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DETERMINANTS OF HOUSEHOLD FOOD SECURITY AMONG SMALLHOLDER VEGETABLE FARMERS IN THE OROMIA REGION OF ETHIOPIA: THE CASE OF ADAMITULU JIDO KOMBOLCHA AND DUGDA WOREDAS

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ABSTRACT

This case study examined the determinants of household food security among smallholder vegetable farmers in the Oromia Region of Ethiopia. The study was conducted in six kebeles of Adami Tulu Jido Kombolcha, and Dugda woredas using a cross-sectional quantitative survey of 359 vegetable-producing households selected through multistage sampling method. Data were collected using structured questionnaires administered through KoboCollect App from December 2023 to March 2024. Primary data were collected from smallholder vegetable farmers through face-to-face interviews using pre-tested structured questionnaires administered via KoboCollect between December 2023 and March 2024, and secondary data were obtained from published and institutional sources. Data analysis was conducted using descriptive statistics, post-harvest loss estimation techniques, and a binary logistic regression model with the support of Microsoft Excel and IBM SPSS Statistics. Household food security status was measured using daily calorie intake per adult equivalent based on the minimum threshold of 2,100 kcalday^{-1}. Food availability was estimated through a stepwise procedure integrating own production, market transactions, income sources, cereal equivalents, and calorie conversion methods. Households were categorized into food-secure and food-insecure groups. The binary logistic regression model incorporated thirteen explanatory variables representing demographic, socioeconomic, institutional, and production-related characteristics to identify the major determinants of household food security. The results revealed that seven variables significantly influenced household food security at different probability levels (1%, 5%, and 10%). These included farm size, family size, post-harvest loss, age of household head, gender of household head, education level of household head, cooperative membership, and access to extension services. The omnibus test of model coefficients produced a Chi-square value of 65.871, which was statistically significant at $p < 0.01$, indicating that the explanatory variables jointly exerted a strong influence on household food security status. The model correctly predicted 77.7% of the sample households, with specificity and sensitivity values of 89.2% and 54.1%, respectively. Farm size positively affected household food security at $p < 0.05$, while post-harvest loss and age of household head negatively affected food security at $p < 0.01$. Gender and education level of the household head showed positive associations with household food security at $p < 0.10$, whereas cooperative membership and extension services showed negative associations at $p < 0.05$. Overall, the findings underscored the importance of reducing post-harvest losses, strengthening institutional support systems, and promoting gender-sensitive and educational interventions to enhance household food security among smallholder vegetable farmers.

Key words: Post-harvest losses, food security, smallholder farmers, vegetable, Binary-logistic-regression, Oromia, Ethiopia

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INTRODUCTION

Agriculture is the primary source of livelihood in Ethiopia and remains central to employment, income, and food security. In the East Shoa Zone of the Oromia Region, the majority of the population depends on smallholder farming, with over 60% of the labour force engaged in agriculture [1]. Nationally, about 64.9% of the employed population works in agriculture, highlighting the sector's continued dominance [2]. However, agricultural productivity is constrained by climatic variability, limited services, and significant post-harvest losses, particularly for perishable crops.

Food and nutrition insecurity remains one of the most pressing development challenges in Sub-Saharan Africa, despite continued efforts to improve agricultural productivity and rural livelihoods [3]. In Ethiopia, where agriculture supports the livelihoods of the majority of the population, improving food availability alone has not been sufficient to ensure household food security [4]. Increasing attention is therefore being directed toward the substantial losses that occur after production, particularly among highly perishable commodities such as vegetables [5]. Post-harvest losses (PHL) represent not only a reduction in physical produce but also a significant loss of income, labor, water, land, and nutritional value, thereby undermining food systems and household welfare [6]. For smallholder vegetable farmers, these losses directly reduce market participation, household consumption, and resilience against food insecurity [7].

Vegetable production has become an increasingly important livelihood strategy in Ethiopia, especially in the Oromia Region, due to its contribution to income diversification, employment generation, and dietary improvement [8]. Vegetables provide essential micronutrients necessary for combating malnutrition and improving dietary diversity [8]. However, the highly perishable nature of vegetables exposes farmers to considerable quantitative and qualitative losses along the value chain [9]. Poor harvesting practices, inadequate storage facilities, limited cold chain infrastructure, weak market integration, transportation constraints, and insufficient post-harvest management knowledge continue to contribute to high levels of losses among smallholder producers [10]. Consequently, a substantial proportion of harvested produce fails to reach consumers in acceptable quality and quantity [10].

