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The role of coffee-based Agroforestry in improving food security through dietary diversification

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Abstract
Agroforestry systems enhance ecosystem services, which helps decrease food insecurity. There is limited evidence addressing its importance in improving food security and diversity despite the recognized benefits of agroforestry. This study was conducted to examine how coffee-based agroforestry systems improved food security through diversified crop production in the agroforestry system in Gimbi district, West Wollega, Ethiopia. A multi-stage sampling procedure was used to select 402 sample households. Data were collected through household surveys, focus group discussions (FGDs), and key informant interviews. Household Dietary Diversity Score (HDDS), based on a 24 h recall period and Household Food Insecurity Access Score (HFIAS) measurements were used to evaluate the impact of crop diversity on the status of food security of the household coffee farmers. The coffee-based agroforestry system management helped farmers to produce various types of fruits, vegetables, cereals, and other crops, leading to a diversified diet year-round. The average dietary diversity score of household heads was 4.4 ± 1.27. About 34.33% of the sampled households had low, 45.77% had medium, and 19.90% had high dietary diversity. All farmers consumed cereal crops during the 24 h recall period, followed by condiments, beans, and vegetables. The household head's age, education, annual income, agroforestry practices, and tropical livestock units influenced the household's dietary diversity positively and significantly. Distance to the nearest market was negatively associated with dietary diversity. The study underscores the potential of coffee-based agroforestry as a sustainable agricultural practice that can enhance food security through crop diversification. Policymakers are encouraged to promote agroforestry systems through supportive policies, extension services, and market access initiatives to improve dietary diversity and resilience among smallholder farmers.

Keywords Agroforestry · Coffee · Crop diversification · Food security · Dietary diversity score · Food insecurity access score

1 Introduction

Food security has been a major issue around the world, particularly in Africa [1]. Evidence indicates that hunger has affected 702 to 828 million people worldwide in 2021, depending on the state of food security and nutrition [2]. According to the Global Report on Food Crises 2022, the number of people facing acute hunger from 155 million in 2020 has

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increased to nearly 193 million in 2021 [2]. Other indicators highlight the tragic scope of the developing crisis, and the 2022 global hunger index (GHI) score demonstrates that the fight against hunger has essentially come to a standstill [3]. In 2023, more people were undernourished as a result [4]. Additionally, the economic development of many smallholder farmers is slow. In times of crisis, food diversity is often negatively affected by an increased focus on producing cheap and energy-rich, but nutrient-poor staple foods, leading to increased food insecurity and lack of adequate nutrition [2].

The incidence is more common in Africa and the problems have adverse implications for growth and development, notably for young children [5]. The number of food insecure people in East Africa was 62.6 million at the end of September 2023. Among the nine countries in the region, Ethiopia and Sudan faced significant challenges, with both countries being part of the most severe global food crises [6]. Ethiopia had approximately 23.61 million people experiencing high levels of acute food insecurity, while Sudan had 11.7 million people. According to Ethiopia's country office report, extended humanitarian crises worsened the country's malnutrition status between 2020 and 2023. Remarkably, 39% of children under five were stunted, 22% were underweight, and 11% were wasted during this time [7].

The main cause of food insecurity in Ethiopia is a reliance on undiversified livelihoods based on low-output rain-fed agriculture, coupled with the impacts of climate change [8]. The difficulties traced back, among other things, to inadequate infrastructure, declining soil fertility, problems with the farming system (e.g. mono-cropping), and climate change [9]. The challenges differ significantly between locations depending on the natural resources that are already available, agroecology, population density, and the community's understanding of environmental management, among other factors [10–12]. The same situation exists in the Gimbi district, where farmers primarily cultivate monocropping and rely on rain-fed agriculture to supplement their food needs [13].

Gimbi district is located in the West Wollega zone, Ethiopia. It is endowed with different forest resources, including coffee-based agroforestry systems [14]. The district is suitable for the cultivation of various seasonal crops such as Teff, Wheat, Barley, Maize, and Sorghum [15]. The land suitability analysis indicates that significant portions of the district are highly suitable for such cropping systems [16]. The district also benefits from numerous small and large water bodies, which are crucial for agriculture [17].

Although there are better natural resources in the Gimbi district, it has been confirmed that there is a big food insecurity problem. Food security is influenced by climate change, poverty, soil degradation, lack of education and training, infrastructure, and health issues [13]. The problem of food security also shows a significant difference between agroforestry users and non-users [18]. Out of the 32 rural kebeles in the district, 18 were food insecure and supported by a productive safety net program (PSNP). According to [18], the kebeles covered by the Safety Net program were not practicing agroforestry systems. The farmers who use agroforestry have better food security and manage their environment in a good manner [19, 20]. As findings conducted in other areas indicate, a coffee-based agroforestry system encompasses mixes of coffee plants and other tree species that can provide a variety of fruits, leafy vegetables, nuts, and other edible products, including animal products, which play a crucial role in enhancing dietary diversity and food security [21–23]. Studies in south-western Ethiopia demonstrated that coffee agroforestry systems, such as home gardens, multistory coffee systems, and multipurpose trees on farmlands, significantly enhance household food access security [22, 24, 25]. Other findings added that the number of plant species and vegetation layers in the agroforestry systems are positively correlated with food security [22, 26].

Since agroforestry systems offer a variety of marketable species and edible plants that contribute to a more varied diet, households using these systems typically have higher dietary diversity, particularly during times of food scarcity [22, 27, 28]. Enhancing household and individual dietary scores is especially possible when various agroforestry practices are combined [29]. In general, integrating coffee with other crops in agroforestry systems not only boosts crop diversity but also enhances food security and diet diversity, providing a more resilient and nutritious food system for smallholder farmers [30].

