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Eucalyptus-based livelihoods: enhancing household food security and resilience in Northwest Ethiopia

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Farmers in northwest Ethiopia have been transforming their livelihood strategies, however, the impact of this transformation on food security status and resilience is hardly investigated. The study aimed to analyze the contribution of livelihood strategy transformation to farmers' food security and capital assets in the Senan district, Ethiopia. A multistage sampling technique was utilized, and a total of 332 households were taken, of whom 166 households that had transformed their livelihood strategy, and 166 households had not. The results of the independent sample *t*-test revealed a statistically significant difference in average scores for the Household Food Insecurity Access Scale (M = 8.06 compared to 11.29) and the Household Dietary Diversity Score (M = 5.28 compared to 4.73) between households with and without eucalyptus plantations. The econometric analysis revealed that variables such as total land holding size, annual income, and livelihood diversification had a positive influence on the probability of a household being categorized as food secure. Moreover, the outcome of the livelihood asset index reveals that households that possess eucalyptus plantations exhibit higher indices for natural, physical, financial, and social assets compared to households without plantations. However, households that own eucalyptus plantations demonstrate a lower index for human capital than those without eucalyptus plantations. These findings underscore the role of eucalyptus plantations in enhancing food security and improving livelihoods for farmers in the study area. Furthermore, diversifying income sources through eucalyptus plantations can significantly amplify its overall benefits for local households.

KEYWORDS

food insecurity, asset index, dietary diversity, principal component analysis, annual income

1 Introduction

Livelihoods, encompassing the activities, assets, and capabilities necessary for survival, are closely linked to food security (Ellis, 2000; Serrat, 2008). In this context, individuals and communities adopt diverse livelihood strategies based on available resources to ensure their wellbeing (Silaban, 2021). Farmers, in particular, adjust these strategies in response to evolving opportunities (Irawan, 2023), risks (Kahan, 2013), and constraints (Kuang et al., 2020) to optimize their circumstances. In recent years, there has been a growing trend

in Ethiopia where croplands are being increasingly converted into eucalyptus plantations (Zerga et al., 2021). This shift in land use patterns is mainly driven by several factors, including land degradation (Jenbere et al., 2011), increased demand for eucalyptus for construction and fuel (Derbe et al., 2018), socioeconomic and demographic characteristics of households (Alemayehu and Melka, 2022; Gebreegziabher et al., 2010), and rising agricultural input expenses (Tefera and Kassa, 2017). Eucalyptus based agroforestry practices have also played a crucial role in supporting rural livelihoods, with findings indicating that farmers who adopt such practices have a higher average annual income compared to those who do not (Tebkew et al., 2024).

However, the relationship between eucalyptus plantations, livelihoods, and food security is complex and often contradictory. Some studies suggest that eucalyptus can enhance livelihoods and food security (Edesa, 2021; Kiyingi et al., 2016), with findings indicating its vital role for smallholder farmers and its contribution to rural household incomes (Zerga and Woldetsadik, 2016). Under current market conditions, eucalyptus plantations often yield higher returns on investment compared to traditional crop production (Alemayehu and Melka, 2022), promoting rural development and poverty alleviation (Tebkew et al., 2024).

Conversely, concerns exist regarding the implications of eucalyptus expansion for food security. Studies by Tesfaw et al. (2022) and Admassu (2016) warn that the rapid conversion of agricultural land to eucalyptus might exacerbate food insecurity. These conflicting findings highlight the necessity for further investigation, particularly within the specific context of the Senan district.

In the Senan district, farmers are increasingly following the national trend of converting cropland to eucalyptus plantations (Tesfaw et al., 2022). Despite the widespread presence of eucalyptus and the conversion of agricultural land, the effects on livelihoods and food security remain unclear. The district's diverse agricultural landscape and reliance on subsistence farming (Ferede et al., 2020) provide a unique opportunity to examine how eucalyptus plantations influence household capital assets and food security. As many households depend on agricultural outputs for their livelihoods, understanding the potential implications of eucalyptus cultivation is crucial. While eucalyptus may enhance income generation (Zerga and Woldetsadik, 2016), its impact on local food systems and market dynamics could complicate food access.

Despite the growing interest in eucalyptus plantations, comprehensive research comparing food security status and livelihood capital assets of households with and without eucalyptus plantations is lacking. Existing literature often overlooks the nuanced impacts of land use changes on local food security and livelihood resilience, indicating a pressing need for comparative studies.

This study specifically addresses the following research questions: What is the effect of eucalyptus plantations on the food security status of households in the Senan district, Northwest Ethiopia? What are the other determinants of food security in the district? How does eucalyptus cultivation influence the capital assets of these households?

2 Materials and methods

2.1 Site description

Senan district is located between 10°20′35″ and 10°50′38″ North and 37°35′10″ and 37°52′20″East as indicated in Figure 1. The district, which covers 436 km^2 (Yimam et al., 2024), has elevations between 2,300 and 4,154 m above sea level (Senan District communication Affairs Office, 2021).

The district's economy is primarily agrarian, with smallholder subsistence farming serving as the main source of income (Tesfaw et al., 2022).

A mixed crop-livestock production system predominates in the area, with cereals, pulses, and oil seeds being the principal crops (Mekuria et al., 2018). According to Belay et al.'s (2023) land use and land cover research, cropland declined from 58.4% in 2010 to 38.1% in 2021, while vegetation cover—primarily eucalyptus—increased from 16.8% to 26.5% during the same period.

2.2 Study design and approaches

To achieve the objective of the study, a cross-sectional survey was conducted. A mixed research approach was employed to collect comprehensive and diverse insights from the study's participants. This approach helps in triangulating the results and improves the validity and reliability of the study (Bryman, 2007).

Data collection in this study were conducted using the Kobo Toolbox, and the analysis was performed using the Statistical Package for the Social Sciences (SPSS) Version 26 and Stata 17.

2.3 Sampling technique and sample size determination

A multistage sampling approach was employed to ensure the sample was representative of the population, accounting for diversity within the study area. Initially, the *Senan* district was chosen due to its extensive eucalyptus plantations. Within this district, sub-districts were classified into two distinct agro-climatic categories: temperate and subtropical. From each category, the Kebeles of *Gedamawit* and *Tach Chabi*, known for their significant eucalyptus plantations, were selected for the study. Lastly, households within these sub-districts were classified into two categories: those with transformed livelihood strategies (eucalyptus owners) and those without (non-owners). Participants were then randomly selected in proportion to their representation in each category.

