on the food security effect of women's empowerment. The third part highlights the materials and methods, including sampling procedure, data collection, analysis and analytical approach. The fourth section presents the results and discussion, while the final section provides concluding remarks.

Empirical literature review

Although it has got little research attention in the past, the empirical literature on the food security effect of women empowerment in agrarian communities is rapidly growing. In most of the previous studies [11, 12, 14, 18, 19, 21, 22, 24, 25, 27, 28, 37–39] women empowerment was found to have a positive and significant effect on the food and nutrition security of agrarian households, while a study from Tanzania [11] does not find a significant relationship.

A study in Nigeria [14] examined the effect of women empowerment in agriculture on food security, measured using household food security scores and household dietary diversity. The study followed the USDA 18 questions HFS module and categorised households into four mutually exclusive food security categories: (1) very low food security, (2) low food security, (3) marginal food security, and (4) high food security. On the other hand, women's empowerment was measured using the A-WEAI. Based on the cross-sectional data and using Instrumental Variable Poisson (IVP) and Zero-Inflated Poisson (ZIP) regression, the study showed that women's achievement in group membership, income control and workload reduces the extent of food insecurity among the smallholder farmers in Nigeria. Surprisingly, however, they found that women's achievement in productive decisions and credit increases the severity of food insecurity among farmers in the study area.

Another study from Nigeria [22] assessed the effect of women's empowerment on HFS. The study measured food security using direct calorie intake method where households with daily per adult equivalent calorie consumption of below 2250 kcal are categorized as food insecure, while those households that are above it are food secure. Women's empowerment is assessed with the A-WEAI. Based on a Logistic regression, the study found that the larger the 5DE score, the more likely the households are food secure. Similarly, a study in South Africa [25] that uses the logit model to examine the effect of women empowerment in agriculture on dietary diversity shows that input in productive decision and speaking in public were positively related to food security, while access to credit is negatively associated.

Studies from Ethiopia [18] and Timor-Leste [24] investigated the effect of women's empowerment in agriculture on the nutrition outcomes of children and women. Using A-WEAI as a measure of women empowerment and multivariate regression and instrumental variable methods, the studies revealed that women's empowerment enhances maternal and children dietary diversity. A similar study in rural Pakistan [37] analysed the relationship between multiple dimensions of women's empowerment and their influence on women's food security. The study shows that the domains of legal rights, information and communication technologies, social support and familial rights can be a significant pathway for enhancing the food security of women as more bargaining power over the utilization of resources could result in a good quality of food choices and more expense on food items. Another study from Pakistan [28] explored women's empowerment in the agriculture-HFS nexus using the Partial Least Square structural equation model. The result shows that achievement in leadership, agricultural production, resource ownership and time domain have significant positive effects on HFS. Surprisingly, however, the study revealed that food security is negatively related to achievement in the income domain.

Essilfie et al. [21] examined the effect of women empowerment on food security in Ghana based on the data from the Ghana Living Standard Survey. Using a Generalised Ordered Logit model, the study revealed that women's empowerment proxied by relative years of schooling and women's decision-making was an essential predictor for HFS—measured by the food insecurity experience scale. A study from south-central Tanzania [19] examined the effect of female and male control of livestock resources on food security among agro-pastoralist and pastoralist households. The study uses the relative control of livestock as a proxy for women empowerment and Mixed Effects Logistic regression of HFS status measured through the household food-insecurity access scale. The research revealed that female-controlled livestock improves HFS status, while male-controlled livestock holdings were not. According to the study, unlike men, women used the income to supplement food supplies and livestock they controlled as a primary response to unanticipated household needs. The study, however, ignored the role of women in crop agriculture and its implication on household food security outcomes.

Using nationally representative survey data, a study from Bangladesh [12] also analysed the role of women empowerment, measured through the original Women empowerment in agriculture index (WEAI), on HFS. The study applied the 2SLS regression and revealed that increases in women empowerment, measured generally in terms of 5DE empowerment score and GPG, are positively related to calorie availability and dietary diversity at the household level. By decomposing the WEAI into its component domains, the study has shown that leadership and control of resources are the most promising areas for policy intervention. At the indicator level, the study highlighted that increasing the number of groups in which a woman actively participates; control of assets and access to credit is positively related to household-level calorie availability and dietary diversity. In a similar vein, Holland and Rammohan [39] analysed the influence of women's empowerment on child food security in Bangladesh. The study adopted the WEAI to measure empowerment, while child stunting was used as a proxy for child food security. The empirical result shows that women's autonomy in productive decisions and confidence in public speaking are significantly associated with better child stunting outcomes. Moreover, the study found that women's 5DE empowerment score is correlated with HDDS.

Unlike the aforementioned studies, a study from pastoralists in Tanzania [11] does not find a significant effect of women empowerment on HFS. The study measured empowerment by the women's empowerment in livestock index (WELI), while it applies the household food security access scale to measure food security. Using a cluster-adjusted regression; the study revealed that there is no significant relationship between empowerment and HFS.

On the other hand, the women empowerment and HFS studies have controlled for other socioeconomic factors in food security. Some studies underline that women's empowerment plays a moderating role in the relationship between other livelihood interventions and food security, and suggested a simultaneous promotion of women empowerment along with other policies to achieve desired changes in HFS [12, 14, 37, 38]. It is in line with the assertion that intra-household allocation of resources and the participation of women determine the outcomes of any development intervention [16, 17]. The studies show that the food security is related to agriculture technology adoption [38], education, crop diversification, staple crop production and livestock holding [12, 14, 40–42], land size [26, 34, 41], off-farm income diversification [26, 30, 32] and household size [12, 26, 30, 32].

Although the literature that establishes the women empowerment—HFS nexus is growing, the limitations of the studies and inconsistency in some of the findings call for additional empirical investigation. Some of the studies [11, 19, 21, 22, 25, 27] fails to account for the endogeneity of women empowerment in their analysis. Women's empowerment could be determined by the same factors that affect food security, and unless appropriately controlled, the empowerment effect estimates are bound to be misleading. On the other hand, some of the results of the previous studies are inconsistent. For instance, a study from Bangladesh [12] found that women's achievement in productive decision increases the severity of food insecurity, while studies from Pakistan [28] and South Africa [25] revealed the opposite. Therefore, this study attempts to fill these research gaps and contribute to the existing literature in developing countries by taking Ethiopia as a case study area.

Materials and methods

Description of the study area

This study was conducted in the Gamo Zone found in the Southern Nations, Nationalities, and Peoples' Regional (SNNPR) state of Ethiopia. It is situated some 500 km south east of Addis Ababa, the capital city of Ethiopia. Geographically, Gamo zone lies between 5.57°-6.72° North latitude and 36.99°-37.99° East longitude. With an elevation ranging between 500 - 4207m above sea level, the zone has a highly diversified landscape. It is characterized by mountains, plateaus, deep gorges, and lowland plains and contains climatic variations from tropical to temperate. It is home to Gughe Mountain –the highest peak point of the region and south west highlands of Ethiopia. The relief features of the zone gives rise to the formation of diverse drainage systems such as rivers, Lakes, waterfalls and springs.[1] Two of the major lakes in Ethiopia –Lake Abaya[2] and Lake Chamo, are part of the Gamo Zone.

Gamo zone has 14 rural Districts and six town administrations. It covers a total area of 8,013.1sq.km with a population density of 258 persons per sq. km. In 2020, an estimated population of 1,665,659 (828,533 males and 837,126 females) lived in the zone [44]. The livelihood of the people depends on a mixed crop-livestock production system.

Parts of the Gamo zone, Chencha and Kucha districts are the study areas. Chencha district has an area of 225.3sq.km and a population density of 424 persons per sq. km. It has 30 rural Peasant Associations (*Kebele*[3]). The total population of the Chencha district is estimated to be 95,575 in 2020. Females constitute about 55% of the people, and the remaining 45% are male. On the other hand, Kucha district has an area of 987.57 sq.km and is consisted of 23 rural *Kebeles*. For the year 2020, the projected population of the district is 124,183. Females account for 50.30%, while 49.70% are males. The district has a population density of 126 persons per sq. km [43]. Chencha is three times more densely populated relative to the Kucha district.

The two districts are entirely rural. Similar to other parts of Ethiopia, the main economic activity of the people in these districts is mixed farming, where about 94% of the population earn their livelihood, and the rest depends on off-farm activities such as weaving, pottery, petty trade, fishing, charcoal and firewood collection and sale, and casual wage works. In these districts, Maize, Haricot bean, Teff, Wheat, Barley and Sorghum are grown under rain-fed conditions. Peppers, Potatoes, Tomatoes, Onions, Yam, Taro and Cabbage are common vegetables and root crops of the districts. The districts are also known for various types of fruit crop production, including Apple, Banana, Avocado, Mango, Orange and Papaya. Cattle, sheep, goats, donkeys, and poultry are the main livestock species reared in the study areas [44]. Figure 1 presents a map demonstrating the location of the study areas.

Though livelihood depends on agriculture, the study area is characterized by very small landholding, high poverty and food insecurity [44–46]. The situation is similar in most parts of Ethiopia. The role of women in the social and economic life of the people in the study areas is immense. They supply labour for crop production, cultivate food for household consumption, raise and market livestock, and generate additional income through off-farm activities, such as petty trade, pottery and weaving. They also collect firewood and water, perform household chores, and carry out birth and childcare responsibilities. Female empowerment is critical to solve the poor rural livelihood outcomes. The reason is that given differences in production and expenditure preferences of primary males and females within a household [16, 17], with females preferring to allocate resources towards the betterment of their family [17, 47], the agency of females in agriculture is likely to imply rural livelihoods and welfare.

Sampling procedure and methods of data collection

The study mainly depends on primary data collected from sample households. We draw samples through probability and nonprobability sampling procedures. Initially, we categorize Districts of the Gamo zone into two: Gamo highland and Gamo lowland Districts, based on the climatic condition of the area.[4] Then we randomly select one District from each category. Following this procedure, Chencha and Kucha Districts were drawn from the highlands and lowlands of the Gamo zone, respectively.

Given the target household population of the two districts (35,402) (GZPD, 2020), sample size was determined using Taro's (1963) formula:

$$n = \frac{N}{1 + N(e^2)} \quad \text{i.e.,} \quad n = \frac{35,402}{1 + 35,402(0.05^2)} \approx 395$$

[1] One instance for the presence of large number of springs is Arba Minch (meaning "40 Springs") –the capital city of Gamo zone derives its name from the existence of about 40 springs in the eastern part of the city.

[2] Lake Abaya is the largest rift valley lake in Ethiopia.

[3] It is the smallest administrative unit in Ethiopia.

[4] Gamo Zone contains tropical (lowland), subtropical (midlands) and temperate (highlands) climatic conditions, with the largest area having the subtropical climate. The traditionally called Gamo highlands include the temperate and subtropical climate zones (& contain eight districts), while lowlands refer to the tropical climate zone (& contain six Districts).

