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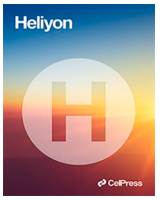

Research article

Analysis of food security among eucalyptus tree farming smallholder farmers in Gurage Zone, Ethiopia: An application of a composite food security indicator

Aklilu Amiga Kerbo [a,*], Degefa Tolossa Degaga [b], Abebe Damte Beyene [c]

[a] College of Development Studies, Addis Ababa University, Addis Ababa, Ethiopia, P.O. Box 16417, Ethiopia
[b] College of Development Studies, Addis Ababa University, Addis Ababa, Ethiopia
[c] Federal Democratic Republic of Ethiopia, Policy Studies Institute, Addis Ababa, Ethiopia

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ABSTRACT

This study examines the contribution of eucalyptus tree expansion on rural households' food security status, focusing on the specific context of Ethiopia. Eucalyptus trees pose a significant challenge to the rural food system, warranting investigation. A composite food security indicator was used, and data were collected through household surveys, Focus Group Discussions (FGDs), and Key Informant Interviews (KIIs). Descriptive analysis and multinomial logistic regression models were employed for data analysis. The findings reveal that among the sampled households, 31.2% were classified as food secured, 24.8% as intermediate food secured, and 44.0% as food insecured. Econometric estimations highlight the positive influence of variables such as total land holding and livestock on the likelihood of being in the food secured category. Moreover, a unit increase in income earned from the sale of eucalyptus trees leads to an 8.5% higher probability of being in the intermediate category, while decreasing the likelihood of falling into the categories of food insecurity by 8.1% and food security by 0.4%. Importantly, this study uncovers the diverse consequences of eucalyptus trees across different food security categories, suggesting that the planting of eucalyptus trees for improving rural livelihoods and food security must be tailored to specific household conditions. The research outcomes provide valuable insights for guiding future policies, practices, and research endeavors aimed at achieving a sustainable food system in rural Ethiopia.

1. Introduction

With respect to food security and the problem of hunger, the world community has set a Zero Hunger target for SDG 2030. Target 2.1 states: "By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round". However, due to various factors, global food insecurity and hunger is rising and around 821 million people (approximately one out of every nine people in the world) are undernourished [1]. The same source indicated that 31.4% of the population of East Africa (132.2 million) was undernourished which was much more than the average of sub-Saharan countries (23.2%). The problem of food insecurity and malnutrition is even worse in Ethiopia which has experienced some of the worst famine of the 20th century-late 1970s and early 1980s. In recent years, the problem seems even to get

* Corresponding author.
E-mail addresses: akliluam77@gmail.com (A.A. Kerbo), abebed2002@yahoo.co.uk (A.D. Beyene).

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worse due to prolonged draught and internal conflicts as a result of which the number of people needing food assistance is increasing year after year [2]. This is why the issue of food insecurity is still at the center of economic, social and political debates in the developing world including Ethiopia. Besides, ensuring food security has always been one of the basic national policy agenda in many developing countries and it is considered as the foundation of national security [3,4]. This suggests that the issue of food insecurity deserves a special attention in developing countries like Ethiopia. In line with this, the analysis of food security and the factors that influence it will provide important inputs to development stakeholders.

FAO [5] described food security as a situation that exists when all people, at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. This means food security encompasses fulfilling sufficient nutrients such as energy, protein, vitamins and minerals that our body needs for healthy and productive lives in a sustainable manner. To ensure food security at household level in a sustainable manner we need to build a sustainable food system which FAO [6] defines it as "a system that delivers food security and nutrition for all in such a way that the economic, social and environment bases to generated food security and nutrition for future generation are not compromised".

The food system encompasses all activities and relationships that exist in food production, processing, marketing, consumption and its final disposal [7]. However, to the rural communities, the agricultural sector is the most critical sector in building a sustainable food system. Hence, maintaining a productive and efficient agricultural sector in general and the smallholders' agriculture in particular is crucial in order to build a sustainable food system in the rural economy [8,9]. With this regard, this study examined the contribution of eucalyptus trees and other socioeconomic factors on the food security conditions of eucalyptus tree farming households in the Gurage highlands located in the central part of Ethiopia.

The expansion of eucalyptus trees has received both supports and criticisms [10]. Some take eucalyptus as a curse believing that it can reduce local food production with its own risk of turning once surplus producers to food deficit areas in the future due to its excessive consumption of soil nutrients and ground water [10,11]. Some others take it as a blessing for its significant economic and social benefits. Among others, the cash obtained from eucalyptus sale assists smallholder farmers to bridge the food shortage gap at household level [12–14].

Though, food insecurity is the result of many interrelated factors, own productive capabilities play essential roles for rural communities [15,16]. Degefa [17] pointed out demographic, economic, infrastructural and social problems to be the causes of seasonal food insecurity in Amhara Region. Among the demographic factors, rapid population growth and the resulting declining landholding of households was found to be the most important factor. This reveals that household own food production play a critical role in rural food system. This is also consistent with the study of Getachew [15] who identified own production of rural households' to be the major sources of food (44%) for family consumption from his study in East Shewa- Ethiopia. This suggests that improving the food security status of rural farming communities should focus mainly on enhancing their food production capabilities. This involves among other things controlling the shift of productive resources such as land away from food production. In relation to this, one of the most important issues demanding the attention of policy makers and experts in Ethiopia is the alarming expansion of eucalyptus trees farming on fertile food producing land of smallholder farmers in the different parts of the country [11,18]. The analysis of the influence of eucalyptus tree on the food security status of smallholder farmers will provide important inputs in future policy formulation with regard to rural land use, eucalyptus plantation as well as food security issues.

Tough eucalyptus tree is increasingly becoming one of the livelihood options to smallholder farmers in many parts of rural Ethiopia [19], literatures do not have a clear cut conclusion about the implication of eucalyptus on food security. Some studies indicate eucalyptus trees may reduce crop yields and income of households not only due to its direct impact of occupying scarce smallholders' land [11,18] but also as a result of its shading effects and competition for water and soil nutrients when planted adjacent to food crops [14,20]. Though studies on the particular case of the impact of eucalyptus tree on smallholders' food security are scarce, some studies argue that cash crop and agro-forestry have positive impact on food security [21–23]. This suggests the need for investigating the contribution of eucalyptus trees on rural households' food security status using standard food security measures.

In Ethiopia, there are very few rigorous studies done on the relationship between eucalypts tree and food security. Most of the available studies such as Getachew [11] did not use standard food security measurement tools and considered only the availability component of food security. This is clearly leaving aside the other components of food security-access, utilization and stability. For instance, eucalyptus trees planted on crop land may reduce own food production (a decline in food availability) but income from its sale can increase the access component of food security which WFP [24] defines it as "a household's ability to acquire adequate amount of food regularly through a combination of purchases, barter, borrowings, food assistance or gifts". Therefore, food security assessments should attempt to consider as many food security components as possible in order to get a more accurate result [25].

In Gurage Zone, the focus of this study, the increasing tendency of planting eucalyptus for cash and other purpose is likely to reduce land and other scarce resources available for food production. Hence, assessing the implication of these trends on the food security status of the rural households is crucial. This study will, therefore investigate the implication of eucalyptus tree farming and other socioeconomic factors on food security status of rural households in Gurage zone by using a food system approach of analysis in which all the four components of food security-food availability, access to food, food utilization and stability are considered and for this we use a composite food security indicator which is derived from two food security indicators- Household Food Security Access Scale (HFSAS) and Food Consumption Score (FCS).