Given the small population size of the study area, the Cochran modified formula, which is specifically tailored for finite populations, was applied.

$$n = \frac{n_o}{1 + (n_0 - 1)/N}$$

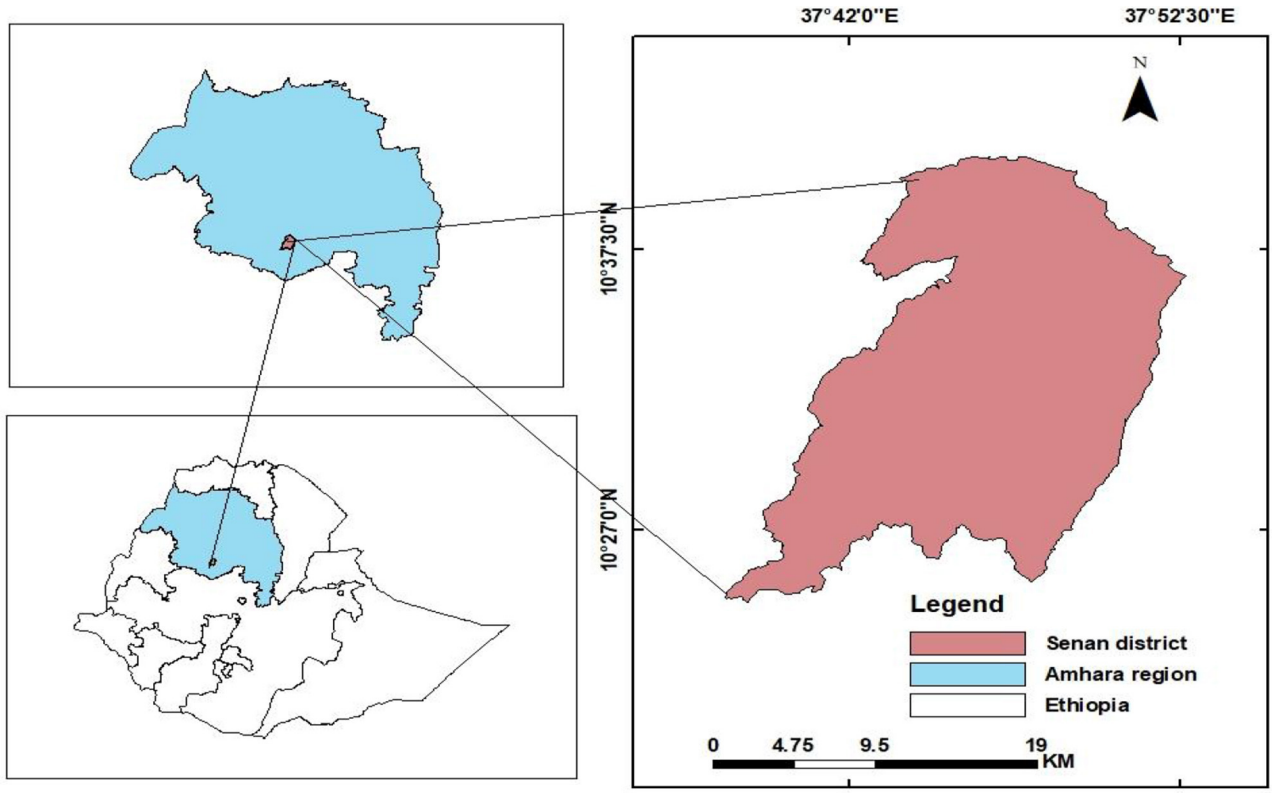

FIGURE 1
Location map of the study area.

Here n_0 is the Cochran sample size recommendation, N is the population size and n is the new adjusted sample size.

$$n = \frac{385}{1 + (385 - 1)/2392} = 331.89 = 332$$

The proportional sampling formula was employed to distribute a total of 332 units to households residing in two *kebeles*.

$$n_1 = \frac{n \times N_i}{N} = \frac{332 \times 1518}{2392} = 210$$
$$n_2 = \frac{n \times Ni}{N} = \frac{332 \times 874}{2392} = 121$$

Where n_i is the sample of strata *I;* N_is is the population of strata; n = total sample size.

2.4 Data types and data collection tools

This study relied on a combination of primary and secondary data to investigate the impact of eucalyptus plantations on household livelihood resilience and food security in the Senan district, Ethiopia.

The primary data for this study involved the utilization of a questionnaire survey, key informant interviews, and focus group discussions. The secondary data were collected from a variety of sources, including reports from the Central Statistical Agency (CSA), the Senan district communication office, and various research studies. The questionnaire was carefully designed with multiple sections to gather different types of data relevant to the research objectives. Notably, specific sections focused on capturing household food security indicators, and the factors influencing their food security status. Additionally, the questionnaire included targeted inquiries to collect data on livelihood capital assets, encompassing human capital, financial resources, social networks, natural resources, and physical assets.

The study employed purposive sampling to select key informants, including women and elders involved in and not involved in eucalyptus cultivation. Focus group participants were also selected purposively, ensuring representation of agricultural experts, elderly farmers, and women in separate groups. Eight key informant interviews and six focus group discussions were conducted, three in each sub-district. Informed consent was obtained from all individual participants included in the study.

To gain a comprehensive understanding of food security in households, we employed two food security measurement methods; the Household Food Insecurity Access Scale (HFIAS) and the Household Diet Diversity Score (HDDS). Both the HFIAS and HDDS data were collected twice (in January and August) to account for seasonal variations in the food security status of the households, and the average results were used for analysis purposes.

2.5 Method of data analysis

To evaluate the effect of eucalyptus plantations on the household's livelihood status, the livelihood asset index method was utilized. Principal component analysis (PCA) was employed to determine the weights for the indicators of livelihood capital assets. A radar chart was then created in Office 365, providing a visual representation of the assets index and offering a comprehensive overview of the household's livelihood status.

Livelihood assets in this study include the physical, financial, human, social, and natural assets which are measured by a set of variables as defined in Table 1.

The food security status of households in the study area was evaluated using two indicators: HFIAS and HDDS. Additionally, an independent sample t-test was performed to compare the average scores of HFIAS and HDDS between households with and without eucalyptus plantations. This analysis aimed to investigate potential differences in food security indicators based on the presence of eucalyptus plantations.

To identify the factors influencing food security, a multinomial logistic regression analysis was conducted. For this analysis, the households were initially categorized into distinct groups based on their food security status. To achieve this, HFIAS was utilized, merging the categories of mildly food insecure and moderately food insecure into a single category called "food insecure." This categorization allowed for the creation of three distinct groups: food secure, food insecure, and severely food insecure. Consequently, the dependent variable became a categorical variable with three groups.

Dependent Variable:

Y represents the food security status of households based on HFIAS categories:
$Y \in \{1,2,3\}$,
1 = severely food insecure,
2 = food insecure,
3 = food secure.

Independent Variables:

X represents the vector of independent variables:
X_1: *Kebele* of households (0 = *Tach chabi*, 1 = *Gedamawit*),
X_2: Sex of household head (0 = Female, 1 = Male),
X_3: Age of household head (in years),
X_4: Marital status of household head (0 = Unmarried, 1 = Married),
X_5: Educational rank of household head (in years),
X_6: Family size (Adult equivalent),
X_7: Ownership of eucalyptus plantations (0 = No, 1 = Yes),
X_8: Livestock ownership (TLU),
X_9: Size of farmland (in hectares),
X_{10}: Distance from the main road (in kilometers),
X_{11}: Livelihood diversification (Eucalyptus only/crop production only = 1, Eucalyptus and crop production = 2, Diversified livelihoods (on-farm, off-farm and non-farm, including eucalyptus plantations) = 3),
X_{12}: Total annual income (in ETB),
X_{13}: Farm fertility (1 = low fertility, 2 = medium fertility, 3 = high fertility),

TABLE 1 A summary of the variables employed to construct the livelihood asset index.