Globally, nearly one-third of food produced for human consumption is lost or wasted, with fruits and vegetables accounting for the highest share of losses in developing countries [6]. In Ethiopia, where food insecurity and malnutrition remain persistent rural challenges, reducing post-harvest losses has emerged as a critical pathway for enhancing food availability without expanding cultivated land or increasing production costs [11]. Beyond increasing food supply, minimizing losses can improve household income, stabilize market participation, strengthen livelihood

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resilience, and contribute to sustainable food systems [12]. Despite these important implications, post-harvest management has historically received less policy and research attention compared to agricultural production enhancement strategies [13].

Empirical evidence on the relationship between post-harvest losses and household food security among smallholder vegetable farmers in Ethiopia remains limited, particularly in the Oromia Region. Existing studies have largely focused on production constraints while giving insufficient emphasis to losses occurring after harvest and their implications for household welfare [12]. Moreover, limited evidence exists regarding how socioeconomic, demographic, and institutional factors interact with post-harvest losses to influence household food security outcomes [14].

Against this background, this case study examined the determinants of household food security among smallholder vegetable farmers in the Oromia Region of Ethiopia. The findings underscore the importance of integrating post-harvest management into food security policies and agricultural development interventions. By addressing avoidable post-harvest losses, Ethiopia can significantly improve food availability and food security, farmer incomes, nutritional outcomes, and the sustainability of smallholder farming systems.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Adami Tulu Jido Kombolcha and Dugda woredas. Adami Tulu Jido Kombolcha, located in the Central Rift Valley, lies between 1500 and 2300 meters above sea level and experiences a semi-arid climate with annual rainfall of 600-800 mm [15]. Dugda woreda, located between 1600-2020 meters above sea level, receives an annual rainfall of 750 mm between the months of June and September [16].

Mixed crop-livestock farming dominates both woredas, with cereals, pulses, and vegetables production as the major crop systems. Irrigated vegetable production, particularly onion and tomato, plays an increasing role in improving household income and food security [8]. Despite these opportunities, post-harvest losses remain a major challenge affecting both income and food availability.

Overall, the study area reflects typical smallholder farming systems in Ethiopia, making it suitable for examining the effects of post-harvest losses on household income and food security.

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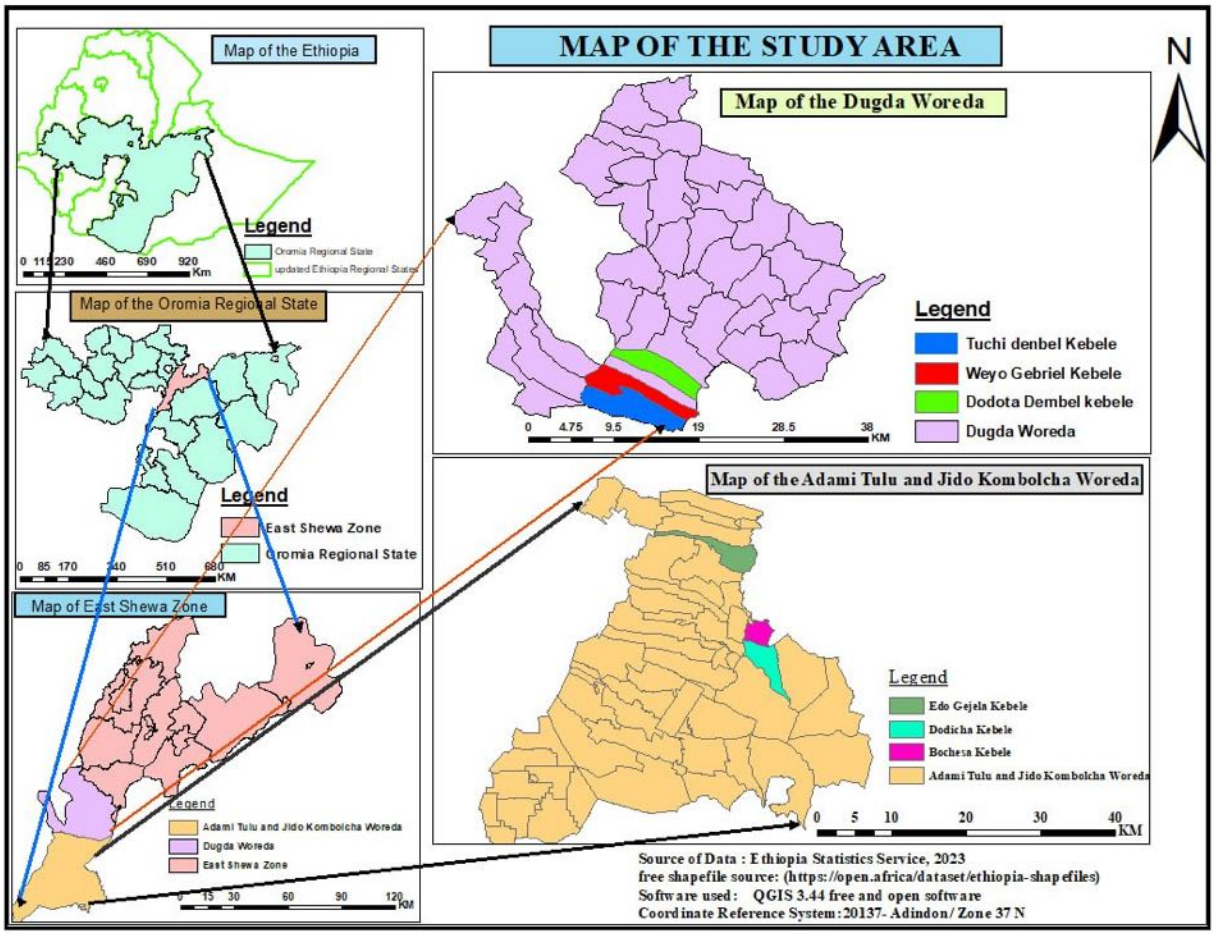


