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# Comparative multidimensional analysis of agroforestry's impact on food security: A study of households in the Awi Zone Highlands, Ethiopia

Amene Afework[a,b], Amare Sewnet Minale[a], Demel Teketay[c]

[a]*Department of Geography and Environmental Studies, Bahir Dar University, Bahir Dar, Ethiopia,*
[b]*Department of Geography and Environmental Studies, Injibara University, Injibara, Ethiopia,*
[c]*Department of Range and Forest Resources, Botswana University of Agriculture and Natural Resources (BUAN), Gaborone, Botswana.*
*ameneafework@gmail.com; amare1974@gmail.com; dteketay@buan.ac.bw*

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## ABSTRACT

This study assesses the food security condition of Acacia-based agroforestry (ABA) user and non-user households in Awi Zone highlands, Ethiopia, using a composite approach. Purposive and random samplings were employed to select sample districts and households. Data were collected through questionnaires, discussions, and interviews, and analyzed quantitatively and qualitatively. Results showed that 42.2% of the households (46.9% ABA-users, 37.5% non-users) were food-secure, while 57.8% were food-insecure. ABA-users' composite food security index was significantly higher than non-users (P<0.05), signifying ABA's contributions. Livestock and farmland size, participation in off-farm activities, irrigation access, plantation experiences, and perceived soil quality positively affected food security, while age, family size, credit access, and market distance negatively impacted it. Addressing lavish sociocultural practices, and intensifying agroforestry helps to combat food insecurity.

***Keywords**: Agroforestry; composite approach; Ethiopia; food security.*

# 1 Introduction

Access to enough and nutritious food is vital for people's health, productivity, and a country's economic progress (Sani and Kemaw, 2019). Recognizing this, achieving food security (FS), ending hunger and improved nutrition have been identified as key pillars of the 2030 Agenda for Sustainable Development (UN, 2015). However, more than a quarter of the world's population still struggles to obtain recommended quantity and quality of food daily (FAO et al., 2021), with 10 out of 100 people going to bed hungry (FAO, 2021) and 30% experiencing moderate to severe food insecurity (FIS). Furthermore, the number of people experiencing chronic hunger rose to 828 million in 2021 (FAO et al., 2021), up from 720 million in 2019 (FAO, 2019). Therefore, attaining food security and improved nutrition by 2030 is increasingly unrealistic, especially for the developing world (Montagnini and Metzel, 2017; Gil et al., 2019). Sustainable solutions like agroforestry are thus more crucial than ever to combat the rising global challenge of FIS and climatic disruptions (Hillbrand et al., 2017; Marques et al., 2022).

Africa's dependency on climate-sensitive agriculture, combined with climate change, land degradation, population pressure, political instability, and mechanization challenges, makes the continent highly vulnerable to FIS (Ayele et al., 2020; Gafa and Chachu, 2023). The issue of FIS is much worse in Sub-Saharan Africa (SSA) (FAO, 2019; Gafa and Chachu, 2023), where one-third of the population is severely food insecure (FAO, 2019) and constituted 95% of the continent's undernourished people (FAO and ECA, 2020). With over half (57%) of its population threatened by FIS, Ethiopia is placed at the top in terms of the prevalence of poverty and FIS in SSA (Diriba, 2020; FAO, 2020). Despite abundant resources such as fertile land, favorable climate, and ample water, Ethiopia's agriculture remains underdeveloped and inefficient in fulfilling the growing food demand of the population (Ayele et al., 2020). Agroforestry, with its long-standing history, now plays a promising role in supporting the Ethiopia's food production system and economy (Jemal and Callo-Concha, 2017; Jemal et al., 2018).

Land degradation and soil acidity problems pose a significant threat to agriculture and rural livelihoods in the Awi Zone highlands (Bazie et al., 2020; Tamirat and Wondimu, 2019; Amare et al., 2021). Not only that, but they also expose local farmers to complex socioeconomic problems like FIS, debt burdens and out-migration (Tamirat and Wondimu, 2019). Farmers in the area have adopted various strategies ranging from growing acidic-tolerant crops to tree plantations to rehabilitate degraded land, improve soil quality, and ultimately increase agricultural yields. In the early 1990s, a new land use system called *Acacia decurrens-based* agroforestry (ABA) was introduced in the study area. This involves covering degraded land and acidic soils with *Acacia decurrens* (*Acacia*) trees in a cyclical rotation (with a gap of 4-5 years) with crops in agricultural fields, making it a typical agroforestry system known as the Tanguya agroforestry system (Nair, 1987). The ABA system has provided indispensable provisional, regulatory, and supportive ecosystem services, contributing to poverty reduction and livelihood improvement in the research area (Nigussie et al., 2021; Afework et al., 2024).

According to the Agriculture Office of Awi Administrative Zone (2021), Fagita Lekoma, Banja, and some *kebeles*[1] of Ankesha Guagusa districts have been facing FIS. Many households in these districts, especially Fagita Lekoma and Banja, are beneficiaries of the Productive Safety Net Program (PSNP). For example, in Banja, 14 out of 18 rural kebeles were aided by the PSNP, with 5487 households (3581 male and 1906 female) being beneficiaries. However, the expansion of ABA in the area has brought promising socioeconomic changes. Given the challenges of a growing population, high levels of land degradation, FIS, and a changing climate, ABA practices are of paramount importance in mitigating these challenges and reducing the associated risks.Therefore, this study intends to: 1) analyze the food security status of households using ABA compared to non-users, and 2) examine the factors determining the food security of farmers in the study area.

This paper is structured into four sub-sections. The first part is the introduction, which gives the background, problem description, and study objectives. The second section explores relevant related literature. The third part describes the methodological framework, followed by the findings and discussions. The conclusions drawn and the policy implications of the findings are discussed in the last section.

# 2 Literature Review

## 2.1 Concepts of Food Security and Agroforestry

FS is a complex and multidimensional concept that comprises the availability, access, utilization and stability of food (Ike et al., 2017; Mccordic et al., 2023). It exists "w*hen 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''*. On the contrary, FIS occurs when there is an inadequate quantity and quality of food due to

*[1] The smallest administrative units in Ethiopia*

financial or other resources dearth (FAO, 2019). Despite the efforts made so far, poverty, hunger, and FIS remain global development challenges, particularly in developing countries. As a result, tackling these problems and ensuring FS is still the top priority of national and international development projects (Jemal et al,. 2017; Goncharova and Merzlyakova, 2021). Agroforestry is widely acknowledged as a viable and smart solution to these challenges, as it promotes sustainable food production systems (Jemal and Callo-Concha, 2017; Jemal et al., 2018; Mukhlis et al., 2022; Ntawuruhunga et al., 2023).