Capital asset	Indicators	Measurement
Natural Capital	Total land	Land size in hectares
	Average fertility level of land	Percentage
Physical capital	Solar lamp	0.No; 1.Yes
	Iron sheet number	in number
	Livestock ownership	TLU
	Radio	0.No 1.Yes
	Mobile phone	0. No; 1.Yes
	Access to drinking water	1. Ponds/rivers 2. Unprotected springs/wells 3. Protected springs 4. Drilled/tube wells with hand pumps 5. Piped water connections and community water taps
Human capital	Sex of household head	0. Female 1. Male
	Educational level of household head	1. Cannot read and write 2. Read and write only 3. Elementary (grade 1–8) 4. Secondary (grade 9–12) 5. College diploma/BA/BSc and above
	Household Size	Adult equivalent
	Labor shortage	0. No; 1. Yes
	Age of household head	Age in years
	Training opportunity	Number of training received in a year
Financial capital	Total annual Income	Income in ETB
	Access to savings and credit	0. No; 1. Yes
	Savings (amount saved)	Saving in ETB
Social capital	High level of participation in *Mahber*[1]	1. I am not even a member. 2. Strongly disagree 3. Disagree 4. Neutral 5. Agree 6. Strongly agree
	High level of participation in *Debo*[2]	
	High level of participation in *Edir*[3]	
	High level of participation in *Equb*[4]	
	Membership of cooperative	0. No; 1. Yes

[1] A community-based socio-religious group where individuals commit to treating each other as equals.
[2] A group of individuals working together to reach a shared objective.
[3] Edir is a traditional system of social funeral insurance.
[4] Rotating savings and credit association (ROSCA).

X_{14}: Membership of cooperatives (0 = No, 1 = Yes),
X_{15}: Access to savings and credit service (0 = No, 1 = Yes),
X_{16}: Savings in ETB (amount saved in local currency).

TABLE 2 Descriptive result of continuous variables.

Variable name	Eucalyptus planters			Non-planters			Total mean
	Min	Max	Mean	Min	Max	Mean	
Age of household head (yrs)	23	78	55.8	21	68	47	51.4
Household size (Adult equiv.)	2	7.5	4.6	2	8	4.8	4.7
Land size (ha.)	0.25	2.75	0.61	0.25	2	0.5	0.5
Livestock ownership (TLU)	0.52	4.3	3.3	1.1	5.7	3.5	3.4
Income (ETB)	25,000	135,000	66,399.4	17,000	85,000	36,387.95	51,393.67

The likelihood of belonging to category k, where k equals 1, 2, or 3, can be represented as:

$$P(Y = k|X) = \frac{e^{\beta_K^T X}}{\sum_{j=1}^{3} e^{\beta_j^T x}}$$

Where $^{\beta}K$ is the vector of coefficients for category K.
For K= 2 (Food insecure):

$$\log\left(\frac{P(Y = 2|X)}{P(Y = 1|X)}\right) = \beta_2^T x$$

For K= 3 (Food secure):

$$\log\left(\frac{P(Y = 3|X)}{P(Y = 1|X)}\right) = \beta_3^T x$$

3 Result

3.1 Socio-economic and demographic characteristics of respondents

Eucalyptus planters and non-planters exhibit notable differences and similarities in their characteristics. On average, eucalyptus planters are older, with a mean age of 55.8 years, compared to 47 years for non-planters. This suggests that older individuals may be more inclined to engage in eucalyptus farming. Additionally, household sizes among eucalyptus planters are slightly smaller, averaging 4.6 members, while non-planters average 4.8 members. In terms of land ownership, planters have a larger average area of 0.61 hectares, compared to 0.5 hectares for non-planters, which may support their agricultural activities. Interestingly, non-planters own a bit more livestock, averaging 3.5 tropical livestock units (TLU) compared to 3.3 TLU for planters. The expansion of eucalyptus plantations has decreased grazing lands, adversely affecting livestock production (Desta et al., 2023). Furthermore, livestock often depend on crop by-products for feed, which has resulted in eucalyptus non owners having a greater number of livestock compared to eucalyptus owners (Table 2).

The other most significant difference, however, lies in income; eucalyptus planters report an average income of 66,399.4 ETB, substantially higher than the 36,387.95 ETB reported by non-planters.

Female-headed households are more prevalent among eucalyptus owners compared to non-owners. In terms of marital status, a substantial majority of both planters (86.2%) and non-planters (88.6%) are married, resulting in an overall average of 87.3% across the population. The percentages of divorced and widowed individuals are relatively low, although planters exhibit a slightly higher divorce rate of 6.6% compared to 3.6% among non-planters.

In addition to these demographic trends, eucalyptus planters generally demonstrate higher levels of education than non-planters as indicated in Table 3. A significant portion of non-planters, 57.2%, are illiterate, while the illiteracy rate among planters is lower at 36.7%. Furthermore, planters are more likely to have completed various educational milestones: 19.3% have finished elementary education compared to just 2.4% of non-planters, and 4.2% have completed secondary education compared to 1.2% of non-planters. Additionally, a small proportion of planter household heads (0.6%) have attained a college diploma or bachelor's degree, while none of the non-planter household heads have with this level of education.

3.2 Livelihood asset estimates

Before calculating the household livelihood index, all indicators were standardized to ensure all variables were on a common scale, enabling a fair comparison of their relative importance. After standardizing each indicator, we performed PCA through SPSS software.

Before the analysis, the main assumptions of principal component analysis have been checked to look at the adequacy of the data for factor analysis. Bartlett's test of sphericity was found significant ($p < 0.05$), indicating a sufficient correlation between the dimensions to continue with the analysis. It indicates that the observed correlation matrix is significantly different from an identity matrix. This suggests that the variables are suitable for factor analysis.

The KMO value was 0.722. This result indicates that the present data are acceptable for principal component analysis. The weights of each variable for the indexes constructed are presented in Table 4.

The livelihood asset index result indicates that households owning eucalyptus plantations have higher natural, physical,

TABLE 3 Descriptive results of categorical variables.

Variable name	Description	Percentage		
		Eucalyptus planters	Non planters	Total
Gender of household head	Female	9.0	7.3	8.2
	Male	91.0	96.7	93.7
Marital status	Never married	0	0	0
	Married	86.2	88.6	87.3
	Divorced	6.6	3.6	5.1
	Widowed	7.2	7.8	7.6
Education level of household head	Cannot read and write	36.7	57.2	47
	Read and write only	39.2	39.2	39.2
	Elementary (grade 1–8)	19.3	2.4	10.8
	Secondary (grade 9–12)	4.2	1.2	2.7
	College diploma, BA/BSc and above	0.6	0	0.3

TABLE 4 Weights of livelihood capital asset indicators generated through principal component analysis.

Capital asset	Indicators	Weight
Natural capital	Total land	0.782
	Average fertility level of land	0.761
Physical capital	Solar lamp	0.777
	Iron sheet number	0.660
	TLU	0.156
	Radio	0.338
	Mobile phone	−0.105
	Access to drinking water	0.103
Human capital	Sex of household head	−0.938
	Educational level of household head	0.646
	HHSize	0.138
	Labor shortage	0.491
	Age of household head	0.453
	Number of training received	−0.938
Financial capital	Total annual Income	0.721
	Savings	0.751
	Access to savings and credit	0.872
Social capital	Level of participation in *Mahber*	−0.483
	Level of participation in *Debo*	0.174
	Level of participation in *Edir*	0.719
	Level of participation in *Equb*	0.740
	Membership of cooperative	−0.432

financial, and social asset indices than those who do not own the plantation as indicated in Figure 2.

The findings presented in Table 5 show that households that own eucalyptus plantations have higher indices for natural capital (0.48 compared to 0.46), physical capital (0.49 compared to 0.25), financial capital (0.57 compared to 0.34), and social capital (0.85 compared to 0.67) in comparison to households without eucalyptus ownership. However, households that own eucalyptus plantations show a lower index for human capital (0.50 compared to 0.58), than those without eucalyptus plantations.

