Factors Influencing the Food Security of Smallholder Farmers in Madagascar

A THESIS SUBMITTED

TO THE FACULTY OF THE

UNIVERSITY OF MINNESOTA

BY

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IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

Marc F. Bellemare

July 2018

ACKNOWLEDGEMENTS

I owe the deepest gratitude to Marc F. Bellemare, my thesis adviser, for providing me with the data set to conduct this study as well as his invaluable and constructive comments and suggestions. Without his professional assistance and guidance, this study would not be realized.

DEDICATION

This thesis is dedicated to my children, Amanuel Belay Abebe and Natnael Belay Abebe.

ABSTRACT

Understanding important factors influencing the food security status of smallholder farmers is crucial for designing interventions to enhance the food security situation of food insecure households. This study was conducted to identify major factors influencing farm household food insecurity in Madagascar. The data collected from a total of 1,178 randomly selected households from six regions of Madagascar was used in the analyses.

The study found that of 1,178 households, 88.7% were food insecure. The linear probability model regression with robust standard error showed that ten variables were significant: age, informal financial loan, household's independent farming experience, total assets per adult equivalent, the log of total household income, household size, marriage status of the household (single), shocks due to crops diseases, shocks due to weather conditions, and shocks resulting from household members' illness. With this information, policymakers can target farmers who have experience in farming and education to reduce food insecurity.

Keywords: food security, food insecurity, linear probability model

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1. INTRODUCTION

Denning *et al*. (2009) report that in Sub-Saharan African (SSA) countries the mean agricultural growth was about 3% per year over the past 25 years. The contributing factors for such a slow growth are low investment in agriculture, poor infrastructure, and downsizing of public agricultural institutions for research, extension, credit, and marketing (PANE, 2010). Moreover, recently emerging issues such as climate change and population growth, the declining scale of agricultural investment in developing countries, inappropriate rules for trade and investment between the rich and poor countries and the extreme global inequality of food resources have a direct and negative influence on food security status. Regardless of the availability of resources and the efforts made by governments in most of these countries, food insecurity and declining food production per capita remained the same or deteriorated over time (Von, 2007).

According to Nagayet (2005), with an estimated 450–500 million smallholder farmers worldwide, representing 85% of the world's farms, smallholder farmers account for a significant portion of the world's population. Also, about half of the hungry worldwide and probably three-quarters of the hungry in Africa are represented by smallholder farmers (Sanchez and Swaminathan, 2005). As a result, success in reducing poverty and hunger worldwide and meeting the Sustainable Development Goals will mainly be determined by the success of smallholder farmers. Morton (2007) and O'Brien K *et al*. (2004), indicate that smallholder farmers in the tropics have been suffering from numerous risks to their agricultural production from pest and disease outbreaks, extreme weather conditions and market shocks, among other factors, which often undermine their household food and

income security. Since smallholder farmers particularly depend on agriculture for their livelihoods and have limited resources and capacity to cope with shocks, any reductions to agricultural productivity can have significant impacts on their food security, nutrition, income and well-being (Hertel and Rosch, 2010; McDowell and Hess, 2012).

Harvey *et al*. (2014), report that climate change is expected to disproportionately affect smallholder farmers by further exacerbating the risks that farmers face. The study conducted by Morton (2007), indicates that even moderate increases in temperature will have negative impacts on rice, maize, and wheat, which are the main cereal crops of smallholder farmers. Climate change is also expected to alter pest and disease outbreaks, increase the frequency and severity of droughts and floods, and increase the likelihood of poor yields, crop failure and livestock mortality (Morton, 2007 and Kevan, 1999).

Minten and Barrett (2008) report that about 70% of the population of Madagascar is farmers. Knowing the vulnerability of farmers to climate change and agricultural risks is important and is expected to be significant (Tadross *et al*., 2008). According to the World Bank (2012), 81% of the island's inhabitants report living on less than the international poverty threshold of $1.25 per day and a *per capita* gross national income (GNI) equal to $430. Madagascar has one of the highest poverty rates in Africa. It stands at 151 out of 187 countries assessed for the Human Development Index (UNDP, 2011). Dostie *et al*. (2002) state that approximately two-thirds of the Malagasy population is undernourished and, according to the Institute National de la Statistique (INSTAT) 2010 report, 82% of the rural population falls below the national poverty line. Zeller *et al*. (1999) indicate that most

farmers are smallholders with a national average upland rice area per farmer of 1.28 ha. They are chronically food insecure and produce primarily for subsistence and generally lack basic services such as improved water sources and electricity (World Bank, 2012). Madagascar has suffered from significant deforestation and forest fragmentation over the last 50 years, with forest cover decreasing almost 40% from the 1950s to 2000 and much of the remaining forest land being highly degraded (Harper *et al.*, 2007). Styger *et al*. (2009) report that much of the country's agricultural land is severely eroded because of unsustainable land-use practices.

Although several studies have characterized the livelihoods of Malagasy farmers and explored factors influencing poverty and food insecurity (Bellemare and Novak, 2017; Minten and Barrett, 2008; Dostie *et al*., 2002; Zeller *et al*., 1999; Barrett and Dorosh, 1996; Raharinjanahary *et al*., 2010) there is no information on the specific explanatory variables' magnitude and relative significance, or influence on the food security of smallholder farmers in Madagascar. To minimize threats of food insecurity and poverty, an understanding of the socioeconomic, demographic, institutional and biophysical factors is critical. Also, this research is vital because it could provide information that will enable effective measures to be undertaken to improve the food security situations of poor farmers and help non-governmental organizations and policymakers to have knowledge as to where and how to channel efforts in order to minimize the problem of food insecurity.