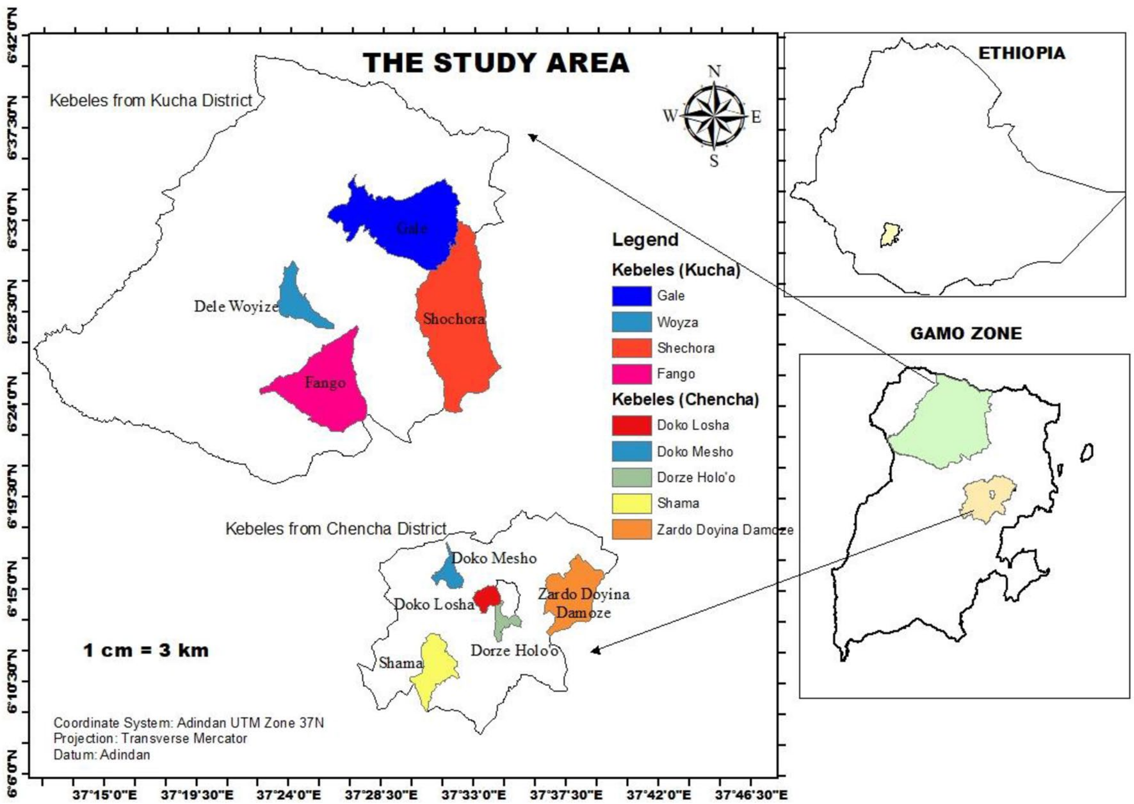

Fig. 1 Map of the study areas

where "*n*" is the sample size, "*N*" total household in the two districts and "*e*" level of precision which is fixed at 5% in this study.

Based on this figure, we collect data from 395 dual-adult households through *schedules*.[5] However, we exclude ten samples from the analysis owing to missing data. For this reason, the data analysis comprised questionnaires administered to 385 dual-adult households for which complete information was available.

To draw samples, a multistage random sampling procedure was followed. First, a sixth of the Kebeles from each District were randomly selected. Following this procedure, five kebeles, namely, Doko Mesho, Doko Losha, Shama, Zardo Doyina Damoze and Dorze Holo'o from Chencha and four kebeles, namely, Gale, Dele Weyza, Fango and Shochora were selected from Kucha District (see Fig. 1). Then the predetermined total sample (385) was allocated for each selected *Kebele* following proportional to total dual-adult household population size procedure. Second, using the list of dual-adult households of each selected *Kebele* as a sample frame; samples were selected through systematic random sampling (See Table 1).

Table 1 Distribution of household and sample size by *Kebele*. *Source*: Own computation based on the Kebele data

S. no	*Kebele*	Total dual-adult households	Per cent	Sample dual-adult households
1	Doko Mesho	486	8.6	35
2	Doko Losha	395	7	32
3	Shama	892	15.7	60
4	Zardo D.Damoze	467	8.2	35
5	Dorze Holo'o	293	5.2	24
6	Gale	1162	20.5	70
7	Dele Weyza	300	5.3	25
8	Fango	505	8.9	32
9	Shochora	1166	20.6	72
	Total	5666	100	385

[5] Following [77], it is a method of data collection whereby appointed enumerators filled in questionnaires administered to respondents in a face-to-face interview format. This method is commonly applied when data is collected from less literate agricultural communities like in rural areas of developing countries, Ethiopia inclusive.

The survey questions cover several topics, including the households' demographic, socioeconomic and institutional characteristics, empowerment indicators, food consumption and livelihood activities—crop production, livestock holding and participation in off-farm activities during the 2020 production year, of the respondents. Following the guideline by Malapit et al. [48], primary females and males were separately interviewed. Household demographic, livelihood activities, institutional characteristics, food consumption and women's empowerment modules were administered to female respondents, while the men's empowerment module was administered to male respondents.

For the data collection, 16 enumerators were appointed and trained on the interview questions and general data collection protocol for three days (one day at the office and two days on-field). After the one-day training at the office, enumerators were trained at the field level during the questionnaire pilot test in the sample *Kebeles*. For the pilot test and field-level training, draft questionnaires were distributed to five dual-adult households in each sample *Kebele*. It has helped to know whether the instruments are appropriate and suited to the intended study, and check the enumerator's awareness of the data collection protocol. Necessary modifications were made based on the comments obtained from pilot test responses from respondents and enumerators to ensure the reliability and validity of the questionnaire. Some misunderstanding among the enumerators was also cleared out. After the training and the pilot test, the data were collected, by the enumerators, with close supervision of the authors on February 2021.

To supplement the primary data, the secondary data were also used through reviewing different documents, such as Gamo zone office reports, published journal articles and books.

Method of data analysis

Both descriptive statistics and econometrics models were employed to analyse the data. Calorie availability, household dietary diversity score and food consumption score were measured and used as a proxy for household food security—the outcome variable of the study, while the A-WEAI was used to measure women empowerment – the key explanatory variable. Econometric models, such as OLS, Instrumental Variable and Poisson Regression were applied. The detailed descriptions of how food security indicators and women empowerment are measured and the analytical methods are presented in what follows.

Measuring household food security

Due to the elusive nature of the concept itself, there is no single measure of food security [49]. Alternative indicators of food availability, access, utilization, stability and coping strategy are used as a proxy for food security [11, 12, 22, 33, 40, 50]. The choice of the indicator to use depends on the food shortage situation and the intended use of the investigation [51]. For instance, the relatively simple and quick-to-use indicator, the Copying Strategy Index (CSI), is often used as a measure of food security [52], while more complex food security measures are in use when there is sufficient time and budget to get the required data. The application of more than one indicator of food security is also widely recommended and applied in many food security studies [12, 41, 49, 52]. It is partly because a single indicator is not supposed to adequately capture all the dimensions[6] of the multidimensional construct–food security [53, 54].

As the study aims to link women's empowerment in agriculture to the quantity and quality of food consumed by households whose source is mainly own crop and livestock production, three food security indicators are used. These are calorie availability, household dietary diversity and food consumption score. These measures are commonly used as a proxy for food availability, access and utilization [12, 14, 40, 41]. The reason is straightforward: while calorie availability fails to capture the quality of food, HDDS and HFCS better measure the quality of food consumed [12, 14, 40]. We apply all of them because they are complementary to each other. We highlight the measurement of these indicators in what follows.

Calorie availability

A commonly used proxy for food security at the household level is calorie availability [12, 31, 33], constructed by converting quantities of food consumed into corresponding energy units. In this study, food consumption data covering around 50 food items were collected at the household level. The data capture quantities consumed from market purchases, home production and food received in exchange for labour. The 7-day data were converted to daily calorie equivalents, based on the Ethiopian Health and Nutrition Research Institute's [55] food composition table for use in Ethiopia, and the resulting calorie values were divided by household size and adult equivalent household size to obtain per capita and adult equivalent calorie availability values, respectively.

Household dietary diversity score (HDDS)

Calorie availability has been criticised for the fact that it does not reflect the quality of food available to households [56]. It is particularly relevant for countries like Ethiopia, where diets are dependent on starchy foods and

[6] Food availability, access, utilization and stability are the four pillars that has to be included in measuring food security [76].

little animal products. Following the research finding that changes in dietary diversity are a good gauge of changes in household per capita consumption and household per capita calorie availability [57], dietary diversity has gained importance as a proxy measure of household food access and food security [11, 12, 50, 58]. It is a qualitative measure of food consumption that reflects a household's access to a variety of foods and is also a proxy for nutrient adequacy of the diet [59].

It is customary to follow the Food and Agriculture Organization's (FAO) [59] guideline to measure HDDS. The measurement approach is to count the number of food groups consumed by a household over a certain period like the previous day, three days, 7 days or even a month.[7] In this study, the 7-day recall period is applied as it is optimal and also conforms to the recall period used in many dietary diversity studies [12, 60]. For this purpose, 16 food groups are used: cereals, white roots and tubers, vitamin A-rich vegetables and tubers, dark green leafy vegetables, other vegetables, vitamin A-rich fruits, other fruits, organ meat, flesh meat, eggs, fish and other seafood, legumes, seeds and nuts, milk and milk products, oils and fats, sweets, and spices, condiments, and beverages [59]. Thus, we measure HDDS by counting the food groups consumed over the previous 7-day by the sample households.

Household food consumption score (HFCS)

HFCS is developed and primarily used by the World Food Programme. Currently, HFCS is increasingly being applied in the empirical assessment of food security [14, 41, 42]. It is superior to the HDDS in that it captures both the quality and quantity of food households consume. FCS is a composite score based on the dietary diversity, food consumption frequency and relative nutritional importance of different food groups consumed [61]. Therefore, following the WFP [49] guideline, we group foods into eight categories: cereals and tubers, pulses, vegetables, fruits, meat and fish, milk and milk products, sugar and sugar products and oils. Then, FCS is computed by multiplying the frequency of the different food groups consumed during 7 days, measured in days, and the relative nutritional importance of the food groups. Finally, we derive a composite score for each household from a weighted sum of the food groups and frequency of consumption.