The higher indices for natural, physical, financial, and social capital among households that own eucalyptus plantations indicate that such ownership can significantly contribute to asset accumulation. Concerning this, one of the key informant farmer expressed that the presence of eucalyptus plantations significantly increased their financial resources as stated below.

"Due to the planting of eucalyptus trees, we have experienced a level of financial prosperity that has been unprecedented for us."

This suggests that the economic benefits gained from eucalyptus farming have provided community members with increased income, enabling them to improve their livelihoods.

An agricultural expert from the district noted, "*Eucalyptus plantations are improving the livelihoods of farmers not only in the Senan district but also in other regions of Ethiopia. For example, communities in Wollo often express that 'survival is challenging without remittances from sending their daughters to Arab countries or through the plantations of eucalyptus trees'.*"

3.3 Food security status of households

3.3.1 Household food insecurity access scale

To better understand the features of household food insecurity, four types of indicators (overview of food security conditions, domains, scores, and prevalence of Household Food Insecurity Access) were computed below.

3.3.1.1 Household food insecurity access-related conditions

Regarding food insecurity access concerns, a larger percentage of households expressed their worries about running out of

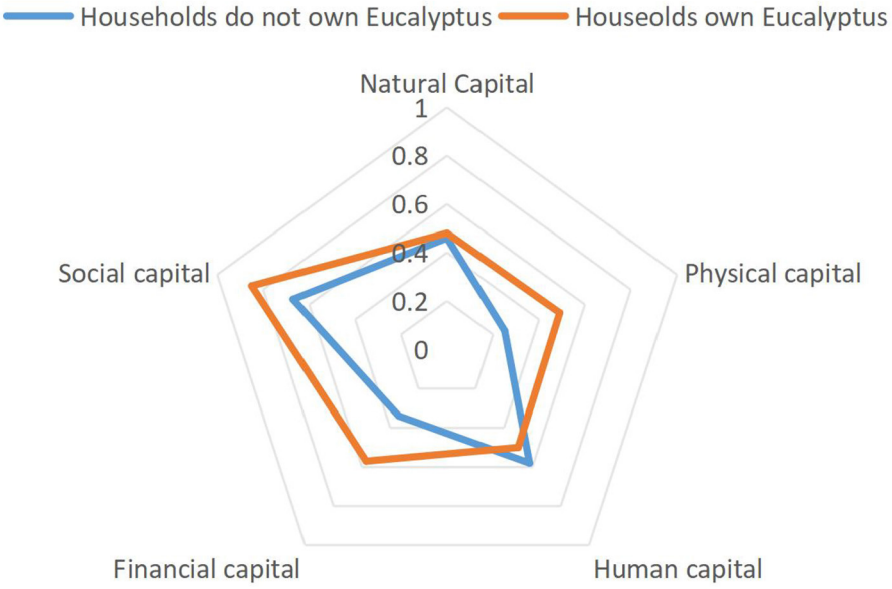

FIGURE 2
Livelihood asset index.

TABLE 5 Livelihood asset index of households.

Capital asset	Households do not own eucalyptus	Households own eucalyptus
Natural capital	0.46	0.48
Physical capital	0.25	0.49
Human capital	0.58	0.50
Financial capital	0.34	0.57
Social capital	0.67	0.85

food, particularly among those who do not own eucalyptus trees (86.1%) as indicated in Figure 3. Additionally, a notable 10.2% of smallholder farming households faced severe conditions where they left home morning and sleep night empty stomach resulting from a shortage of food.

Contrarily, 79.5%, and 3.6% of eucalyptus owner households worry about running out of food and going days and nights on empty stomachs respectively as presented in Figure 4.

3.3.1.2 Household food insecurity access-related domains

The findings in Figure 5 indicated that a significant portion of households (86.1%) without eucalyptus plantations faced concerns and uncertainties regarding having enough food to meet the needs of all household members. Additionally, 83.3% of households experienced challenges related to insufficient food quality and limited access. Furthermore, ~42.9% of the households surveyed were able to cope with inadequate food intake during the past 4 weeks.

3.3.1.3 Household food insecurity access scale score

Table 6 displays the outcomes of the independent sample t-test, which compares the HFIAS and HDDS between households that own eucalyptus plantations and those that do not. The result indicated that, on average, households with eucalyptus plantations scored a lower with mean score ($M = 8.06$, $SD = 5.0$), indicating a better food security status, compared to households without the plantation ($M = 11.29$, $SD = 5.6$).

3.3.1.4 Household food insecurity access prevalence

The prevalence results of HFIAS among the sampled households in Table 7 reveal a striking disparity in food security between households with eucalyptus plantations and those without. Specifically, households without eucalyptus plantations experience a higher incidence of food insecurity (81.9%) compared to those who own the plantation (75%).

Among the households without plantations, detailed classifications of food security status underscore the severity of the issue: only 18.1% are categorized as food secure, while a substantial 39.2% are classified as mildly food insecure, 35.5% as moderately food insecure, and 7.2% as severely food insecure. So the prevalence of household food insecurity was 81.9%.

When we compare the levels of food insecurity between households with and without eucalyptus plantations, the HFIAS results show a positive correlation between eucalyptus plantations and food security. As Table 8 shows a quarter (25%) of households with eucalyptus plantations are classified as food secure. This stability may be attributed to the income generated from the eucalyptus plantations, which can enhance households' purchasing power and allow them to invest in food and other essential resources. The data also shows that 43.7% of eucalyptus owner households experience mild food insecurity. This means they may face occasional food shortages but generally have sufficient food to meet their basic needs. On the other hand, a relatively

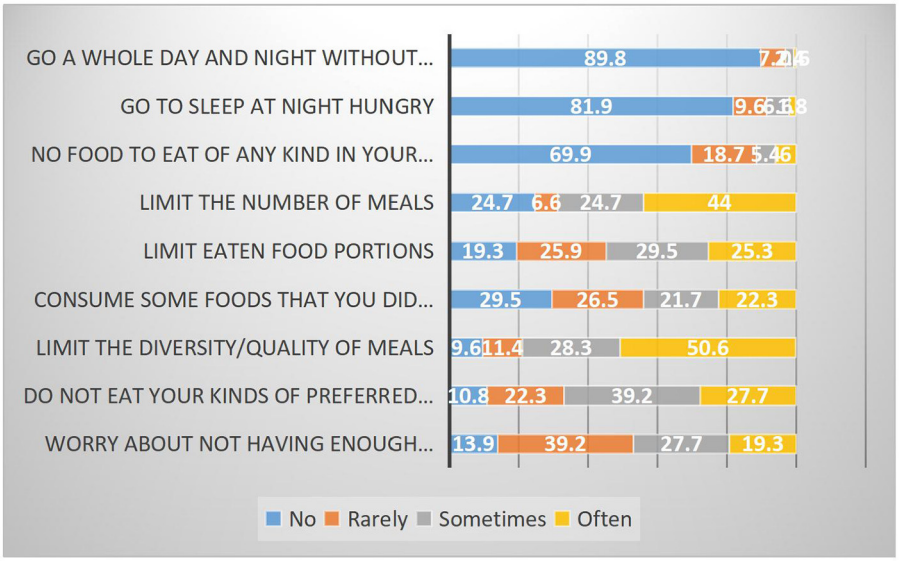

FIGURE 3
Household food insecurity access conditions of households without eucalyptus ownership.