Similarly, trees in the systems contribute to soil fertility through nitrogen fixation and organic matter addition, resulting in increased crop yields [31]. The system also helps in maintaining ecosystem services like pollination and soil conservation, which are crucial for sustainable food production [32, 33]. Finally, agroforestry systems are more resilient to climate change and extreme weather, lowering the risk of crop failure [34, 35].

Therefore, food insecurity was identified as the primary problem of the Gimbi district, which could be caused by climate change, land degradation, poverty, limited access to markets, a lack of education and training, infrastructure, and health issues. It is believed that food insecurity imposes significant impacts on health, economic strain, educational outcomes, social stability, and agricultural productivity [36]. This research gap or problem attracted our interest and inspired us to conduct the study and contribute to bridging the gap. Because it is believed that this study attempts to bridge the evidence gap and recommend development strategies for how coffee-based agroforestry improves food security through dietary diversification. The output of this paper would benefit local farmers or community members, environmental sustainability and resilience experts, as well as researchers and policymakers [13].

This study aimed to examine how coffee-based agroforestry systems help cultivate diversified crops and improve the food security status in the Gimbi district. The household dietary diversity score (HDDS) and household food insecurity access score (HFIAS) measures were used to assess the level of food security within coffee farmer households. It attempted to show the gaps by answering the subsequent research questions: (1) What was the factor that prompted farmers to adopt a coffee-based agroforestry system? (2) Does a coffee-based agroforestry system help farm households produce diversified crops and access nutritious food? (3) Do the farmers sustainably produce and access diversified food resources from the existing coffee farming system? (4) What factors affect a household's dietary diversity and access?

The study has focused only on assessing the role of coffee-based agroforestry in improving food security through dietary diversity in the Gimbi district. It did not include assessing the types of agroforestry systems in the district with their contributions. Furthermore, reliance on self-reported dietary information can introduce recall bias, as participants might not accurately remember or report their food intake.

2 Materials and methods

2.1 Ethics statement

The researchers obtained a formal support letter from Addis Ababa University. The letter was submitted to the West Wollega Zone Administration Office, and its consent was obtained. The zonal administration office then wrote an official letter to the Gimbi District Environmental Protection Office (GDEPO), where the study was conducted. Based on this, the GDEPO wrote a permission letter to the researcher and copied it to the kebele administrations of the respective kebele to cooperate with the research. In view of that, the kebele administration arranged the dates (starting from March 2, 2022) and the places where to contact the households and focus group discussants for the interviews and the discussions. Accordingly, verbal informed consent was obtained from the households, discussants, and informants before data collection in conformity with the anonymity of the study participants.

2.2 Description of the study area

Gimbi district is situated between 142000 and 174000 E (UTM) and 993000 and 1029000 N (UTM) in the Oromia National Regional State, Ethiopia (Fig. 1). Lowland and midland altitudinal zones are included in the region, with an altitudinal range of 1200–2222 m above sea level. The district has 32 rural villages. The region's typical annual minimum and maximum temperatures range from 10 °C to 30 °C, and 1400–1800 mm of rainfall each year. From June to September, there is a bimodal pattern of rainfall, followed by a prolonged dry spell from October to April. Mid-October to April, and occasionally into May, is the duration of the Bona season, a protracted drought (data obtained from the district agricultural office and personal communication, March 2022).

The district's estimated total population was 163,480 [18]. There were 80,381 women and 83,099 men in total. With 125 people per km^2, it has an area of 1, 18 km^2. A 1.2 ha landholding with 0.8 head of livestock is a typical rural landholding. A little over 21% of the population works outside agriculture. Rivers and streams that run both year-round and seasonally surround the study area.

The area has abundant potential for agricultural production, primarily used for small-scale farming. The main crops grown are coffee, sesame, corn, beans, bananas, fruit, sweet potatoes, cardamom, and sugarcane. Coffee farming dominates the southwest, while other crop products dominate the northeast part of the district. Crops are cultivated using rainwater except for a few locations where vegetables and fruits are grown. Most of the land in the district is dominated by agriculture; the most common exports are corn, coffee, and sesame.

2.3 Sampling techniques

A multi-stage sampling procedure was used in the actual data collection. First, western Ethiopia was chosen as the primary study area. At the second stage Gimbi district was selected from the 20 districts in the zone. Third, six kebeles were selected of the 32 kebeles in the district, based on their altitudinal representatives (lowland, midland, and highland) and