Though some researchers such as Getachew [15] and Dereje [22] have used two different food security indicators simultaneously to assess the food security status of their respective target population, using a combination of two or more indicators by merging them together as used in this study are very rare in Ethiopia. Therefore, applying a composite food security indicator in Ethiopia will be one of the contributions of this study. Moreover, this study will contribute to the debate on food versus trees (i.e. eucalyptus) by adding scientific information on the influence of eucalyptus tree on rural households' food security. As a result, it will contribute its share to

the proper utilization of rural land and other scarce resources in order to achieve food security in rural areas through building and maintaining a sustainable food system.

In general, this study aims to address the following research questions: i) how do the food security situation of households in the study area look like? II) How do the various demographic, socio-economic and institutional factors influence farm households' food security in the study area? And iii) How does eucalyptus tree influence households' food security status in the study area?

2. Material and methods

2.1. Analytical framework

The analysis of the contribution of eucalyptus tree on food security is undertaken based on the analytical framework given by Fig. 1 which shows the basic issues addressed in this study. These issues are associated with the rapid expansion of eucalyptus plantation and their implication on households' food security in the study area. This study also bases itself on food system theoretical framework since this theory allows a comprehensive and holistic approach to analysis the food security status of rural households by considering all aspects of food security-availability, access, utilization and stability [7,27]

The plantation of eucalyptus trees is influenced by many interrelated demographic, socioeconomic, institutional and environmental factors [28,29]. These plantations are primarily undertaken to get higher income and to satisfy own fire wood demands [19,30]. However, these benefits are likely to come at the cost of households' own food production. Empirical studies indicate that there is a trade-off between food production and eucalyptus plantation in an area where land is highly fragmented, agricultural inputs are in short supply and there is lack of technological innovations [31,32]. This expansion of eucalyptus tree is expected to influence the food production of the area in many ways not simply as a direct loss of food crop but also from a decline in livestock holding of households since eucalyptus tree can also occupy grazing lands [11].

Eucalyptus trees can also provide both ecological and economic benefits to the households [28,33] and its expansion may not necessarily lead to a fall in the food security status of households. This is because increased purchasing power from the sale of tree products may give rural households the opportunity to purchase more food (increasing food access) and improve food security [20]. On the other hand, given the poor development of marketing facilities and ever increasing price of food, it is very difficult to ensure access to adequate food at household level at affordable prices in such rural settings [14,34]. Therefore, the implication of eucalyptus tree on rural households' food security status requires a rigorous investigation.

The four components (pillars) of food security (FAO, 5) suggest that households' food security is influenced by multiple interconnected factors as suggested by the food system approach. As a result, no single indicator is capable of fully capturing all aspects of food security [25,35]. In this study, therefore, we used a composite measurement derived from two prominent food security indicators-HFIAS and FCS. HFIAS mainly measures the access components of food security and to some extent the stability component [36] while

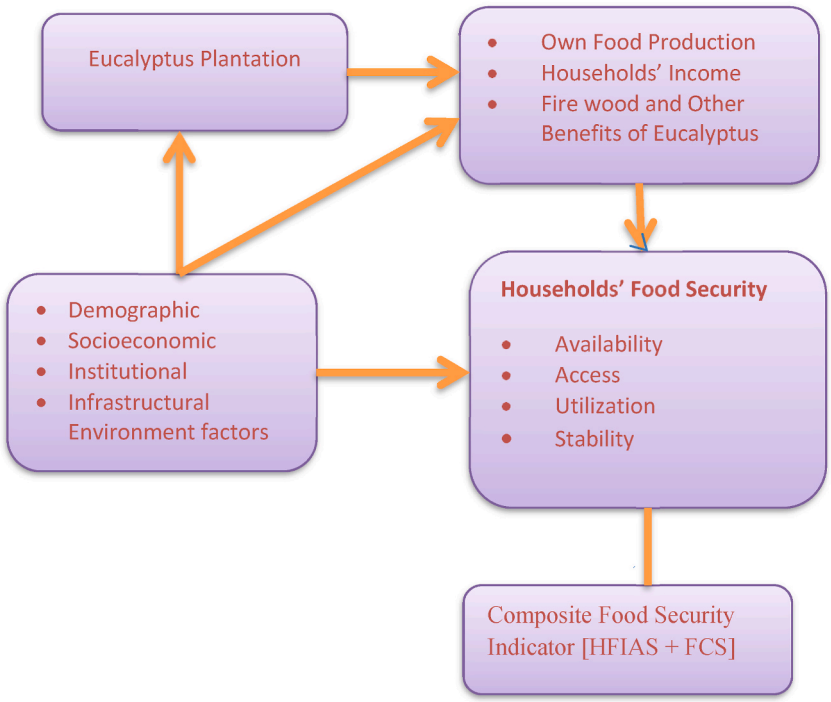

Fig. 1. Analytical framework (Adapted from Rosenzweig et al. [27]; Van Berkum et al. [7]).

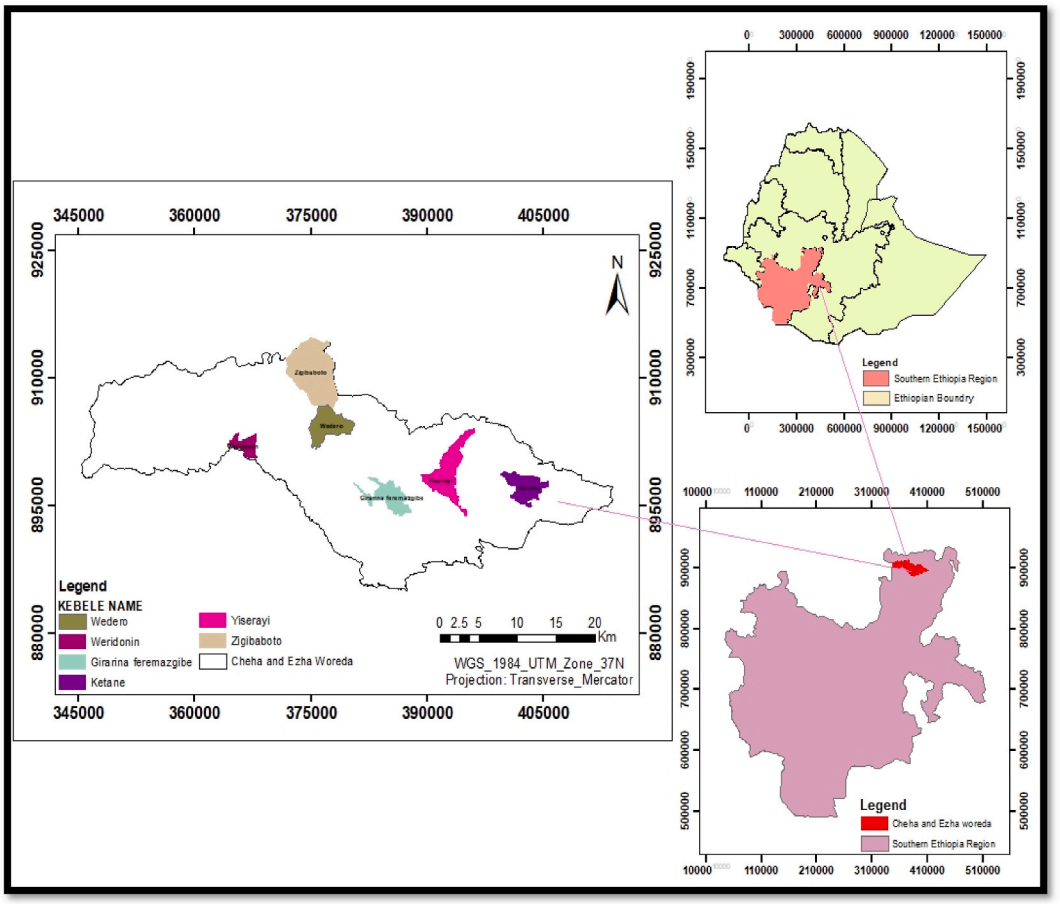

Fig. 2. Location of study area (Sources: CSA [39]).