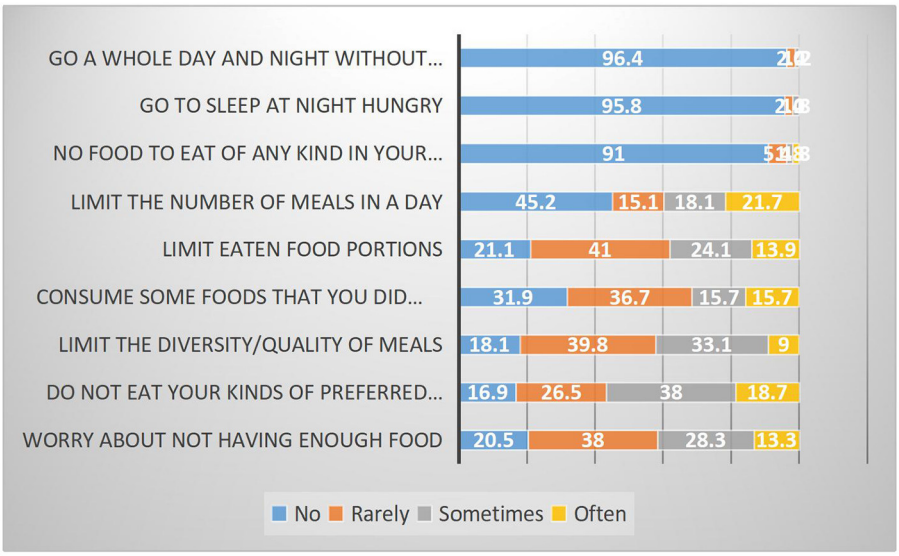

FIGURE 4
Household food insecurity access-related conditions of eucalyptus owners.

small proportion of households specifically, 26.2% are classified as moderately food insecure, while 5.1% are categorized as severely food insecure, as presented in Table 8.

3.3.2 Household dietary diversity score

The results of the independent sample *t*-test revealed a significant average difference in food security levels between households that owned eucalyptus plantations (M = 5.28, SD = 1.5) and those without the plantation (M = 4.73, SD = 1.3), with a significance level of 0.005. This finding underscores the positive impact of eucalyptus ownership on food security, suggesting that households with plantations are better positioned to access a more diverse and nutritious diet compared to their non-plantation counterparts.

The dietary patterns observed in the study provide further insights into the food consumption habits of these households. All sampled households reported consuming cereals, indicating that this staple food forms a fundamental part of their diet. However, the absence of fish consumption across the board highlights a potential gap in protein sources, which may have implications for overall nutritional health.

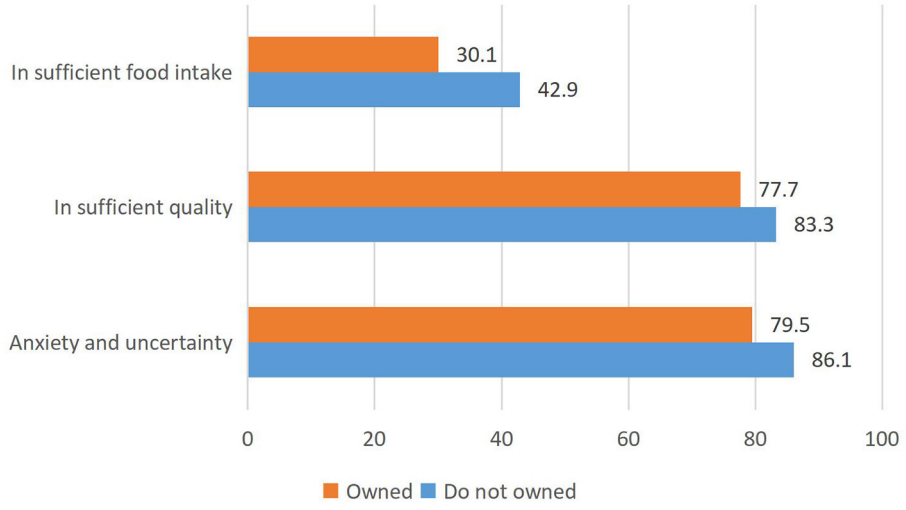

FIGURE 5
Household food insecurity access-related domains.

Legumes, roots, and spices emerged as the most widely consumed food groups in the study area, as illustrated in Figure 6. Among households without eucalyptus plantations, a notable majority reported consuming legumes, nuts, and seeds (81.1%), indicating a reliance on these nutrient-dense foods. Additionally, tubers and roots were consumed by 76.5% of these households, along with spices and beverages by 57.8%. However, the consumption of animal products was markedly low, with only 4.8% consuming eggs, and 7.8% meat. This limited intake of animal-based foods could reflect economic constraints, which may affect the overall nutritional quality of their diets. Fruits were consumed by 7.2% of eucalyptus non owner households.

In contrast, households that owned eucalyptus plantations demonstrated slightly higher consumption rates of certain food groups. A significant 84.3% consumed legumes, nuts, and seeds, while 72.2% consumed tubers and roots, and 61.4% reported eating spices and beverages. This suggests that the additional income generated from eucalyptus cultivation may enable these households to access a wider variety of foods. However, similar to eucalyptus plantation non owners, the consumption of eggs (9.6%), fruits (15%), and meat (10.8%) remained low among plantation owners as well, indicating that despite the economic benefits of eucalyptus cultivation, gaps in dietary diversity persist.

Generally while eucalyptus plantation ownership correlates with slightly greater dietary diversity, both groups still face challenges in accessing a well-rounded diet that includes more protein sources and fresh products.

Generally among the households that owned eucalyptus plantations, 60.2%, 36.7%, and 3% had low, medium, and high dietary diversity consumption, respectively. In contrast, among households without eucalyptus plantations, 74.1%, 23.5%, and 23.5% had low, medium, and high dietary diversity consumption, respectively as clearly presented in Figure 7.

3.4 Determinants of food security

To investigate the factors influencing households' food security status, a multinomial logit (MNL) model was employed. Before conducting the model, an assessment was carried out to identify any multicollinearity among the explanatory variables. The Variance Inflation Factor (VIF) values were calculated, and it was found that all of them were below the threshold of 10, indicating the absence of significant multicollinearity. The model fitting information revealed a log-likelihood ratio of 78.4 and a chi-square value of 528.4, both of which were highly significant ($P < 0.001$). Furthermore, the pseudo-R-squared value of 0.839 (with a p-value of 0.001) suggests that the explanatory variable accounted for approximately 83.9% of the variation observed in households' food security status. These results indicate that the model provides a good fit and possesses strong explanatory power concerning households' food security status.

Table 9 displays the computed MNL model coefficients and their corresponding standard error. The coefficients revealed that several variables influenced household food security. The variables found to have a positive significant influence include the location of the household where they live (*kebele*), eucalyptus ownership status, land size, livelihood diversification, and annual income. On the other hand, family size and distance from the main road have a negative significant influence on the food secure group compared to the food insecure group.

A positive coefficient on the *kebele* variable indicates that households residing in *Gedamawit* have a higher likelihood of falling into the food secure group compared to food insecure category. According to the marginal effect result, holding all other variables constant, households living in *Gedamawit kebele* have a 9.1% higher probability of being in the food secure category, and a 6.1% lower probability of being in the severely food insecure category compared to households living in *Tach Chabi kebele*. This implies that the food security status of households is influenced

TABLE 6 HFIAS and HDDS scores of households.