The definition of the dependent variable in this study is based on the basic definition of food security or food insecurity, which is established by the World Food Summit (1996):

"*There is food security when all people at all times have sufficient physical and economic access to safe and nutritious food to meet their dietary needs including food preferences, in order to live a healthy and active life*" (FAO, 2008). When an individual or population lacks or is potentially vulnerable due to the absence of one or more factors outlined above, then it suffers from or is at risk of food insecurity.

Accordingly, the dependent variable (food insecurity) in this study is a dummy variable defined as anyone with a reported duration of a hungry period (in months) greater than zero, which is the number of months during which members of the household go without three meals per day. This proxy for food insecurity assumes a value of one if the reported hungry period is greater than zero and takes a value of zero if the reported hungry period is equal to zero.

This research, therefore, was conducted to analyze the extent to which, how, and how much various factors influence food insecurity of smallholder farmers in Madagascar. In so doing, the study aims to generate data on food security of smallholder farmers in the area and contribute to the literature providing information and informing policymakers in designing appropriate policy to reduce poverty / food insecurity. Specifically, this study was carried out to answer the following questions: what are the major household characteristics and socio-economic, institutional and biophysical factors that affect the food security of smallholder farmers in the study area? What are the magnitude and direction of influence of those variables on food security? What are the most important factors affecting food security?

This thesis is organized into six sections. Section two covers a review of the literature on the concepts and the definition of food security. Section three presents the description of data and descriptive statistics. Section four deals with the econometric model, working hypotheses, and definition of variables used in the study. Section five portrays results and discussion, and lastly, section six summarizes the overall findings of the research with policy implications.

2. LITERATURE REVIEW

2.1. Concepts and Definitions of Food Security

The concerns about food security can be traced back to the Conference of Food and Agriculture in 1943, since then the issue has undergone several redefinitions. Starting from the World Food Conference in 1974 due to the food crises and major famines in the world, the term food security was introduced, evolved, developed and diversified by different researchers. According to Maxwell and Frankenberger (1992), there are 194 different studies on the concept and definition of Food Security and 172 studies on indicators. Clay (1997) provided a review of 72 additional references that updated this literature. There is a distinction between the work by Maxwell and Frankenberger, regarding process indicators describing (food supply and food access) and outcome indicators describing (food consumption).

Until the mid-1970's food security was understood as adequacy of food supply at global and national levels. This view is mainly favored food production-oriented variables and

overlooked the multiple forces which in many ways affect food access. Although evidence shows that during the last two decades, food production has been increasing in the world, a large amount of food at the global level does not guarantee food security at the national level. Furthermore, availability of enough food at the national level does not necessarily ensure household food security. For example, according to the UNDP report, in 1990, the calorie supply at the global level was more than 110 percent compared to the total requirement; however, during the same period, more than 100 million people were affected by famine and more than a quarter of the world's population was short of enough food (UNDP, 1992).

Barrett (2002) reported that even though food production has been increased from time to time, food insecurity, malnutrition and hunger and much more serious problems remain the main agenda around the globe today. Based on the occurrence of hunger, famine, and malnutrition in developing countries, the conceptual framework of food security has progressively developed and expanded. According to Debebe and Tesfaye (1995), the idea of food security attained wider attention since the 1980s after the debate on '*access'* to food and the focus of the unit shifted from global and national levels to household and individual levels. This paradigm shift resulted in the emergence of the new concept and definition of food security and led to two additional major shifts in thinking; from a first food approach to a livelihood perspective and from objective indicators to subjective perceptions (Maxwell *et al.*,1994).

The most commonly accepted definition of food security is "*access by all people at all times to enough food for an active and healthy life"* (World Bank, 1986). Food insecurity is a *situation in which individuals have neither physical nor economical access to the nourishment they need.* A household is said to be food insecure when its consumption falls to less than 80% of the daily minimum recommended allowance of caloric intake for an individual to be active and healthy. Especially, food insecurity includes low food intake, variable access to food, and vulnerability- a livelihood strategy that generates adequate food in good times but is not resilient against shock. According to Devereux (2000), these outcomes correspond broadly to chronic, cyclical, and transitory food insecurity.

World Food Summit (WFS) held in Rome in 1996, was established that "*There is food security when all people at all times have sufficient physical and economic access to safe and nutritious food to meet their dietary needs including food preferences, in order to live a healthy and active life*"(FAO, 2008). When an individual or population lacks or is potentially vulnerable due to the absence of one or more factors outlined above, then it suffers from or is at risk of, food insecurity. The WFS (1996) definition focuses on three distinct but interrelated elements, all three of which are essential to achieving household food security:

1. **Food availability**: having sufficient quantities of food from household production, other domestic output, commercial imports or food assistance.

2. **Food access**: having adequate resource to obtain appropriate foods for a nutritious diet, which depends on available income, distribution of income in the household and food prices.
3. **Food utilization**: proper biological use of food, requiring a diet with sufficient energy and essential nutrients, potable water and adequate sanitation, as well as knowledge of food storage, processing, basic nutrition and child care and illness management.

However, the World Food Summit says that stability must be present "at all times" in terms of availability, access, and utilization for food security to exist. The literature distinguishes between chronic food insecurity where food needs cannot be met over a protracted period of time and transitory food insecurity, where the time period is more temporary (Maxwell and Frankenberger,1992).