FCS examines the availability and the utilization component of food security [37].

2.2. Study area setting

Gurage zone is found in the central part of Ethiopia. It is characterized by various land forms such as plateaus, mountains and valleys. The zone covers wide ranges of altitude below 2000 m and highlands of more than 3000 m - its highest point being mount Gurage which is 3719 m above sea level. As a result, all the three main agro-ecologies are found in the zone - *Kolla* (lowland), *weyinadega dega* (mid altitude) and dega (high altitude). The annual mean temperature of the zone ranges from 13 °C to 30 °C. Its mean annual rainfall ranges from 600 to 1600 mm.

Most smallholders in the study area practice mixed farming and *ensete* (enseteedulis, äsät or "false banana plant") is the most important sources of food for the Gurage people. In addition, barely, pulses, potatoes and vegetables especially cabbage are widely cultivated. Wheat and *teff* are also cultivated in some of the mid altitude areas of Gurage zone. *Chat* (catha edulis), a perennial crop is also widely cultivated as cash crop in many areas of Gurage land. Nowadays, the rapid expansion of eucalypts tree in Gurage zone could be the most critical challenge due to its effect on changing land use patterns from food production to the production of tree products [38].

2.3. Sampling techniques and data collection

Belay and Abraham [30] stated that the top *weredas* in Gurage zone's eucalyptus plantations are Enemor and Ener, Cheha, Ezha, and Gumer. Due to resource limitations and the need to consider households in all the tree climatic conditions, the study was undertaken in Ezha and Cheha *weredas* only. Three *kebeles* from each *wereda* were purposively selected based on the extent of eucalyptus tree expansion and one *kebele* from each of the three agro-ecological Zones. Experts from each *wereda* were consulted in selecting *kebeles*. We used systematic random sampling procedure to select sample households from each *kebele* from a list of households obtained from their respective *kebele* offices.

Based on Yemane [40], the total sample size of the study was determined to be 480 households which then were divided to the six

kebeles proportional to their respective population size. As a result, 87 from Zigbaboto, 45 from Yesray, 103 from Ketane, 53 from Weredene, 88 from Wodro and 104 from Girar and Yefermazigibe households were selected. A face-to- face households' survey was undertaken to get the relevant data to achieve the objectives of this research from the households and their farms. Enumerators who were familiar with the study area and those who speck the local language 'Guragigna' were selected and given a day-long training based on FANTA guidelines. A pilot survey was undertaken in three *kebeles* with 50 households to test the reliability of the questionnaire and the effectiveness on the enumerators. The feedbacks obtained from the pilot survey were used to further refine the questionnaire.

The field survey was undertaken in January and February during which there were no fasting of both Orthodox Christianity and Muslim religion followers in the study area. This period was selected because especially information on food consumption can be highly biased in rural Ethiopia during festive and fasting seasons [41]. Especially, the FCS measurement will be irrelevant during fasting months of Orthodox Christians who refrain from consuming any animal products such as meat, eggs, milk and milk products. In addition, these months are less likely to represent neither extreme case of food shortage (like months of March to August) nor food abundance (like the months of September to December) which probably makes them the ideal months to take the average picture of the food security situation of the study area.

In addition, qualitative data were collected using FGDs and KIIs methods using structured guiding questioners. Participants in FGDs were selected to represent the youth, elderly and women. In total, six FGDs (one in each *kebele*) were undertaken. KIIs at *wereda* and *kebele* level were also conducted with government officials, experts and DAs (Development Agents) who are more familiar with the socioeconomic conditions of the study area. The findings from the descriptive and econometric analysis were triangulated with the results obtained from FGDs and KIIs.

2.4. Data analysis

2.4.1. Food security measurement tools

Although there are agreements on some aspects of food security, due to its complexity and multidimensional aspect, the absence of standardized measure of food insecurity has been one of the controversies in the discussion of food security [25,35,36]. For many years, age-adjusted per-capita caloric intake was considered as "the golden standard" for access to food at the household level, and anthropometric measures of nutritional status at the individual level [42]. In addition to being very costly and time taking, this method does not reflect all components of food security [16] and it reflects only one aspect of nutritional status [43].

Even though, there are a number of food insecurity measurements, the most commonly used indicators are quite a few, and it is advisable to use more than one indicator in order to have a better reflection of food security status of the target population [25]. For this reason, we have used a composite food security indicator derived by combining HFIAS and FCS. HFIAS mainly captures the element of food quantity (sufficiency) and quality (diversity) as well as to some extent the issues of stability and acceptability [25,36]. On the other hand, FCS attempts to objectively capture issues of food diversity for checking the availability of the required nutrients from the food actually consumed by the household not from the psychic of the respondents unlike HFIAS [25,37].

I) Household food insecurity access scale (HFIAS)

This method was designed to capture households' behavior as a result of uncertainty to assess sufficiency of food in quality and quantity as well as the resulting anxiety. It is based on the idea that the experience of food insecurity (access) causes predictable reactions and responses that can be captured and quantified through a survey and summarized in a scale [36]. It involves providing nine occurrence questions-whether the condition in the questions have happened at all in the past 30 days. If the respondent answers 'yes' to the occurrence question, then frequency of occurrence questions will follow to know whether the specific condition happened 'rarely' (once or twice), 'sometimes' (three to ten times) or 'often' (more than ten times) in the reference period of the past 30 days. Based on their responses, it is possible to examine three important food insecurity domains and determine households' food security status as food secured, mildly food insecured, moderately food insecured and severely food insecured. It is also possible to get a continuous number (0–27) reflecting the extent of food insecurity which is called household's food insecurity access scale score. Getachew [15], Dereje [26], Garedew [44] and Adane [45] are some of the researchers who used this method in Ethiopia.

II) Food consumption score (FCS)

FCS is a composite score calculated based on dietary diversity, food frequency and nutritional importance of different food groups. Extensive testing and applications have proved this tool to be valuable to the context of developing countries [37]. FCS is calculated by collecting data from households who are asked about the number of days they consumed food items which are grouped in to 8 standard groups with different weights reflecting their nutritional importance. FCS is calculated for each household based on the number of days the household consumed the particular food group items in the past seven days and multiplying each by its corresponding weight [37]. A continuous food consumption score with a maximum value of 112 is obtained based on which households can be categorized as 'poor', 'borderline' and 'acceptable' reflecting their food security status.

Since every food security indicator has its own limitations, using two or more indicators to predict the food security status of a given target population will provide a better result [25]. Hence, using these two indicators, we derived a composite food security indicator to get more accurate information about the food security status of households in the study area.

2.4.2. Econometric model specification

To identify factors that influence the food security status of households and evaluate the contribution of eucalyptus farming to household food security, we first categorized households into different groups based on their food security status. For this purpose, the composite food security indicator enabled us to have three categories of households-food secured, intermediate group and food insecured. As a result we have a categorical dependent variable with three categories.