Figure 1: Map of the study area

Research design

This case study adopted a quantitative research approach, utilizing a survey method within a cross-sectional study design. The choice of this method was to effectively achieve the study's objectives, examine relationships among variables through deductive reasoning, and address the research questions in a systematic approach [17].

The quantitative approach to the study ensured an objective assessment of the subject matter in a structured way by using statistics for data analysis and enabling the generalization and replication of findings [18]. The use of pre-tested structured questionnaires enabled the collection of substantial data from the sampled population in the study area, reflecting a systematic and objective research design [17].

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Data collection methods

Target population of the study area

A research population is defined as a large group of individuals or objects with similar characteristics on which the research is based [17]. In this study, the target population (research population) was smallholder vegetable farmers in Adami Tulu Jido Kombolcha (ATJK) woreda and Dugda woreda. Besides the smallholder farmers, research data were also collected from agriculture officers in each woreda, and from institutional support organizations that provide support to the smallholder farmers.

Sampling techniques and sample size

Sampling involved selecting participants who represented the target population [17, 19]. A multistage sampling technique was adopted to ensure representativeness of the research participants. First, two woredas (Adamitulu Jido Kombolcha and Dugda) were purposively selected from the East Shoa Zone based on their high vegetable production potential and concentration of smallholder farmers. Second, six kebeles were selected based on production similarity, market participation, accessibility, and security conditions. Third, from a sampling frame of 8,730 registered vegetable-producing households, simple random sampling was applied to select 359 respondents (Table 1). The sample size was determined using the Krejcie and Morgan formula below, ensuring reliability and representativeness of the study population [20].

Krejcie and Morgan formula

It is a common phenomenon to employ Krejcie and Morgan formula for sample size estimation in research [20]. The following formula was used to determine the sample size [20]:

$$S = \frac{X^2 NP(1-P)}{\mathrm{d}^2(N-1) + X^2 P(1-P)}$$

Where:

S = required sample size
X^2 = the table value of chi-square for one degree of freedom at the desired confidence level
N = the population size
P = the population proportion (assumed to be .50 since this would provide the maximum sample size)
d = the degree of accuracy expressed as a proportion (.05)

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Using this formula, 359 households were sampled from a total of 8,730 households which was considered adequate enough to obtain a representative sample for the study (Table 1).

Primary and secondary data

Data sources for the research were from single households in the vegetable producing community in the study area. Primary data were collected in person from the smallholder vegetable farmers (SHFs).

Secondary data were based on reports, research findings from published papers and information from relevant institutions including the Ethiopian Public Health Institute (EPHI), Ethiopian Statistaicl Services (ESS), FAOSTAT, AdamiTulu Jido Kombolcha, and Dugda Woredas Agriculture Offices.

Data collection instrument and questionnaire design

Research data was collected using a structured survey questionnaire consistent with study objectives [17]. The data collected included answers to pre-coded questions on socio-economic characteristics, production, post-harvest practices, and market participation. The survey instrument was pre-tested on 5% of the sample and administered using KoboCollect, ensuring clarity, reliability, and improved data quality [21].

Data analysis

The Microsoft Excel 2024, and Statistical Package for Social Sciences (SPSS) version 24 were used for data entry and analysis. Binary logistic regression model was used to examine the determinants of household food security.