Hoddinott (1999) reported that the concept of food security also has spatial and temporal dimensions. The spatial dimension refers to the degree of aggregation at which food security is being considered. It is possible to analyze food security at the global, continental, national, sub-national, village, household, or individual level.

The temporal dimension refers to the time frame over which food security is being considered. In much of the food security literature, the temporal dimension is almost universally classified into two states-chronic or transitory (Hoddinott,1999; Tweeten, 1997; Devereux, 2006). ***Chronic food insecurity*** is a long-term or persistent inability to

meet minimum food consumption requirements; while ***transitory food insecurity*** is a short-term or temporary food deficiency. An intermediate category is ***cyclical food insecurity***, such as seasonality.

Devereux (2006) indicated that the term transitory is often used to imply acute, with the corollary assumption that chronic equates to mild or moderate food insecurity. The same source revealed that the worst form of transitory food insecurity is famine. The transitory food insecurity faced by farm households will be understood in this study as a seasonal food shortage.

When facing food shortages, households respond in different ways to reverse the situation. The variety of measures taken by households are commonly known as coping strategies. As a result, the food security status of the households can be improved. But if the frequency of the problems increases over time, a negative outcome on food security can follow.

Frank *et al*. (1999) described this reality as "Over time, as a crisis deepens, household responses become increasingly costly, leading to the loss of productive assets (e.g. land degradation, loss of ox, etc.) which can ultimately undermine future livelihoods and, again, their long-term food security status."

3. Description of Data and Descriptive Statistics

The data used for this study are identical to that used by Bellemare (2012); and Bellemare and Novak (2017). According to the same source, the data were collected from the rural part of Madagascar by Bellemare and other members of the survey team, and the work was facilitated by the World Bank's Madagascar office. The data cover six regions and two communes per region. Based on figure 1, the six regions selected and the corresponding numbers on the map were Alaotra-Mangoro (11), Analamanga (4), Anosy (22), Diana (1), Itasy (3), and Vakinankaratra (5).

Two lists were obtained within each commune having lists of all households that took part in contract farming and those that were not participating in contract farming. Then employing a random sampling technique, 50 households were randomly chosen from the lists of households that participated in contract farming and 50 households from those that did not. It was also stated that about 96% of the households in the sample generated their income at least from agricultural activities. The dataset has 1,178 observations with no missing values and 158 variables.

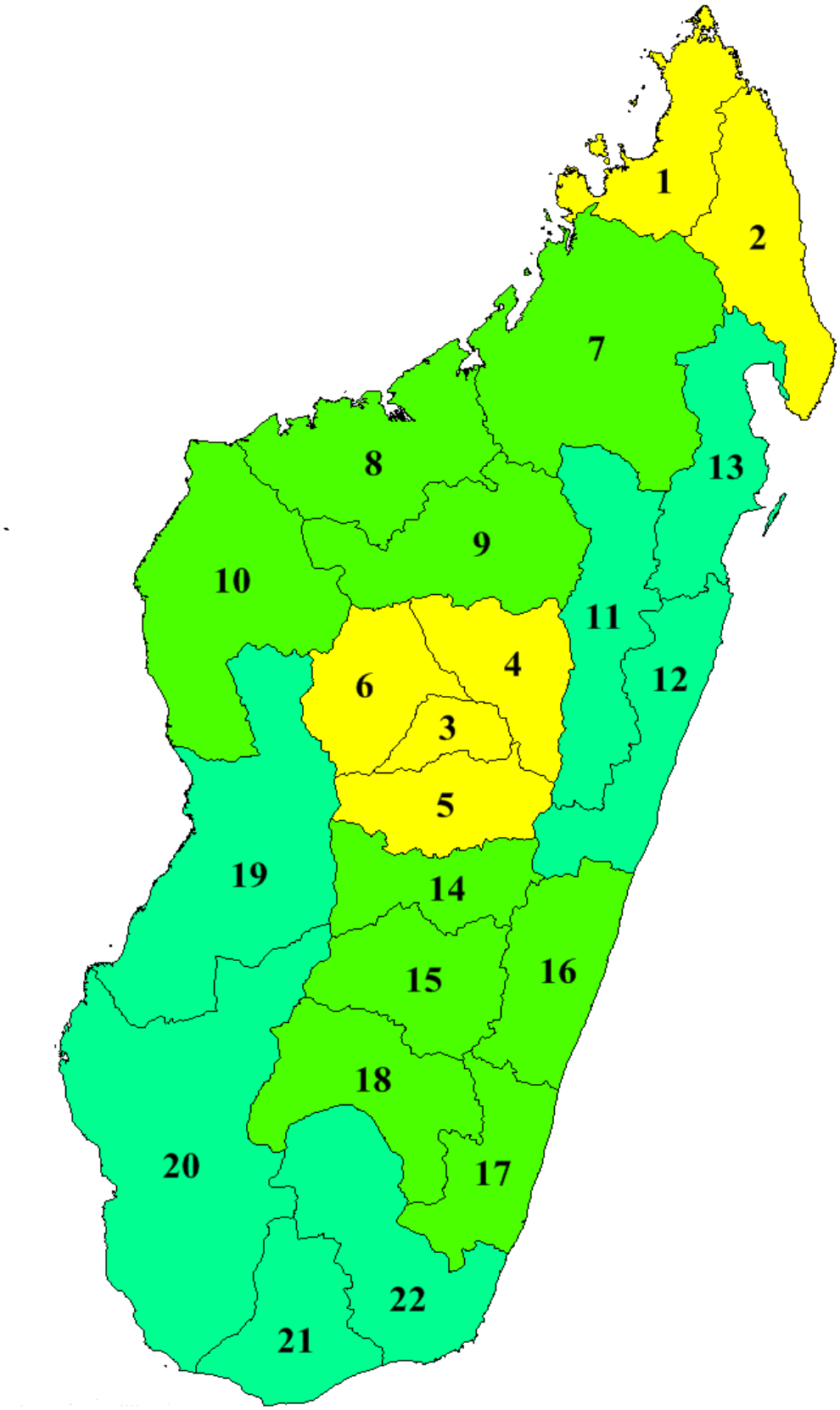

Figure 1. Map of Madagascar. Numbers denote regions and colors denote provinces. (Source: Per Johansson/Wikimedia Commons). Adapted from (Bellemare, 2012).