The model, we used for the purpose of identifying factors that influence the probability of falling into one of the three food security categories is the multinomial logit model (MLM). When the dependent variable is more than two categories and where there is no clear ordering of the choice, the most appropriate model is the MLM [46]. MLM uses maximum likelihood estimation to predict the probability of categorical membership. Dereje [26], Pakravan-Charvadeh et al. [47], Jackson et al. [48] and Singh et al. [49] are some of the researchers who used multinomial logit model to identify factors that influence households' food security status.

To evaluate the contribution of eucalyptus tree to food security status of households, we used the log value of the annual income earned from sale of eucalyptus tree as a proxy variable to capture the extent of eucalyptus plantation by households. We used income earned because, when we use land allocated to eucalyptus or number of eucalyptus trees planted or share of land allocated to eucalyptus, these variables were found to be highly correlated with the total landholding of the household which we have included as one of the most important explanatory variable in the model. In addition, income earned from sale of eucalyptus tree is likely to be directly proportional to the amount of land and other resources allocated to it since smallholders farmers are usually price takers who receive farm gate prices set mainly by middle men [34]. Therefore, we took the log value of the annual income earned from the sale of eucalyptus products as one of the independent variables in our MLM to assess the influence of eucalyptus tree on food security status of households. We made initial tests including univariate, bivariate, and multivariate assessments. More specifically, a multicolinearity test was undertaken and the result is shown in the Appendices part (Appendix A) and based on the results some independent variables were excluded from the final estimation.

The dependent variable in the multinomial logistic regression was assumed to take a value of 0, 1 and 2 for food insecured, intermediate and food secured categories, respectively while the various socio-economic variables as well as the log of annual income obtained from eucalyptus sale were considered as the explanatory variables. Eq. (1) shows the expression used to estimate the coefficients of the independent variables.

$$\mathrm{pro}(Y_{ki}) = \frac{e^{\beta_k^{i} X}}{\sum_{k=0}^{2} e^{\beta_k^{i} X}} = 0, 1, 2 \tag{1}$$

In Eq. (1) X represents the vector of explanatory variables and Y = 0 for food insecured, Y = 1 for the intermediate group and Y = 2 for food secured group. The coefficients in multinomial logit are difficult to interpret and not intuitive, though they do tell us the direction of influence a given explanatory variable has on the dependent variable [46].

By differentiating Eq. (1) with respect to the explanatory variables, we get Eq. (2) - the marginal effect equation which is more meaningful for numerical interpretation.

$$m_i = \frac{\partial Y_j}{\partial X_i} = Y_j \left[\beta_j - \sum_{k=0}^{2} Y_k \beta_k \right] = y_j \left[\beta_j - \overline{\beta} \right] \tag{2}$$

Marginal effect measures the probability of falling into the jth categories as a result of a unit change in an independent variable, keeping all other variables constant.

2.4.3. Description of variable and hypothesis

A summery statistics on the variables included in the estimation and their expected influence on the dependent variable is given in Table 1.

Gender of Household Head: This is a dummy variable which takes a value of 1 if the household head is male and 0 otherwise. Cultural practices and economic deprivation are expected to make female headed households to be less food secured compared with male headed households.

Marital Status: This is a dummy variable taking a value of 1 if the household head is married and 0 if single. This means all individuals who had no partner during the time of the survey which include those who were divorced or separated or widowed or those who were never married will be considered as 'single' in this analysis. Married household heads are expected to be more food secured than single once because of the likelihood of the contribution of both partners for the wellbeing of the household. On the contrary, married household heads are likely to have more children who are not yet old enough for work. As a result the effect of the variable marital status can be positive or negative.

Age of Household Head: This is a continuous variable measured in years. In this study, age is expected to influence food security status negatively since older people are expected to be less economically active and more risk averse than younger households and therefore they are expected to be less food secured [50]. On the other hand, older household heads are expected to have more experiences in agricultural works and decision making and this is likely to make them more food secured than younger household heads [51]. As a result, in this study we expect the influence of age on food security to be either positive or negative.

School year of Household Head: This variable measures the educational level of household head in terms of school year. In this study, school year is expected to have a positive impact on food security since more educated people are likely to make better decision

Table 1
Summery statistics of explanatory variables used in the multinomial logit estimation.

Variables	Descriptions	Statistics	Expected Sign
Wereda of Households	Cheha	245 (51.04%)	+
	Ezha	235 (48.96%)	
Gender of Household Head	Male	367 (75.63%)	+
	Female	117 (24.38%)	
Marital Status of Household Head	Married	359 (74.79%)	+/−
	Single	121 (25.21%)	
Participation in non/off-farm activities	Participant	167 (34.79%)	+
	Non-participant	313 (65.21%)	
Suitability of Land for crop production	Suitable	293 (61.04%)	+
	Not suitable	187 (38.96%)	
Age of Household Head (years)	Mean	47.17	+/−
	Min.	23	
	Max.	87	
Educational Level of Household Head (years of Schooling)	Mean	5.11	+
	Min.	0	
	Max.	14	
Total Land Holding (Ha.)	Mean	0.75	+
	Min.	0.25	
	Max.	3	
Annual income from eucalyptus (ETB)	Mean	11,391.3	+/−
	Min.	1500	
	Max.	69,000	
Livestock ownership (TLU)	Mean	3.25	+
	Min.	0.26	
	Max.	9.46	
Family size	Mean	7.65	+/−
	Min.	3	
	Max.	12	
Distance from main roads (minuets)	Mean	43.78	−
	Min.	0	
	Max.	120	

in production and consumption. Though, some studies such as Gebre [51] claimed education to have either insignificant or negative impact on food security; in our study we expect educational level of household head to have positive contribution to households' food security as was the case in the study of Dereje [26].

Annual income earned from sale of Eucalyptus products: Higher income increases the purchasing power of households, enabling them to buy food which may improve their food security status [20]. However, this higher purchasing power may come at the expense of households' own food production, with its own negative implication on food security [11]. As a result, we expect the influence of this variable to be either positive or negative.

Total Livestock Holding: This is a continuous variable, reflecting the livestock resource a given household has measured in Tropical Livestock Unit (TLU)[1] as proposed by Storck and Dopper [52]. Livestock holding is expected to influence food security positively since it serves as a direct source of food in addition to being sources of income to purchase consumption and productive inputs in addition being a capital input in farm production [50,53].

Total land holding of household: Land is locally measured in a unit called zheng. However, for our analysis we converted it to Hectare (Ha.). Land which is, the major critical resource in a farming community, determines all agricultural outputs including the production of eucalyptus trees. In this study, land size is expected to have a positive contribution to food security of households as was the case in the study of Kahsay and Muluget [50] and Dereje [26].

Suitability of land for crop production: This is a dummy variable taking a value of 1 if the land is suitable for any type of crop production and 0 if it is not (hillside, marginal land, etc.). This is expected to have a positive influence on food production since suitable lands are more conducive not only for crop production but also for tree planting. We expect this variable to have positive impact on food security.

Family size: This variable represents the total number of persons living in the household and this determines both the productive capacity of households (labour force) and the number of mouths to be feed. We expect this variable to be either positive or negative.

Participation in non/off-farm activities: This is a dummy variable taking a value of 1 if the household involves in a non/off-farm activities and 0 otherwise. This variable is expected to have positive impact since those who engage in non/off-farm activities are expected to generate additional income compared to non-participants [53].