Measuring women empowerment

This study aims to establish causality between HFS indicators and women empowerment. Despite the growing interest in its measurement and research, measuring women empowerment has remained to be a big challenge. To measure empowerment, empirical inquiries often begin with the women empowerment definition provided by Kabeer [62], who defined it as a process by which those who have been denied the ability to make strategic life choices acquire such an ability. Scholars and development practitioners try to ascertain what determines such ability and identify the key domains of women's empowerment to allow for its measurement [13, 63]. The choice of which domain (familial, legal, psychological, economic, political and cultural) to focus on depend on the local context or topic of analysis [64]. Thus, different studies [9, 11, 12, 14, 22, 64] measure women empowerment based on a mixture of different domains with keen attention to its multidimensional nature.

However, these days, the focus of the research is on the application of a multidimensional composite women empowerment index aligned with the research objective [12–14, 18, 27]. The survey-based A-WEAI, designed to measure women's empowerment in agriculture [13], is one of such indices.

In this study, women's empowerment is measured using the A-WEAI, which is an abbreviated version of the original Women's Empowerment in Agriculture Index (WEAI). A-WEAI[8] was developed as an improvement over WEAI based on the challenges encountered during its implementation such as the lengthy time it takes to complete the questionnaire and the inability to comprehend some of the sections [48]. The WEAI was initially developed in 2013 as a tool to track progress in women empowerment that arises from the Feed the Future Initiative of the US government. However, the WEAI and its revised version (A-WEAI) has also been used extensively by researchers to assess the state of women empowerment in agriculture, to identify key areas in which empowerment needs to be strengthened, and track progress over time [14, 22].

The A-WEAI is an aggregate index measured based on individual-level data on men and women within the same household. It is a weighted average of two sub-indexes: (1) the five domains women's empowerment (5DE) and (2) Gender Parity Index (GPI). The 5DE sub-index shows how women are empowered, capturing the roles and extent of women's participation in agriculture in five domains: (1) production, (2) resources, (3) control over

[7] It should be noted that a short recall period like the previous 24-h does not provide an indication of household's habitual diet though it is less subject to recall error, while a long recall period such as the previous month can be cumbersome for the respondent and subject to error.

[8] The A-WEAI similar to WEAI measures women empowerment in their roles and extent of engagement with respect to five domains, namely, production, resources, income, leadership and time allocation. However, WEAI is computed using ten indicators while the A-WEAI uses only six indicators [48].

income, (4) leadership, and (5) time allocation. Table 2 describes the five domains and the corresponding six indicators. The 5DE assesses the degree to which women are empowered in these domains, and for those who are not empowered, the percentage of domains in which they are empowered. "Empowerment" within a domain means that the person has adequate achievement for that domain.

A woman is said to be empowered if she has adequate achievements in at least four of the five domains or has achieved 80% adequacy from a combination of the weighted indicators. Each indicator measures whether a respondent has achieved adequacy based on the threshold given in Table 2. It is also clear from Table 2 that each domain receives equal weight.

In the application of the A-WEAI, it is customary to interview both a principal male and principal female [14, 48]. This allows the computation of 5DE measures for both the principal male and female in dual-adult households. Computation of men's 5DE scores and their comparison to women's 5DE enables the comparison of the agricultural empowerment of men and women living in the same household. This comparison is embodied in the GPI (gender parity index), a relative inequality measure that reflects the inequality in 5DE profiles between the primary adult male and female in each household. The aggregate A-WEAI uses the mean GPI value of dual-adult households. GPI combines two key pieces of information: (1) the percentage of women who lack gender parity relative to their male-household counterparts and (2) the extent of the inequality in empowerment between those women who lack parity and the men with whom they live [13].

Both measures, taken together, make up the A-WEAI. The aggregate index, therefore, shows the degree to which women are empowered in their households and communities (5DE) and the degree of inequality between women and men in their households (GPI). Details regarding the construction of the index can be found in Malapit et al. [48].

The 5DE index is computed according to the formula:

$$5\text{DE} = H_{\text{e}} + H_{\text{n}} * A_{\text{e}} \quad (1)$$

where H_{e} is the percentage of women who are empowered, H_{n} is the percentage of women who are not empowered and A_{e} is the percentage of domains in which disempowered women have adequate achievement. Hence, the 5DE index yields a value that ranges between 0 and 1, where higher values imply greater empowerment.

The GPI shows the percentage of women who are equally empowered as their male counterparts. For those pairs with disparity, the GPI shows the relative empowerment gap between the woman's 5DE score and the man's. The GPI is calculated as:

$$\text{GPI} = 1 - (H_{\text{W}} * H_{\text{G}}) \quad (2)$$

H_{W}—the percentage of women without gender parity; H_{G}—the average 5DE empowerment gap between women and men living in households with gender disparity; A-WEAI gives a weight of 90% to the 5DE score and a weight of 10% to the GPI. Thus, the A-WEAI is computed as:

$$\text{A-WEAI} = (5\text{DE} * 0.9) + (\text{GPI} * 0.1) \quad (3)$$

In this research, we use women's 5DE score, gender parity gap and asset ownership of women to examine the relationship between women's empowerment and food security.

Analytical methods

Ordinary least squares (OLS) and two-stage least squares (2SLS) regression were used to model continuous variables such as calorie availability and household food

Table 2 The five domains of empowerment in the A-WEAI. *Source* [48]:

Domain	Indicator	Definition of indicator	Weight
Production	Input in productive decisions	Sole or joint decision making over food and cash-crop farming, livestock and fisheries	1/5
Resources	Ownership of assets	Sole or joint ownership of major household assets (farmland, livestock, farming tools, off-farm equipment, durable goods, etc.)	2/15
	Access to and decisions on credit	Access to and participation in decision making concerning credit	1/15
Income	Control over use of income	Sole or joint control over income and expenditures	1/5
Leadership	Group membership	Respondent is an active member in at least one economic[a] group (e.g., production, agricultural marketing, saving and credit, consumer cooperative, etc.)	1/5
Time	Workload	Respondent is time poor if s/he worked more than 10.5 h in previous 24 h	1/5

[a] We make a very slight modification on the group membership indicator. The A-WEAI considers membership in a single group as adequate (be it social or economic). However, we consider adequate if the respondent is an active member of at least one economic group since traditional/cultural and religious groups such as *edir*, *mahber*, etc., are very common and almost every one is a member in the study areas. Thus, to have a meaningful assessment and also evaluate the role of economic groups to women's empowerment, we introduce economic group membership

consumption score, while Poisson and instrumental variable Poisson (IVPoisson) regression were applied to model household dietary diversity score which is a count data.

Ordinary least squares (OLS) regression

The continuous dependent food security indicator variables were modelled as

$$Y_i = \beta_0 + \beta_1 \mathrm{WE}_i + \beta_2 D_i + \beta_2 X_i + \varepsilon_i \quad (4)$$

where Y_i is calorie availability or household food consumption score, WE_i is women's empowerment, D_i is the vector of household demographic characteristics, X_i is the vector of others socio-economic variables[9] associated with the ith household, β_i are coefficients to be estimated and ε_i is the error term.

Poisson model

To model the count outcome variable, HDDS, Poisson regression is the appropriate technique. In the Poisson distribution framework we estimate how the explanatory variables influence the number of times the outcome variables occurred. One of the basic assumptions of the Poisson regression model is that the expected value of the Poisson distribution is equal to its variance. Following Greene [65], the Poisson regression model assumes that the dependent variable y given the vector of explanatory variables x has a Poisson distribution (Eq. 5):

$$f\left(y_i/x_i\right) = \frac{e^{-\mu_i} {\mu_i}^{y_i}}{y_i} \quad y_i = 0, 1, 2, \ldots . \quad (5)$$

The main assumptions of the Poisson regression model is that the log-linear conditional mean function $E[y_i/x_i] = \mu_i$ and its equidispersion $\mathrm{Var}[y_i/x_i] = \mu_i$[65]:

$$E[y_i/x_i] = \mathrm{Var}[y_i/x_i] = \mu_i = \exp(x_i\prime\beta) \quad \text{for} \quad i = 1, 2, \ldots, n \quad (6)$$

In this study, three models were estimated using three measures of women's empowerment, the key explanatory variable, in alternative specifications.

Model 1: We use women's 5DE score as an empowerment measure. It is the aggregate empowerment score of the primary female in the household. It is measured as the weighted average of her achievements in the six indicators that comprise the five domains of the A-WEAI. This measure gives values that range from zero to one and is increasing in empowerment.

Model 2: We use the gender parity gap (GPG) to measure empowerment. It follows from the evidence that there is a need to pay due attention to intra-household gender inequality and bargaining power as a factor in household welfare outcomes and in attaining development goals in general [14, 66, 67]. Therefore, it is interesting to see whether women's relative empowerment within their households is associated with household food security outcomes. One component of WEAI, the Gender Parity Index (GPI), is a composite index that reflects the percentage of women who have gender parity and the 5DE empowerment gap between women and men in households that do not have gender parity. Since our interest is to examine how differences between empowerment levels of women and men affect household food security, we use the GPG component of the GPI as one of the measures of empowerment. GPG is calculated by taking the difference between the men's and women's 5DE scores. A household enjoys gender parity if the woman is empowered or her empowerment score is greater than or equal to that of the male in her household [13, 48]. Thus, the gender parity gap is zero if the household enjoys gender parity. Otherwise, the gap equals the difference in the male and female aggregate empowerment score.

Model 3: In this specification, we use the number of assets woman has sole or joint ownership of as indicator of women's empowerment. It is the total number of household asset types for which the primary female reports sole or joint ownership. This is due to evidences that insist asset ownership of females determines their bargaining power [10, 16, 17] and hence highly related to empowerment [47, 68] and thereby food security [10, 12, 14, 19, 28, 67].

Based on theoretical and empirical evidence [11, 12, 18, 37, 38, 58, 68], women who are more empowered—represented by higher 5DE score, lower GPG or ownership of a larger number of assets [10], are expected to have food secure households.

Since we expect that women's empowerment might be determined by the same variables that affect food security indicators, we apply the instrumental variables method to correct for potential endogeneity bias, using the ivreg2 and IVPoisson procedures for the continuous and count data food security indicators, respectively, in Stata 15.

It is well-known that the identification of valid instruments is hard to fix. However, based on the empirical evidence from similar previous studies [12, 18] and our logical reasoning, we identify and use three instruments for all empowerment indicators. These include (1) age difference between the primary male and female decision-makers. The differences in ages can reflect differences in human capital between the female and male decision-makers and therefore reflect relative bargaining strengths [69]. (2) The count of types of informal credit sources

[9] Table 3 presents summary statistics of the demographic and socioeconomic variables included in the model.