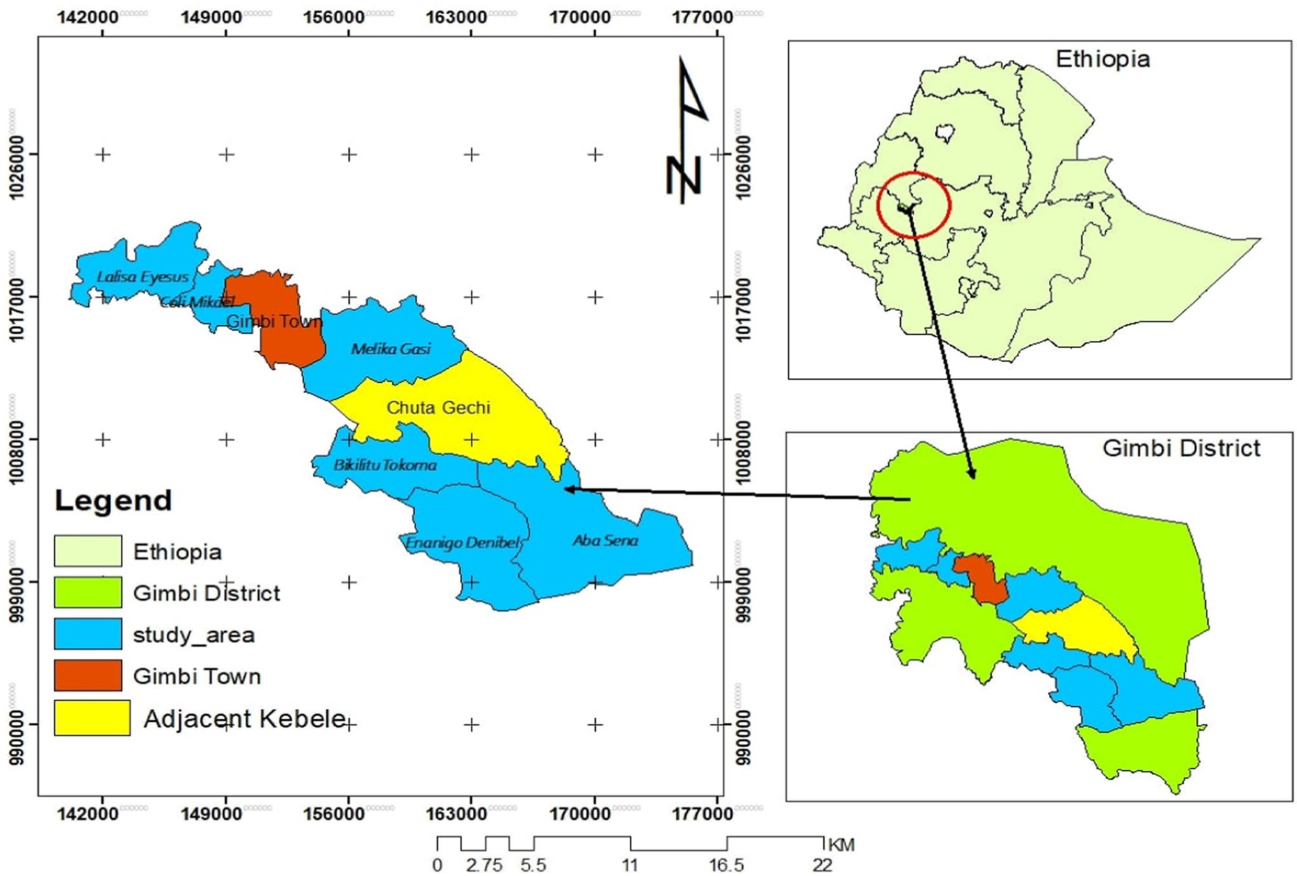


Fig. 1 Map of the study area

agricultural practices. Accordingly, the Enango Dembel and Aba Sena kebeles from the lowlands, Choli Mikael and Melka Gasi kebeles from the midlands, and Bikiltu Tokuma and Lelisa Yesus kebeles from the highlands were selected. The total households (n) that were sampled in each kebeles were determined using a proportionate-to-size sampling strategy.

The study employed the sample size determination formula given by [37].

$$n = \frac{N}{1 + N(e^2)} = \frac{32696}{1 + 32696(0.05^2)} = 402$$

where n is the sample size, N is the total households in the six kebeles, which is 32,696 and e is the level of precision. The sample size was 402 with a uniform sample size representation for each agroecological zone as they have nearly the same number of households.

Before the data collection, field training was given to six enumerators on the objective of the farmers' household survey. The field training included interpretation of questions, data types and quality, research ethics, probing, and triangulation before collecting data under the close supervision of the researcher. Pre-testing of the questionnaire was performed to avoid any missing information using 12 households in Inango Dambel and Biqiltu Tokkuma kebeles, after which the households were excluded from the main survey. Primary data were gathered from household heads, community elders, health extensions, developmental agents, and researchers. A computer-generated random number table was used to select participants from lists of the names of kebele household heads. Accordingly, 402 participants and six focus group discussions (FGDs) comprising 12 participants were interviewed and discussed for each kebele. The purpose of the FGDs was to gather crucial qualitative information on issues about economic activity, food security, farm household consumption patterns, and the elements influencing dietary diversity and access. The interview was administered using the Afan Oromo language.

2.4 Data analysis

Descriptive and econometric model analysis was used to organize, summarize, and code the survey data. Data analysis was done using Stata version 12.0. The quantitative data were analyzed using ordinary least squares (OLS), while the qualitative data were analyzed using narration and conceptual explanation, ordered logit model, and multinomial logit models. The independent variables did not exhibit multicollinearity.

Several predictors (independent variables) were considered when analyzing coffee-based agroforestry in terms of improving food security through dietary diversification. Before the analysis, a crucial checking of the appropriateness of the models was conducted for the relevant statistics such as Model specification, Assumption, Multicollinearity, Heteroscedasticity, and Model Fitness test. The test statistics result has ensured that the econometric models were robust and reliable, which can lead to more accurate and meaningful results in the coffee-based agroforestry impact in improving food security through dietary diversification (Table 1).

2.5 Crop diversification in coffee-based agroforestry systems

The agroforestry system implies the production of multiple crops in the same unit of land throughout the year by households. In this study, crop diversification in the agroforestry system is the main variable of interest to diversify food items. The Herfindahl index (HI) is used as a measure for crop diversification or specialization. In other words, the Herfindahl index is calculated for each farm separately to measure the degree of diversification. The index captures the degree or extent of diversification for an individual farm household using an equation:

$$P_i = \frac{A_i}{\sum_{i=1}^{n} A_i} \tag{1}$$

where, Pi = proportion of i^{th} crop, Ai = area under i^{th} crop (ha), $\sum_{i=1}^{n} A_i$ total cropland (ha) and i = 1, 2, 3..., n (number of crop).

$$\text{Herfindahl Index } = (\text{HI}) = \sum_{i=1}^{n} {P_i}^2 \tag{2}$$

$$\text{Crop diversification index } = \text{ CDI } = 1 - \text{HI} \tag{3}$$

2.6 Food security analysis

Food security is achieved when everyone has constant access to adequate, safe, and nourishing food that satisfies the nutritive necessities and is preferred for an active and healthy lifestyle [38]. It relies on four important variables: food consumption, physical and financial access to food, food availability, and the persistence of the other three variables over time [39]. This study aimed to assess the food security status of coffee farmers using the Dietary Diversity Scale and the Household Food Security Access Score (HFIAS).