***Wereda* Dummy:** This is a dummy variable which takes a value of 1 if the household is in Cheha *wereda* and 0 if it is in Ezha *wereda*.

[1] We converted and expressed the total number of livestock in tropical livestock unit (TLU), which is a composite index of livestock ownership calculated by assigning different weights to different types of domesticated animals as proposed by Storck and Dopper [46]. The conversion factors used for this study are given in Appendix B.

Economic infrastructures and climatic conditions play an important role in determining the food security status of rural households [54]. We expect households in Cheha *wereda* to be more food secured than household in Ezha *wereda* due to better environmental and economic conditions in the former *wereda*.

Distance from main roads: This variable is taken as a proxy to access to market and households were asked to report the time needed to reach the nearest main road. This means the shorter it takes, the closer they are to the main road. The location of households relative to markets can influence the food security status of households. For instance, Pakravan-Charvadeh et al. [47] in their study of food insecurity among Afghan refugees living in Tehran-Iran, indicated that the further away households were located from the central market, the more food insecured they were found to be. This variable is expected to take a negative coefficient in our estimation which means the longer the time households need to reach the main roads, the less food secured the households are expected to be.

3. Results and discussions

Aklilu et al. [55] provides the data set used for calculating the results and drawing the conclusion of this research.

3.1. Food security as measured by HFIAS

The results of analysis from HFIAS indicator for conditions, domains, scale score and prevalence are discussed in this section. Condition refers to percentages of households that responded 'yes' to each of the nine occurrence questions and the results are summarized in Table 2 which shows more than half (54.2%) of the households not to be worried at all about having enough food for their family in the past 30 days. While the remaining 45.8% of the surveyed household have experienced problem of access to food at various degrees- 35% 'rarely', 9% 'sometimes' and 1.9% 'often'. From Table 2, we can also see that out of the total score of 1999, 1277 (63.9%) of them experienced access problem 'rarely' while 27.4% and 8.8% experienced the problem with frequency of 'sometimes' and 'often'.

HFIAS can also be used to calculate food insecurity related domains. There are three domains-anxiety and uncertainty domain, insufficient quality domain and inefficient food intake and its physical consequences domain [36]. When it comes to the first domain, 45.8% (the ratio of respondents who responded 'yes' to Q1 (240) to the total number of respondents responding to Q1 (480)) experienced anxiety and uncertainty about food availability. While those who felt the food they eat was insufficient in quality (the ratio of those who replied 'yes' to Q2 or Q3 or Q4 (465) to the total number of respondents responding to Q2 or Q3 or Q4 (480)) made 96.9% of the total households. This in general, reflects low quality and monotonous type of households' food consumption in the study area. Our observations and FGDs also reflect food variety to be a common problem in the study area. Most household consume *kocho* and other *enset* products day in and day out, potatoes, roasted barley and pulses. When it comes to the third domain which is on the quantity of food intake and its physical consequences (the ratio of those who responded 'yes' to Q5 or Q6 or Q7 or Q8 or Q9 (224) to the total households responding to Q5 or Q6 or Q7 or Q8 or Q9 (480)) made 46.7% of the total respondents, which indicates the existence of food quantity problem as well though not as severe as the quality problem.

The household food insecurity access scale score (HFIASS) is a continuous variable which measures the degree of food insecurity, and it has a minimum value of zero for those who answer 'no' to all the nine questions and a maximum of 27 for those who answer 'yes' to all the nine questions with a frequency of 'often'. The household's level of food insecurity increases with the score's value, and vice versa. The value of the HFIAS score for our study was found to have a minimum value of 0 and a maximum value of 21 with a mean value of 6.03 which is below the half point mark of 13.5 and this in general suggests the score for the study area to be fairly satisfactory.

One important outcome from HFIAS indicator is the determination of households' food security status which is done by categorizing households into different food insecurity prevalence categories based on the degree of food insecurity. Based on the recommendation given by Coates et al. [36], households were categorized in to four food security statuses. The categorization is based on households' responses to the prevalence and frequency of occurrence questions which categorizes them in order of increasing food insecurity as they reply 'yes' to more severe conditions of food insecurity and/or experience those condition more frequently (see

Table 2
Results on access related condition of HFIAS.

No.	Questions	Never		Yes with severity status of					
				Rarely		Sometimes		Often	
		(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
1	Worry about enough food	260	54.17	168	35.00	43	8.96	9	1.88
2	Unable to eat preferred food	22	4.58	264	55.00	146	30.42	48	10.00
3	Eat limited variety of food	95	19.79	215	44.79	114	23.75	56	11.67
4	Eat what you didn't want to eat	64	13.33	305	63.54	92	19.17	19	3.96
5	Eat smaller meal than you want	200	41.67	166	34.58	87	18.13	27	5.63
6	Eat fewer meals in a day	332	69.17	96	20.00	40	8.33	12	2.50
7	No food at all to be accessed	432	90.00	28	5.83	16	3.33	4	0.83
8	Go sleep hungry at night	450	93.75	21	4.38	9	1.88	0	0
9	Eat no food for a whole day	466	97.08	14	2.92	0	0	0	0
	Total			**1277**	**63.9**	**547**	**27.4**	**175**	**8.8**

Source: Own Survey (2021)

Appendix C).

Based on the analysis, we discovered that 3.12%, 30.42%, 54.58%, and 11.88% of the study area's households were found to be food secured, mildly food insecured, moderately food insecured and severely food insecured, respectively. In order to classify the households into the more common dichotomous classification of food secured and food insecured households, we followed the recommendation of Maxwell et al. [25] and households in the category of food secured and mildly food insecured were taken to be food secured which were found to be close to 34% of the total sample households while those in the category of moderately and severely food insecured were taken as food insecured household which were almost 66%.

3.2. Food security as measured by FCS

The food groups used in our analysis and the proportion of households consuming each group are shown in Table 3 which indicates all sampled households to have consumed main staples for 3 or more days. The major food items were *kocho* and other *enset* products together with potatoes and some cereals like barley which is usually consumed in the forms of roasted barely *(kollo)*- served during coffee ceremony. Cereals are also used to prepared *injera* by mixing with *teff*. Households in the study area also consume pulses next to main staples with 25.1% of the households reporting to have consumed it at least for 5 days.

The consumption of vegetables is also fairly good as 31.8% of the household consumed it once or twice in the past 7 days before the interview, while 14.7% of the households consume vegetables for 5 days or more. The problem with vegetables consumption is that they mostly consume cabbage by cooking it sometimes with other food items such as meat. The consumption of fruit is almost nonexistence. The consumption of animal products is not satisfactory since almost 67.2% of households reported not to have consumed it even for one day in the past 7 days. With respect to protein nutrient, the good news is households' common practice of pulse consumption which is also a source of protein. From Table 3, we can also see that almost 50% of households consumed milk and milk products for two or less days which is very low, though better than the consumption of animal protein. The consumption of sugar is also very poor since 90.8% of the households did not consume sugar even once in the reference period. In general, the result of assessing the consumption of food groups indicates that households in the study area were not getting balanced diet due to low consumption frequency of animal protein, milk and milk products as well as fruits and vegetables.