Binary logistic regression model to examine the determinants of household food security

Having examined total household income, the study proceeded with the objective of assessing the effect of post-harvest losses and related household and farm-level factors on the household food security status. The dependent variable, household food security, was measured as a binary variable, where 1 indicates food secure and 0 indicates food insecure (Eq.1).

$$Y_i = \begin{cases} 1 \; if \; household \; i \; is \; food \; secure \\ 0 \; if \; household \; i \; is \; food \; insecure \end{cases} \quad \text{Eq. 1}$$

Where:

Y_i= food security status of household i

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Estimation of household food availability

Food availability was calculated by combining own production and net market transactions. First, the quantity of fruits and vegetables available from own production was determined as:

$$Quantity_{prod,i}\ (kg) \qquad \textit{Eq. 2}$$

Where:

$Quantity_{prod,i}$ = *quantity of fruits and vegetables produced by household i (kg)*

Estimation of household net-food availability

Food availability was assessed by combining household production of fruits and vegetables with quantities purchased and sold, enabling the computation of net food transactions. Specifically, net food availability (in kg) for each crop was calculated as:

$$Quantity_{net,i}\ (kg) = (Quantity\ Produced + Quantity\ Purchased) - (Quantity\ Sold + Quantity\ Lost + Quantity\ Given\ Away) \qquad \textit{Eq. 3}$$

Conversion of production into monetary value

The available fruits and vegetables were converted into monetary terms based on local market prices and subsequently expressed as cereal equivalents (wheat and maize). This conversion allowed for the estimation of calories using the central role of cereals in household energy intake [22, 23]:

$$V_i = Quantity_{net}\ x\ P_i \qquad \textit{Eq. 4}$$

Where:

V_i = value of food (fruits & vegetables) available (ETB)

$Quantity_{net,i}$ (kg)= net food available

P_i= average market price per kilogram of the commodity

Conversion into cereal equivalents

$$CE_i = \frac{V_i}{P_{cereal}} \qquad \text{Eq. 5}$$

Where:

CE_i= cereal equivalent quantity (kg)

V_i = value of food (fruits & vegetables) available (ETB)

P_{cereal} = price per kilogram of wheat or maize

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Conversion into calorie availability

The total calorie availability for each household was computed by converting the cereal equivalent into calories using standard conversion factors (kcal per kg of cereal):

$$Cal_i = CE_i \, x \, CF \qquad \textit{Eq. 6}$$

Where:

Cal_i= total calorie availability for household i
CE_i= cereal equivalent quantity (kg)
CF= calorie conversion factor (kcal/kg) for cereals

Typical values:

- Wheat ≈ 3400 kcal/kg
- Maize ≈ 3600 kcal/kg [24]

Adjustment for household size

Total calories were adjusted for household size in adult equivalent units (AE).

$$Cal_{AE,i} = \frac{Cal_i}{AE_i} \qquad \textit{Eq. 7}$$

Where:

AE_i = adult equivalent household size

Estimation of daily calorie availability

Finally, per capita daily calorie availability was determined by dividing total household calories by the household size and the number of days in the year (365):

Daily calorie availability per adult equivalent was calculated as:

$$DC_i = \frac{Cal_{AE,i}}{365} \qquad \textit{Eq. 8}$$

Where:

DC_i = daily calorie intake per adult equivalent (kcal/day)

In addition to crop production, the study incorporated other sources of household income into the calorie estimation. These included income from livestock products, government safety-net program transfers, salaries or wages, and pension income. Each of these income sources was converted into monetary value and subsequently expressed in cereal equivalents using the same procedure, ensuring that all household resources contributing to food availability were accounted for in the estimation of total calorie availability.

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A minimum daily energy requirement of 2,100 kcal per adult equivalent was adopted, consistent with Ethiopian standards [23, 25]. Households whose per capita calorie availability met or exceeded this threshold were classified as food secure (1), while those below the requirement were classified as food insecure (0).

This stepwise procedure allowed for a robust measurement of household food security, integrating both own production and income-based purchasing power, and provided a suitable dependent variable for subsequent binary logistic regression analysis.

Food security classification

Households were classified based on the minimum daily calorie requirement of 2,100 kcal per adult equivalent [26]:

$$Y_i = \begin{cases} 1 \; if \; DC_i > 2100 \\ 0 \; if \; DC_i < 2100 \end{cases} \quad \text{Eq. 9}$$

This stepwise procedure allowed for a robust measurement of household food security, integrating both own production and income-based purchasing power, and provides a suitable dependent variable for subsequent binary logistic regression analysis.

Given the dichotomous nature of the dependent variable, a binary logistic regression model was employed to estimate the probability of households being food secure as a function of post-harvest losses and selected socioeconomic and demographic characteristics. The model was appropriate for binary outcomes and allows the inclusion of continuous, categorical, and discrete explanatory variables within a unified framework, thereby ensuring robust estimation of marginal effects. The application of logistic regression in this study was consistent with earlier studies examining determinants of household food security in Ethiopia and related contexts [25].The estimation procedure was implemented using SPSS version 24.