Variables	Eucalyptus	Mean	Std. deviation	Std. error	*t*-value	*p*-value	Sig.
HFIAS	No	11.29	5.6	0.436	5.509	0.000	***
	Yes	8.06	5.0	0.391	5.509	0.000	***
HDDS	No	4.73	1.3	0.105	−3.756	0.000	***
	Yes	5.28	1.5	0.104	−3.756	0.000	***

***$p < 0.01$.

TABLE 7 Household food insecurity access prevalence of households who do not own eucalyptus plantations.

HFIAS question; non owners	Frequency		
	Rarely	Sometimes	Often
1a	65	46	32
2a	37	65	46
3a	19	47	84
4a	44	36	37
5a	43	49	42
6a	11	41	73
7a	31	9	10
8a	16	11	3
9a	12	4	1

Key:

Food secure = 18.1%.

Mildly food insecure = 39.2%.

Moderately food insecure = 35.5%.

Severely food insecure = 7.2%.

TABLE 8 Household food insecurity access prevalence of households who own eucalyptus plantations.

HFIAS question; Owners	Frequency		
	Rarely	Sometimes	Often
1a	63	47	22
2a	44	63	31
3a	66	55	15
4a	61	26	26
5a	68	40	23
6a	25	30	36
7a	9	3	3
8a	4	3	0
9a	4	2	0

Key:

Food secure = 25.0%.

Mildly food insecure = 43.7%.

Moderately food insecure = 26.2%.

Severely food insecure = 5.1%.

by location-specific factors including infrastructure and resulting market conditions.

Our findings also suggest that the coefficient for distance from the major road shows households located closer to roads are more likely to be food secure as compared to the food insecure category. It also implies that, in comparison to food insecure households, those located farther away from the major route are more likely to experience severe food security, indicating geographical proximity to major roads is a significant factor influencing food security.

Similarly, the coefficient for distance from the major road shows that a one-unit increase in the distance from the main road is associated with a 3.2% decrease in the probability of a household being in the food secure category and a 5.2% increase in the probability of a household being in the severely food insecure category holding all other variables constant. This negative marginal effect suggests that households located farther away from the main road are less likely to be food secure, likely due to reduced access to markets, and transportation, that are more readily available near the main road. The positive coefficient on the eucalyptus ownership variable indicates that households with eucalyptus trees are more likely to fall into the food secure category than the food insecure category. The result also shows that compared to the food insecure category, households with eucalyptus trees are less likely to be identified as severely food insecure.

The marginal effect of eucalyptus ownership in Table 10 shows that holding all other variables constant, a household owning eucalyptus trees is associated with an 11.4% increase in the probability of being in the food secure category. This positive marginal effect indicates that owning eucalyptus trees increases the possibility that a household will have access to food, possibly as a result of the several advantages it may offer, mainly income. Households with eucalyptus plantations may also be able to engage in other income-generating activities, as eucalyptus farming is relatively less labor-intensive. On the contrary, the marginal effect of eucalyptus ownership on the probability of being in the food insecure category is 0.013. This indicates that a household owning eucalyptus trees is associated with a 1.3% increase in the probability of being in the food insecure and a 7.5% lower probability of being severely food insecure category. Although owning eucalyptus could improve food security for certain households, it may also raise the chance of food insecurity for other households, as indicated by the positive marginal effect for the food insecure group. This may be the result of unforeseen effects or trade-offs associated with eucalyptus

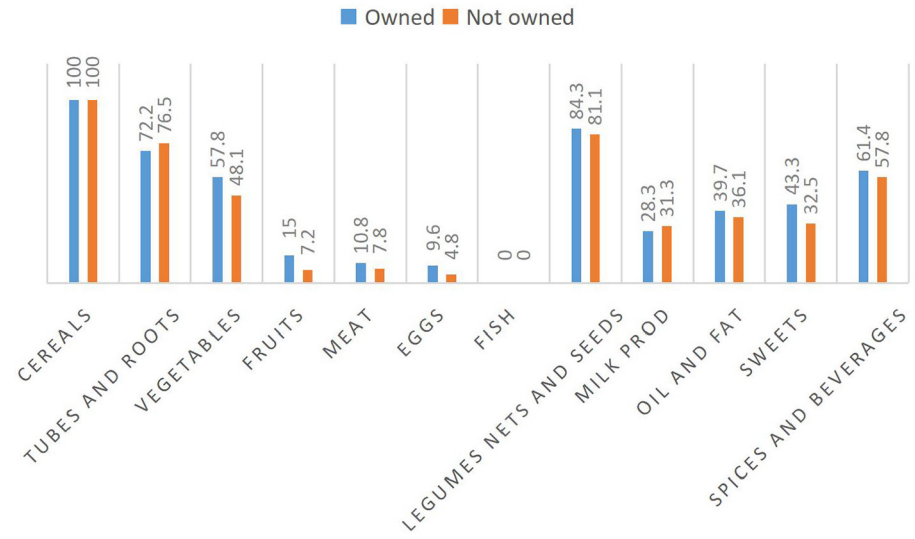

FIGURE 6
Household dietary diversity score.

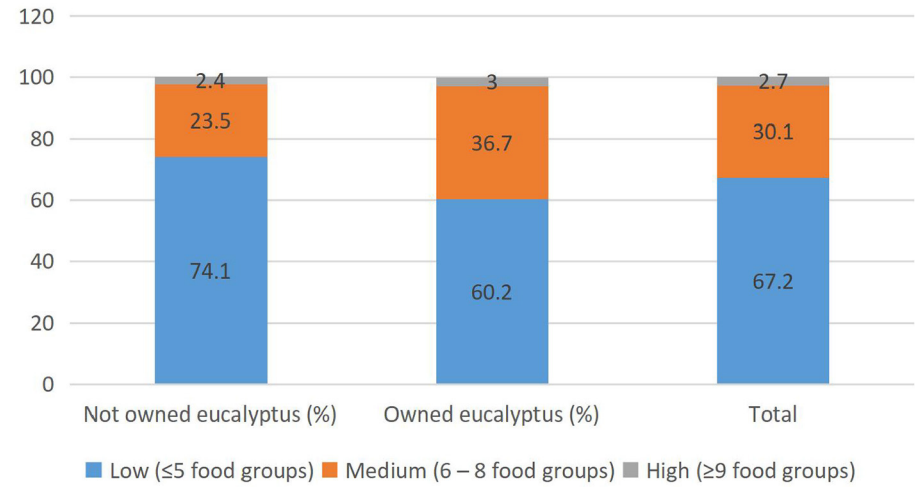

FIGURE 7
Level of dietary diversity score.

planting, such as the location of the plantation, and other socio-demographic issues that could have a detrimental effect on food supply or access.

A positive coefficient on the farmland size and annual income variables implies that all else equal, households with higher land size and annual income have a higher probability of being in the food secure category and a lower probability of being in the severely food insecure category compared to the food insecure category. Holding all other variables constant, the marginal effect also shows that a one-hectare increase in land size is associated with a 19.0% increase in the probability of a household being in the food secure category, a 4.5% decrease in the probability of a household being in the food insecure category, and 69.1% decrease in the probability of a household being in the severely food insecure category. Similarly, the marginal effect of livelihood diversification shows that a one-unit increase in livelihood diversification is associated with a 15.7% increase in the probability of a household being in the food secure category, 9.1% decrease in the probability of a household being in the food insecure category, and 14.8% decrease in the probability of a household being in the severely food insecure category. It indicates that households with more diversified livelihoods are more likely to be food secure (or less likely to be moderately food insecure) compared to those with less diversified livelihoods.