Agroforestry is a sustainable farming system that combines the production of crops and/or livestock, or other farm products, with trees and shrubs to enhance land productivity and ecosystem services at large (Atangana et al., 2014; Nair et al., 2021). Agroforestry systems are broadly grouped into forest-based and farm-based systems. The former includes *silvopastoral practices* in forested lands, *improved fallows*, and utilizing *forests for non-wood products*, while the latter comprises *home gardens*, *alley cropping*, *trees in agricultural lands*, *woodlots*, *fruit and tree plantations in cropland/pasture*, *crop cultivation under tree shade*, and *trees near farmlands* (Atangana et al., 2014; Nair et al., 2021; Mukhlis et al., 2022; Ghimire et al., 2022). The extent of these agroforestry systems' use varies throughout Ethiopia (Jemal et al., 2018); however, improved fallows (or Tanguya agroforestry) is widely practiced in the Northwestern highlands of Ethiopia, particularly in the Awi Zone (Nigussie et al., 2021; Afework et al., 2024).

The need for sustainable agroforestry has been increasing over time, mainly due to ongoing problems of food demand gaps, land degradation, climate change, and population growth (Mukhlis et al., 2022). Agroforestry generally provides wide-ranging socioeconomic and environmental benefits that directly or indirectly contribute to achieving food and nutritional security (Jemal and Callo-Concha, 2017; Jemal et al., 2018; Mukhlis et al., 2022). Recognizing its multifaceted advantages, international organizations like the World Bank, United Nations, and various governmental and non-governmental groups keenly promote and support the adoption of agroforestry (Kiyani et al., 2017).

### 2.22 Agroforestry's Contribution to Rural Food Security

Agroforestry is crucial for FS, contributing to sustainable food systems by providing diverse crops, income, biofuels, forest foods, food trees and essential nutrients (Jemal and Callo-Concha, 2017; Jain and Verma, 2020; Mukhlis et al., 2022; Bhattacharya, 2024). Aside from directly providing food and increasing productivity, agroforestry offers a range of ecosystem services, including erosion control, nitrogen fixation, soil fertility improvement, climate change mitigation, pest control, and water and nutrient cycling (Jain and Verma, 2020; Marques et al., 2022; Bhattacharya, 2024). The diversified services provided by agroforestry play a vital role in enhancing food production, dietary diversity, and ultimately ensuring FS while maintaining environmental equilibrium (Jemal and Callo-Concha, 2017; Bhattacharya, 2024).

The agroforestry system impacts all dimensions of FS in various ways (Jemal and Callo- Concha, 2017). Specifically, it increases food availability by producing diverse food crops, animal feed, and a wide variety of fruits and vegetables. Agroforestry also promotes food access by generating income from the sale of fruits, vegetables, fuelwood, timber, and other products. Additionally, the integrated approach of combining crop and animal farming enhances food utilization by providing organic and nutrient-rich foods. Food stability is typically achieved when the three aforementioned components of food security exhibit relative stability (Jemal and Callo-Concha, 2017; Jemal et al., 2018; Jain and Verma, 2020).

Ethiopia has an age-old tradition of utilizing agroforestry systems for various purposes (Jemal and Callo-Concha, 2017; Jemal et al., 2018). One of the prevalent and widely practiced agroforestry systems in the Northwestern highlands, specifically Awi Zone, is *improved fallow* through Acacia trees or acacia-based agroforestry. This practice plays a crucial role in supporting rural livelihoods and preserving the environment (Nigussie et al., 2021; Afework et al., 2024). However, the potential impact of these agroforestry practices on rural households' FS has not been examined. Although some studies have studied various aspects of ABA practices, including its livelihood/socioeconomic benefits (Tamirat and Wondimu, 2019; Chanie and Abewa, 2021; Nigussie et al., 2021 Afework et al., 2024), and soil quality effects (Bazie et al., 2020; Amare et al., 2021; Beshir et al., 2022), they have not addressed the implications of ABA practices on rural FS. The current study therefore addresses this gap by examining ABA-users' and non-users' FS condition using a composite method.

## 3 Research Methods and Materials

### 3.1 Description of the study area

The study is geographically delimited to the *Ankesha-Guagusa, Banja,* and *Fagita Lekoma* districts of the Awi Administrative Zone, Northwestern Ethiopia. It covers an area of 1,666.24 $Km^2$ and is located between

10°43′00′′-11°10′00′′ North and 36°40′00′′-37°10′00′′ East. The area exhibits temperate (*dega*) and sub-tropical (*woina dega*) agro-climates, with altitudes ranging from 1,799 to 2,968 meters a.s.l. (Fig. 1). The mean yearly temperature ranges between 9.7 and 25.5 °C, while the total annual precipitation exceeds 1800 millimeter (https://climexp.knmi.nl/get_index.cgi, accessed on 23 May 2022). Mixed agriculture and tree plantations are the main sources of livelihood for the population. The major crops cultivated in the area include potato, wheat, barley, and teff  (Nigussie et al., 2021; Afework et al., 2024). Farmland, forests, grazing land, bushland, and settlements are the major land use/cover types in the study area (Afework et al., 2023).

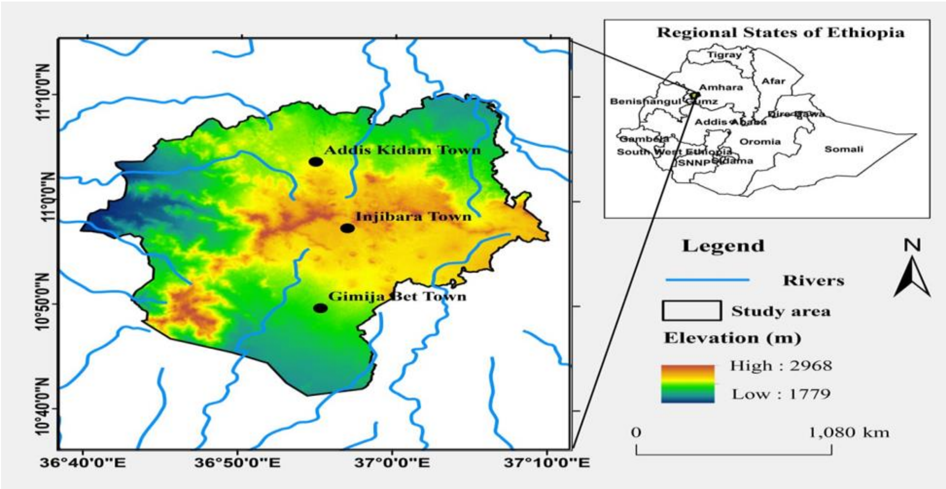


**Figure 1**. Study area map

### 3.2 Sample size and Sampling procedures

A multi-stage sampling method was employed in this study to select districts, sample *Kebeles*, and households. Firstly, three districts, namely *Ankesha-Guagusa, Banja*, and *Fagita Lekoma* , were purposefully chosen due to the high degree of *Acacia* expansion and its wide coverage. Secondly, a sample of nine *Kebeles* (two, three, and four *Kebeles* from *Ankesha-Guagusa, Banja, and Fagita Lekoma*, respectively) were purposefully selected. The purposes for selecting sample *Kebeles* were familiarity with ABA establishment, accessibility, and the extent of ABA practice. Farm-households were then stratified into two groups, ABA-user and non-user, to examine the impacts of ABA on farm-households' FS.