Table 1 Illustration for test statistics on how coffee-based agroforestry impacts food security through dietary diversification

Test Statistic	Description	Values
R-squared (R^2)	Proportion of variance in the dependent variable explained by the model	0.70
Adjusted R-squared	Adjusted measure of R^2 accounting for the number of predictors	0.68
F-test	Tests the overall significance of the model	$F(5, 294) = 15.32$, $p < 0.001$
Variance Inflation Factor (VIF)	Measures multicollinearity among predictors	Mean VIF = 2.5
Breusch-Pagan Test	Tests for heteroscedasticity in the residuals	$\chi^2(1) = 3.45$, $p = 0.063$
Goldfeld-Quandt Test	Alternative test for heteroscedasticity	GQ = 1.98, $p = 0.075$

2.7 Household dietary diversity score (HDDS)

A dietary diversity questionnaire can be used to collect data from households or individuals [40]. According to FAO's guidelines for assessing household dietary diversity, the population of interest should be selected before the start of the data collection. Because it helps to adapt the questionnaire to the local survey context [41]. The survey goal and objective determine the method used to collect data. Assessing household dietary diversity would be the best approach if the purpose of the survey is to analyze the level of nutrition [40]. The Household Dietary Diversity (HDD) was assessed using a 24 h recall of food types eaten by members of the household as either a shared meal in the home or as food made at home to be eaten by household members outside [42].

Similarly, the HDDS in this study was based on 12 food groups, using the guidelines for measuring HDD developed by INDEX Project [43]. The 12 food groups included cereals, tubers, vegetables, fruits, meat, eggs, fish, beans, dairy products, fats/oils, sugar/honey and condiments. If the food group was consumed, one point was provided; if the food group was not consumed during the reference period, no points were given. The sum of all the points for each household was then computed.

The factors significantly associated with the dietary diversity of the households were found by fitting the ordered logistic regression model to the data. The equation of the ordered logit model regression is specified as:

$$Y^{*} = \sum_{k=1}^{k} \beta_k X_k + \varepsilon, \tag{4}$$

where Y^* is unobserved, X_k is a vector of independent variables, β denotes coefficients to be estimated and ε denotes a random error term.

From the above model, the observed or defined categorical variable Yi is determined as follows:

$$Y = 0 \text{ if } Y^{*} \leq 0$$

$$\mathrm{Y} = 1 \text{ if } 0 < Y^{*} \leq \mu_1$$

$$\mathrm{Y} = 2 \text{ if } \mu_1 < Y^{*} \leq \mu_2$$

$$\mathrm{Y} = j \text{ if} \mu_{j-1} \leq Y^{*}$$

In case y is observed in j number of ordered categories, μ_s are unknown threshold parameters differentiating the adjacent categories to be assessed with βs; then μ_1, $\mu_{2,}$ and μ_3 represent the different levels of the HDDS that are to be estimated. The general form for the probability that the observed y falls into category j and the μs and the βs are to be estimated with an ordered logit model i.

$$Prob(Y = j) = 1 - L\left(\mu_{j-1} - \sum_{k=1}^{k} \beta_k X_k\right), \tag{5}$$

where L (·) represents cumulative logistic distribution.

2.8 Household food insecurity access score (HFIAS)

Apart from HDDS, HFIAS was employed to analyze the food security status of farm households. The HFIAS is a continuous measure of the degree of food insecurity in the household in the past 30 days. It asks nine questions about household access to food and members' experiences and perceptions of hunger. Despite the limits of all measures, the HFIAS is comprehensive and appropriate in a variety of scenarios [44]. Each question has four response options: never, rarely, sometimes, and often, coded as 0, 1, 2, and 3 in order of increasing frequency. Responses to these nine questions are summed to construct a food insecurity score, with a maximum score of 27 indicating most food-insecure households [45].

The HFIAS represents three common categories of household food insecurity: worry about household food insecurity, insufficient food quality, and insufficient food quantity [46]. According to [47], this indicator reflects the household's attitude toward their diet, regardless of its nutritional composition. The minimum score of HFIAS is zero when a household head responds 'no' to all questions. Alternatively, 27 is the maximum score of HFIAS. It is obtained when a family responds yes to all inquiries and 'often' as the frequency of occurrence to all nine items. HFIAS (0–27) at a higher value presents that a household is food insecure. Simultaneously, a low score indicates that the family is less vulnerable to food insecurity.

The results of the HFIAS analysis were used as supplementary data, as the main discussion part was mainly based on the dietary diversity score variable. The HFIAS was computed as follows:

$$\mathrm{HFIAS}\,(0-27) = \mathrm{Q1a} * \mathrm{F1} + \mathrm{Q2a} * \mathrm{F2} + \mathrm{Q3a} * \mathrm{F3} + \mathrm{Q4a} * \mathrm{F4} + \mathrm{Q5a} * \mathrm{F5} + \mathrm{Q6a} * \mathrm{F6} + \mathrm{Q7a} * \mathrm{F7} + \mathrm{Q8a} * \mathrm{F8} + \mathrm{Q9a} * \mathrm{F9} \quad (6)$$

2.9 Effects of agroforestry by crop diversification on household food security

In the relationship between crops diversification in agroforestry systems and food security, the study used an ordinary least squares (OLS) regression. Crop diversification index (a continuous variable) and food security outcomes HDDS and HFIAS are taken as dependent variables (all continuous variables), so we decided to use OLS regression. According to this, it is appropriate to use OLS to ascertain the influence of a continuous variable on another continuous variable similar to the current study [48]. The OLS model is specified as:

$$Y_i = \beta_0 + \beta_i X_{i1} + \beta_2 X_{i2} \ldots + \beta_n X_{in} + \mathrm{e} \quad (7)$$

where Y_i = household food security outcome (either DDS or HFIAS), X_{i1} = crop diversification index, X_{i2} = sex of household head, X_{i3} = age of household head (in a year), X_{i4} = education level of household head, X_{i5} = household size, X_{i6} = farmland size, …., β_0 = intercept, β_1 to β_n are coefficients, and *e* is the error term. Table 2 shows the description of variables used in the analysis.