The value of FCS is a continuous variable and reflects the level of food insecurity the household faces. The household's level of food insecurity will decrease with increasing FCS value and vice versa. The mean food consumption score of the sample was 50.6 with standard deviation of 26.41. The minimum and maximum values were found to be 16 and 103, respectively. It is also possible to categorize households into different categories of food security based on the recommendation of WFP [37]. We classified households into three categories in which FCS value of 21 and less are considered as 'poor; while a score between 21 and 35 is considered as 'borderline', and a score above 35 is considered as 'acceptable'. Accordingly, 259(54%) of the households were found to be in the acceptable range, while 139 (29%) and 82 (17%) of them were found to be in the borderline and poor categories, respectively. To classify households into food secured and food insured categories using FCS, we used the suggestion of Maxwell et al. [25], according to which those who are in the category of acceptable rage are taken as food secured while those in the range of borderline and poor are considered as food insecured households. Accordingly, food secured and food insecured households were found to be around 54% and 46%, respectively.

3.3. A composite food security indicator

Households' food security statuses obtained from the two measurements are not quite same. As expected the more conservative measure HFIAS showed larger proposition of food insecured households than FCS. This is also what Maxwell et al. [25] obtained in their study of food insecurity in Tigray region of Ethiopia. They found the proportion of food insecured households to be 49.7% from HFIAS indicator which was the highest of all the seven indicators used in the study including FCS which gave only 11.7%. Though, the two measurements give different figures of food insecurity, they are both widely used. In order to examine the consistency of these measures, we calculated the Pearson's correlation coefficient of the two indicators and the Stata output showed a correlation coefficient of −0.73 and a p-value of 0.001, indicating a strong negative correlation implying the two indicators tell almost the same "story".

Table 3
Share of food groups consumed by households (%).

Food Groups	Days eaten in the past 7 days			
	0	1 or 2 days	3–4 days	≥ 5 days
Main Staples (Cereals & starchy tubers & roots)	0	0	2.9	97.1
Pulses	0	17.5	57.4	25.1
Vegetables	0	31.8	53.5	14.7
Fruits	92.8	4.8	2.4	0
Animal Protein	67.2	26.2	4.3	2.3
Milk and milk products	7.5	42.2	38.9	11.4
Sugar	90.8	8.6	0.6	0
Oils, fats & butter	3.5	60.6	34.2	1.7

Source: Own Survey (2021)

As mentioned earlier to capture more dimensions of food security, a composite indicator which is derived from HFIAS and FCS is used in this study. Using either of the two indicator alone may lead to capturing less dimensions of food security and also a misclassification of a large segment of households as either food secured while in the other measures they are categorized as food insecured and vice versa. Hence, based on the suggestion of Maxwell et al. [25], we used a composite indicator in which households were categorized into three distinct categories of food security-food insecured, intermediate group and food secured. Table 4 shows the cross tabulation of households into the three distinct food security groups based on the results obtained from HFIAS and FCS indicators.

In Table 4, let C_{ij} represents the cell of the nth household who is having a status of i and j from HFIAS and FCS indicators, respectively. According to Maxwell et al. [25], the green color (C_{11}, C_{12} and C_{21}) includes those households who fall in the category of food secured when we use both indicators, and it constitutes households who are doing well from both indicators-food secured from HFIAS and acceptable or borderline from FCS or mildly food insecured from HFIAS and acceptable from FCS. The composite indicator showed the food secured households to be 150 (31.2%) which is lower than using either HFIAS (34%) or FCS (54%).

The red color (C_{23}, C_{32} and C_{33}) includes those who fall in the category of mildly food insecured from HFIAS and poor from FCS or moderately/severely food insecured from HFIAS and borderline or poor from FCS and it indicates the food insecured households who were almost 44% of the total sample households. Using HFIAS alone yielded a food insecurity level of 66% while FCS alone gave almost 46%.

The yellow color (C_{13}, C_{22} and C_{31}), represents the intermediated group who are neither food secured nor food insecured when we use the composite indicator. These 119 (24.8%) households could have been misclassified, had we used either of the two indicators separately.

The use of a combined indicator has produced three categories instead of just two. In addition to using both indicators for our classification which is better than using either of the two separately, it can also help us identify the most vulnerable groups and determine the kind of support they need [25] (see Fig. 2).

From our own observations and reports of DAs of the existence of an evident difference in terms of conducive climatic conditions, soil fertility and infrastructural development, we compared the food security status of households in the two *weredas*. From Fig. 3, we can observe that Ezha *wereda* has higher proportion of households in the food insecured category and lower proportions of households in the intermediate and food secured categories than Cheha *wereda.* From this, we can conclude that Cheha *wereda* is more food secured than Ezha *wereda*. This is also consistent with the information obtained from DAs who claimed that Chaha *wereda* is better-off in resources availability than Ezha *wereda*. This issue is further examined using econometric model in the coming section.

3.4. Food security and eucalyptus tree

In the discussion of food security, the issue of input diversion is a very critical issue [9]. This diversion is observed mainly on the limited land smallholder farmers have. According to the result obained from KIIs, ecualypsut tree is taking lands meant not only for crops but also *ensent* cultivation. We also observed eucalypsut trees planated on fertile lands which are suitable for all kinds of crop production and also grazing lands.

Table 5 provides statistics on total land holding and annual income earned from sale of eucalyptus products by the sample households for the three food security groups. As indicated in Table 5, the mean of land holding for the sample households was around 0.75 ha (Ha) while the minimum and maximum land holdings were found to be 0.25 Ha and 3 Ha, respectively From our FGDs and KIIs, it was learnt that especially absentee farmers who live in towns and cities such as Addis Ababa allocate larger proportion of their land to eucalyptus trees and earn higher amount of income. These individuals usually come to their villages once in a year for *Meskal* or *Arefa* celebration and they are not that much interested in regular farm works.

Table 4
Cross-classification of HFIAS and FCS of households' categories.

		FCS Categories			
		Acceptable	**Borderline**	**Poor**	**Total**
HFIAS Categories	**Food Secured**	15 (3.1%)	0 (0%)	0 (0%)	15 (3.1%)
	Mildly Food Insecure	135 (28.1%)	10 (2.1%)	1 (0.2%)	146 (30.4%)
	Moderately/ Severely Food Insecured	109 (22.7%)	129 (26.9%)	81 (16.9%)	319 (66.5%)
Total		259 (54%)	139 (29%)	82 (17%)	480 (100%)

Source: Field Survey (2021) — Food Secured | Intermediate Group | Food Insecured

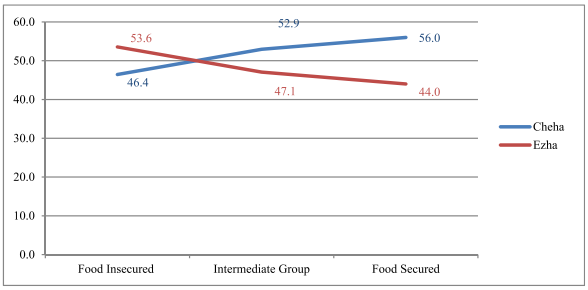

Fig. 3. Proportion of households in food security categories by *wereda.* (Source: Own Survey, 2021).

Table 5
Land size and Annual income from eucalyptus trees by food security groups.