Table 3 Definitions of variables and summary statistics (n = 385). *Source*: Survey data, 2021

Variables	Summary statistics			
	Mean	**SD**	**Min**	**Max**
Food security indicators (dependent variables)				
Per capita calorie availability	2569.15	1256.77	244	6625.18
Per adult equivalent calorie availability (calorie consumption)	3013.77	1433.63	267	6902.22
Calorie consumption is adequate (1 if yes, 0 otherwise)	0.67	0.47	0.00	1.00
Household Food Consumption Score	48.72	24.08	8.00	105.00
Household Dietary Diversity Score	6.75	2.40	2.00	12.00
Women empowerment variables				
5DE Empowerment score of women	0.61	0.19	0.20	1.00
5DE Empowerment score of men	0.83	0.13	0.53	1.00
Gender parity gap	0.22	0.16	0.00	0.80
Number of assets woman has self/joint ownership of	4.65	1.98	0.00	9.00
Other control variables				
Age of primary male respondent (years)	48.04	12.18	26.00	90.00
Age of primary female respondent (years)	41.24	10.13	23.00	78.00
Primary male respondent is literate (1 if yes, 0 otherwise)	0.59	0.49	0.00	1.00
Primary female respondent is literate (1 if yes, 0 otherwise)	0.37	0.48	0.00	1.00
Household size	6.90	2.47	2.00	15.00
Adult equivalent household size	5.89	2.18	1.58	13.12
Proportion of male household members	0.49	0.15	0.10	1.25
Proportion of female household members	0.51	0.15	0.13	1.00
Proportion of 0–15 years old household members	0.38	0.23	0.00	1.25
Proportion of 65 + years old household members	0.2	0.50	0.00	3.00
Proportion of adult (16–65 years old) household members	0.60	0.23	0.00	1.33
Proportion of dependent members (< 15 and > 65 years old)	0.41	0.21	0.00	1.00
Distance from main market (Walking Minutes)	113.94	47.12	15.00	240.00
Landholding size (in hectare)	0.65	0.41	0.06	2.00
Number of food crops produced by s	4.32	1.68	1.00	10.00
Value of food crops produced by households (2021)	30,372	20,186	2533	197,867
Tropical life units	3.15	2.09	0.00	16.03
Number of Dairy Cows owned by households	1.48	1.26	0.00	6.00
Households participate in off-farm activities (1 if yes, 0 otherwise)	0.40	0.48	0.00	1.00
Instruments				
Age difference (primary male less primary female)	6.79	5.50	− 5.00	36.00
Number of informal credit source types available	2.42	1.28	0.00	5.00
Number of community activities woman has provided support in the previous year (2020)	3.30	1.36	0.00	6.00

available for the woman. The data on whether informal credit source types like informal money lender—usury and idir, within/outside the woman's village, shopkeepers who offer consumable items on credit, agricultural input providers who sell input on credit and whole buyers who buy farm products on advance payment were present in the community were collected during the survey. The presence of a large number of informal creditors may indicate the size of the informal credit market and social capital within the community [12], which could influence a woman's participation in community groups or credit decisions and the accumulation of assets.

iii) The count of community activities the woman provides support in the previous year. The more active woman in the community is likely to be empowered in terms of participation in community groups. We have collected data on whether the woman has contributed money or labour to different community activities – building/maintenance of schools, healthcare facilities, irrigation canals, roads, Watershed development work, Church, and helping out others who suffered from COVID-19 during the previous year.

Description of other control variables

Though the very objective of the study is to identify the effect of women empowerment –a key explanatory variable, on the food security outcome of farm households, our analysis also controls other demographic and socioeconomic characteristics of sample households, informed by the A-WEAI literature and food security studies in Ethiopia. Demographic features include the age of primary males and females, household size, the proportion of males, and the proportion of adult household members. While education, landholding size, number of staple food crops produced, the value of food crop production, Tropical Livestock Units, number of cows owned by households, off-farm participation and location are the socioeconomic characteristics.[10]

Age of household decision-makers is often associated with greater access to livelihood assets and more experience in resource allocation to achieve the household need, including food consumption. This idea is supported by a study from Ethiopia by Awoke et al. [30] who found that higher age is positively associated with HFS. *Household size is,* almost invariably, found to increase the probability of food insecurity in households in developing countries [12, 30, 32, 70]. Large household size adversely affects asset holdings, like livestock and resource per capita, such as land and consumption per capita. In line with this, we expect a negative relationship between household size and HFS in the study area.

On the other hand, food security is expected to positively relate to the *proportion of male and adult household members* as male and adult members participate more in productive activities in rural Ethiopia. *Education:* As an indicator of human capital, the education of household decision-makers often provides better income-earning opportunities for farm households. For instance, more educated household heads participate in non-farm employment. Moreover, literate household heads absorb improved agriculture technologies. In line with this, studies [12, 34, 40, 70] revealed that households with literate head are food secure.

Landholding size: Since cropping is the most important source of livelihood in the study area, access to a larger farm size is highly likely to ensure food security. Previous studies [12, 34, 70, 71] also confirm that larger landholding size is positively associated with food security. Yet, other studies from Ethiopia [32, 35] refute this claim and indicated that landholding size does not guarantee food security unless farmers' access productivity-enhancing farm technologies. Given the relatively small landholding size of households in the study area, we predict that larger landholding size to positively relate to food security.

*Number of staple food crops produced (*crop diversification). Farmers that diversify crop production could diversify the potential risk of a particular crop failure in a production season and cope with food insecurity. Moreover, as households in rural Ethiopia consume most of the food they produce, the more diverse crop production is likely to increase dietary diversity at the household level. Studies from African countries [40, 42, 70] also reaffirm that crop diversification reduces the probability of falling into food insecurity. Thus, the diversity of staple food crops produced is expected to positively affect household food security outcomes. *Value of food production:* own production is the most important source of food for rural households in Ethiopia. It is expected to determine food availability and access to households and influence HFS as proved true by previous empirical studies [12, 70].

Tropical Livestock Units (TLU): It is a measure of household livestock holding and wealth. Livestock plays a role in mixed-farming communities. It supports food security efforts of households by (1) providing input, such as draught animal for crop production and transport; (2) serving as a coping strategy to food insecurity during crop failure [35]; and (3) providing food (meat, milk, butter and egg) for home consumption and enhances dietary diversity, in particular, and food security, in general [12, 40, 70]. Similarly, *the number of cows owned* by households is expected to affect HFS through the pathway of production and consumption of dairy products (milk, cheese and butter). Therefore, the more dairy cows households own, the better their access to dairy food and the more likely they would be food secure [12].

Off-farm participation: in the face of diminishing landholding among farm households, livelihood diversification into off-farm activities is widely recommended as a strategy for rural welfare. Off-farm participation provides additional income and improves access to food, and tends to ensure food security [30, 34]. We also include *location dummies* in the regression to capture the location-specific cultural and environmental differences with implications for households' food security situation.

Results and discussion

Socioeconomic characteristics of sample households

Table 3 presents the socioeconomic profile of the sample households included in the analysis. It contains the food security outcome variables, empowerment indicators, other control and instrumental variables. The average daily per adult equivalent calorie availability of households

[10] Summary statistics of all the variables are presented in Table 3.

is about 3014 kcal (SD = 1433.63) with a minimum as low as 267 kcal and a maximum of 6902 kcal. In particular, the result shows that the adult equivalent calorie consumption of 33% (128) of the sample households falls below the nationally recommended (2100 kcal) calorie consumption. On the other hand, the average household food consumption and dietary diversity score are 48.72 (SD = 24.08) and 6.75 (SD = 2.40), respectively. Women's empowerment indicators show that females are less empowered relative to their male counterparts in the study areas. It is because the average empowerment score of women (61%) is lower than their men counterparts (83%), and this gives a gender parity gap of 22%.

Mean age of primary male [47] is higher than their female counterparts [40]. Literacy varies by sex of respondents in that majority of primary male respondents (59%) are literate while majority of primary female respondents are illiterate (63%). The mean household size is found to be 6.9 ranging from 2 to 15 persons with a standard deviation of 2.47. This statistics is much higher than the national average household size [5]. Meanwhile the average landholding size (0.65 ha) is lower than the national average (0.92 ha). This reveals the fact that households in the study areas are relatively more land constrained. Cropping, livestock raising and off-farm activities are the major sources of livelihood in the study areas. Though households held small farms, crop production is highly diversified. The data shows that the average number of staple food crop produced by households is 4.32 (SD = 1.68) with the minimum of 1 and maximum of 10. It is pertinent to note that only six households do not diversify their crop production in that they produce a single crop in the reference period. Since the rural households practice mixed farming, livestock rising is a popular supplementary livelihood practice in the study areas. In line with this, the data shows that 97.4% of the sample households raise animals while 77% own one or more dairy cows. The average number of dairy cows and livestock owned by a household –measured in tropical livestock units, is 1.5 (SD = 1.26) and 3.15 (SD = 2.09), respectively. 23,859,005.

The study areas have a longstanding indigenous handicraft-making tradition, especially in weaving and pottery. In line with this, off-farm activity is a popular supplementary source of livelihood in the study areas. The study areas are characterized by relatively high participation in off-farm activities, partly due to the high scarcity of farmland. Weaving, non-agricultural wage employment, pottery, petty trade, fishing, charcoal and firewood collection and selling are the most common off-farm income-generating activities.

Among the surveyed households, 40% (153) participated in off-farm income-earning activities in the reference period. The majority of off-farm participants (60%) are from the Chencha district—the area well-known for handicraft-making, while the remaining (40%) are from the Kucha district.

Adequacy scores of respondents in the five domains of empowerment

Table 4 shows the unweighted adequacy scores for the indicators that make up the five domains of empowerment by the primary male and female respondents. A value of one represents adequacy, and a value of zero implies inadequacy in an indicator. In this study, female respondents are less-adequate in four of the indicators compared to their male counterparts in the same household. Nevertheless, they are slightly more adequate in group membership compared to males. Moreover, the table shows that primary males were completely more empowered in four out of the five domains of empowerment relative to their female counterparts.

Table 5 presents the overall A-WEAI results for the sample households and its sub-indices –the weighted 5DE score and the GPI. The A-WEAI score is 0.629, with a women's and men's 5DE sub-index score of 0.612 and 0.834, respectively, and a GPI sub-index of 0.782.

Following Malapit et al. [48], an individual is empowered if she or he achieves adequacy in 80% or more of the weighted indicators. In this regard, we find that 31.2% (120) of sample primary female respondents are empowered against 67.5% (260) of sample primary male respondents. Table 5 clearly shows that primary females are less empowered, achieving adequacy in only 61.2% of the weighted indicators, on average, relative to their male counterparts, who achieved adequacy in 83.4% of the weighted indicators. The female's adequacy achievement

Table 4 Five domains of empowerment adequacy scores of respondents (male vs. female). *Source*: Survey data, 2021

Five domains of empowerment	Male ($n = 385$) Mean (Std. Dev.)	Female ($n = 385$) Mean (Std. Dev.)
Production		
Input in productive decisions	0.987 (0.113)	0.909 (0.288)
Resources		
Ownership of assets	0.935 (0.247)	0.875 (0.331)
Access to and decisions on credit	0.377 (0.486)	0.354 (0.485)
Income		
Control over use of income	0.987 (0.113)	0.783 (0.398)
Leadership		
Group membership	0.392 (0.489)	0.410 (0.493)
Time		
Workload	0.888 (0.315)	0.208 (0.404)

Values in parenthesis are standard error of mean (SEM)

Table 5 Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) scores for the study areas (*n* = 385 households). *Source*: Survey data, 2021

Indicators	Male (*n* = 385)	Female (*n* = 385)
5DE—5 Domains of Empowerment Score, sub-index	0.834	0.612
GPI—Gender Parity Index, sub-index	0.782	
A-WEAI Score	0.629	

is higher relative to the finding of a study in Nigeria [14], who revealed that females achieved adequacy in 57% of the weighted indicators, while it is lower than the 67% women's adequacy achievement in Ethiopia [18]. The result implies a gender gap in empowerment and the need to embrace policies that target female agency and inclusion in agriculture.