3 Result and discussions

3.1 Socioeconomic and demographic aspects

The average age of households was 47 years (Table 3). The ages of the participants ranged from 20 to 90. About 23% of the households were under the age of 35, 69% were between the ages of 36 and 65, and 8% were beyond 65. The average Tropical livestock unit (TLU) was 1.32, with the lowest at 0.78 and the highest at 1.88. The average landholding size of the households was 2.6 hectares, while the average annual income was 560 USD. The average distance to travel from home to the nearest marketplace was 5.1 km. The average number of contacts with the agricultural extension agent for

Table 2 Variables used to assess household food security status of smallholder farmers

Variables	Description	Sign
Dependent variables		
HDDS	Continuous	
HFIAS	Continuous	
Explanatory variables		
CDI	Continuous	+
Education	1 if obtained a minimum of primary education, 0 otherwise (Dummy)	+
Marital status	1 if married with a couple, 0 otherwise (Dummy)	±
Age	Age in years (Continuous)	±
Family size	Number of individuals in the HH (Continuous)	+
Annual income	Total annual income (Continuous)	+
Farmland size	Total farm size in hectares (Continuous)	+
Fertilizer	1 if used, 0 otherwise	+
TLU	Reference total tropical livestock units (unit less number) (Continuous)	+
Market access	Distance to input markets (km) (Continuous)	–
Credit access	1 if accessed credit, 0 otherwise (Dummy)	+
Agricultural training	1 if accessed training, 0 otherwise (Dummy)	+
Extension services	1 if accessed extension, 0 otherwise (Dummy)	+

Table 3 Household dietary diversity categories (continuous explanatory variables) of coffee-based agroforestry practicing farmers in Gimbi district, Ethiopia

Variables	Household dietary diversity category								
	Low		Medium		High		Total		F
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Age	38.4	6.8	53.0	6.2	49.6	7.1	47.0	6.2	12.53**
Educational level	0.5	1.6	0.8	2.1	0.9	1.8	0.7	2.6	19.56***
Family size	4.6	1.3	5.8	1.4	6.2	1.7	5.3	1.5	6.78***
Farmland size	1.2	0.7	2.6	1.3	3.8	2.5	2.6	1.4	10.10***
TLU	0.9	1.0	1.3	1.4	1.7	2.4	1.3	1.7	8.28***
Annual income	11708	8626	24380	25398	42342	71364	26278	41260	13.56**
Market distance	6.5	1.4	5.8	1.4	3.2	1.1	5.1	1.3	9.23***
Extension service	3.0	6.6	8.6	10.4	12.0	12.6	7.5	10.4	6.82***

***, **, * significance level (at 1%, 5% and 10%, respectively)

training was 7.5 times per year (Table 3). The result revealed that the age of the household head, education status of the head, household size, and farmland and livestock holdings of the households had a significant mean difference among household dietary diversity groups that also resulted in food security differences (Table 3).

The findings revealed a considerable difference in income, distance to market, and agricultural extension services among HDD categories. The cultivated crops are mostly rain-fed near residential areas and only 12% of heads of the households had access to irrigation. Approximately 23.4% of families had access to credit and used the services. Nearly 80.6% of respondents were aware of the importance of dietary diversity obtained from their farm for a balanced diet and household health (Table 4).

The frequency of animal-rich food sources intake was significantly low except for dairy products in the sample. For instance, the proportion of fish consumption was only about 3.7%, followed by egg and meat consumption in the households, which accounted for only 18.4% and 38.3%, respectively (Fig. 3).

The households with high household dietary diversity consumed mostly cereals (100%), condiments (94.2%), tubers (80.2%), dairy products (76.2%), sugar and honey (67.4%), and vegetables (61.6%). Households with medium dietary diversity consumed mainly cereals (100%), vegetables (79.3%), tubers (73.6%), condiments (62.6%), and fats/oils (53.7%). The low household dietary diversity consumed primarily fats and oils (91.4%), beans (88.6%), and vegetables (85.7%) in addition to cereal crops. None of the households in the low dietary diversity households consumed fish. This variation in dietary diversity consumption across levels could be attributed to high income, which allowed people to purchase expensive food items such as meat, eggs, and fruits (Fig. 3; Table 3). The gap between the low and high annual income of household heads was quite large (250 and 901 USD respectively). Low and medium-income households may have limited purchasing power and are unable to afford expensive goods like meat (Table 3). This finding agrees with the results of a previous investigation [49–51]. Similar findings have reported that fish was

Table 4 Household dietary diversity categories (dummy explanatory variables)

Variables		Household dietary diversity category								
		Low		Medium		High		Total		χ^2
		N	%	N	%	N	%	N	%	
Gender	Female	5	5.8	26	12.2	13	12.7	44	10.9	15.286**
	Male	82	94.2	187	87.8	102	87.3	358	89.1	
Marital status	Yes	54	62.1	174	81.7	92	90.2	320	79.6	22.628**
	No	33	37.9	39	18.3	10	9.8	82	20.4	
Credit access	Yes	18	21.4	50	26.3	26	20.3	94	23.4	2.104
	No	66	78.6	140	73,7	102	79.7	308	76.6	
Agricultural training	Yes	62	75.6	98	76.0	164	85.9	324	80.6	29.206***
	No	20	24.4	31	24.0	27	14.1	78	19.4	