From the total 7,170 household heads in the target kebeles, 6,061 (84.5%) were ABA-users, and the remaining 1,109 (15.5%) were non-users. Sample size determination in scientific studies depends on population heterogeneity, available resources, and desired accuracy factors, however, documented evidence recommends 5-10% samples from a population (Cochran, 1977). Thus, considering factors like heterogeneity and resources, a sample size of 441 households (319 ABA-users and 122 non-users) was initially chosen. However, 8 questionnaires were not returned and 17 were not correctly filled, resulting in a final sample of 416 (296 ABA-users and 120 non-users).

### 3.3 Data sources and methods of collection

A combination of primary and secondary data was used in this study. Surveyed households, government officials, development agents, and FS and agriculture experts in the area were the sources of primary data. The secondary data were obtained from journal articles, books, policy papers, government reports, and guidelines from World Food Program (WFP) and Food and Nutrition Technical Assistance.

Standardized questionnaires on the Months of Adequate Household Food Provisioning (MAHFP), Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS), Household food insecurity Access Scale (HFIAS), and Reduced Coping Strategies Index (rCSI) were customized to gather data on FS conditions, while a non-standardized questionnaire was developed to collect respondents' background information. The questionnaire was evaluated by experts in the field, translated into *Amharic*, and piloted among local farmers. The feedback from professionals and the pilot was incorporated into the final English version, then translated back into *Amharic* and disseminated to the respondents. Key informant interview (KIIs) and focused group discussion (FGDs) were employed to collect qualitative data. KIIs were conducted with purposefully selected local elders, farmers, officials, and experts on the issues, while FGDs were conducted with the farmers (ABA-users plus non-users) and experts, participants were selected based on age, gender, and livelihood strategies diversity.

### 3.4 Food security measurement techniques and procedures

Measuring food security is challenging due to its multidimensional nature and the absence of a single indicator. Experts suggest using a combination of measures to assess all aspects comprehensively (FAO, 2013b; Ike et al., 2017; Mccordic et al., 2023). Consequently, this study used a combination of FS indicators, namely: MAHFP, HFIAS, HDDS, FCS, and rCSI (Table 1).

**MAHFP:** assesses household food availability over one year, regardless of its origin (Swindale and Bilinsky, 2010; Mccordic et al., 2023). Participants were asked to report the number of months they experienced insufficient food in the past year prior to the survey. Based on their responses, they were grouped into not, low, moderate and very adequate food provisioning (Table 1).

**HDDS:** measures a household's food accessibility based on self-reported data about the 12 food groups (cereals, roots and tubers, vegetables, fruits, meat, eggs, fish, pulses/legumes, milk/dairy, oil/fats, sugar/honey, and others such as coffee and tea) consumed within the past 24-hours (FAO, 2013b; Deléglise et al., 2022). Lastly, households classified into low, medium, and high diet diversity based on FAO guidelines (Table 1).

**FCS:** a weighted measure of household food security, considering food diversity, consumption frequency, and nutritional value. It involves grouping food items, assigning weights, multiplying by consumption frequency, and summing the values. Respondents of the study were asked about their food group consumption frequency 7 days prior to the survey. The FCS was then calculated using assigned weights for different food groups: vegetables (1), fruits (1), meat and fish (4), pulses (3), cereals and tubers (2), milk (4), sugar (0.5), and oil (0.5), based on the collected data and above-mentioned procedures (WFP, 2008; WFP, 2016). Finally, households grouped into different groups based on WFP recommendation (Table 1).

**HFIAS:** assesses food inadequacy and related psychological stresses in a household, consisting 9 generic questions (Coates et al., 2007). Respondents were asked if they experienced any of 9 food insecurity-related conditions in the month preceding the survey, and the frequency of occurrence was recorded as rarely (1-2 times), sometimes (3-10 times), or often (more than 10 times) (Castell et al., 2015). Based on the computed score, households were classified as FS or FIS (Table 1).

**rCSI:** measures the actions individuals take in situations of insufficient food availability. It uses a standardized set of coping behaviors with assigned severity weights. The five widely used coping behaviors include consuming less-expensive foods, obtaining food/money from friends/relatives, reducing meal sizes, cutting adult intake, and decreasing meal frequency with a weight of 1, 2, 1, 3, and 1, respectively (WFP, 2016; REAL, 2022). The rCSI score was calculated by multiplying the frequency of coping strategies used by households in a week before the survey by their severity and then summed to obtain rCSI. Finally, households grouped into distinct levels of FIS (Table 1).

The above-mentioned FS/FIS indicators vary in their purpose, thresholds, and timeframes, resulting in different groupings for households across indicators (Mutea et al., 2019). The study, therefore, used a comprehensive measure called the Composite Food Security Index (FSI) to accommodate indicator variations. The composite FSI was developed by normalizing the scores of the MAHFP, HDDS, FCS, HFIAS, and rCSI indicators (Mutea et al., 2019). The Min-Max normalization was used to convert each score to a scale of 0-1 (Mccordic et al., 2023):

$$\mathrm{Xi} = (\mathrm{Ri} - \mathrm{V}min)/(\mathrm{V}max - \mathrm{V}min) \quad (1)$$

Where $X_i$ = n$^{th}$ household's normalized score; $R_i$ = row score; and $V_{min}$ and $V_{max}$ = minimum and maximum scores of the indicators. Since higher scores in rCSI and HFIAS scales indicate less FS, the Min-Max normalization technique was modified by reversing the direction of the scales (Mccordic et al., 2023):

$$\mathrm{Xi} = (\mathrm{Ri} - \mathrm{Vmax})/(\mathrm{Vmin} - \mathrm{Vmax}) \quad (2)$$

All indicators in the study were considered equally important, without assigning any special weight to them. Finally, the composite FSI was calculated by adding the normalized scores of the above five indicators and dividing the result by five. The FSI ranges from 0 to 1, with higher values indicating better food security. A FSI between 0.5 and 1.00 classifies households as 'FS', while a FSI below 0.5 categorizes households as 'FIS' (Sahu et al., 2017; Mutea et al., 2019).