Several empirical studies have successfully applied binary logistic regression to assess household food security determinants in Ethiopia. A logistic model using pooled household survey data identified key socioeconomic drivers of food security in Ethiopia [27]. The approach was also applied to rural households in Fedis Woreda, East Hararghe Zone of Oromia Region to analyze determinants of household food security [28]. Additional studies in Mojaena Wodera and East Gojjam Zone further demonstrated the utility of binary logistic regression for examining household food security determinants [29].

In this study, the model was applied to identify the key factors influencing households' vulnerability to food insecurity. The explanatory variables were grouped into demographic factors (For example, household size, age, gender, education level of the household head) and socioeconomic factors (For example, farm size, post-

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harvest loss, access to credit, cooperative membership, vegetable production training, extension service access, crop variety, and application of post-harvest management practices), totaling 13 independent variables (Table 2).

Methodologically, the binary logit model assumes a linear relationship between the explanatory variables and the log-odds of the outcome, rather than the probability itself. By transforming the probability into its natural logarithm of the odds (logit), the model overcomes key limitations of the Linear Probability Model (LPM), particularly heteroscedasticity and the possibility of predicted probabilities falling outside the [0,1] interval. Let Y_i^* denote the latent (unobserved) variable representing the underlying propensity of a household to be food secure. The structural relationship can therefore be expressed stepwise as:

Latent (unobserved) variable: $Y_i^* = \alpha+\beta_1X_{1i}+\cdots+\beta_{12}X_{12i}+\varepsilon_i$

The observed binary outcome is defined as: $Y_i = \begin{cases} 1 \; if \; Yi^* > 0 \\ 0 \; otherwise \end{cases}$

Probability of being food secure: $P_i = P(Yi = 1|x_i) = \frac{1}{1+e^{-zi}}$

Where, $zi = \alpha+\beta_1X_{1i}+\cdots+\beta_{12}X_{12i}$

The probability of not being food secure: $1 - P_i = \frac{e^{-zi}}{1+e^{-zi}}$

The odd ratio: $\frac{Pi}{1-Pi} = e^{zi}$

Logit Transformation: $(L_i) = ln\left\{\frac{Pi}{1-Pi}\right\} = z_i$

Marginal effects: The marginal probabilities of factors determining food security among households were estimated based on expressions derived from the logit model [30]. The formulation is presented as:

$$dP_i/dX_{ji} = \beta_j P_i(1 - P_i)$$

Where:

β_i =Estimated logit regression coefficient for the i[th] factor
P_i= Estimated probability of a household being food secure

Independent variables (Table 2) considered in the model are aligned with previously identified determinants of household food and nutrition security [31].

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RESULTS AND DISCUSSION

Determinants of household food security among smallholder vegetable farmers

The food security status of the respondents, specifically those households engaged in vegetable production, was examined as a dependent variable through the application of binary logistic regression analysis. This analytical approach used 13 independent variables to predict the food security of the dependent variable (Table 3).

Out of the 13 predictor variables which were used to assess the food security status of the households, only 7 variables emerged as statistically significant at various probability levels of 1%, 5% and 10% (Table 3). These significant variables included farm size, family size, Age of household head, gender of household head, education level of household head, cooperative membership, and extension service.

The omnibus test of the model coefficients yielded a Chi-square value of 65.871 with 13 degrees of freedom, demonstrating a highly significant result at $p < 0.01$. This test result ($p < 0.01$) indicates that the selected predictor variables collectively exerted a strong influence on predicting the food security status of households. This result further suggests that the predictor variables chosen also had a substantial joint effect on predicting the state of household food security. In general, both analyses underscored the effectiveness of the selected variables in understanding the dynamics of food security in the study area.

The predictive efficiency of the model indicates that of the 359 sample households included in the analysis, 279 (77.7%) were accurately predicted in terms of their food security status. This means that the model was able to correctly classify a significant majority of households in terms of their food security status.

Furthermore, the performance of the model was evaluated with the two important metrics: sensitivity and specificity. Sensitivity, which measured the model's ability to accurately identify households that were food insecure, was calculated to be 54.1%. This result indicates that above half of the households that were food insecure were correctly classified as such by the model. Alternatively, specificity, which assesses the model's ability to correctly identify food-secure households, was found to be 89.2%. This high specificity suggests that the model was particularly effective in recognizing households that were food-secured, and successfully classified a substantial majority of them. Overall, while the model demonstrated a commendable level of precision in predicting food security status, particularly for food-secure households; there was a notable challenge in accurately identifying food-insecure households, as reflected in the sensitivity score.