*** & ** are significance levels (at 1% and 5% respectively)

Fig. 2 Dietary diversity scores of coffee-based agroforestry farmers

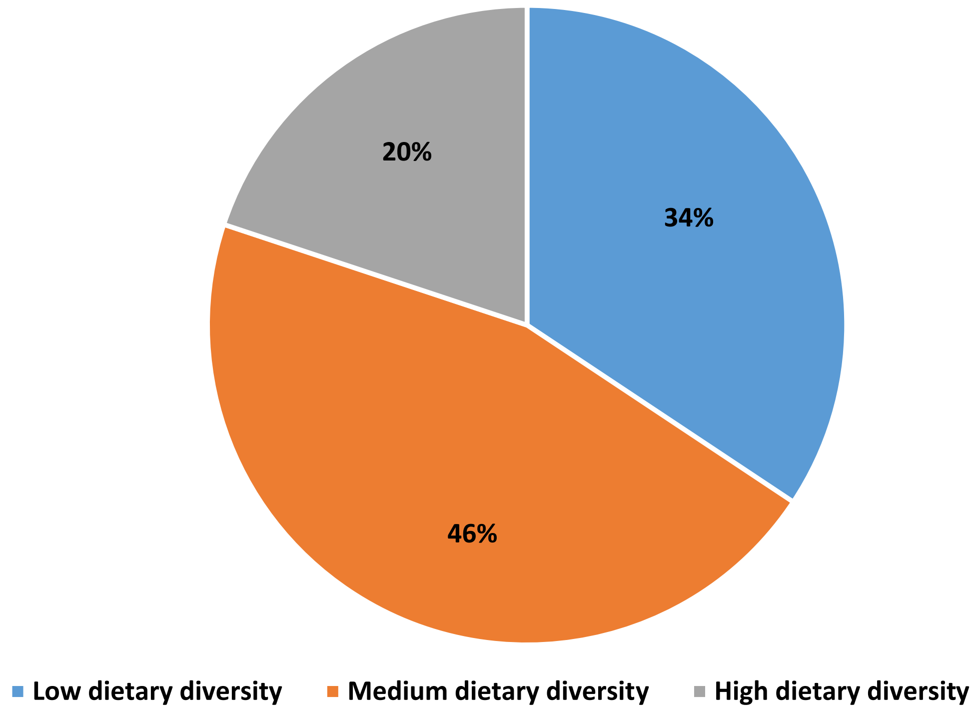
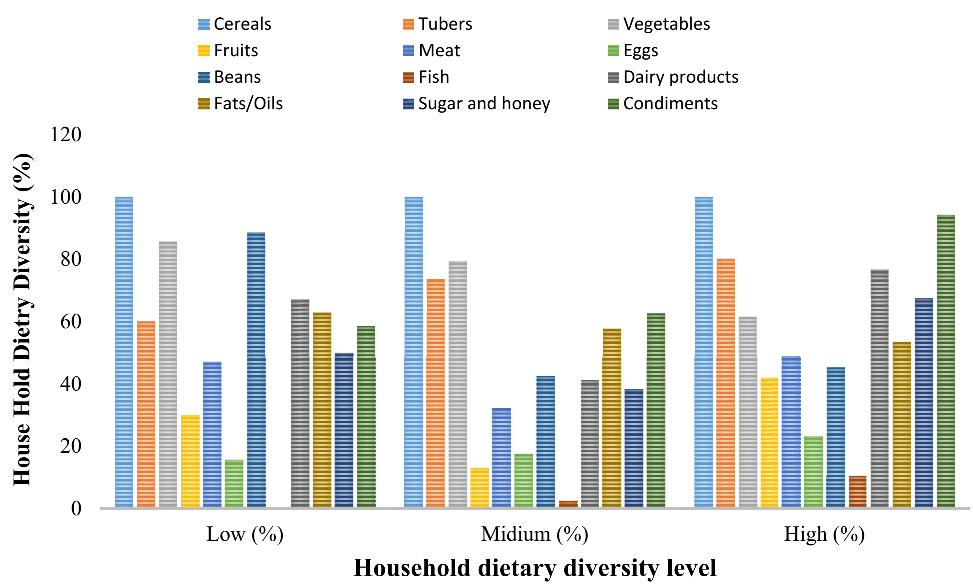


Fig. 3 Food groups of households consumed by coffee-based agroforestry farmers



not consumed at all among other dietary diversity scores [52]. This could be due to its economic or environmental inaccessibility. The same holds, as only certain households with medium- and high-dietary diversity and none with low-dietary diversity consumed fish.

Furthermore, participants have stated that practicing agroforestry management enabled them to cultivate diversified crops in agroforestry systems. Households with higher crop diversification intensities are more likely to have diversity in food crops. The diversified agroforestry crops can be consumed within the household and have justified the positive relationship that indicates crop diversification in the system has improved dietary diversification. It is proved that crop diversification in the system reduces the severity of food insecurity. It implies that households with higher crop diversification intensities are more likely to diversify food crops. This indicates the coffee-based agroforestry system's crop diversification improves dietary diversification in the study area. In other words, households participated in multiple cropping in agroforestry systems are distributing the possible risk of a particular crop failure in a season. Households that cultivate multiple crops are better assured of food availability and access than households that practice mono-cropping.

Farmers who have high crop diversity were observed having better productivity as compared to those with low crop diversity [53]. This revealed that farmers who increase crop diversification using agroforestry systems outperform their counterparts because diversification is related to dietary diversification and, negatively, to food insecurity [54, 55]. This is mainly due to the advantages of crop diversification, which include increased farm productivity and income reduced production and price risks [56]. The current finding is consistent with similar findings, which demonstrated a positive relationship between crop diversification in agroforestry systems and household food security [57, 58], found that farm production diversity was consistently and positively associated with household dietary diversity. It is also stated that agroforestry systems promote crop diversification, increase farmland production, increase fodder yields, and minimize soil erosion [55]. Moreover, [29] found that agroforestry improves access to and utilization of traditional foods.