**Table 1.**
Summary of FS indicators' measurement, purposes, and classification thresholds

| Indicators | Measurement method | Dimension Covered | Time reference | Scored Values | Classification guidelines | Source |
|---|---|---|---|---|---|---|
| **MAHFP** | 12 months minus the months of inadequate food supply per year | Availability | 12 months | 0-12 | 0-3 months: not AFP<br>4-6 months: low AFP<br>7-9 months: Moderate AFP<br>10-12 months: Very AFP (Berihun and Ejigu, 2018) | (Swindale and Bilinsky, 2010; Mccordic et al., 2023) |
| **HDDS** | The total number of different food groups consumed by a household on the previous day | Access and utilization | 24 hours | 0-12 | ≤ 3: low<br>4-5: moderate<br>≥ 6: high (FAO, 2013b) | (FAO, 2013b; Ike et al., 2017; Mccordic et al., 2023) |
| **FCS** | The frequency of consuming diverse standardized foods multiplied by the food's nutritional value in the past week | Access and utilization | 7 days | 0-112 | < 21: Poor<br>21-35: Borderline<br>> 35: Acceptable<br>(WFP, 2008) | |
| **HFIAS** | The occurrence of 9 generic questions on food quality/quantity and anxiety, multiplied by their frequency in the month before the survey | Access and stability | 1 month | 0-27 | 0-1: FS<br>2-8: Mild FIS<br>9-16: Moderate FIS<br>≥17: Severe FIS (Dekker et al., 2018) | (Castell et al., 2015; Ike et al., 2017; Mccordic et al., 2023) |
| **rCSI** | The extent of coping mechanisms employed by households in the seven days before the survey, multiplied by their frequency. | Access and stability | 7 days | 0-56 | 0-3: FS<br>4-8: mildly FIS<br>9-18: Moderate FIS<br>> 18: severe FIS (Maxwell et al., 2014) | (Ike et al., 2017; REAL, 2022) |

AFP= adequate food provisioning

### 3.5 Data analyses techniques

A combination of quantitative and qualitative data analysis techniques was used in this study. Descriptive statistical tools, like percentages, means, range, and standard deviations, were utilized to analyze respondents FS conditions. Inferential statistics, such as independent sample t-test was used to compare the mean differences in various FS measures (MAHFP, HDDS, FCS, rCSI, HFIAS, and FSI) between ABA-users and non-users. Besides, binary logistic regression was applied to identify factors influencing FS (Table 2). Furthermore, content analysis technique were employed to analyze data collected through KIIs, and FGDs.

### 3.6 Binary logit model specification

The binary logit model was used to forecast the relationship between a binary dependent variable and manifold explanatory variables. The logit model was chosen over the probit model for this study due to its computational advantage, flexibility, simpler interpretation, and wider applicability in estimating the dependencies of a dummy dependent variable on multiple independent variables (Gujarati, 2003; Sani and Kemaw, 2019). In addition, the estimated probabilities of logit model range between 0 and 1 and establish a non-linear relationship between the probability (Pi) and the independent variables (Xi), unlike the probit model. The odds ratios in logit model are also more intuitive than the probity's coefficients (Gujarati, 2003; Hahn, 2005).

In this study, the dependent variable (FS) is dichotomous, with two values: 1 food-secure and 0 food-insecure households. The potential explanatory variables influencing FS status were identified from relevant literature and the authors' prior knowledge of the area (Table 2).

**Table 2**.
Independent variables description and their anticipated sign

| Variable name and type | Variable description and its measures | ES* |
|---|---|---|
| Age (continuous) | Household head's age (years) | - |
| Sex (dummy) | Household head's sex (1=male, 0=female) | ± |
| Marital status (dummy) | marital status of respondents (1=married, 0= unmarried) | ± |
| Family size (continuous) | Family size of the household (numbers) | ± |
| Education (continuous) | Years of schooling of the household head (years) | + |
| Land size (continuous) | Households' landholding size (hectares) | + |
| Livestock size (continuous) | Total livestock holding of the household (TLU) | + |
| Off-farm (dummy) | Engagement in off-farm activities (1 =yes, 0=no) | + |
| Non-farm (dummy) | Involvement in non-farm activities (1=yes, 0=no) | + |
| Plantation experiences (continuous) | Experiences in tree plantations (years) | + |
| Irrigation (dummy) | Access to irrigation (1=yes, 0=no) | + |
| Credit access (dummy) | Access to credit services (1=yes, 0=no) | + |
| Training access (dummy) | Access to work-related training (1=yes, 0=no) | + |
| Market distance (continuous) | Distance to nearest market (minutes of walking) | - |
| Extension services (dummy) | Access to agricultural extension (1=yes, 0=no) | + |
| Land productivity (dummy) | Perceived land productivity status (1=high, 0=low) | + |

**Note:** *ES= Expected sign

## 4 Results and Discussion

### 4.1 Food security status of households using different indicators

#### *4.11 Dietary diversity and food consumption scores of households*

The study revealed that the majority of households (40.6%) had moderate dietary diversity, while 35.8% and 23.6% had high and low dietary diversity, respectively. The disaggregated result shown that about 37.2%, 41.6%, and 21.2% of ABA-users exhibited high, moderate, and low diversity, respectively, compared with 32.5%, 38.3%, and 29.2% for non-users (Fig. 2). The t-test also disclosed significant diet diversity scores difference between ABA-users (M=6.05±2.85) and non-users (M=5.38±1.72); t(418)=4.59, p=0.008 (Table 4). This reflects the positive contribution of *ABA* in improving diet diversity, although the overall dietary intake was not in good status. Regarding consumption frequency, cereals (*injiera,* bread), root crops (potatoes), and legumes were commonly consumed, while vegetables, fruits, meat, and eggs were consumed less frequently in the area. Support this, Jemal and Call-Concha (2017) documented the vital benefits of agroforestry practices in improving dietary diversity. Vansant et al. (2022) also indicated the significant contributions of tree-based farming in improving dietary diversity and quality through providing foods and additional income.