Figure 2 shows the contribution of each of the five domains to the disempowerment of women in the study areas. This helps identify the domains that contribute substantially to the disempowerment. Accordingly, time was the leading indicator of women disempowerment contributing 34%. We found that 79% of women and 11% of men had an excessive work burden and were time poor as defined by Alkire et al. [13] as paid or unpaid work for > 10.5 h in the previous 24 h. Time poverty is indeed a critical constraint among women in rural Ethiopia. The second high contributor to women disempowerment is the resource domain accounting for 27% closely followed by leadership that contributes for 26% of disempowerment.

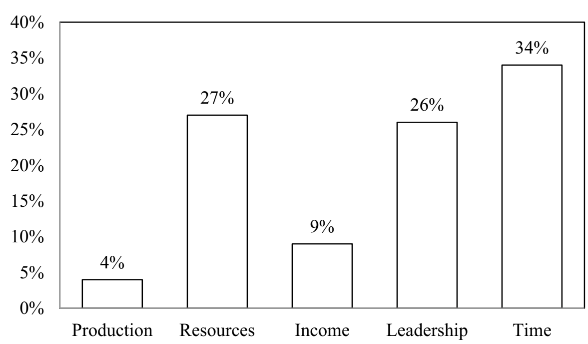

Fig. 2 Contribution of each of the five domains to disempowerment of women

Moreover, Fig. 3 presents a further breakdown of the contribution of each indicator to the disempowerment of women. The indicator that contributes the most to the disempowerment of women is workload with 32%. Access to and decision over credit emerges as the leading indicator of women disempowerment in the resource domain. It accounts for 26% of overall women disempowerment. We found that 64.6% of women and 62.3% of men do not have access to credit. Group membership is the third leading contributor with 24%. This implies that efforts should be targeted towards reducing women workload and improving access to credit and group membership.

It is pertinent to note that the contribution of decisions on production and asset ownership to women's disempowerment is small, and surprisingly, we found small gender gaps in these indicators relative to other similar empirical studies [12, 58]. As one of the essential resources for rural households whose livelihood depends on agriculture, farmland is one of the household assets included in the assessment of asset ownership of respondents. In the Gamo culture, daughters do

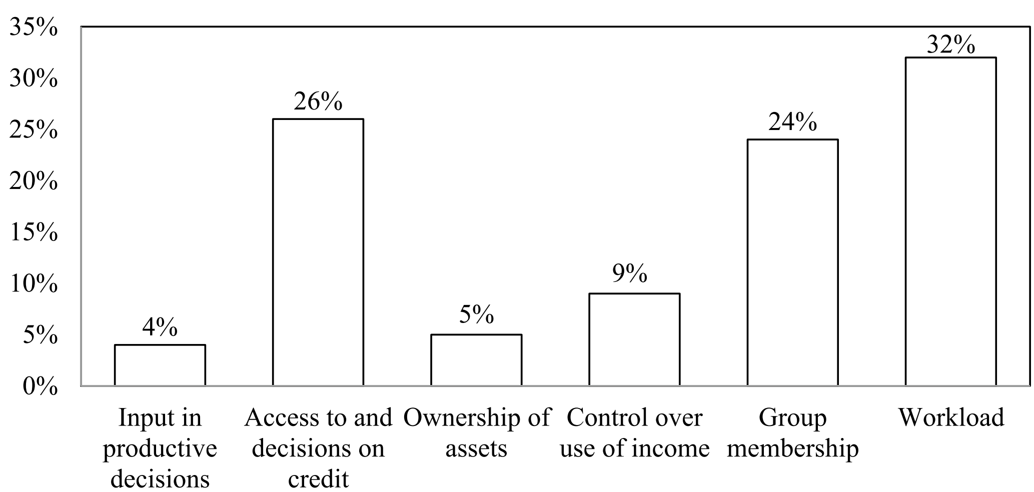

Fig. 3 Contribution of each of the indicators to disempowerment of women

not inherit farmland and homestead, especially if there are sons in the household. However, the lower gender gap in asset ownership could be due to the government's gender mainstreaming effort. The Ethiopian government has tried to improve intra-household resource allocation, especially farmland through its land certification program since 2002, which allows women to own farmland jointly with their spouses [6, 72]. Women's ownership of assets could, in turn, improve their bargaining power [16, 17] and participation in agricultural production decisions.

Effect of women's empowerment in agriculture on household food security (HFS)

Tables 6, 7 and 8 present the ordinary least squares (OLS),[11] two-stage least squares (2SLS), Poisson and instrumental variable Poisson (IVPoisson)[12] regression results for the determinants of HFS. In all the tables, HFS outcomes are modelled as a function of the key explanatory variable –women empowerment indicators and other demographic and socioeconomic covariates of food security. Such a setting helps examine whether women's empowerment gives rise to any significant differences in the food security outcomes of the surveyed households after controlling for other covariates to food security.

Diagnostic tests for the instrumental variables are presented at the bottom of each table. For the regressions involving per adult equivalent calorie availability and household food consumption score (columns 1–4), the Anderson–Rubin and Durbin–Wu–Hausman endogeneity test results indicate that the women empowerment indicators are in fact endogenous, except in the per adult equivalent calorie availability model given in Table 6 and the household food consumption score model given in Table 8 where the Durbin–Wu–Hausman endogeneity test result is insignificant. That means, endogeneity is not a problem in these two models, and therefore, the OLS is the preferred estimation technique in these cases. Based on the endogeneity test, the relevant models worthy of interpretation include columns 1, 4 and 6 of Table 6, columns 2, 4 and 6 of Table 7 and columns 2, 3 and 6 of Table 8. The over-identification test (Hansen's *J*) result confirms the instruments are valid –that they are uncorrelated with the error term, and that the excluded instruments are rightly excluded from the equations estimated. Similarly, the under- and weak identification test results reveal that the instruments are valid and the models are identified.

The estimated models reported in Tables 6, 7 and 8 have an overall good fit. That is, the *F* tests for the calorie availability and food consumption score models and the likelihood ratio test for the dietary diversity score model showed a good fit to the data, since the calculated *F* statistics and chi-square values, respectively, were statistically significant at 1% level.

Table 6 presents the regression results of the effect of the five dimension weighted empowerment score of the primary female on household food security outcomes. The OLS, Poisson and IV estimates of the aggregate women empowerment score are positive and statistically significant. This result suggests that food security, measured in calorie consumption, household food consumption score and household dietary diversity, increases as the primary female is more empowered. This result corroborates previous research in Ethiopia [18], Nigeria [14], Tunisia [27], and Bangladesh [12].

The study [18] from Ethiopia found that women's empowerment leads to improvements in women's and children's dietary diversity. A study from Bangladesh [12] found that higher aggregate women empowerment score is strongly correlated with calorie consumption and dietary diversity. Similarly, Kruse [27] has revealed that aggregate women empowerment score has strong positive effect on household dietary diversity. The Nigerian study [14] has also reported that female achievement in group membership, income control and workload reduce the severity of food insecurity among the farm households in Nigeria.

The overall implication of this finding is that active participation of women in the decision-making of agricultural production, control of household income, resource ownership, participation in community groups, and access to credit tends to improve household crop production and food security. This is consistent with the literature, which shows that when women are empowered in the 5DE, they: (1) choose to produce diverse crops for household consumption, (2) access inputs, including seed and credit to support the production of staple food crops, and (3) decide on how the produce or income generated from the farm will be used [73] to smooth household consumption and ensure food security. Generally, the strong positive food security effect of the 5DE women empowerment score suggests that it is essential to promote improvements in all the dimensions of women empowerment simultaneously.

Table 7 presents the regression results of the gender parity gap and household food security outcomes. In line with theoretical and empirical expectation, all the food

[11] Diagnostic tests for the OLS regression were carried out concerning heteroskedasticity and multicollinearity, it was confirmed that the data suffered from both heteroskedasticity and multicollinearity problems. As a result, variables such as age squared of primary male and primary female were eliminated to get rid of multicollinearity, while the robust regression option was used as a remedy to the heteroskedasticity problem.

[12] The generalized method of moments (GMM) was used to estimate the IVPoisson model.

Table 6 Model 1: Women's empowerment and household food security outcomes. *Source*: Survey data, 2021