Variables	Statistics	Food Security Status			
		Food secured	Intermediate group	Food Insecured	Total
Total landholding (Ha)	Obs.	150	119	211	480
	Mean	0.99	0.80	0.54	0.75
	Std. Dev.	0.25	0.13	0.14	0.27
	Min.	0.75	0.45	0.25	0.25
	Max.	3	1.1	1	3
Annual income from sale of eucalyptus products (ETB)	Obs,	150	119	211	480
	Mean	13,062.9	13,015.5	9286.8	11,391.3
	Std. Dev.	6147.2	8696.4	3217.4	6197.1
	Min.	3500	3580	1500	1500
	Max.	36,000	69,000	20,000	69000

Source: Own Survey (2021)

As was the case in the study of Belay and Abraham [30], all sampled households reported to have earned some income from the sale of eucalyptus products in the past 12 months. The minimum annual income earned was ETB (Ethiopian Birr) 1500 while the maximum was ETB 69,000. The mean annual income from eucalyptus was found to be around ETB 11,391.3. Participants in the FGDs also stressed the contributions of income households get from eucalyptus tree to be critical for buying farm inputs and also sometimes food from local markets in case of food shortage. They claimed eucalyptus tree to be like their 'cash' that they can sell it whenever they face cash shortage to meet household demands. This means eucalyptus tree is also serving them as a security tree against cash and food shortage to households in the study area. From this, we can conclude that eucalyptus tree can affect the access components of food security and this is likely to have a positive contribution to households' food security by enabling them to get food from the market. This is consistence with the findings of Zenebe et al. [13] and Jagger and Pender [14].

From Table 5, we can also see that food insecured households have not only the least mean land size holding (0.54 ha) but also the smallest mean annual income earned from the sale of eucalyptus products (ETB 9286.8) of all the three groups. This clearly suggests that resources endowments influence the food security status of rural households since land is the most critical economic resources to rural communities.

The descriptive assessments indicated that the study area not to be as food secured as most people thinks. The reliance on *enset* which is a resilient plant in the face of drought and other environmental problem, can surely avoid chronic food shortage and starvation, but this does not mean the area is food secured. From our analysis, we can say that there are food insecurity issues in relation to both quantity and quality as well as anxiety and uncertainty that households felt during the survey because though most households have some amount of *kocho* at their disposal; getting it ready for consumption requires labour, fire wood and other inputs which may not be easily available to all households. In addition, the consumption of *kocho* usually requires complement food items to be consumed with. Such complement items include preferably and sometimes meat or cheese but usually cooked potato, cabbage, etc.

3.5. Econometric results

In this section the results obtained from multinomial logistic regression are presented. Using Stata 14.2 software, we have estimated both the coefficients and marginal effects of the various socio-economic variables including annual income earned from the sale of eucalyptus products in order to assess the contribution of eucalyptus tree to food security. The estimation for coefficients is made using the food insecured group as a base category (reference group). The multinomial logistic regression showed a likelihood of −190.1636, LR chi square of 647.40 and Pseudo R-square of 0.6299 with a p-value of 0.001, which in general suggests the estimation to be sound and at least one of the explanatory variables is significantly different from zero i.e., they have joint significance of predicting households' food security status. A summary of results of estimation for coefficient and marginal effects are given in Table 6 and Table 7, respectively.

The annual income earned from sale of eucalyptus tree has positive and significant contribution to the probability of being in the intermediate group, while its contribution to the probability of falling into the food secured group compared to the base group is also positive but insignificant. From Table 7, we can see that when income from sale of eucalyptus increases by one unit, the probability of falling in to the categories of food insecured and food secured decreases by 8.1% and 0.4%, respectively, where as it increases falling in the intermediate group by almost 8.5%. This means income from eucalyptus tree can help pull households out of the food insecured category and bring them to the intermediate group and this as the same time prevents households from entering the food secured category.

This means income from eucalyptus tree will be the right call only to bring households to the intermediate group. In other words, to improve food security of households using eucalyptus tree, we need first to identify the group to which that particular household belongs. The general positive contribution of income on the food security of households is due to its contribution in increasing the access component of food security and some studies such as Dereje [26], Pakravan-Charvadeh et al. [47] and Getachew [15] have confirmed the positive contribution income have to improve the food security status of households.

Age of household head is found to influence the probability of households to be in the category of intermediate group and food secured group as compared to the base category. As indicated in Table 7, as the age of the household increases by one year, the probability of the households to be in the categories of food insecured and intermediate group increases by 0.42% and 0.47%, respectively. While it decreases the probability of being in the food secured category by 0.89%. This in general suggests that older household heads are less likely to be in the food secured group compared to younger household heads. This finding is consistent with Dereje [26].

Total land holding of households was found to be one of the most significant factors influencing food security. As can be seen in Table 6, one additional hectare of land increases the probability of falling in the categories of intermediate and food secured group compared to being in the food insecured category. The marginal effect shows as the total land holding increases by one Ha, the probability of falling in the food insecured category decreases almost by 74.4%. On the contrary, it increases the probability of falling into intermediate and food secured group by 19.1% and 55.3%, respectively. The contribution of land to food security is expected to be through its impact on food availability by increasing owe food production and access to food through its impact on increasing farm households' income from selling different farm products. This indicates how critical land holding is in determining households' food security status. This finding is consistence with the finding of Getachew [15], Dereje [26] and Kahsay and Mulugeta [50].

We also included livestock ownership to capture its influence on food security. Livestock serve as direct source of food product, productive aids and source of income to purchase households' necessities such as food and other consumption items [15]. The main livestock available in the study area include cattle, sheep, horses, mule and chickens. As mentioned earlier, we used Tropical Livestock Unit (TLU) to examine the influence of livestock on the food security status of sample households. The result shows that an additional unit of TLU increases the probability of households to fall into the category of intermediate and food secured group compared to the base group-the food insecured. It is also observed that one additional unit of TLU decreases the probability of falling into the categories of food insecured and intermediate group by 3.16% and 0.26%, respectively; while it increases falling into the category of food secured by 3.42%, if all other factors remain as they are. Since livestock holdings can be a direct source of food to rural households in addition to being a source of income, it can influence both food availability and food access components of food security of smallholder farm households. In general, our study indicated that livestock to be important resource in improving the food security status of households in the study area and this finding is consistence with the finding of Dereje [26] and Alem [54].

In one of the KIIs held in Ezha *wereda*, the officials claimed that eucalyptus expansion is affecting the food security of smallholder farmers in two ways in relation to livestock raring. According to the sources, the first consequence is through its direct impact on the conversion of grazing lands into eucalyptus plantation which reduces livestock ownership and the other one is its impact on the reduction of animal dung which is used as manure in *enset* cultivation which is the source of the main staple of the Gurage people, *kocho*.

Table 6
Coefficient estimation of multinomial logit model (base outcome, food insecured).

Var.	Description of Variables	Intermediate Group Food Secured					
		Coef.	St. E.	p>|z|	Coef.	St.E	p>|z|
gedr	Gender of Household Head	−0.2838	0.4953	0.567	−0.3418	0.6182	0.580
mrstt	Marital Status	0.3941	0.4815	0.413	−0.8405	0.6614	0.204
ageh	Age of Household Head	−0.0592	0.0267	0.027*	−0.1938	0.0385	0.001[a]
elhh	School year of Household Head	−0.0197	0.0594	0.740	−0.0159	0.0814	0.845
lnsz	Total Land of Household	11.7443	2.2814	0.001[a]	19.5818	2.9970	0.001[a]
lieet	Income from eucalyptus	1.3590	0.5196	0.009[a]	1.2075	0.6363	0.058
htlu	Total Livestock holding (TLU)	0.4869	0.1866	0.009[a]	0.9876	0.2526	0.001[a]
pnof	Part. in Non/Off-farm activities	−0.1590	0.4323	0.713	−0.4563	0.5488	0.406
sulne	Suitability of Land for crop	1.4950	0.4357	0.001[a]	4.3104	0.6314	0.001[a]
wedm	Dummy for *Wereda*	2.5966	0.5386	0.001[a]	3.1192	0.6516	0.001[a]
flsz	Family Size	−0.0684	0.1334	0.608	−0.0737	0.1712	0.667
actr	Proximity to main roads	0.0034	0.0088	0.700	−0.0088	0.0125	0.484
Con.	Constant	−20.569	5.2647	0.000	−22.785	6.5316	0.000

[a] = significant at 0.01 level; * = significant at 0.05 level.