3.2 Status of household's dietary diversity (HDDS)

The study results showed that from 402 households, 138 (34%) participants consumed up to three food groups (low dietary diversity), 184 (46%) consumed four to six food groups (medium dietary diversity), and 80 (20%) participants consumed seven or more food groups (high dietary diversity) in their diet during the preceding 24 h. The household dietary diversity scores ranged from 2 to 11 food groups with a mean of 4.4 ± 1.27 standard deviation. The majority of the households had medium dietary diversity scores Fig. 2. The result is consistent with [52, 59, 60].

3.3 Groups of food consumed by households

All participants consumed cereals in everyday meals (Fig. 3). Cereals were the mainstay of the households' diet. Studies have reported that cereal crop consumption has shown dominance over other diets [52, 61, 62]. In the previous 24 h, vegetables and tubers were meals in 76.6% and 72.6% of households, respectively. Similarly, 68.7% and 62.7% of households consumed condiments and fats/oils as meals, respectively. Our finding concurs with previous similar studies reported before [49, 52]. Fruit was consumed by 22.1% of the sampled households; 41.9% of the high household dietary diversity category consumed it, while only a small number of the low and medium household dietary diversity categories consumed fruits.

The findings indicate that, except for dairy products, the intake of foods rich in animal sources was significantly low in terms of frequency in the sample. For instance, the proportion of fish consumption was only about 3.7%, followed by egg and meat consumption in the households, which accounted for only 18.4% and 38.3%, respectively (Fig. 3).

The households with high household dietary diversity consumed majorly cereals (100%), condiments (94.2%), tubers (80.2%), dairy products (76.2%), sugar and honey (67.4%), and vegetables (61.6%), while those with medium household dietary diversity consumed mainly cereals (100%), vegetables (79.3%), tubers (73.6%), condiments (62.6%), and fats/oils (53.7%). None of the households in the low dietary diversity households consumed fish. This variation in dietary diversity consumption across levels could be attributed to high income, which allowed people to purchase expensive food items such as meat, eggs, and fruits (Fig. 3; Table 3). This shows that low and medium-income households may have limited purchasing power and are unable to afford expensive goods like meat (Table 3).

Furthermore, respondents have stated that practicing agroforestry management enabled them to cultivate diversified crops in agroforestry systems. Households with higher crop diversification intensities are more likely to have diversity in terms of food crops. The diversified agroforestry crops can be consumed within the household and justified the positive relationship that indicates crop diversification has improved dietary diversification. The crop diversification in the system reduces the severity of food insecurity. It implies that households with higher crop diversification intensities are more likely to diversify food crops which supports the findings of [63]. This indicates crop diversification in agroforestry systems improves dietary diversification in the study area [53]. In other words, households in multiple cropping in agroforestry systems are distributing the possible risk of a particular crop failure in a season. Households that cultivate multiple crops are better assured of food availability and access than households that practice mono-cropping [64].

According to respondents, only about 5 percent of the rural community often worries about food in the area (Table 6). This is mainly due to the advantages of crop diversification, which include increased farm productivity and income reduced production and price risks. This might be because farmers have easier access to informational resources like agricultural training (Table 4). The current finding is consistent with similar findings, which demonstrated a positive relationship between crop diversification and household food security. A finding from Kenya and Tanzania indicated that farm

Table 5 Parameter estimates of ordinal logistic regression

Variables	Coefficients	SE	Wald	P-value	Odds ratio
Age	0.304	0.081	13.412	0.000***	1.302
Education	0.962	0.088	18.001	0.000***	1.642
Annual income	0.178	0.060	8.204	0.001**	1.104
Marital status	– 0.145	0.372	0.231	0.634	0.746
Family size	0.124	0.139	0.632	0.501	1.201
Farmland size	0.224	0.168	1.544	0.203	1.196
Livestock own in TLU	0.322	0.128	4.89	0.021**	1.296
Market distance	– 0.462	0.140	6.029	0.001***	0.586
Credit access	0.004	0.018	0.064	0.821	1.003
Agricultural training	0.176	0.781	0.135	0.697	0.838
Extension services	0.039	0.021	0.048	0.784	1.004

***, **, * significance level (at 1%, 5% and 10%, respectively)

Table 6 Distribution of households by HFIAS condition

HFIAS	Rarely		Sometimes		Often	
	N	%	N	%	N	%
Worry about food	141	73.06	30	15.54	22	11.40
Unable to eat preferred foods	200	52.49	112	29.40	69	18.11
Eat just a few kinds of foods	102	31.10	92	28.05	134	40.85
Eat foods they do not want to eat	52	13.83	99	26.33	225	59.84
Eat smaller meal	106	49.77	79	37.09	28	13.15
Eat fewer meals in a day	91	70.00	22	16.92	17	13.08
No food of any kind in the household	29	72.50	7	17.50	4	10.00
Go to sleep hungry	22	95.65	0	0	1	4.35
Go a whole day and night eating	3	100	0	0	0	0

Hints to the severity status: (1) Rarely (once or twice in the past 4 weeks); (2) Sometimes (three to ten times in the past 4 weeks); (3) Often (more than ten times in the past 4 weeks)

production diversity was consistently and positively associated with household dietary diversity [57]. Similar finding also stated that agroforestry systems promote crop diversification, increase farmland production, increase fodder yields, and minimize soil erosion [55]. Moreover, [29] found that agroforestry improves access to and utilization of traditional foods.