The dependent variable for this study is defined based on the self-reported hungry period encountered by the respective sample households. This dependent variable is a dummy variable taking a value of one if the farmer is food insecure, which is the number of hungry periods in months is greater than zero (>0), and food secure taking a value of zero if the reported hungry period is zero . According to Bellemare and Novak (2017), the analysis of the same data showed that the average reported duration of the hungry season that is the number of months during which members of the household go without three meals per day, was their proxy for food insecurity. Description of variables used in the analyses is depicted in Table 1.

Table1. Description of Variables

Variable Name	Definition
Food insecurity	It is a dependent variable having a value of one if the duration of the hungry period in months is greater than zero (>0) and zero otherwise.
Age	It is defined as the age of the household in years.
Household size	It is defined as the total number of household members
Years of education	It is defined as years of education of the household.
Single	It refers to if the household head is single or not married. It is a dummy variable assuming a value of one if the household head is not married and zero otherwise.
Informal financial loan	It is defined as a loan borrowed from informal financial institutions or local money lenders. It assumes a value of one if borrowed and zero otherwise.
Ownership of plow	It refers to the household's ownership of a plow. It has a value of one if a household owns a plow and zero otherwise.
Farming experience	It is the household's years of independent agricultural work experience.
Member of farmers' organization	It represents whether a household head is a member of a farmers' organization or not. It has a value of one if the head is a member and zero otherwise.
Sickness of household	It is a dummy variable assuming a value of one if a household member is ill and zero if not.
Weather shock	It is a dummy variable having a value of one if a household encountered weather shock and zero otherwise.
Price Shock	It is a dummy variable having a value of one if a household faced price shock and zero if not.
Crop disease	It is a dummy variable having a value of one if a household's crops are affected by diseases and zero otherwise.
Assets per adult equivalent	It refers to total assets per adult equivalent in '00,000 Ariary.
Log of total income	It refers to the log of the total income of the household in '00,000 Ariary.
Participation in contract farming	It is a dummy variable with a value of one if a household participated in contract farming and zero otherwise.

For the analysis, 1,178 observations were used. Based on the analysis of the sample data, the mean value of each continuous variable with its respective value is as follows: age in years (43.4), household size (5.7), household head independent farming experience in years (20.4), years of education (6.0), assets per adult equivalent in Ariary (480,000) and total income in Ariary (231,000,000). Out of 1,178 respondents, 1,045 (88.7%) were found to be food insecure. 11.5% of respondents were single. Whereas 209 (17.7%) of 1,178 respondents borrowed money from informal financial institutions and the remaining 969 (82.3%) did not. 254 (21.6%) out of 1,178 households were members of farmers' organization. 331(28.1%) of households encountered illness, 386(32.8) price shocks, 592(50.3%) crop diseases, and 802(68.1%) households had weather shocks. Out of 1,178 respondents, 481 (40.8%) owned a plow. 579 (49.2%) households were participants of contract farming. For further information, the summary of the descriptive statistics of the continuous variables and binary variables are depicted in Tables 2 and 3, respectively.

Table 2. Descriptive statistics of continuous variables(N=1178)

Variable	Mean	Median	Std.Dev	Maximum	Minimum
Age	43.4	42.0	12.4	88.0	19.0
Household size (number)	5.7	5.0	2.3	20.0	1.0
Farming experience (year)	20.4	20.0	12.7	68.0	0.0
Years of education	6.0	6.0	3.4	16.0	0.0
Assets per adult equivalent ('00,000)	4.8	1.9	8.7	95.8	0.0
Total income ('00,000)	23.1	9.6	54.3	1193.7	4.0

Table 3. Frequency Table of binary variables (N=1178)

Variable	Definition	Frequency	%
Food insecurity	food insecurity=1 if the duration of the hungry period is greater than zero (> 0)	1045	88.7
Single	=1 if not married	136	11.5
Informal financial loan	=1 if borrowed	209	17.7
Member of farmers organization	=1 if member	254	21.6
Sickness of household	=1 if the household is sick	331	28.1
Ownership of plow	=1 if owns	481	40.8
Price Shock	=1 if yes	386	32.8
Crop disease	=1 if yes	592	50.3
Weather shock	=1 if yes	802	68.1
Participation in contract farming	=1 if participated	579	49.2

The mean age of food insecure and food secure households were about 43 and 45 years, respectively, and there is no statistical difference in age between the two groups. The average household size of food insecure respondents was 5.7 persons while for food secure household it was 5.3. The observed difference between the two groups is statistically significant at 10% probability level. The average years of education of food insecure households was about 5.9 and that of food secure was 7.0, which is statistically significant at 1% level of significance. The mean difference between households not married (single) was significant at 10% level between the two groups. Similarly, the mean difference between households' participation in contract farming was significant at 10% between the food insecure and food secure households.