Table 7
Marginal effect estimation of multinomial logit model.

Var.	Food Insecured			Intermediate Group			Food Secured		
	M. Ef.	St. E.	p>|z|	M. Ef.	St. E.	p>|z|	M. Ef.	St.E	p>|z|
gedr	0.0174	0.0298	0.559	−0.0124	0.0382	0.745	−0.0050	0.0260	0.849
mrstt	−0.0183	0.0287	0.523	0.0955	0.0411	0.020	−0.0772	0.0309	0.012
ageh	0.0042	0.0015	0.007[a]	0.0047	0.0021	0.026*	−0.0089	0.0016	0.001[a]
elhh	0.0012	0.0036	0.743	−0.0013	0.0051	0.794	0.0002	0.0039	0.968
lnsz	−0.7437	0.1143	0.001[a]	0.1906	0.1523	0.211[a]	0.5531	0.1131	0.001[a]
lieet	−0.0814	0.0303	0.007[a]	0.0851	0.0380	0.025*	−0.0037	0.0256	0.886
htlu	−0.0316	0.0107	0.003[a]	−0.0026	0.0145	0.859	0.0342	0.0107	0.001[a]
pnof	0.0109	0.0260	0.675	0.0088	0.0339	0.795	−0.0197	0.0236	0.404
sulne	−0.1027	0.0234	0.001[a]	−0.0840	0.0307	0.006[a]	−0.0249	0.0169	0.142
wedm	−0.1591	0.0282	0.001[a]	0.1142	0.0351	0.001[a]	0.0449	0.0238	0.059
flsz	0.0042	0.0080	0.605	−0.0035	0.0106	0.741	−0.0006	0.0075	0.932
actr	−0.0002	0.0005	0.776	0.0009	0.0008	0.232	−0.0008	0.0006	0.203

[a] = significant at 0.01 level; * = significant at 0.05 level.

Wereda dummies were included to capture the variation in economic and environmental conditions, which are not captured by our analysis. The estimates show that being in Cheha *wereda* increases the chance to be in the intermediate and food secured group compared to the base category. Finally, households who have suitable land for crop production are more likely to be food secured as compared to those whose land is less suitable for crop production. This is due to the fact that the quality of the soil affects the production of agricultural products.

4. Conclusions and recommendations

The main objective of this study was to assess the contribution of eucalyptus trees and other socioeconomic factors on households' food security status in Gurage zone, Ethiopia. By using income earner from sale of eucalyptus trees as a proxy variable to the extent of eucalyptus plantation by the households and using a composite indicator of food security derived from HFIAS and FCS measurement, we found that 31.2% of the households to be food secured, 44.0% food insecured and almost a quarter (24.8%) to be in the intermediate group. The HFIAS analysis indicated a considerable proportion of households (45.8%) to face anxiety and uncertainty problem in relation to food access and 96.9% of households expressed the food they eat to be unsatisfactory in food quality while 46.7% of the households expressed that the food they eat is insufficient in quantity as well. In addition, the food consumption of households in the study area was found to be poor in variety due to very low consumption frequency of animal protein, milk and milk products as well as fruits and vegetables which implies households in the study area are consuming monotonous food items such as *kocho* and other *enset* products and depending on the season cooked potatoes, roasted barley and cabbage.

The multinomial estimation indicated income earned from the sale of eucalyptus products to have positive impact on the probability of being in the intermediate group category; however, it was not found to be significant in influencing the probability of falling into the food secured category. Therefore, increasing income from the sale of eucalyptus products can help to pull households out of the food insecured category only as far as the intermediated group, but not necessarily to the food secured group which in other words means it may trap them in the intermediate group. This is maybe why Bayle [33] described eucalyptus tree as a tree of "not good, not bad". Thus, we need to find the right balance in allocating scarce resources to satisfy the food, tree products and income needs of the rural community.

The estimation further indicated that land holding, livestock and suitability of land for crop production to be important factors that positively influence the food security status of households in the study area. This is due to the positive impact of economic resources on the food availability and access components of food security. In addition, our estimation showed significant food security differences to exist between households in the two *weredas*. Households in Ezha *wereda* were found to be in a disadvantaged position when it comes to food security, due to poorer infrastructural development and less conducive environmental conditions for agricultural production.

Furthermore, the study indicated eucalyptus expansion to influence food security not only through its direct impact of taking land meant for crop production but also on livestock holding of households through its impacts on grazing lands. This indicates the need to identify appropriate sites for eucalyptus plantation so that it may not negatively impact food production in the study area. This will require the formulation and implementation of land use policy in order to achieve a balance between food production and the demand for tree products. We propose that the planting of eucalyptus trees by households should be customized according to their unique circumstances, as it does not always have the same impact on households belonging to different food security categories. Moreover, the government and other stakeholders should take the livestock sector seriously since it contributes to rural households' food security in many ways not only as important source of food and income but also as productive aid with tremendous positive implication on rural livelihood. Furthermore, improving rural infrastructure such as road, irrigation facilities and rural institutions should be the focus areas of development stakeholders in order to improve the livelihood and hence the food system of the study area.

Availability of data and material

The data used for this research is available at https://doi.org/10.5281/zenodo.7752197.

CRediT authorship contribution statement

Aklilu Amiga Kerbo: Writing – original draft, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Degefa Tolossa Degaga:** Writing – review & editing, Visualization, Validation, Supervision, Methodology. **Abebe Damte Beyene:** Writing – review & editing, Validation, Supervision, Software, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

This research has not received any financial support from a third party. The authors declare that they have no known competing financial or non-financial interest or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Collinearity Statistic for variable in the Multinomial Model

Description of Variables	VIF	**1/*VIF***
Total Livestock holding (TLU)	3.08	0.324
Total Land of Household	2.96	0.337
Age of Household Head	1.46	0.687
Suitability of Land for crop	1.28	0.783
Part. in Non/Off-farm activities	1.19	0.839
Income from Eucalyptus	1.17	0.853
School year of Household Head	1.14	0.881
Wereda dummy	1.10	0.911
Family size	1.09	0.922
Proximity to main roads	1.06	0.939
Gender of Household Head	1.06	0.940
Marital Status	1.06	0.943
Mean VIF	**1.47**	

Source: own calculation (2021)

Appendix B

Conversion factor for livestock unit (Tropical Livestock Unit)

Animal	Livestock Unit
Cow and Oxen	1.00
Heifer	0.75
Calf	0.25
Weaned Calf	0.34
Horse	1.00
Donkey (adult)	0.7
Donkey (young)	0.35
Camel	1.25
Sheep and Goat (adult)	0.13
Sheep and Goat (young)	0.06
Chicken	0.013
Sources [46]:	

Appendix C

Categories of food insecurity using HFIAS

Categories of food insecurity using HFIAS

Questions	Frequency: Rarely	Sometimes	Often
1a			
2a			
3a			
4a			
5a			
6a			
7a			
8a			
9a			

Source: [30]

Food Secured	Mildly insecured	Moderately insecured	Severly Insecured

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