The FCS results indicated that most households (46.4%) had borderline food consumption scores. Households with acceptable and poor consumption scores account for one-third and one-fifth of the total samples, respectively. Specifically, ABA-users had largest share in the acceptable consumption score group; contrary non-users were dominant in the borderline and poor categories (Fig. 2). Consistent with this, the mean comparison result revealed a significant difference in FCS between ABA-users and non-users, t(418)=2.40, p=0.043 (Table 4). Generally, 67.1% of households fell into the borderline and poor consumption groups, indicating the need for support for the vulnerable population.

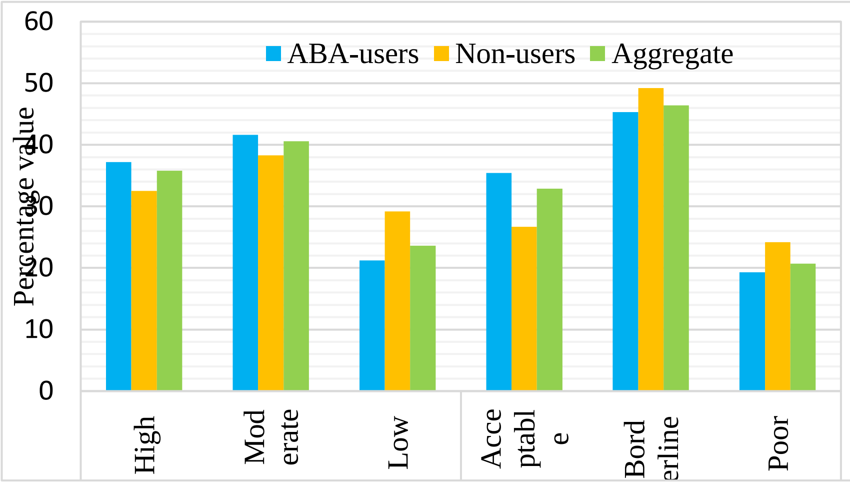


**Figure 2.** Food security conditions of households by dietary diversity (a) and food consumption (b) scores

### *4.12 Households Food security condition as measured by MAHFP*

As Table 3 shows, more than half of households had a high FS status, with sufficient food for 10 to 12 months. The second largest group (30.3%) had moderate FS, ensuring adequate food for 7 to 9 months. The third-ranked group (15.6%) experienced FIS, with enough food for 4 to 6 months.

Severe FIS (≤ 3 months of sufficient food) was rare, accounting for only 2.9% of households. Comparatively, households practicing *ABA* had a better food availability status (53%) than non-users (47%) in the year preceding the survey. However, the statistical analysis showed no significant mean difference in the MAHFP between the two groups.

**Table 3.**
Respondents' food security situation based on MAHFP

| Groups (number of months) | Number of households (%) | | | T | p-value |
|---|---|---|---|---|---|
| | ABA-users | Non-users | Total | | |
| Very AFP (10-12) | 157 (53) | 56 (47) | 213 (51.2) | 1.07 | .282 |
| Moderate AFP (7-9) | 92 (31.2) | 34 (28) | 126 (30.3) | | |
| Low AFP (4-6) | 41 (13.8) | 24 (20) | 65 (15.6) | | |
| Not AFP (0-3) | 6 (2) | 6 (5) | 12 (2.9) | | |

AFP =adequate food provisioning

Moreover, the survey results uncovered that food provision inadequacy in the research area occurred in a seasonal and cyclical pattern (Fig. 3). According to FGDs, households faced severe food shortages during the summer (June to August) and early spring (September) seasons. These shortages were not only due to limited annual production capacity but also poor agricultural produce management and wasteful ceremonial culture. FGDs discussants described this situation as follows:

> *"Food availability is a pressing problem in our area, particularly from June to September, due to many factors, including mismanagement of own produce. The community's lavish ceremonial culture, comprising weddings, teskar[2], mahber, and other events, leads to excessive spending. Farmers often sell their agricultural produce and assets to fund expensive celebrations, leading to food shortages. This recurring issue calls for effective measures from stakeholders."*

Key informants also reported that households hosting weddings and/or *teskar* events mostly experience food shortages, particularly on the eve and beginning of the Ethiopian New Year. Similarly, Berlie (2013) identified extravagant socio-cultural ceremonies as a significant factor contributing to households' vulnerability to FIS.

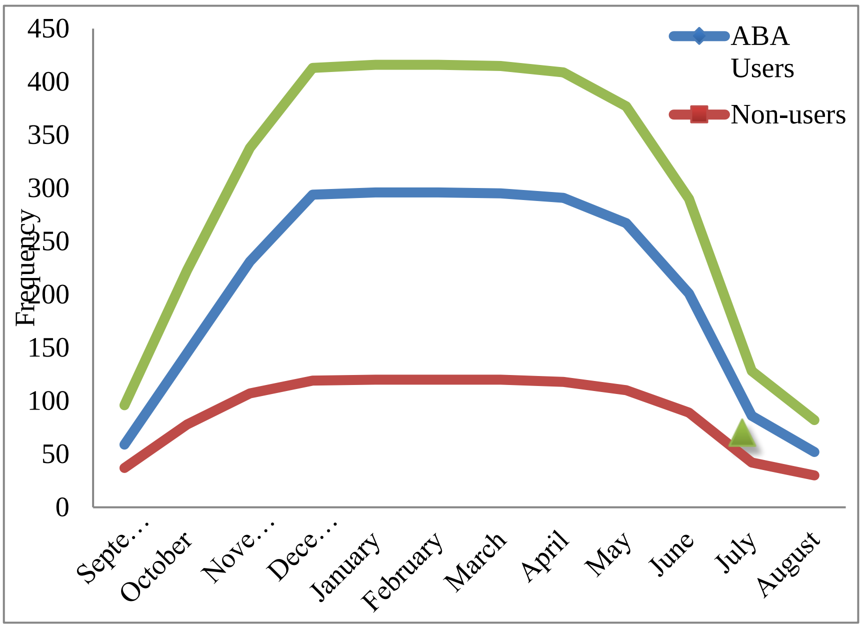


**Figure 3.** Annual consumption pattern of households from their production

*4.13 Food insecurity situation of households based on HFIAS*

Figure 4 shows that over half of surveyed households experienced anxiety /uncertainty about food availability, 30 days before the survey. Relatively, non-user households (55.8%) experienced more worry about getting enough than ABA-users (49.7%). Among ABA-users, 79.1%, 82.3%, 41.5%, and 13.5% were unable to eat preferred foods, had limited food varieties, consumed undesired foods, and reduced meal frequency, respectively, a month before the survey. Non-users also faced similar challenges, with percentage shares of 86.7%, 91.7%, 50.8%, and 15%, respectively. The incidence of more severe challenges, like meal size reduction, complete food absence, skipping dinner, and not eating for a whole day, was relatively low for both groups (Fig. 4). The findings generally indicate that both ABA-users and non-users encountered food access and stability challenges, but non-users experienced greater difficulties on the HFIAS parameters.