The means of the loans from informal financial institutions, assets ownership to plough the land, shocks from crop diseases, assets per adult equivalent, and total income of household were significantly different between the two groups (food insecure and secure) at 1% probability level, while households' membership to farmers' organization and shocks from illness of household members and weather were statistically significant at 5% probability levels between the food insecure and food secure households.

However, variables, namely household experience in agriculture, and shocks due to prices were not statistically significant between those food insecure and food secure households. The details of the comparison between the food insecure and food secure groups are depicted in Table 4.

Table 4. Mean comparison by group category (food security status)

Variables	Food security status		Significance
	Insecure (1)	Secure (0)	Level
Age	43.254	44.519	0.270
	(0.380)	(1.177)	
Household size	5.723	5.331	0.066*
	(0.072)	(0.196)	
Years of education	5.860	7.000	0.000***
	(0.102)	(0.317)	
Single	0.109	0.165	0.056*
	(0.010)	(0.032)	
Informal financial loan	0.194	0.045	<.000***
	(0.012)	(0.018)	
Farming experience	20.155	22.000	0.114
	(0.389)	(1.161)	
Membership of farmers organization	0.205	0.301	0.011**
	(0.013)	(0.040)	
Sickness of household	0.292	0.196	0.020**
	(0.014)	(0.035)	
Ownership of plough	0.392	0.534	0.002***
	(0.015)	(0.043)	
Price Shock	0.328	0.323	0.909
	(0.015)	(0.041)	
Crop disease	0.518	0.384	0.004***
	(0.016)	(0.042)	
Assets per adult equivalent	4.008	10.891	0.000***
	(0.205)	(1.464)	
Total income	1858.0	5823.6	0.000***
	(105.1)	(1089.9)	
Participation in contract farming	0.482	0.564	0.076*
	(0.016)	(0.043)	
Weather shock	0.691	0.602	0.037**
	(0.014)	(0.043)	

N.B. Standard errors are indicated in parentheses.
***, ** and * indicates significant at 1 %, 5% and 10% probability levels, respectively.

4. THE ECONOMETRIC MODEL

Farmers level of food security status is influenced by a complex set of socio-economic, demographic, institutional and biophysical factors. In the studies involving response (dependent) variable, which is dichotomous taking two values, in this case for food insecure household one (1) and zero (0) for food secure ones. Estimation of this type of relationship requires the use of qualitative response models. In this regard, the linear probability model (LPM) is the possible alternative. In LPM, the dichotomous dependent variable is expressed as a linear function of the explanatory variables. Although one can estimate LPM by the standard Ordinary Least Squares (OLS) method as a mechanical routine, the results will be beset by several problems (Aldrich and Nelson, 1990). The OLS regression technique, when the dependent variable is binary (0,1), produces parameter estimates that are inefficient and a heteroscedastic error structure. Consequently, hypothesis testing and construction of confidence interval become inaccurate and misleading. Likewise, a linear probability model may generate predicted values outside the 0–1 interval, which violate the basic tenets of probability.

Nevertheless, it is commonly argued that although significance tests in multiple regression are inaccurate when the dependent variable is binary, the parameter estimates are unbiased (Aldrich & Nelson, 1984). For example, Pindyck and Rubinfeld (1981) argue that “the signs (and frequently the relative magnitude) of the estimated parameters obtained from linear probability models and the maximum likelihood logit estimators are usually the same.” This provides an additional rationalization for the use of the linear probability

model." Also, many textbooks describe the linear probability model as a good modeling technique for the case of a binary dependent variable (e.g., Cohen and Cohen, 1983). Although the OLS estimator is still unbiased, the conventional formula for estimating the standard errors, and hence the t-values, will be wrong. The easiest way of solving this problem is to obtain estimates of the standard errors that are robust to heteroskedasticity.

The other problem with LPM is that, because the residual can only take two values, it cannot be normally distributed. The problem of non-normality means that OLS point estimates are unbiased but its violation does mean that inference in small samples cannot be based on the usual suite of normality-based distributions such as the t-test. This is not an issue in this study as the sample size (1,178) is large enough to address this problem.

However, LPM is more straightforward to interpret as compared to logit and probit models. LPM remains a reasonably popular modeling framework (Miguel, Satyanath, and Sergenti, 2004) because certain econometric problems are easier to address within the LPM framework than with probits and logits. If we use the LPM, it is important to recognize that it tends to give better estimates of the partial effects on the response probability near the center of the distribution than at extreme values (i.e. close to 0 and 1).

Hence, for the analysis of data in this research, LPM was employed, with the maximum care in the choice of explanatory variables and minimizing the expected problems. However, for the sake of robustness, the parameter estimates using logit and probit models were also done.

4.1. The Linear Probability Model (LPM)

In this model, the linear regression model is written as follows:

P (y = 1) =β_0 + $\beta_1 X_1$ + $\beta_2 X_2$ + - - - + $\beta_n X_n$ + ε

where y is defined as a dummy variable with a value of 1 for food insecure households and zero for food secure households, $\beta_i{}'$s are parameters to be estimated, $X_i' s$ are control variables, and ε is an error term with a mean of zero.

4.2. Working Hypothesis and Definitions of Variables

Based on the literature review and my personal experiences, the main socioeconomic, demographic, biophysical and institutional factors hypothesized to influence the food security situation of rural farmers are described below.