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Farm Size: In examining the predictors of food security, farm size was identified as a crucial factor with coefficient 2.657 and a significance level of $p < 0.05$. This test result ($p < 0.05$) implies that farm size is a significant positive predictor of food security. In the context of logistic regression, a positive coefficient revealed a direct relationship between the predictor (farm size) and the outcome (food security). The estimated odds ratio of 1.426 suggested that a one-unit increase in farm size raised the odds of being food secure by about 42.6%, holding all other factors constant. Previous empirical studies conducted in different parts of Ethiopia had consistently shown that increasing the land size for crop production had a positive effect on household food security status [32]. These studies reported that households with larger cultivated landholdings tend to produce more output, diversify crops, and generate higher farm income, which in turn improved food availability and access at the household level.

Family size: Family size showed a statistically weak but positive association with household food security at $p<0.1$ significance level. The estimated odds ratio of 0.714 indicated that, holding other factors constant, an increase in family size increased the odds of being food secure by approximately 28.6%. The regression results in this model indicate that larger family size is associated with an increased likelihood of being food secure (OR = 0.714).

Empirical evidence showed that the effect of family size can vary depending on context. In some cases, larger household size is associated with improved food security, possibly because additional family members contribute labor or engage in income-generating activities that enhance household resources [33]. However, studies have similarly reported that larger household size can negatively impact food security [34].

Post-harvest loss: The regression results in Table 3 show that post-harvest loss (PHL) was statistically significant at $p<1\%$ significance level, with a p-value of 0.002. This level of significance indicated a very strong statistical relationship between post-harvest loss and household food security. Statistically, a significance difference at the 1% (0.01) level implies that there is less than a 1% probability that the observed relationship occurred by chance. Thus, allowing the null hypothesis to be rejected with a high degree of confidence. Therefore, the result confirms that post-harvest loss was a highly significant determinant of household food security.

This finding was consistent with previous empirical studies that highlighted the important role of post-harvest loss in influencing food security. For instance, a study found that significant amounts of food are lost after harvest in Ethiopia, which has serious implications for national and household food security [35]. Similarly, another study reported that post-harvest losses of crops significantly contribute to food shortages and food insecurity among farming households [36]. These studies

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supported the regression result, indicating that reducing post-harvest losses can play a crucial role in improving household food security.

Age of household head: In this study, the age of the household head emerged as a significant predictor of food security status, evidenced by a negative coefficient of -0.224 and a highly significant p-value (< 0.01). This negative relationship indicated that a one-unit increase in the age of the household head reduced the odds of being food secure by about 25.1%. Consequently, older household heads are notably less likely to attain food security than their younger counterparts. This finding underscores the critical implications of aging on food security; older household heads may encounter a myriad of challenges such as declining physical health, reduced labour capacity, or limited economic opportunities, which collectively hinder their ability to secure sufficient food for their families.

Thus, the results highlighted the necessity for targeted interventions to support older household heads in enhancing their food security. Older heads may face multiple barriers, including declining labour capacity [37], limited access to credit and agricultural inputs [38], and reduced ability to adopt improved farming practices which can negatively affect their households' food security.

Overall, the results underscore the importance of considering the age of the household head in food security assessments, as it appeared to be a significant determinant of maintaining household food security. This insight could inform targeted interventions aimed at supporting older household heads in enhancing their food security outcomes.

Gender of household head: The variable gender of the household head revealed remarkable insights regarding its influence on food security status. The coefficient for this variable was 2.707, suggesting a strong positive relationship with food security outcomes at a probability level of $p<0.1$. This means that if the household head is male, the likelihood of achieving food security increases significantly compared to households led by females.

These findings could be reflective of underlying socioeconomic factors, such as access to resources, decision-making power, and cultural norms that often favour male household heads in agricultural or economic activities. Empirical evidence from Ethiopia showed that female-headed households are generally more vulnerable to food insecurity than male-headed households, often due to unequal access to productive land, good credit, and extension services, and the greater care burdens that limit economic participation (systematic review: female-headed households had nearly double the odds of food insecurity compared to male-headed households [36]. Similar findings from high-frequency survey data during the COVID-19 pandemic revealed that female-headed households in Ethiopia experienced a significantly

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higher probability of moderate or severe food insecurity than male-headed households, suggesting structural socioeconomic disadvantages for women in accessing food and income opportunities [37]. Moreover, regional research in Oromia emphasized that gender dynamics and intra-household inequalities often shape differential food security outcomes, with female decision-making constraints linked to lower resilience and food access relative to male counterparts [38].