Variable	Per adult equivalent calorie availability		Household Food Consumption Score		Household Dietary Diversity Score	
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	Poisson (5)	IVPoisson (6)
5DE Empowerment score of woman	1161.663*** (288.792)	1163.933*** (492.233)	14.465*** (5.437)	32.615*** (10.561)	0.322*** (0.091)	0.489*** (0.161)
Age of primary male (years)	−14.972*** (4.283)	−13.647*** (4.188)	−0.024 (0.100)	0.021 (0.092)	0.001 (0.001)	0.011 (0.012)
Age of primary female (years)	18.511*** (4.392)	17.551*** (4.363)	0.260** (0.112)	0.233** (0.111)	0.001 (0.001)	0.001 (0.001)
Primary male is literate (=1, 0 otherwise)	−37.994 (92.152)	−53.360 (90.549)	1.681 (1.962)	1.213 (1.971)	−0.006 (0.032)	−0.010 (0.032)
Primary female is literate (=1, 0 otherwise)	−36.191 (88.613)	−46.452 (89.031)	5.943*** (2.152)	5.631*** (2.134)	0.073** (0.030)	0.069** (0.033)
Household Size	−153.323*** (18.481)	−143.506*** (19.549)	−1.120** (0.450)	−0.825* (0.462)	−0.011* (0.006)	−0.012 (0.011)
Proportion of male household members	−598.181 (415.552)	−665.561 (421.357)	12.613** (5.561)	10.572* (5.651)	0.072 (0.122)	0.062 (0.123)
Proportion of female household members	−381.913 (417.632)	−414.474 (421.250)	12.192** (5.733)	11.210** (5.701)	0.082 (0.122)	0.070 (0.119)
Proportion of adult (15–65 years old)	1227.731** (511.912)	1258.593** (495.989)	30.585*** (8.792)	31.521*** (8.554)	0.214* (0.122)	0.212* (0.121)
Proportion of dependent (< 15 and > 65 years old) household members	1579.87*** (517.65)	1612.51*** (503.283)	31.531*** (9.112)	32.523*** (8.889)	0.313** (0.131)	0.322** (0.133)
Landholding size (in hectare)	180.272** (88.740)	155.317** (73.890)	0.601 (2.672)	−0.151 (2.642)	0.124*** (0.032)	0.113*** (0.042)
Market distance (walking minutes)	−0.126 (1.271)	0.076 (1.201)	0.032 (0.021)	0.027 (0.023)	0.001 (0.001)	0.001 (0.010)
Number of staple food crops produced	141.175*** (39.68)	141.789*** (38.649)	0.462 (0.700)	0.483 (0.695)	0.022* (0.012)	0.024* (0.013)
Value of food crop production (2021)	373.185*** (95.439)	324.633*** (100.155)	5.092** (2.064)	3.625** (1.091)	0.112*** (0.030)	0.095*** (0.036)
Tropical life units	49.830* (27.589)	49.968* (26.989)	−0.511 (0.482)	−0.502 (0.482)	0.003 (0.006)	−0.003 (0.006)
Number of cows owned by households	106.964** (46.994)	102.470** (46.168)	5.311*** (1.020)	5.115*** (1.001)	0.062*** (0.011)	0.063*** (0.011)
Household participates in off-farm activities (=1, 0 otherwise)	340.501*** (102.236)	306.631*** (99.619)	8.751*** (2.261)	7.722*** (2.273)	0.082*** (0.031)	0.071** (0.033)
Location dummies: household is from						
Holo'o Kebele (=1, 0 otherwise)	686.946*** (246.423)	603.374** (243.808)	−16.265*** (4.334)	−18.792*** (4.592)	−0.072 (0.051)	−0.092* (0.049)
Shama Kebele (=1, 0 otherwise)	165.522 (129.537)	185.614 (128.821)	4.242 (3.051)	4.854* (2.873)	0.113*** (0.040)	0.113*** (0.039)
Doko Masho Kebele (=1, 0 otherwise)	654.038*** (172.935)	653.085*** (163.338)	0.601 (3.142)	0.567 (3.075)	0.012 (0.051)	0.011 (0.051)
Zardo Kebele (=1, 0 otherwise)	502.946*** (145.496)	510.383*** (141.923)	−16.151*** (3.892)	−15.922*** (3.811)	−0.023 (0.041)	−0.020 (0.049)
Losha Kebele (=1, 0 otherwise)	−723.618*** (180.046)	−722.999*** (173.504)	12.662*** (4.294)	12.680*** (4.162)	0.092 (0.050)	0.103* (0.062)
Dele Weyza Kebele (=1, 0 otherwise)	199.120 (160.553)	238.455 (154.076)	−2.292 (3.755)	−1.112 (3.911)	0.052 (0.071)	0.072 (0.073)
Gale Kebele (=1, 0 otherwise)	790.781*** (133.488)	792.565*** (130.355)	−1.233 (2.384)	−1.174 (2.392)	0.089** (0.044)	0.092** (0.045)
Fango Kebele (=1, 0 otherwise)	214.181 (145.052)	204.163 (140.345)	−4.292 (2.573)	−4.595 (2.492)	0.061 (0.042)	0.066 (0.045)
Constant	−2440.875** (1024.132)	−2294.052** (1015.351)	−74.731*** (19.626)	−72.341 (19.642)	−0.091 (0.343)	−0.092 (0.343)

Table 6 (continued)

Variable	Per adult equivalent calorie availability		Household Food Consumption Score		Household Dietary Diversity Score	
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	Poisson (5)	IVPoisson (6)
F(25, 359)	52.60		36.21			
Wald chi2 [25]		1390.45		937.28		
LR Chi sq. [25]					224.46	
R^2	0.78	0.79	0.66	0.65		
Pseudo R^2					0.13	
Model diagnostics						
Hansen J. *p*, Ho: instruments valid		0.242		0.539		0.811
Under ID test *p*, Ho: underidentified (Kleibergen–Paap rk LM test)		0.000		0.000		
Weak ID test, *p* (Kleibergen–Paap rk Wald *F* test)		0.000		0.000		
Anderson–Rubin test: Ho: endogenous variable is irrelevant						
A–R Wald *F* test, *p* value		0.001		0.014		
A–R Wald Chi2 test, *p* value		0.000		0.009		
Endogeneity test, *p*, Ho: exogenous (Durbin–Wu–Hausman chi-sq test)		0.153		0.039		

***, ** and * represent significance at 1%, 5% and 10% level of statistical significance

Values in parentheses are robust standard errors

security indicators are negatively and significantly related to the extent of gender parity gap. The higher the gender parity gap, the lower is the calorie intake, food consumption score and dietary diversity of households. In columns 2, 4 and 6, after instrumenting for the potentially endogenous variable, gender parity gap, the coefficient estimates retain a similar pattern, with the IV coefficient estimates being larger than the OLS and Poisson estimates. Provided the good performance of the instruments, the result suggests that calorie intake, household food consumption score and dietary diversity decreases if the gender parity gap is larger. The larger IV coefficient estimates suggest that neglecting endogeneity of gender parity gap may underestimate the effect of reducing gender gap on these household food security outcomes. The result that gender parity gap is negatively related to calorie intake and household diet diversity is consistent with prior research in Nigeria [14] and Bangladesh [12]. Kehinde et al. [14] reported that gender parity reduce the severity of food insecurity among the farming households in Nigeria, while [12] revealed that a reduction in the gender gap in empowerment is associated with an increase in calorie availability and household dietary diversity. This is because reduction in the gender gap or increase in women's bargaining power can translate into reallocation of household resources toward women's preferences, including the production and/or purchase of food crops for household consumption and higher investment in human capital like health and nutrition of the household [47]. In conclusion, reducing the gender gap in agriculture or improving the gendered intra-household resource allocation and decision-making power is associated with higher household food security.

Table 8 provides the regression result of food security indicators modelled as a function of number of assets woman has self or joint ownership of—the key regressor and indicator of women empowerment, and the other demographic and socioeconomic characteristics of sample households. In all the relevant models (columns 2, 3 and 6) of Table 8, the number of assets a woman has self or joint ownership of has a positive and statistically significant effect on all the household food security outcomes. That is, as the number of assets a woman has self or joint ownership increases by one more unit, calorie availability, household food consumption and dietary diversity score rises. Household asset ownership of women would increase women's bargaining power and hence affect food security outcomes [10, 16, 17] through the production and consumption pathways. First, if women own assets, such as land, livestock and off-farm implements, they would allocate the assets to produce more diverse food groups required for household consumption. Second, asset ownership gives women the authority to control the income obtained from the services of the assets, which would help them allocate increased budget shares on food [17].

Table 7 Model 2: Gender parity gap and household food security outcomes. *Source*: Survey data, 2021

Variable	Per adult equivalent calorie availability		Household Food Consumption Score		Household Dietary Diversity Score	
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	Poisson (5)	IVPoisson (6)
Gender parity gap (=0 if woman enjoys gender parity, "gap" if not)	−628.592*** (241.551)	−3819.295*** (1229.753)	−10.332** (4.962)	−67.402*** (25.333)	−0.238 (0.146)	−1.100*** (0.421)
Age of primary male (years)	−16.508*** (4.442)	−11.272*** (5.105)	−0.039 (0.112)	0.053 (0.112)	0.001 (0.002)	0.003 (0.002)
Age of primary female (years)	20.516*** (4.538)	21.348*** (5.684)	0.283** (0.111)	0.303** (0.132)	0.001 (0.003)	0.001 (0.002)
Primary male is literate (=1, 0 otherwise)	−20.376 (92.019)	−81.802 (114.904)	1.849 (1.948)	0.752 (2.386)	−0.003 (0.053)	−0.002 (0.004)
Primary female is literate (=1, 0 otherwise)	−12.097 (88.348)	9.447 (111.072)	6.257*** (2.146)	6.645*** (2.526)	0.078 (0.053)	0.076** (0.035)
Household Size	−164.175*** (18.486)	−122.730*** (27.526)	−1.218** (0.428)	−0.479 (0.559)	−0.015 (0.014)	−0.011 (0.012)
Proportion of male household members	−498.639 (399.302)	−655.192 (482.857)	13.723** (5.818)	10.916 (7.802)	0.096 (0.215)	0.051 (0.110)
Proportion of female household members	−354.529 (406.261)	−535.344 (490.128)	12.387** (6.039)	9.162 (8.153)	0.073 (0.231)	0.002 (0.131)
Proportion of adult (15–65 years old)	1256.449** (517.794)	1705.395*** (562.580)	31.286*** (8.728)	39.324*** (9.246)	0.232 (0.245)	0.321** (0.132)
Proportion of dependent (< 15 and > 65 years old) household members	1620.524*** (521.454)	2147.506*** (583.422)	32.452*** (9.078)	41.868*** (9.869)	0.334 (0.259)	0.472*** (0.163)
Landholding size (in hectare)	188.525** (82.746)	144.729** (72.717)	0.543 (2.686)	−3.089 (3.301)	0.117* (0.068)	0.082* (0.042)
Market distance (walking minutes)	−0.082 (1.323)	−1.636 (1.535)	0.033 (0.024)	0.004 (0.031)	−0.001 (0.001)	0.001 (0.001)
Number of staple food crops produced	149.999*** (40.157)	200.828*** (46.469)	0.621 (0.703)	1.510* (0.851)	0.017 (0.018)	0.031** (0.012)
Value of food crop production (2021)	433.941*** (94.638)	265.404** (125.988)	5.723*** (2.013)	2.702 (2.513)	0.118** (0.049)	0.078** (0.039)
Tropical livestock units	45.287* (27.305)	23.574 (28.519)	−0.584 (0.483)	−0.973* (0.545)	−0.005 (0.013)	−0.012 (0.013)
Number of cows owned by households	116.598* (46.798)	121.361** (54.487)	5.435*** (1.023)	5.514*** (1.077)	0.068*** (0.023)	0.072*** (0.024)
Household participates in off-farm activities (=1, 0 otherwise)	402.606*** (101.061)	385.144*** (119.401)	9.513*** (2.303)	9.189*** (2.603)	0.103** (0.049)	0.090*** (0.031)
Location dummies: household is from						
Holo'o Kebele (=1, 0 otherwise)	782.631*** (248.949)	447.398 (285.598)	−15.344*** (4.23)	−21.328*** (5.239)	−0.052 (0.112)	−0.129* (0.068)
Shama Kebele (=1, 0 otherwise)	143.059 (132.428)	226.396 (161.691)	4.033 (3.134)	5.518* (3.286)	0.102 (0.080)	0.133*** (0.052)
Doko Masho Kebele (=1, 0 otherwise)	626.882*** (182.545)	479.669** (202.112)	0.155 (3.183)	−2.478 (3.953)	0.001 (0.103)	−0.023 (0.062)
Zardo Kebele (=1, 0 otherwise)	486.445*** (148.050)	475.725*** (171.592)	−16.365*** (3.913)	−16.555*** (4.153)	−0.029 (0.078)	−0.022 (0.062)
Losha Kebele (=1, 0 otherwise)	−742.797*** (184.593)	−834.066*** (211.172)	12.349*** (4.309)	10.732** (4.745)	0.078 (0.112)	0.079 (0.068)
Dele Weyza Kebele (=1, 0 otherwise)	186.889 (164.660)	511.195** (224.861)	−2.189 (3.749)	3.612 (5.613)	0.055 (0.114)	0.129 (0.089)
Gale Kebele (=1, 0 otherwise)	834.508*** (136.217)	1073.984*** (176.918)	−0.493 (2.354)	3.788 (3.358)	0.106 (0.083)	0.162*** (0.060)
Fango Kebele (=1, 0 otherwise)	208.967 (149.390)	84.099 (184.741)	−4.446* (2.589)	−6.685** (3.156)	0.053 (0.092)	0.012 (0.051)
Constant	−2633.931** (1041.839)	−963.838 (1406.372)	−71.23*** (19.71)	−41.35 (27.06)	0.01 (0.59)	0.39 (0.39)