The aggregated HFIAS analysis revealed that the majority of households (41.2% ABA-users, 46.7% non-users) had moderate FS. The second-ranked groups (51% ABA-users, 37.5% non-users) were foods secure, and only 10% of households were severely FIS. The figures demonstrates that *ABA*-users were dominant in the food-secure groups, while non-users were largely concentrated in the food-insecure categories. The statistical analysis further indicated a significant mean difference between ABA-users and non-users in HFIAS scores (t(418)=-3.38, p=0.001) (Table 4). This discloses the significant benefits of *ABA* in enhancing farmers' welfare and reducing vulnerability to FIS. Supporting this, (Jemal and Callo-Concha, 2017; Jemal et al., 2018; Jemal et al., 2021; Afework et al., 2024) documented the multifaceted benefits of small-scale agroforestry practices in rural areas of Ethiopia.

[2] *A burial ceremony celebrated 40 days after death by Orthodox Christian followers*

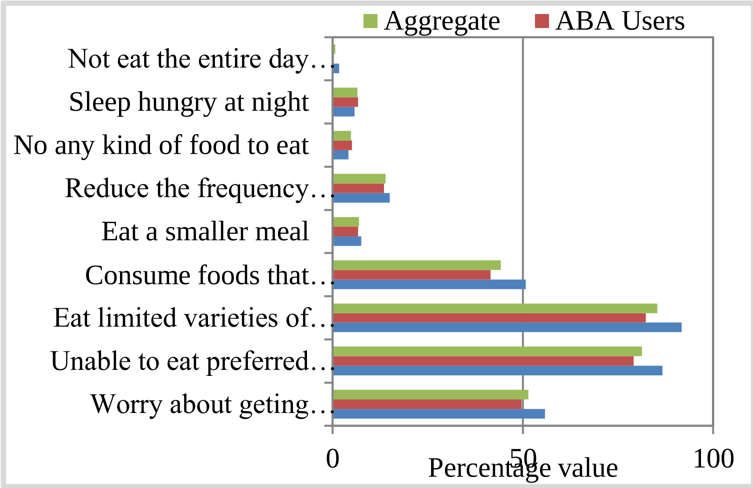


**Figure 4.** Distribution of households by their response to HFIAS questions

### *4.14 Households food insecurity as measured by rCSI*

Regarding rCSI, nearly three-quarters (68.4%) of households were FS, with the mild and high food-secured groups accounting for 45.4% and 23%, respectively. The remaining 31.6% were FIS (23.8% moderately, 7.8% severely). In the mild FIS and FS groups, the percentage of *ABA*-users was 7.5% higher than non-users. Conversely, in the moderate and severe FIS group, non-user households exceeded by 15.5%. Similarly, the t-test revealed a significant mean difference (t(418)=-3.82, p<0.01) between *ABA*-users (7.56±4.58) and non-users (9.48±4.92) (Table 4). The findings further uncovered that food-insecure households coped with the challenges largely by consuming less-expensive foods, borrowing food/money from friends/relatives, and reducing meal frequency, accounting for 83.5%, 79.2%, and 41.7%, respectively. Comparatively, decreasing meal sizes and adult intake were less commonly employed strategies in the study area.

### *4.15 Food security status of households based on the composite FSI*

As Table 3 and 4 displays, the different food (in)security indicators classified households into varied groups. Specifically, HDDS, FCS, and HFIAS indicate lower FS status than MAHFP and rCSI due to varying cutoff points and assessment questions. The composite FSI was thus calculated to address these gaps. According to the composite FSI result 42.2% of households were FS (FSI≥0.5), while the majority (57.8%) were FIS (FSI<0.5). Specifically, 46.9% of ABA-users and 37.5% of non-users were FS, but above half of both groups were FIS. Likewise, the mean comparison analysis showed that ABA-users have a significantly higher mean FSI than non-growers (P<0.05). This indicates the promising advantages of ABA in improving rural households FS.

According to key informants, ABA's agroforestry generates significant revenue for FS, allowing them to buy and consume diverse foods. Supporting the positive roles of ABA practices, an elderly informant from Endewuha Kebele shared his experiences as follows:

> *"I had 1.5 hectares of less-productive land and supported nine family members. Despite using much artificial fertilizer, the output couldn't cover family expenses before Acacia cultivation. Providing diverse and nutritious food was impossible, and we struggled to afford basic food items, especially from July to September. To cope, we ate less preferred foods, worked for wages, and borrowed food/money. Repaying debts consumed our winter harvest, creating a cyclical food availability problem. However, cultivating Acacia trees improved our income and land quality. Now, I grow crops alongside Acacia trees for socioeconomic benefits. However, Acacia diseases/pests and market inflation pose challenges in recent times."*

Several studies have confirmed the immense contributions of agroforestry systems in enhancing food and nutrition security (Sarvade and Singh, 2014; Jemal and Callo-Concha, 2017; Montagnini and Metzel, 2017; Jemal et al., 2018; Jemal et al., 2021; Mukhlis et al., 2022). Specifically, Jemal and Callo-Concha (2017), Jemal et al. (2018, 2021), and Mukhlis et al. (2022) have emphasized the crucial roles played by agroforestry in stabilizing food systems by providing nutritious foods, cash income, and diverse supportive environmental services.

This study generally found divergent levels of FS compared to studies conducted in other parts of Ethiopia. Indeed, the FS status in the Awi highlands was found to be lower compared to studies conducted in East and West Gojam Zone

(Motbainor et al., 2016), East Hararghe Zone (Sileshi et al., 2019), and Kaffa Zone (Sisay and Girma, 2023). In contrast, the study area demonstrated a higher FS level compared to previous findings in Western Ethiopia (Sani and Kemaw, 2019), North-Eastern Rift Valley (Getaneh et al., 2022), Central and North Gondar Zone (Awoke et al., 2022), and North Shewa Zone (Abera and Mekonin, 2022).