Dependent variable food insecurity: Is a dummy variable taking a value of one if the reported duration of the hungry period by a household is greater than zero (>0) and equal to zero if the duration of the hungry period is zero. According to Bellemare and Novak (2017), the analysis of the same data showed that the average reported duration of the hungry season—the number of months during which members of the household go without three meals per day, that is, their proxy for food insecurity—for the households in the sample was 3.7 months for households that do not participate in contract farming, versus 3.3 months for households that do participate. Hence, for this study, the categorization of farmers into food secure and insecure groups is based on the self-reported response of respondents in the hungry period.

Hungry period (season) is defined as the period from October to March where, in normal years 75% of farming households lack sufficient food to feed their families and spend on average 3.8 months without sufficient food. The food pressure is most acute in the months immediately prior to main rice harvest at the beginning of the rainy season (Harvey *et al*.; 2014). The question asked on the survey was "How many months did you experience food shortages during the last hungry season?"

Age: Is defined as the age of the head of household in years. Older people have relatively richer experiences of the social and physical environments, as well as the greater experience of farming activities (Haile *et al*., 2005). That is, when heads get older, they are expected to have a stable economy in farming. Moreover, older household heads are expected to have better access to land than younger heads because younger men either have to wait for land redistribution or have to share the land with their families. However, Babatunde *et.al*. (2007) and other related studies stated that younger heads of households were stronger and were expected to cultivate larger-size farms than older heads. Hence, the expected effect of age on food insecurity could be positive or negative.

Household size: Is defined as the total number of household members. Increasing family size tends to exert more pressure on consumption than the labor it contributes to production. Hence, the larger the household is hypothesized to have a negative effect on food security.

Years of education: Is defined as years of education of the head of the household. Education is a social capital, which could impact positively on the household ability to make good and well-informed decisions on production and nutritional status (Babatunde *et al*., 2007). Based on Amaza *et al*. (2006) and other literature, the higher the educational level of household head, the more food secure the household is expected to be. Therefore, more education is expected to have the negative effect on food insecurity.

Single: Refers to household heads who are single or not married. It is a dummy variable assuming a value of one if the household head is not married and zero otherwise. Being single is expected to have a negative relation to food insecurity.

Informal financial loan: Is defined as loans borrowed from informal financial institutions or local money lenders. It excludes money borrowed from banks and micro-financing institutions. It is a dummy variable with the value of one if borrowed and zero otherwise. Borrowing is expected to have a positive relation to food security.

Ownership of plow: Refers to a household's ownership of a plow. It is a dummy variable with a value of one if a household owns a plow and zero otherwise. Owning a plow is expected to have a positive correlation to food security.

Farming experience: Refers to household's years of independent agricultural work experience. More farming experience is expected to be positively related to food security.

Membership of farmers' organization: Represents whether a household head is a member of a farmers' organization or not. It has a value of one if the head is a member and zero otherwise. Households that are members of farmer organizations have better access to extension services than nonmember farmers because of a chance of frequent contact with extension agents. Hence, membership in a farmers' organization is expected to be positively related to food security.

The sickness of household: Is a dummy variable assuming a value of one if a household member is ill or zero if not. Having been ill is hypothesized to have a negative correlation with food security**.**

Weather shock: Is defined as short term weather variability in terms of unexpected heavy rainfall accompanied by flooding, storms, unusual increase in temperature, very erratic rainfall patterns, and extreme weather events particularly cyclones affecting the agricultural production as well as human life in the last year before the survey. From November to May, cyclone season makes an appearance in different parts of Madagascar causing widespread flooding damaging infrastructure, destroying crops and often times leaving an area of food insecurity in its path (World Bank, 2015). Weather shock is a dummy variable having a value of one if a household encountered weather shock and zero otherwise. Weather shock is expected to be negatively related to food security.

Price shock: Is defined as unusual increase in the market prices of staple cereals such as rice, maize and wheat during lean period before the harvest being encountered by the

farmers. Market price is a dummy variable having a value of one if a household faced price shock and zero otherwise. It is expected to be negatively related to food security.

Crop disease: Is a dummy variable having a value of one if a household's crops are affected by diseases and zero otherwise. Crop disease is expected to be negatively related to food security.

Assets per adult equivalent: Refers to total assets per adult equivalent in 100,000 Ariary**.** This variable was calculated by dividing total assets of each household's in Ariary by respective adult equivalent. For this purpose, a household's total number of adult equivalents was calculated by considering each family member under 15 as 0.5 adult, each person between the ages of 15 and 65 as one adult, and each individual over 65 as 0.75 adults (Deaton, 1997). Assets per adult equivalent is expected to have a positive relation to food security.

Log of total income: Refers to the log of the total income of the household in 100,000 Ariary. Log of total income is hypothesized to have a positive relation to food security.

Participation in contract farming: Based on Eaton and Shepherd (2001), contract farming is defined as "an agreement between farmers and processing and/or marketing firms for the production and supply of agricultural products under forward agreements, frequently at predetermined prices. The arrangement also invariably involves the purchaser

in providing a degree of production support through, for example, the supply of inputs and the provision of technical advice. The basis of such arrangements is a commitment on the part of the farmer to provide a specific commodity in quantities and at quality standards determined by the purchaser and a commitment on the part of the company to support the farmer's production and to purchase the commodity."

The same source indicated that intensity of the contractual arrangement varies according to the depth and complexity of the provisions in each of the following three areas:

- Market provision: The grower and buyer agree to terms and conditions for the future sale and purchase of a crop or livestock product;
- Resource provision: In conjunction with the marketing arrangements the buyer agrees to supply selected inputs, including on occasions land preparation and technical advice;
- Management specifications: The grower agrees to follow recommended production methods, inputs regimes, and cultivation and harvesting specifications.