Finally, the negative coefficient for family size indicates that the likelihood of falling into the food secure category decreases with increasing family size while the coefficient for the severely food insecure group shows that the probability of falling into the severely food secure category increases when family size increases.

TABLE 9 Coefficient estimation of multinomial logit model (base outcome, food insecure).

Variables	Food secure		Severely food insecure	
	Coeff	Std. err	Coeff	Std. err
KebeleHH	0.409**	0.026	−0.722*	0.051
SexHH	0.034	0.481	0.193	0.688
AgeHH	−0.401	0.331	0.013	0.371
MariStat	0.004	0.244	0.351	0.335
EduStat	0.293	0.017	−0.521	0.052
FamilySize	−0.656*	0.591	1.061**	0.443
Eucalyptus	2.01**	0.051	−0.629*	0.154
Livestock	0.053	0.536	−0.144	0.598
LandSize	7.021***	0.103	−3.015**	0.006
DistanceFromRoad	−0.716***	0.215	0.331***	0.322
Livelihood diversification	1.137***	0.769	−5.226**	0.001
AnnualIncome	1.320	0.021	−0.908*	0.003
LandQuality	0.034	0.538	0.329	0.491
CooperativesMembership	0.015	0.066	0.002	0.115
Savings	0.414	0.131	−0.680	0.271

The symbols *, **, and *** represent the findings at the 1, 5, and 10% probability levels, respectively.

The marginal effect of family size shows that adding one extra person to a household is associated with a 7.3% decrease in the probability of a household being in the food secure category and an 8.1% increase in the probability of a household being in the severely food insecure category holding all other variables constant.

4 Discussion

The observed variations in food security status and livelihood asset ownership between households that own eucalyptus plantations and those that do not reveal significant insights into the link between eucalyptus plantations, livelihoods, and food security. The findings of the livelihood asset index revealed that households that own eucalyptus plantations had higher levels of various livelihood assets than households that do not have plantations. Specifically, these households did better on their natural, physical, financial, and social assets. This finding aligns with the research by Gusu et al. (2023), which argues that eucalyptus owners have more sustainable household livelihoods and improved food security status. It also supports research highlighting the significant role of eucalyptus in improving rural livelihoods compared to traditional crops and livestock (Bezabih et al., 2019). Regarding the role of eucalyptus plantations on the financial capital assets of households, research consistently demonstrates that they can significantly enhance household income and improve overall lifestyles. Belay et al. (2024) found that households with eucalyptus plantations in the Senan district experienced a 40.2% increase in total household income compared to those without, indicating a significant positive treatment effect. Moreover, the economic viability of eucalyptus has increased significantly, with recent trends showing that eucalyptus tree production is now more profitable than food crop production (Kassie, 2018). Supporting this observation, Bayle (2019) cautioned that the economic benefits derived from eucalyptus cultivation can exacerbate income inequality between landowners and non-owners in rural areas. Furthermore, eucalyptus can be successfully integrated into agroforestry systems, such as those involving intercropping with species like cowpea, wheat, rice, and maize. These systems, as highlighted by Thumbar et al. (2023), offer greater economic profitability compared to traditional monoculture crop production.

Furthermore, a key informant farmer remarked, "*the eucalyptus plantation has played a crucial role in transforming housing in the Senan community, prompting the shift from traditional grass structures to more resilient iron sheet houses*." This suggests that the economic benefits gained from eucalyptus farming have provided community members with increased income, enabling them to enhance their livelihoods.

Getnet et al. (2022) found households involved in eucalyptus plantations allocate more resources toward education which improves their human capital. However, our findings contradict this, indicating lower human capital indices for eucalyptus-growing households. Several factors related to family structure might explain this discrepancy. Age, gender, and family size could influence the prioritization of human capital development. Research suggests that age and gender influence tree-planting decisions (Gebreegziabher et al., 2010; Derbe et al., 2018; Gebretsadik et al., 2006). For example, older household heads are more likely to plant eucalyptus, which might come at the expense of human capital development. This could be because elderly farmers are less inclined to participate in capacity-building programs or pursue further education. Similarly, female-headed households, whose opportunities for human capital development are often limited by social factors, favor eucalyptus over crop production. Moreover, Belay et al. (2023) found that farmers with larger families are less likely to plant eucalyptus. The size of a household can have important implications for the accumulation and utilization of various forms of human capital. Our findings suggest that households with eucalyptus plantations have a greater abundance of natural resources compared to those without them, as measured by the natural capital index. This finding aligns with existing research (Pattanayak and Sills, 2001) which suggests that incorporating trees into agricultural practices can improve the natural resources available to rural communities.

Our findings indicate that the physical and social capital indices are higher among households that grow eucalyptus compared to non-growers. This suggests that eucalyptus cultivation may be associated with a greater accumulation of physical and social capital for these households. Some studies suggest eucalyptus plantations might create competition for scarce resources and lead to social conflict within communities (Larson and Ribot, 2007). Conversely, others such as Gebreegziabher et al. (2010) have argued that tree plantations, such as eucalyptus, can potentially generate income that households can then invest in

TABLE 10 Marginal effect estimation of Multinomial logit model.

Variables	Food secure		Food insecure		Severely food insecure	
	dydx	Std. err	dydx	Std. err	Dydx	Std. err
KebeleHH	0.091**	0.162	0.017**	0.023	−0.061***	0.010
SexHH	0.005	0.034	0.002	0.001	−0.009	0.003
AgeHH	−0.016	0.028	0.009	0.007	0.002	0.006
MariStat	0.008	0.041	0.001	0.012	0.044	0.001
EduStat	0.059	0.011	0.021	0.005	−0.14	0.021
FamilySize	−0.073**	0.033	0.081	0.025	0.040**	0.003
Eucalyptus	0.114*	0.012	0.013*	0.101	−0.075**	0.020
Livestock	0.004	0.002	0.002	0.022	0.032	0.009
LandSize	0.190***	0.009	−0.045**	0.004	−0.691**	0.015
DistanceFromRoad	−0.032**	0.014	−0.059	0.012	0.052*	0.021
LivelihoodDiversification	0.157**	0.030	−0.091*	0.006	−0.148	0.002
AnnualIncome	0.133	0.010	−0.801	0.001	−0.192	0.022
LandQuality	0.007	0.006	0.004	0.015	0.025	0.033
CooperativesMembership	0.004	0.040	0.002	0.061	0.006	0.002
Savings	0.078	0.005	−0.051	0.003	0.081	0.006

*, **, and *** indicate statistical significance at 1, 5, and 10% probability levels, respectively.

building their physical and social capital. The fact that eucalyptus is a good source of income for rural families, the income could allow them to participate more actively in community religious and social organizations such as *edir*, and *mahber*, which potentially strengthen social ties. Moreover, since eucalyptus plantation activities do not require much time, the resulting free time has the potential to strengthen social ties within the community.

Furthermore, recent studies, such as Datta et al. (2024) and Ramesh et al. (2023), emphasize the importance of well-managed agroforestry systems. Some of the most common types of agroforestry practices worldwide include agrisilviculture, silvopasture, multi-layered systems, and boundary plantations (Raskin and Osborn, 2019). The integration of fast-growing tree species like eucalyptus in these systems can enhance biomass production, providing an eco-friendly approach to carbon sequestration, increasing green cover, and improving farmers' economic conditions (Chavan et al., 2022). Promising intercropping options with eucalyptus include Irish potatoes and common beans (Nadir et al., 2018), as well as other crops like small onions, red gram, sesame, and sorghum, which can boost income and food security while minimizing environmental impacts (Thumbar et al., 2023). Moreover, studies indicate that households cultivating fast-growing trees like eucalyptus exhibit greater resilience to seasonal food shortages compared to those without such resources (Owusu et al., 2011).