3.4 Determinants of household food insecurity

The econometric model has shown the statistical relationship that is thought to exist between several economic parameters relevant to the variables used in this study. The variables assumed to influence on household dietary diversity were tested in the model. Accordingly, out of 12 variables entered into the model, five of them were found to be significant while seven of them were not found to be statistically significant. This finding is consistent with the report by [52].

The age of the household head was found to be among the five variables having a significant positive impact on the household's knowledge of dietary diversity. The study confirmed that the older the household heads, the more they consume diverse diets (Table 5). As most studies confirm, as the age of the household head increases, the household acquires more farming experience, becomes more risk-averse, and diversifies its production [65].

Similarly, education level of household head had a positive influence on the household dietary diversity. The positive and significant coefficient for education in the food secure category suggests that higher education levels are associated with better food security. This highlights the importance of education in leveraging the benefits of coffee-based agroforestry (Tables 3; 7). In addition, by holding the influence of other variables constant, a one unit increase in household head education level, the odds ratio in favor of high category with household dietary diversity increased by the factor of 1.642 (Table 5). Education of the household head plays a positive role in household dietary diversity [66, 67].

Table 7 Multinomial logit model

Variables	Food secure			Moderately food insecure			Severely food insecure		
	Coefficient	Standard error	Marginal effect	Coefficient	Standard error	Marginal effect	Coefficient	Standard error	Marginal effect
Gender	0.652	0.498	0.083	0.283	0.512	0.079	0.280	0.502	0.018
Age	− 0.027**	0.002	− 0.048	0.008	0.019	0.019	0.021	0.018	0.029
Education	0.485**	0.210	0.081	0.078	0.210	0.032	0.003	0.218	0.015
Marital status	1.329**	0.802	0.122	1.312	0.780	0.116	1.020	0.793	0.042
Family size	− 0.013	0.081	− 0.006	0.080	0.072	0.011	0.061	0.085	0.039
Annual income	0.120	0.203	0.059	− 0.220	0.215	− 0.016	− 0.790*	0.281	− 0.082
Farmland size	0.007	0.120	0.010	0.005	0.097	0.009	− 0.092	0.134	− 0.020
TLU	0.015	0.004	0.006	− 0.076**	0.041	− 0.018	0.030	0.040	0.005
Market access	0.003	0.002	0.018	− 0.004	0.017	− 0.005	0.005	0.002	0.011
Credit access	0.879**	0.450	0.100	0.300	0.471	− 0.021	0.772	0.550	0.061
Agri_training	0.260	0.452	− 0.017	− 0.512	0.410	0.089	− 0.830***	0.453	0.050
Extension services	0.370	0.532	− 0.021	− 0.480	0.420	0.049	− 0.364	0.518	0.032
_cons	− 2.710	1.623		− 2.362	1.474		− 4.981	1.608	
Log likelihood =−442.867			Number of observations =					402	

***, **, * significant level (at 1%, 5% and 10%, respectively)

The odds ratio in favor of a high category with dietary diversity in the household was observed to increase by a factor of 1.202 for every unit increase in household income when the effects of other variables were held constant (Table 5). The result concurs with the findings [66]. It states that a household with more money can purchase more food with better nutrition, increasing dietary diversity at the household level. In addition, [9] indicated that a household's likelihood of consuming a varied diet is significantly positively correlated with higher agricultural revenue. Furthermore, [68] has also addressed that the level of consumption in a household is determined by income.

Livestock ownership of households significantly and positively influenced household dietary diversity. The model output indicates that keeping other variables constant, a unit increase in livestock ownership leads to the odd ratio in favor of the high category with household dietary diversity increasing by a factor of 1.296. Owners of large livestock are therefore more likely to experience income growth (Table 5). The result supports the findings of other studies that found a relationship between owning livestock and a varied diet [52, 69, 70]. Moreover, [62, 71] described that rural households that own livestock are more likely to transition from a medium to a high dietary diversity status.

It is also shown that the distance to the marketplace had significant and negative influence on household dietary diversity at $\alpha = 0.05$. A one-unit increase in the marketplace leads the odds ratio in favor of high-category household dietary diversity to decrease by a factor of 0.586 (Table 5). This agrees with the findings of [9, 72] who reported a strong relationship between remoteness from markets and household dietary diversity. Furthermore, other findings also addressed that increased dietary diversity may be facilitated by improved market access through shorter travel distances [73, 74].

4 Conclusion

It has been demonstrated that agroforestry systems improve ecosystem services, which lowers food insecurity by producing a variety of agricultural products in various locations. In order to address the research gap, this study in Gimbi district, West Wollega, Ethiopia, emphasizes the value of agroforestry systems in enhancing food security, in an area that was previously lacking substantial scientific evidence.

The finding has revealed that coffee-based agroforestry management enables farmers to produce a variety of fruits, vegetables, cereals, and other crops, leading to a diversified diet throughout the year. Farm households with better systems for dietary diversification are more secure in their food supplies and income and can therefore meet their households' needs for food. The coffee-based agroforestry systems enabled farmers to get better availability, access to, and utilization of food resources in the study area. As a result, all sampled households could consume cereal crops during the 24 h recall period, followed by condiments, beans, and vegetables.

Accordingly, it is implied that dietary diversity increases food security in terms of quantity and variety, as well as income from the sale of crops made from a variety of crops grown, which in turn improves household consumption trends within the coffee-based agroforestry system. Thus, to improve farmers' food security, agroforestry practices must be promoted to encourage farm households to diversify their crop production, allowing rural farmers to achieve better food security sustainably.

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Author contributions Beshea Abdissa Chemeda: conceived and designed the research survey; Performed the data collection; analyzed and interpreted the data; contributed materials, analysis tools, or data; wrote the paper. Feyera Senbeta Wakjira: conceived and designed the research survey, supervised, edited the paper. Emiru Birhane: conceived and designed the research survey, supervised, edited the paper.

Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

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