This variable, participation in contract farming, is important to see whether participation in contract farming is related to the food security of households or not. Participation in contract farming is a dummy variable having a value of one if a household participated in contract farming and zero if not. Participation in contract farming is expected to have a positive relation to food security.

5. Results and Discussion

The model results confirm the a priori expectation that food security is affected by several factors. The overall fitness of the model is significant at less than 1% probability level. Further diagnostics including interaction terms of dummy variables also revealed that the test for the association between pairs of the dummies that the overall global test of the null hypotheses (all coefficients equal to zero) is accepted and the test was not significant. For comparing purposes of the results of LPM of the original variables with the same model with the interaction terms of dummies and the quadratic terms of age of household and household farming experiences (continuous variables), the regression results are depicted in Table 7.

5.1. The Linear Probability Model Results

The model results of the estimated parameters employing linear probability model are depicted in the following Tables, namely Table 5 and Table 6 depicting parameter estimates with clustered standard error at the village level and with heteroscedasticity consistent standard errors, respectively.

Table 5. Parameter estimates of linear probability model with clustered standard error at village level

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	0.921	0.046	20.01	<.000
Age	0.003**	0.001	2.35	0.019
Household size	0.008**	0.004	2.05	0.040
Years of education	-0.005	0.003	-1.55	0.120
Single	-0.069**	0.031	-2.24	0.025
Informal financial loan	-0.092***	0.017	5.37	<.000
Farming experience	-0.004***	0.001	-3.38	0.000
Membership of farmers organization	-0.015	0.023	-0.66	0.510
Sickness of household	0.038**	0.018	2.14	0.032
Ownership of plow	-0.007	0.022	0.31	0.759
Price Shock	0.003	0.019	-0.17	0.865
Crop disease	0.034*	0.018	1.84	0.065
Assets per adult equivalent	-0.005***	0.002	-3.04	0.002
Log of total income	-0.063***	0.009	-6.73	<.000
Participation in contract farming	-0.008	0.018	0.45	0.651
Weather shock	0.049**	0.020	2.41	0.016
R-squared	0.143			

N.B. Number of observations =1178

***, ** and * indicates significant at 1%, 5% and 10% probability levels, respectively.

Table 6. Parameter estimates of linear probability model with heteroscedasticity consistent standard error

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Heteroscedasticity Consistent		
					Standard Error	t Value	Pr > |t|
Intercept	0.921	0.047	19.59	<.000	0.046	20.14	<.000
Age	0.003**	0.001	2.30	0.022	0.001	2.36	0.018
Household size	0.008**	0.004	2.02	0.044	0.004	2.07	0.039
Years of education	-0.005	0.00287	-1.61	0.108	0.003	-1.57	0.118
Single	-0.069**	0.029	-2.42	0.016	0.031	-2.25	0.024
Informal financial loan	-0.092***	0.023	3.93	<.000	0.017	5.41	<.000
Farming experience	-0.004***	0.001	-3.15	0.002	0.001	-3.41	0.000
Membership of farmers org	-0.015	0.021	-0.70	0.482	0.023	-0.66	0.507
Sickness of household	0.038**	0.019	1.97	0.049	0.018	2.15	0.032
Ownership of plow	-0.007	0.020	0.33	0.744	0.021	0.31	0.758
Price shock	0.003	0.019	-0.17	0.866	0.019	-0.17	0.864
Crop disease	0.034*	0.018	1.87	0.062	0.018	1.86	0.064
Assets per adult equivalent	-0.005***	0.001	-3.99	<.000	0.002	-3.06	0.002
Log of total income	-0.063***	0.009	-7.12	<.000	0.009	-6.77	<.000
Participation in contract farming	-0.008	0.018	0.45	0.653	0.018	0.46	0.649
Weather shock	0.049**	0.019	2.53	0.012	0.020	2.42	0.016
R-squared	0.143						

N.B. Number of observations =1178

***, ** and * indicates significant at 1%, 5% and 10% probability levels, respectively.

Table 5 and 6 show the signs, magnitudes, and statistical significance of the estimated parameters by linear probability model with the clustered standard errors at the village level and with heteroscedasticity consistent standard errors, respectively. Comparing the results of the two Tables, of the fifteen proposed explanatory variables to explain food security status of farmers, ten variables were significant based on Table 5. Similarly, Table 6 depicts that the same number and kind of significant variables were estimated.

The results of the model estimates are discussed as follows:

Household head characteristics

Among household head characteristics hypothesized to determine food security of respondents, the farming experience of the household head was significant at 1% probability level. Whereas age, household size, and variable single (household head not married) were all significant at 5% level of significance.

Household head wealth and income

Out of the variables considered under this category, informal financial loan, the log of total income and assets per adult equivalent were significant at 1% probability level.

Shocks

Out of the hypothesized shocks to influence the food security situations of a household, sickness of household and weather shocks were found to be significant at 5% probability level, while shocks due to crop diseases was significant at 10% level of significance.

5.2. Discussion of the Marginal Effects

In the linear probability model, the marginal effect for each explanatory variable would be its coefficient (Table 5 and 6).