Despite these advantages, the adoption of eucalyptus-based agroforestry in the *Senan* district remains limited. This highlights the need for increased awareness and implementation of these beneficial systems. A key informant farmer from the district shed light on some reasons behind this limited adoption.

"We are concerned about the competition for water and nutrients from eucalyptus trees, as well as the potential negative impact of tree shade on crop growth, which we believe reduces productivity. The shade of the tree from neighboring land concerns us, let alone planting eucalyptus between crops. These concerns often discourage us from adopting agroforestry practices."

Addressing these concerns through proper management practices, including the incorporation of appropriate silvicultural techniques as emphasized by Raj et al. (2023), is crucial. This will help maximize the benefits of eucalyptus-based agroforestry while minimizing negative impacts, ultimately enhancing income and supporting ecological stability.

However, the impact of eucalyptus plantations on household food security is context-dependent. While our study and others suggest benefits, Schreckenberg et al. (2006) documented a contrasting effect, linking the expansion of commercial tree plantations, including eucalyptus, to decreased dietary diversity and food access for nearby communities. These divergent findings likely reflect the complex and context-dependent nature of the relationship between eucalyptus cultivation and household food and nutrition outcomes. Factors such as household characteristics, land use patterns (over-investment in eucalyptus at the expense of food crop production), market access, and environmental conditions all play a role in determining the impact. That's why Kerbo et al. (2020) concluded that planting eucalyptus trees needs to be customized to the particular situation of each household to improve rural livelihoods and food security.

Our study confirms existing knowledge about factors influencing household food security in the study area. Location, land size, livelihood diversification, and annual income positively influence food security, while larger family size and road

inaccessibility are associated with higher food insecurity. This aligns with research by Bahiru et al. (2023) (income), Astemir (2014); Assefa and Abide (2023); Abafita and Kim (2014) (farm size), Abafita and Kim (2014); Aysheshim et al. (2023); Astemir (2014) (household size), Derso et al. (2021); Abegaz (2017) (location), Minyiwab et al. (2024); Abera et al. (2021); Zeleke (2017) (livelihood diversification). Furthermore, key insights from a key informant farmer emphasized the importance of diversifying income streams for eucalyptus owners to maximize their profits.

Despite the benefits of eucalyptus plantations, some researchers have raised concerns about their potential environmental impacts. Allelopathy, which can adversely affect the growth of nearby crops (Ali et al., 2018), is one of the main environmental problems associated with eucalyptus plantations. As stated by Sasikumar et al. (2002), the harmful chemicals emitted from the extracts of eucalyptus leaves, stems, and roots can hinder the germination of crops and the growth of seedlings. Hence, food security may ultimately be threatened by this deterioration, particularly in areas where subsistence farming is a major source of income for local populations. Jagger and Pender (2003) also stated that eucalyptus plantation has a limited economic impact on neighboring farmers' crops, especially in comparison to the financial benefits gained by the eucalyptus owners.

On the other hand, under certain circumstances, eucalyptus plantations may also benefit soil health (Chavan et al., 2022). For example, the decomposition of eucalyptus litter can improve the physical and chemical characteristics of the soil, increasing soil fertility (Mengistu et al., 2020). Additionally, eucalyptus has demonstrated the ability to restore damaged areas that were formerly utilized for subsistence farming, which can enhance soil fertility (Liang et al., 2016). Accordingly, Durai et al. (2019) state that eucalyptus may have restorative effects in some situations but may also be harmful to soil health in others. The adverse impact of eucalyptus plantations on the environment can be mitigated by careful species selection, site suitability assessments, and effective management practices (Amenu, 2017). However, there are significant concerns about relying on a single cash crop. As noted by Abokyi et al. (2020), smallholder farmers in developing countries often face income instability due to price fluctuations in their products. Households that depend too heavily on monoculture eucalyptus plantations are particularly vulnerable to price changes. The ongoing armed conflict between *Fano* and the Ethiopian government in the Amhara region could significantly impact the demand and price of eucalyptus products. This poses a risk for households in the *Senan* district, especially those heavily dependent on eucalyptus income. As *Senan* is located within the conflict zone, these economic uncertainties are compounded by the challenging circumstances. Notably, the conflict erupted after the completion of our data collection.

Effective land-use planning is crucial to overcoming these obstacles. Promoting eucalyptus growth on marginal land instead of ideal agricultural areas can lessen competition with food crops and ensure food security. As noted by Alemayehu and Melka (2022), when planted and managed appropriately, eucalyptus can have positive impacts that outweigh its negative effects.

5 Conclusion and recommendations

Eucalyptus ownership was identified as a significant factor influencing household livelihood assets and food security in the study area. Households with eucalyptus plantations displayed significantly higher livelihood asset index scores across multiple categories compared to those without plantations. This suggests that eucalyptus ownership contributes to overall household wellbeing.

Food security analysis further strengthens this association. Households owning eucalyptus plantations had a statistically lower HFIAS score ($M = 8.06$, $SD = 5.0$) compared to non-owning households ($M = 11.29$, $SD = 5.6$). This indicates a more secure food supply for eucalyptus-owning households. Furthermore, their higher HDDS ($M = 5.28$ compared to $M = 4.73$), implies a greater dietary variety, suggesting a more balanced and nutritious diet.

In addition to ownership of eucalyptus plantations, several additional factors influenced food security. Households in *Gedamawit Kebele* have enhanced food security as a result of improved market access and infrastructure. Road connectivity was also important, as closeness to the main road permitted market access and transportation, so improving food security. Livelihood diversification, larger land holdings, higher income, and smaller family sizes were all associated with increased food security.

In conclusion, although ownership of eucalyptus plantations appears to be a significant driver of improved livelihood assets and enhanced food security in the study area. There are risks associated with relying solely on this resource, making it crucial for households to manage trade-offs effectively.

- Diversifying livelihoods using income from eucalyptus products can enhance resilience and food security.
- Implement policies to invest in rural infrastructure development, particularly improving road accessibility, to enhance market access and transportation, thereby boosting household food security.
- Sustainable land use planning is essential to maximize the advantages of eucalyptus and minimize its negative impacts.
- Tailoring food security interventions to specific locations and households by considering the socioeconomic characteristics of households, market access, and infrastructure, could be more effective.

5.1 Limitations of the study

While this study offers valuable insights into the relationship between eucalyptus plantations, household livelihoods, and food security in the Senan district, it is important to acknowledge certain limitations. The reliance on self-reported data may introduce biases, as respondents might overestimate or underestimate their benefits. Additionally, longitudinal studies are needed to track changes over time and assess the long-term impacts of eucalyptus plantations on capital assets and food security.

5.2 Future research directions

To track changes over time and assess the long-term impacts of eucalyptus plantations on capital assets and food security, longitudinal studies are essential. This design will allow for monitoring changes in market conditions and environmental factors, offering valuable insights into the evolving dynamics of eucalyptus cultivation. Furthermore, the study of eucalyptus-based forestry activities will help farmers adopt suitable agroforestry practices in the study area.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

FB: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft. MM: Conceptualization, Funding acquisition, Project administration, Supervision, Validation, Visualization, Writing – review & editing. TM: Conceptualization, Funding acquisition, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2025.1496756/full#supplementary-material

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