These studies provided contextual evidence that female household heads may face barriers such as limited access to land and credit, lower participation in economic networks, and disproportionate caregiving roles, all of which can constrain their capacity to secure sufficient food for their families relative to male heads. In general, the finding highlighted the significant disparity in food security based on the gender of the household head, reinforcing the need for gender-sensitive policies and interventions aimed at supporting female-headed households to improve their food security outcomes. Addressing these inequalities is crucial for fostering more equitable food security across different household types.

Education level of the household head: The educational status of the household head was one of the predictor variables examined in relation to the food security status of the respondents within this model. The education level of the household head had a positive and statistically significant effect on household food security at the $P < 0.1$ significance level. The positive coefficient ($\beta = 2.179$) indicated that higher educational attainment increases the probability of a household being food secure. The odds ratio of 8.835 implied that, holding other factors constant, each additional level of education attained by the household head increases the likelihood of the household being food secure by about 8.8 times compared to those at a lower education level. This may be attributed to the fact that better-educated household heads are more capable of adopting improved agricultural practices, accessing and interpreting market and extension information, and making more efficient production and consumption decisions that enhance food security outcomes.

The positive association between the education level of the household head and household food security in this study was consistent with empirical evidence from Ethiopia and elsewhere. Education enhances human capital by improving access to agricultural information, decision-making capacity, and adoption of improved farming practices, which in turn increases production and food availability [39]. In rural settings, households with formally educated heads have been found to be more likely to secure food because education enables them to use efficient production techniques and respond better to market signals and extension advice [40]. Similarly, education has been identified as a significant predictor of food security in Ethiopian contexts, where households with at least basic formal education were less likely to experience food insecurity compared to those without formal education [41].

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This supported the findings that education has a positive link with improved household food security outcomes in the Gurage Zone of Ethiopia [42]. These studies collectively suggested that increasing the educational attainment of household heads can play a critical role in reducing food insecurity through enhanced agricultural productivity, income-earning opportunities, and improved management of household resources.

Cooperative member: Membership of farmers' cooperatives had a significant negative relationship with the food security status of households at $p < 0.05$ significance level (Table 3). The odds ratio (0.406) showed that food security is less likely to occur for being a member of a farmer's cooperative compared to its absence. This finding is consistent with a study which implied that membership in farmers' cooperatives does not have a direct impact on food security [43], but is not consistent with previous studies [43].

The contradictory outcome of studies may reflect institutional and contextual limitations. Although cooperatives are intended to enhance market access and resilience, membership fees and compulsory contributions may strain household resources [44]. Weak governance, elite capture, and unequal benefit distribution can further limit cooperative effectiveness [45]. Additionally, inadequate provision of tailored services such as training and inputs, and market failures, may undermine expected food security gains [7]. These findings suggest the need for institutional reforms to better align cooperative activities with local food security needs.

Access to Extension Services: The binary logistic model analysis revealed a coefficient of -0.349, accompanied by a statistically significant $p < 0.05$. This result indicates that the relationship between access to extension services and food security was marginally significant but negative. The odds ratio of 0.705 and a negative coefficient of -0.349 show a negative association between extension service and food security. Therefore, an increase in the extension service is likely to decrease in the odds of achieving food security. The implication of odds ratio of 0.705 is that for every unit increase in the extension service, the food security status of the households decreases by a factor of 0.705.

Empirical evidence showed that the effect of extension services on household food security is mixed and highly context-dependent. A systematic review of agricultural extension interventions reported that although many programs improved food security outcomes, several evaluations found no impact and even negative effects in certain settings, indicating that results vary with program design and implementation quality [39]. Similarly, panel evidence from Ghana showed that access to extension services is associated with higher per-capita food consumption and dietary diversity, but also produced null or negative effects on poverty probability, suggesting that extension benefits are not uniform across welfare

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indicators [40]. In contrast, evidence from Ethiopia indicated that households receiving extension support achieved higher crop yields than non-receivers, highlighting the productivity-enhancing role of extension contact [41]. Related findings from Tanzania further suggest a positive relationship between extension access, farm productivity, and household food security, reinforcing the assertion that extension is often beneficial but that negative associations such as observed in this study can arise due to local institutional and implementation constraints [42].