**Table 4.**

Summary of households' food (in)security status based on different indicators

| Indicators | Classifications | Percentage share | | | T | p-value |
|---|---|---|---|---|---|---|
| | | ABA-users | Non-users | Total | | |
| HDDS | High | 37.2 | 32.5 | 35.8 | 5.08 | 0.008 |
| | Moderate | 41.6 | 38.3 | 40.6 | | |
| | Low | 21.2 | 29.2 | 23.6 | | |
| FCS | Acceptable | 35.4 | 26.7 | 32.9 | 2.40 | .043 |
| | Borderline | 45.3 | 49.2 | 46.4 | | |
| | Poor | 19.3 | 24.2 | 20.7 | | |
| HFIAS | FS | 16.9 | 11.5 | 14.2 | -3.38 | .001 |
| | Mildly FS | 34.1 | 26 | 30 | | |
| | Moderately FIS | 41.2 | 46.7 | 43.9 | | |
| | Severely FIS | 7.8 | 15.8 | 11.8 | | |
| rCSI | FS | 25.4 | 17.5 | 23 | -3.68 | .000 |
| | Mildly FS | 47.6 | 40 | 45.4 | | |
| | Moderately FIS | 20.6 | 31.7 | 23.8 | | |
| | Severely FIS | 6.4 | 10.8 | 7.8 | | |
| FSI | FS | 46.9 | 37.5 | 42.3 | 2.68 | .041 |
| | FIS | 53.1 | 62.5 | 57.8 | | |

## 4.2 Relationship between the various food (in)security indicators

The correlation analysis revealed significant relationships (p<0.01) among the six food (in)security indicators. Table 5 shows strong positive relationships between MAHFP and HDDS, FCS, and FSI (r =0.508, 0.481, and 0.779, respectively), and moderate but significant negative associations between MAHFP and HFIAS (r =-0.422) and MAHFP and rCSI (r =-0.397). Higher MAHFP values correspond to improved HDDS, FCS, and FSI, and lower HFIAS and rCSI . The study by Mutea et al. (2019) supports our findings, except for the MAHFP and rCSI.

The results also shows a strong positive relationship between HDDS and FCS (r=0.506) and FSI (r=0.717). Additionally, a moderate negative correlation was found between HDDS and HFIAS (r=-0.386) and rCSI (r=-0.375). These suggests that households with a diversified diet tend to have higher FCS and lower HFIAS and rCSI, which is consistent with Maxwell et al. (2013) and Mutea et al. (2019) study findings.

Furthermore, the results indicate a significant negative correlation between FCS and both HFIAS (r=-0.397) and rCSI (r=-0.348) but a strong positive association with FSI (r=0.693). This implies that higher FCS associated with greater FS, while lower FCS scores indicate vulnerability to FIS. The study also found a strong positive relationship between HFIAS and rCSI (r=0.703), and a significantly strong negative correlation between HFIAS and rCSI with FSI (r=-0.788, r=-0.744, respectively) (Table 5). The findings agree with Maxwell et al. (2013) study, but contradicts Mutea et al. (2019) on FCS and HFIAS association.

**Table 5.**

Correlation analysis between different food (in)security indicators

| Indicators* | MAHFP | HDDS | FCS | HFIAS | rCSI | FSI |
|---|---|---|---|---|---|---|
| MAHFP | 1 | | | | | |
| HDDS | .506 | 1 | | | | |
| FCS | .481 | .510 | 1 | | | |
| HFIAS | -.422 | -.386 | -.397 | 1 | | |
| rCSI | -.397 | -.375 | -.348 | .703 | 1 | |
| FSI | .779 | .717 | .693 | -.788 | -.744 | 1 |
| N | | 427 | | Sig. (2-tailed) | | .000 |

*. All are significant at 0.01 level

### 4.3 Determinants of food security in the study area

The logistic regression analysis revealed a highly significant regression model ($X^2$= 199.552; df = 16; p <0.001) with no multicollinearity problem (VIF <10). The model accounted for 50.9% (Nagelkerke $R^2$) of the variance in FS and accurately classified 80% of cases. Among the 16 variables analyzed, 10 significantly influenced households' FS (Table 6).

The age of household heads had a notable detrimental impact on their FS status, with a coefficient of -0.035 (p<0.05). Table 6 shows that there is a 96.5% decline in the likelihood of FS for every unit rise in the age of household heads. This suggests that younger family heads have a higher likelihood of being FS than older ones, possibly due to declining physical and mental abilities with age. Moreover, older household heads often have larger families, causing resource-sharing challenges, which may hinder their FS. This result aligns with (Sani and Kemaw, 2019; Getaneh et al.,2022) findings, but contradicts the findings of (Kim, 2014; Aragie and Genanu, 2017; Awoke et al., 2022; Fikire and Zegeye, 2022; Worku, 2023) studies.

The survey results demonstrated a significant negative relationship between family size and FS (β= - 0.183, p= 0.013). The odds ratio showed that larger families have lower FS (0.83 factor) compared with smaller families. This is due to the presence of large dependent family members, especially those under the age of 15, burdening the productive population and imposing pressure on food availability in the locality. The outcomes corroborate the conclusions drawn by various authors (Aragie and Genanu, 2017; Awoke et al., 2022; Fikire and Zegeye, 2022; Getaneh et al., 2022). However, the finding was not in agreement with that of Worku (2023).

The study found a substantial negative association between credit availability and FS (B = - 0.993, p = 0.0001), meaning that the possibility of FS decreased as credit availability rose. Specifically, the likelihood of FS was 0.37 times lower in households with credit access than those without credit. During the FGDs, participants mentioned that households in Awi highlands obtained credit from Tsedey Bank (formerly *Amhara Credit and Saving Institution*) relatively at high-interest rates. However, they used the funds for domestic purposes instead of income-generating activities, leading to repayment difficulties and the sale of fixed properties, including livestock. Concerning this, Kim (2014) reported a similar finding, whereas others (Sani and Kemaw, 2019; Getaneh et al., 2022) found conflicting results.

Land access and size significantly influence the FS of rural communities. According to this study, landholding size significantly increased FS (B= 0.351, p <0.01). Moreover, the results showed that increasing farmland by one unit led to a 1.42 times higher probability of achieving FS. Hence, FS increased with larger landholding sizes and *vice versa.* This conclusion is supported by findings of other authors (Aragie and Genanu, 2017). However Awoke et al. (2022) reported a different result.

Households participating in off-farm activities greatly enhanced FS (B= 0.684, p= 0.015). Specifically, households who had access to off-farm activities had a 1.98 times higher chance of achieving FS compared to those without. This signifies the crucial importance of off-farm activities in improving the FS of farmers. Regarding this, FGDs and KII participants noted that farmers who practice off-farm activities alongside farming have better living conditions. They emphasized that farming is not viable year-round, so participating in off-farm activities during free time is crucial to improving socioeconomic life of households. This research outcome did not agree with results reported by Sani and Kemaw (2019), but it is consistent with the findings of other authors (Aragie and Genanu, 2017; Awoke et al., 2022; Fikire and Zegeye, 2022).