Table 7 (continued)

Variable	Per adult equivalent calorie availability		Household Food Consumption Score		Household Dietary Diversity Score	
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	Poisson (5)	IVPoisson (6)
F(25, 359) Wald chi2 [25]	50.80	1031.78	36.43	801.96		
LR Chi sq. [25]					222.82	
R^2	0.77	0.68	0.66	0.55		
Pseudo R^2					0.13	
Model diagnostics						
Hansen J. *p*, Ho: instruments valid		0.422		0.550		0.716
Under ID test *p*, Ho: underidentified (Kleibergen–Paap rk LM test)		0.000		0.000		
Weak ID test, *p* (Kleibergen–Paap rk Wald *F* test)		0.000		0.000		
Anderson–Rubin test: Ho: endogenous variable is irrelevant						
A–R Wald *F* test, *p* value		0.001		0.014		
A–R Wald Chi2 test, *p* value		0.000		0.009		
Endogeneity test, *p*, Ho: exogenous (Durbin–Wu–Hausman chi-sq test)		0.002		0.007		

***, ** and * represent significance at 1%, 5% and 10% level of statistical significance

Values in parentheses are robust standard errors

The result agrees with previous studies [12, 19, 26, 67], who found that increases in number of assets owned by a woman is positively linked with calorie availability and household dietary diversity. The finding that after instrumenting, the coefficient estimates of women's asset ownership increases imply the cause that ignoring the endogeneity of women's asset ownership underestimates its effect on food security outcomes.

Food security and socioeconomic characteristics

In addition to the women empowerment variables analysed so far, demographic and socioeconomic variables were included in our food security models. In this regard, the result shows that food security is positively linked to the proportion of adult household members, proportion of dependent household members, household landholding size, crop diversification, the value of food crop production, the number of dairy cows owned by the household and participation in off-farm income generating activities in most of the models.

In rural agricultural households, an increase in adult household members implies an increase in the availability of household labour for crop production, off-farm employment and animal husbandry practices which require more intensive physical work. Thus, the result suggests that as the farm household's pool of adult household labour increases, their food security outcomes would improve. This result agrees with a prior research in southern Ethiopia [26]. This finding would be related to the cause that as rural households' adult household members rise, they diversify productive income-earning activities, accumulate wealth, and consequently have a better opportunity for improved food security outcomes.

The result that food security outcomes are positively related to the proportion of dependent household members is quite a surprise, and conflicts with previous studies such as by Gebre et al. [26]. However, we would argue that it suggests the fact that in the per adult equivalent calorie intake measure of food security, households with large number of children or old age household members would have higher per adult equivalent calorie intake since calorie consumption is divided by the calorie equivalence scale weighted household size. On the other hand, in the study areas, households commonly feed egg and milk products to their children. Given that the nutritional weight of these products is high, it is possible for households with large children to have higher food consumption and dietary diversity score.

Total landholding size of household's has a significant positive effect on household food security in most of the models. Provided that cropping is by far the dominant source of livelihood in rural Ethiopia in general and the study area in particular, access to large farm size is highly likely to ensure food security. A possible explanation is that higher landholding allows households to produce more and

Table 8 Model 3: number of assets woman has self/joint ownership of and household food security outcomes. *Source*: Survey data, 2021

Variable	Per adult equivalent calorie availability		Household Food Consumption Score		Household Dietary Diversity Score	
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	Poisson (5)	IVPoisson (6)
Number of assets woman has self or joint ownership of	78.692*** (25.544)	299.857** (81.514)	1.505*** (0.540)	4.009** (1.786)	0.021 (0.014)	0.075*** (0.027)
Age of primary male (years)	−15.652*** (4.453)	−10.348** (5.209)	−0.019 (0.102)	0.040 (0.109)	0.001 (0.002)	0.002 (0.002)
Age of primary female (years)	19.924*** (4.526)	18.718*** (5.106)	0.274** (0.115)	0.259** (0.118)	0.001 (0.003)	0.001 (0.002)
Primary male is literate (= 1, 0 otherwise)	−18.290 (88.494)	−46.439 (93.603)	1.856 (1.914)	1.538 (1.941)	−0.001 (0.054)	−0.013 (0.033)
Primary female is literate (= 1, 0 otherwise)	−68.978 (86.743)	−216.914** (108.478)	5.182** (2.205)	3.507 (2.532)	0.067 (0.053)	0.033 (0.035)
Household Size	−162.924*** (18.380)	−136.462*** (20.856)	−1.176*** (0.444)	−0.876* (0.465)	−0.014 (0.011)	−0.007 (0.007)
Proportion of male household members	−486.224 (401.663)	−538.011 (457.180)	13.878*** (5.393)	13.292** (5.339)	0.096 (0.206)	0.082 (0.154)
Proportion of female household members	−328.264 (412.385)	−354.561 (466.953)	12.797** (5.540)	12.499** (5.309)	0.084 (0.210)	0.062 (0.152)
Proportion of adult (15–65 years old)	1159.832** (555.425)	1136.868* (636.979)	29.683*** (8.788)	29.423*** (8.598)	0.172 (0.238)	0.149 (0.161)
Proportion of dependent (< 15 and > 65 years old) household members	1501.063*** (559.998)	1457.101** (646.879)	30.444*** (9.098)	29.947*** (8.932)	0.271 (0.257)	0.236 (0.171)
Landholding size (in hectare)	197.106* (102.670)	108.683* (60.365)	0.599 (2.668)	−0.401 (2.695)	0.126* (0.067)	0.109*** (0.38)
Market distance (walking minutes)	−0.102 (1.348)	−1.019 (1.467)	0.031 (0.025)	0.020 (0.027)	−0.001 (0.002)	0.001 (0.001)
Number of staple food crops produced	137.090*** (39.616)	128.952*** (40.739)	0.391 (0.721)	0.298 (0.732)	0.015 (0.018)	0.012 (0.010)
Value of food crop production (2021)	441.521*** (96.085)	369.509*** (105.399)	5.772*** (1.976)	4.957** (2.127)	0.126** (0.053)	0.109*** (0.033)
Tropical livestock units	36.141 (26.260)	−1.583 (27.358)	−0.769 (0.482)	−1.196** (0.495)	−0.006 (0.012)	−0.016* (0.010)
Number of cows owned by households	108.033** (45.552)	86.601* (47.958)	5.268*** (1.012)	5.025*** (1.046)	0.064*** (0.024)	0.061*** (0.015)
Household participates in off-farm activities (= 1, 0 otherwise)	376.519*** (98.193)	293.534*** (108.271)	8.999*** (2.282)	8.060*** (2.438)	0.089* (0.052)	0.070** (0.033)
Location dummies: Household is from						
Holo'o Kebele (= 1, 0 otherwise)	769.086*** (250.607)	545.405** (274.820)	−15.773*** (4.305)	−18.305*** (4.625)	−0.048 (0.112)	−0.094* (0.056)
Shama Kebele (= 1, 0 otherwise)	130.208 (130.953)	140.233 (144.349)	3.828 (3.066)	3.941 (2.962)	0.095 (0.085)	0.097** (0.047)
Doko Masho Kebele (= 1, 0 otherwise)	582.448*** (180.588)	376.057* (196.036)	−0.779 (3.309)	−3.116 (3.792)	−0.013 (0.099)	−0.055 (0.062)
Zardo Kebele (= 1, 0 otherwise)	509.879*** (152.138)	569.805*** (176.866)	−15.916*** (3.825)	−15.238*** (3.672)	−0.022 (0.088)	−0.006 (0.046)
Losha Kebele (= 1, 0 otherwise)	−812.508*** (181.577)	−1058.965*** (212.556)	10.971** (4.441)	8.181 (5.006)	0.064 (0.111)	0.012 (0.065)
Dele Weyza Kebele (= 1, 0 otherwise)	182.017 (168.147)	347.887* (198.628)	−2.116 (3.702)	−0.238 (4.108)	0.046 (0.112)	0.085 (0.078)
Gale Kebele (= 1, 0 otherwise)	871.171*** (135.316)	1106.810*** (159.411)	0.332 (2.493)	2.999 (3.096)	0.108 (0.079)	0.168*** (0.055)
Fango Kebele (= 1, 0 otherwise)	307.571** (150.264)	515.555*** (187.921)	−2.633 (2.575)	−0.278 (3.123)	0.079 (0.090)	0.132** (0.054)

Table 8 (continued)

Variable	Per adult equivalent calorie availability		Household Food Consumption Score		Household Dietary Diversity Score	
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	Poisson (5)	IVPoisson (6)
Constant	−3031.27*** (1071.426)	−3223.277*** (1152.508)	−77.939*** (19.217)	−80.113*** (18.838)	−0.110 (0.583)	−0.146 (0.372)
F(25, 359)	49.76		27.93			
Wald chi2 [25]		1103.24		701.02		
LR Chi sq. [25]					222.38	
R^2	0.78	0.73	0.66	0.64		
Pseudo R^2					0.13	
Model diagnostics						
Hansen J. *p*, Ho: instruments valid		0.316		0.078		0.357
Under ID test *p*, Ho: underidentified (Kleibergen–Paap rk LM test)		0.000		0.000		
Weak ID test, *p* (Kleibergen–Paap rk Wald *F* test)		0.000		0.000		
Anderson–Rubin test: Ho: endogenous variable is irrelevant						
A–R Wald *F* test, *p* value		0.000		0.014		
A–R Wald Chi2 test, *p* value		0.000		0.009		
Endogeneity test, *p*, Ho: exogenous (Durbin–Wu-Hausman chi-sq test)		0.004		0.115		

***, ** and * represent significance at 1%, 5% and 10% level of statistical significance

Values in parentheses are robust standard errors

diversify crop production that would, in turn, help them access more nutritious food and consume better. The result is consistent with previous studies in Ethiopia [26, 34, 71] and Mozambique [41]. On the contrary, a recent study from Central and North Gondar Zone of Ethiopia [30] found that landholding size negatively affects food security. The study argued that large farm size reduces farmer's capacity to adopt improved farm technology resulting in low productivity and production and consequently to food insecurity. However, this type of influence of landholding size on food security is unlikely in our study areas since the area is relatively more land constrained.