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The binary logistic regression analysis revealed that several socio-economic and institutional factors significantly influence the food security status of vegetable-producing households in the study area of Ethiopia. Out of the 13 explanatory variables considered, 8 namely farm size, family size, post-harvest loss, age of the household head, gender of the household head, education level of the household head, cooperative membership, and extension services were found to have a statistically significant effect on household food security at different significance levels. The overall model was highly significant, as demonstrated by the omnibus Chi-square test, confirming that the selected variables jointly provided strong explanatory power in predicting food security outcomes. Moreover, the model demonstrated good predictive performance, correctly classifying 77.7% of the sampled households. Although the model showed high specificity in identifying food-secure households, its moderate sensitivity revealed some limitations in accurately detecting food-insecure households. Nevertheless, the findings highlight the important role of household characteristics, resource endowment, and institutional support in shaping food security among vegetable-producing households.

Based on the findings of this study, the following recommendations are suggested to improve household food security among smallholder vegetable farmers in Oromia Region.

- Efforts should focus on increasing agricultural productivity through improved land utilization, irrigation expansion, and access to quality inputs. Since post-harvest loss significantly affected food security, investment in storage facilities, transportation, cold-chain systems, and farmer training on post-harvest handling is essential.
- Educational opportunities and agricultural training programs should also be strengthened to enhance farmers' decision-making and technology adoption capacity.
- Special support mechanisms are needed for older household heads and female-headed households, who are more vulnerable to food insecurity.

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- Reforms are required to improve the effectiveness, transparency, and service delivery of farmers' cooperatives and extension systems.
- Policies should further encourage income diversification, youth employment, and climate-smart agricultural practices.
- An integrated rural development strategies involving government, cooperatives, and development partners are necessary to sustainably improve household food security and livelihoods in the study area.

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AUTHORS' CONTRIBUTIONS

- **Michael Tarekegn:** conceptualization. data curation, formal analysis, funding acquisition, investigation, methodology, visualization, writing original draft.
- **Sibongile Tekana:** supervision, validation, data verification.
- **Michael Antwi:** supervision, writing-review and editing.
- **Shimelis Admassu:** supervision, validation,

CONSENT FOR PUBLICATION

A consent letter was also sent by the co- author (Aman Kiniso) for approval of the final version of the manuscript to AJFAND editorial assistance board.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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Table 1: Sample size of the study

SN	Woreda	Kebele	Number of smallholder farmers (Sample size at 5% margin of error)
1	AdamiTulu Jido kombolcha (ATJK)	Bochesa	69
		Dodicha	57
		Edo Gejela	57
		Subtotal	**183**
2	Dugda	Dodota Denbel	55
		Tuchi Denbel	60
		Woyo Gebriel	61
		Subtotal	**176**
		Total	**359**

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Table 2: Description of the variables used in the model

Variable	Description/definition	Measurement	Category
	Dependent variable		
Y_1	Food security status	1= food secure, 0 otherwise	Dummy
	Explanatory variables		
X_1	Farm size	Hectare	Continuous
X_2	Family size	Number of persons	Continuous
X_3	Post-harvest loss	Quintal	Continuous
X_4	Family members/non-working/	Number of persons	Continuous
X_5	Age of Household Head HHH	Number of years	Continuous
X_6	Gender of HHH	0=male, 1=female	Dummy
X_7	Education Level HHH	0=literate, 1=non-literate	Dummy
X_8	Access to credit	0=Yes, 1 otherwise	Dummy
X_9	Cooperative membership	0=Yes, 1 otherwise	Dummy
X_{10}	Vege. production training	0=Yes, 1 otherwise	Dummy
X_{11}	Ext. service	0=Yes, 1 otherwise	Dummy
X_{12}	Variety	0=local, 1 otherwise	Dummy
X_{13}	Appln of PHM practices	0=Yes, 1 otherwise	Dummy

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Table 3: Determinants of household food security

Variables	Coeff. (β)	S.E.	Wald	Sig.	Odds ratio Exp(B)
Farm size	2.657	0.31	4.113	0.043**	01.426
Family size	0.336	0.192	3.064	0.08**	0.714
PHL	-0.432	0.032	9.175	0.002***	1.351
Family members/non working/	0.37	0.238	2.422	0.12	1.448
Age of HHH	-0.224	0.065	11.699	0.001***	1.251
Gender of HHH	2.707	1.603	2.851	0.091*	14.991
Education Level of HHH	2.179	1.303	2.795	0.095*	8.835
Access to credit	-1.315	0.85	2.394	0.122	0.268
Cooperative member	-0.901	0.565	2.54	0.013**	0.406
Production training	-1.641	0.757	4.703	0.103	2.161
Ext. service	-0.349	0.525	0.442	0.013**	0.705
Variety	-20.533	7207.33	1.205	0.998	0.112
Appln of PHM practices	-0.463	0.482	3.922	0.337	0.631
Constant	-2.282	0.878	27.587	0.000***	0.005

*Significant at 0.1, **significant at 0.05, *** significant at 0.01

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