Livestock is vital for farmers in the study area, providing power, income, food, and transportation. The study revealed that owning livestock assets positively and significantly impacts FS (0.034 coefficient), 5% significance level. The odds ratio indicates that increasing livestock possession by one TLU raises the likelihood of FS by 1.04 times. This implies that having more livestock in a family results in better FS and *vice-versa.* This finding matches with the findings of other authors (Kim, 2014; Aragie and Genanu, 2017; Getaneh et al., 2022), but was not in conformity with Awoke et al. (2022) study findings.

Market distance affects transportation costs for buying/selling goods. The empirical analyses revealed a negative association between market distance and FS status (coefficient: 0.010, odds ratio: 0.990, p = 0.016). The likelihood of FS dwindled by 0.99 times with increasing market distance. This implies that farmers nearer to the market are better in FS than those in distant areas. Regarding this, Fikire and Zegeye (2022) found a similar result, while the findings of other authors (Aragie and Genanu, 2017; Sani and Kemaw, 2019) contradict this result.

In agrarian countries, like Ethiopia, access to irrigation is crucial for boosting farmers' economy. It increases crop production frequency, leading to higher yields and a wider variety of crops. Access to irrigation significantly and positively affects the FS of households (B= 0.944, p = 0.001), with a 257.1% increase in the probability of FS. This indicates that compared to households with irrigation access, those without irrigable land are more likely to experience FIS. Previous studies have also highlighted the significant contribution of irrigation in enhancing farm outputs, dietary diversity (Passarelliet al., 2018), and FS status (Passarelliet al., 2018; Sani and Kemaw, 2019; Worku, 2023).

Plantation experiences have multiple socioeconomic and environmental benefits (Nigussie 2021; Afework et al., 2024). The regression analyses confirmed that plantation experiences of households positively impact their FS status, with a coefficient of 0.172 (p <0.01). The results further show that plantation experiences increase the likelihood of achieving FS by 118.8%.

Land quality directly impacts crop productivity and households FS. This study discovered a strong positive connection between household FS and perceived land quality. Perceived land quality improves FS by a factor of 2.10, assuming other factors constant. Therefore, households with more perceived fertile land experience better FS than those with less fertile land. KIIs and FGDs participants underlined the significant impacts of land quality difference on FS, and further highlighted as ABA introduced in Awi highlands in response to soil acidity and land degradation challenges. Supporting this, Liang et al. (2020) and Rojas et al. (2016) reported the vital roles of soil quality in producing healthy food and ensuring FS.

**Table 6.**

Binary logistic regression results on the determinants of food security

| Variables | Coefficient | Standard Error | p-value | Odds ratio | |
|---|---|---|---|---|---|
| Age | -.035 | .016 | .029 | .965 | |
| Sex | .337 | .384 | .380 | 1.401 | |
| Marital status | .310 | .450 | .491 | 1.364 | |
| Educational status | .036 | .290 | .901 | 1.037 | |
| Family size | -.183 | .074 | .013 | .833 | |
| Livestock holding | .034 | .017 | .046 | 1.035 | |
| Farmland size | .351 | .062 | .000 | 1.421 | |
| Credit service | -.993 | .279 | .000 | .371 | |
| Off-farm | .684 | .282 | .015 | 1.982 | |
| Non-farm | .205 | .417 | .624 | 1.227 | |
| Irrigation | .944 | .285 | .001 | 2.571 | |
| PE | .172 | .042 | .000 | 1.188 | |
| Training | .333 | .272 | .221 | 1.395 | |
| Extension service | -.375 | .403 | .352 | .687 | |
| Market distance | -.010 | .004 | .016 | .990 | |
| Soil fertility | .742 | .274 | .007 | 2.100 | |
| Constant | -3.063 | 1.144 | .007 | .047 | |
| N | 416 | Prob > $chi^2$ | .000 | Cox and Snell $R^2$ | 0.378 |
| LR $chi^2(16)$ | 199.552 | -2 Log likelihood | 371.663 | Nagelkerke $R^2$ | .509 |

*, ** significant at 1, and 5 % probability level, respectively, PE= Plantation experiences

## 5 Conclusion and policy implications

The research findings demonstrate that ABA-user households have higher FS compared to non-users, highlighting the positive effects of agroforestry on rural FS. However, FS remains high in the Awi Zone highlands, especially for non-ABA households. Livestock and farmland size, participation in off-farm activities, irrigation access, plantation experiences, and perceived soil quality significantly contribute to FS. Conversely, age, family size, credit access, and market distance have a detrimental effect on FS. To combat FIS and its associated challenges, concerned stakeholders (governmental and/or non-governmental) interventions are needed to: (1) address extravagant ceremonial culture, (2) enhance human and physical capital development instead of the current productive safety net program, and (3) promote and support agroforestry practices.

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## Appendix: The binary logistics regression formulas

The formulas of the binary logit model used in the study written as follows (Gujarati, 2003):

$$P(Y_i = 1) = \frac{1}{1+e^{-(B_0 + B_i X_i)}}, \qquad (3)$$

For simplicity, equation (3) rewritten as: $P(Y_i = 1) = \frac{1}{1+e^{-(z_i)}}$,

Where: P (Yi = 1) represents the likelihood of a household being FS, then 1 - P(Yi = 1) represents the possibility of being FIS.

It can be described as:

$$1 - P(Y_i = 1) = \frac{1}{1+e^{-(z_i)}}, \text{ thus, this can rewrite as, } \frac{P(Y_i = 1)}{1 - P(Y_i = 1)} = e^{z_i} \qquad (4)$$

Equation (4) represents the odds ratio comparing the probability of household's FS to the probability of FIS. Taking its natural logarithm yields:

$$L_i = \ln \frac{(P_i)}{(1-Pi)}, \text{ it can also described as } Z_i = B_0 + B_1X_1 + B_2X_2 + \ldots\ldots + B_nX_n + u_i, \qquad (5)$$

Where: Li is the natural logarithm of the odds ratio, $Z_i$ is the function of a vector of n[th] explanatory variables, $X_i's$ are the explanatory variables, $P_i$ is the probability of FS, $P_i - 1$ $is$ the likelihood of being FS, $B_0$ $is$ the intercept, $B_i's$ are the regression coefficients of predictor variables and $u_i$ $is$ error term.