The regression result on crop diversification, measured by the number of staple food crops produced by the household in 2021, is shown to have positive and statistically significant effect on food security outcomes in most of the models. Crop diversification is important in ensuring food security in several ways. First, farmers that produce variety of crops at a time diversify the potential risk of crop failure and this reduces production risks. Second, as households in rural Ethiopia consume most of the food they produce, a more diverse crop production is likely to increase availability of diverse food items and access to food at the household level. It is also important as poor access to finance and poor quality of infrastructure in rural areas in developing countries [40], like Ethiopia, makes most of the household food access to depend on what they produce. Consequently, food diet is mostly linked with domestic staple food crops production. Third, crop diversification may also improve food security through raising farm productivity and income [42]. The finding agrees with similar previous research in Ethiopia [70], Benin [40], and Mozambique [41] who found that in rural Africa where household access to food relies on what the households produce, more diverse production systems could lead to more diverse household diets and food security. Mango et al. [42] from Malawi further indicated that the merit of crop diversification to ensure food security is manifested through improving the management of production and price risks.

The regression result shows that off-farm participation positively and significantly affects food security outcomes in all models. Off-farm activities provide supplementary income for farm households and thus positively influence their food security outcomes. The Gamo people are well-known for their long-standing indigenous handicraft[13] making tradition, especially weaving and pottery. In the Gamo people, weaving is commonly practised by the more prestigious population groups, while the marginalized and landless communities practise pottery as their main livelihood [74]. These off-farm

[13] Gamo zone is called "*The Land of Art*" due to its peoples' long tradition of handicraft making.

activities are commonly practised as a source of livelihood along with subsistence cropping and contribute to ensuring food security. The result is in line with previous studies in Ethiopia [26, 30, 32, 34, 75] who revealed that off-farm participation provides farm households with additional income to spend on foodstuff for household consumption, and ensure food security by enabling them to smooth consumption.

Moreover, the result shows a positive and significant relationship between household food security outcomes and the number of dairy cows owned by households. From the data, it is evident that only 23% of the surveyed households do not have dairy cows; 33% have a single dairy cow, while the rest 45% have two or more dairy cows during the survey period. Dairy cow ownership is likely to affect food security through the pathway of production and consumption of dairy products. In the study areas, in particular, and rural Ethiopia, in general, where the purchase of dairy products from the market is almost inexistence, dairy cows are the common source of dairy food (milk, cheese and butter) for home consumption. Moreover, it is an importat source of cash—as households often sell milk and butter to consumers in nearby towns. This would also enhance households' access to food by increasing their income [29, 40]. The result is in line with that of the study by Sraboni et al. [12], who found that the more dairy cows households own, the better their access to diverse food diet and the more food secure in rural Bangladesh.

Livestock holding –measured in tropical livestock units is found to have a statistically significant effect on household food security indicators in some of the models. Livestock ownership tends to facilitate the consumption of meat and dairy products causing diversity in household diets [41, 75]. Moreover, it provides income and allows farm households to purchase food items and cope with food shortages, especially during lean seasons [35]. Livestock holding also enhance production via providing draft power and manure [42]. Generally, livestock holding as an indicator of household wealth in the study areas contribute to household food security directly by improving access to food (meat and dairy) and indirectly by increasing crop production and household income.

Consistent with theoretical and empirical expectations, the value of staple food crop production has a significant positive effect on all food security indicators in all models. In rural Ethiopia where food availability and access depends on what farm households produce [29], higher production is often associated with favourable household food security outcomes. The result is consistent with studies from Ethiopia [34, 70], Mozambique [41] and Bangladesh [12] who underscored that with own production accounting for the lion's share of household consumption among the agricultural communities, the more staple food crops they produce, the better the household's access to food [40], and household food security.

The age of the female primary decision-maker has a significant positive impact on both calorie availability and household food consumption in all models. The reason is that experience provides females with the capacity to produce and procure food crops and properly allocate household food resources in a manner that could improve calorie intake and household food consumption relative to primary females of lower experience.

Households with a literate female primary decision-maker have statistically and significantly higher food consumption and dietary diversity than their counterparts with an illiterate female primary decision-maker. This result underscores the importance of female education in household nutrition. Most of the research related to food security in developing countries so far focuses on analysing the effect of household head education on food security [12, 26, 30, 34, 70], yet they found a statistically significant positive effect on food security.

On the other hand, calorie consumption and household food consumption scores are negatively and significantly related to household size. The result is compatible with the finding of previous studies in Ethiopia [26, 30, 32, 71]. The possible explanation for this result is that large household size adversely affects rural households' wealth accumulation or asset holdings like livestock and resource per capita, including land and consumption. It, in turn, reduces their capacity to adopt productivity-enhancing farm technologies leading to low productivity and crop income. Consequently, households with large household sizes would face difficulty feeding the members. Apart from this, the dietary diversity indicator, household food consumption score could also be low due to the reliance of households with large household sizes on relatively more productive to produce, cheap to purchase, but low-calorie foods[14] as a coping strategy to food insecurity [35].

Kebele dummies were considered in the regression models to account for unobserved location-specific factors to food security. The result shows that calorie intake is positively and significantly higher for households that reside in Holo'o, Doko Masho, Zardo and Gale Kebles, while it is negatively and significantly lower for Losha Kebele households relative to Shochora Kebele –the reference category. Household food consumption score and dietary diversity are significantly lower for Holo'o and Zardo Kebele households compared to Shochora Kebele

[14] Yam, Taro and Potatoes are root crops commonly produced and consumed by land-scarce and poor households in the Gamo zone, including our study districts –Chencha and Kucha.

households. This result implies that higher calorie intake does not guarantee a quality diet.

Conclusion

Food security has remained a critical challenge and a policy priority for developing countries, including Ethiopia. On the other hand, women's empowerment has gathered attention, especially since the 1990s, as an integral element of development. However, women and girls still suffer from constraints and are marginalized from pursuing economically rewarding opportunities, household crop production and expenditure decision-making, asset ownership, and access to financial markets and services. Evidence suggests that women's empowerment is critical to ensure food and nutrition security, especially among agricultural households. However, still, in the perspectives of Ethiopia, rare research has been done on the relationship between women's empowerment in agriculture and household food security. Therefore, this study attempts to measure the state of women's empowerment in agriculture and examine its effect on household food security based on the data collected from randomly selected dual-adult households.

The result of the study supports the existing evidence [11, 12, 14, 25, 27] that women's empowerment directly contributes to household-level food security outcomes. The findings of the study are the following. First, the study has confirmed that there is indeed a gender gap in the study areas, in that the five domains empowerment score shows that women achieved empowerment adequacy in 61% of the weighted indicators, while it is 83% for their men counterparts. Second, workload (time constraint), access to and decision on credit and group membership contribute the most to the disempowerment of women in the study areas.

Third, the evidence on women's empowerment shows that improvement in the 5DE score, gender parity and the number of assets solely or jointly owned by a woman is positively associated with household food security outcomes –adult equivalent calorie availability, household-level food consumption and dietary diversity in the study areas. Fourth, the study reveals that the age and education of primary females, proportion of adult household members, landholding size, crop diversification, food crop production, the number of dairy cows owned, and off-farm participation are the main factors that positively influence almost all household food security outcomes. We, however, discover that food security is negatively related to household size.

Based on the findings, the paper suggests that the government and other development partners should promote women's empowerment and eliminate the gender gap in agriculture through proper gender mainstreaming intervention of dual-adult households. Policies and interventions should target the improvement of women's access to productive resources, including land, livestock, credit, and participation in cooperatives. It will enhance their income generation and decision-making power and improve household food security. Female education and income diversification will also improve farmers' access to food and its utilization. Moreover, improved agricultural extension services designed to stimulate crop diversification and food production will improve household food security. Finally, promoting family planning awareness and improving access to contraceptive methods among farm households will be indispensable.

Our study is likely to have some limitations, however. First, we used the 7-day recall period in measuring the consumption data. Therefore, the data might have recall errors though limited. Second, we enumerated the data on household socio-economic, food consumption and women's empowerment modules from primary females. However, the length and complexity of the questions might have negatively impacted the accuracy of the data. To counter this, we designed the survey instruments to minimize respondent fatigue and train enumerators to cross-check responses to complex questions. Third, we may not be able to generalize our results to other communities with different social, cultural and livelihood features. Fourth, our study did not address the impact of women's empowerment on intra-household food security, such as mothers and children, and the impact of all indicators that constitute the A-WEAI on household food security. In this regard, we suggest future studies that address intra-household food security outcomes and the effect of individual empowerment indicators on food security. Finally, though we apply three complementary food security indicators, our measure of food security is not comprehensive enough to capture all the pillars of food security: availability, access, utilization and stability [76]. Therefore, we recommend future studies that develop and use a Multidimensional Food Security Index.

Abbreviations

A-WEAI	Abbreviated Women Empowerment in Agriculture Index
CSI	Coping Strategy Index
EHNRI	Ethiopian Health and Nutrition Research Institute
GPG	Gender parity gap
GPI	Gender Parity Index
HDDS	Household dietary diversity score
HFCS	Household Food Consumption score
FAO	Food and Agriculture Organization
FSIN	Food Security Information Network
NPC	National Planning Commission
OLS	Ordinary least squares
SDG	Sustainable Development Goals
2SLS	Two stage least squares
IDRC	International Development Research Center
IFAD	International Fund for Agricultural Development
IV	Instrumental variable
SNNPR	Southern Nations, Nationalities and Peoples' Region

UNICEF United Nations International Children's Emergency Fund
WFP World Food Programme
WHO World Health Organization

Acknowledgements
The authors would like to extend deep gratitude to Arba Minch University for the financial support for the study through its small-scale research funding. The authors also would thank farm households who provided the required data, district administrators, and development agents for their support throughout the survey.

Author contributions
SAJ is the principal author of this study. He initiated the proposal, developed the survey questionnaire, coordinated and supervised the fieldwork for data collection, conducted the data management and analysis and wrote the manuscript. EMS has provided support during the questionnaire development, data collection and management and manuscript write-up. Both authors read and approved the final manuscript.

Funding
Arba Minch University has provided financial support through its small-scale research funding. The funding covers the data collection cost for the study. The University had no role in study design, data collection, analysis, or manuscript writing.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication

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

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Received: 10 January 2023 Accepted: 12 August 2023
Published online: 02 December 2023

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