Household head characteristics

Table 5 and 6 shows that other things being equal, an increase of household head age by one-year was associated with about 0.3%-point increase in the probability of food insecurity; an increase of household size by one person was related to an increase of the probability of food insecurity by about 0.8%-point. One-year increase of a household's independent farming experience was correlated with about 0.4%-point decrease in the probability of food insecurity; and unmarried household head (single) was associated with the decrease in the probability of food insecurity by about 7%, other things held constant.

Household head wealth and income

Other things held constant, borrowing money from informal financial institutions was correlated with about 9%-point increase in the probability of food security. Also, other things being equal, an increase of total assets per adult equivalent by 100,000 Ariary was associated with a decrease of the probability of household food insecurity by about 0.5%-points. Similarly, an increase of the log of the total income of household by 100,000 Ariary was related to a decrease of the probability of food insecurity by about 6.3%-points, ceteris paribus.

Shocks

The shocks caused by the sickness of the household member and crop diseases were associated with an increase of the probability of food insecurity by about 3.8%- and 3.4%-points, respectively, other factors kept constant. While the incidence of weather shock was related with an increase of the chance of the household to become food insecure by about 4.9%-points, other factors held constant.

The most important explanatory variables affecting the food insecurity of households, in order of importance from the highest to the lowest, are found to be borrowing money from informal financial institutions, households being unmarried (single), log of total income of the household, shocks encountered due weather conditions, sickness of household, crop diseases, household size, assets per adult equivalent, farming experience and age of the household, respectively.

For the sake of comparison, the LPM parameter estimates of the dummy variables with the interaction terms, and the quadratic terms of two continuous variables—the age of household and household farming experiences—were portrayed in Table 7. As it is evident from Table 7, the number of total significant variables were reduced to nine from 10 compared to the LPM estimates of original variables with no interaction and quadratic terms, depicted in Table 5 and 6.

Furthermore, for comparison purposes of the results of LPM estimates to other binary choice models, the regression results of the logit and probit models are presented.

The regression results of the logistics regression model in Table 8, shows that the explanatory variables such as loans from informal financial institutions, household's independent farming experience, the log of total household income, and shocks induced by weather were significant at 1% probability level. Whereas, the age of household, household size, household head single or not married, sickness of household, and shocks due to crops diseases were significant at 5% probability level. Finally, one explanatory variable viz, years of education of household was significant at 10 %.

Likewise, the results of the analyses, employing the probit model revealed that the same explanatory variables as that of logistics regression model were significant at the same probability levels, except years of education of household, which was significant in probit model at 5%. For further information, refer to Table 9 below.

Table 7. Parameter estimates of LPM with the squares of age and farming experience, and interaction terms of dummies

Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|	Heteroscedasticity Consistent		
					Standard Error	t Value	Pr > |t|
Intercept	0.756	0.117	6.46	<.000	0.114	6.64	<.000
Age	0.013**	0.006	2.16	0.031	0.006	2.23	0.026
Age square	0.000*	0.000	-1.71	0.088	0.000	-1.72	0.085
Household size	0.007	0.004	1.52	0.129	0.004	1.55	0.1222
Years of education	-0.005*	0.003	-1.85	0.065	0.003	-1.82	0.069
Single	-0.131*	0.051	-2.55	0.011	0.067	-1.91	0.056
Informal financial loan	-0.156***	0.059	2.66	0.008	0.048	3.25	0.001
Farming experience	-0.008***	0.003	-2.46	0.014	0.003	-2.91	0.004
Farming experience square	0.000	0.000	1.34	0.182	0.000	1.45	0.148
Membership of farmers organization	-0.040	0.029	-1.35	0.179	0.030	-1.31	0.190
Sickness of household	0.042	0.042	0.99	0.323	0.0442	0.95	0.345
Ownership of plough	-0.018	0.025	-0.71	0.478	0.026	-0.68	0.494
Price Shock	0.029	0.026	-1.09	0.275	0.025	-1.14	0.256
Crop disease	0.016	0.035	0.46	0.644	0.038	0.42	0.671
Assets per adult equivalent	-0.005***	0.001	-4.30	<.000	0.002	-3.31	0.001
Log of total income	-0.060***	0.009	-6.69	<.000	0.009	-6.40	<.000
Participation in contract farming	-0.011	0.018	0.59	0.553	0.018	0.61	0.542
Weather shock	0.034	0.030	1.14	0.253	0.031	1.08	0.282
Single*informal loan	-0.005	0.083	-0.06	0.951	0.040	-0.13	0.899
Single*household sick	0.030	0.062	0.49	0.624	0.052	0.58	0.561
Single*crop disease	-0.091	0.061	-1.49	0.137	0.064	-1.43	0.153
Single*weather shock	0.107	0.062	1.73	0.084	0.073	1.48	0.140
Informal loan*household sick	-0.022	0.049	-0.44	0.657	0.033	-0.66	0.509
Informal loan*crop disease	-0.068*	0.047	-1.46	0.145	0.035	-1.93	0.054
Informal loan*weather shock	-0.029	0.059	-0.50	0.618	0.047	-0.62	0.532
Household sick*crop disease	0.032	0.040	0.81	0.418	0.039	0.83	0.404
Household sick*weather shock	-0.032	0.043	-0.75	0.455	0.042	-0.76	0.448
Crop disease*weather shock	0.038	0.039	0.97	0.331	0.042	0.91	0.362
Member of farmers org*owner of plow	0.046	0.042	1.07	0.287	0.047	0.97	0.333
Single*price shock	0.086	0.065	1.33	0.184	0.060	1.43	0.153
Owner of plough*price shock	0.047	0.038	1.25	0.212	0.040	1.20	0.229

N.B. ***, ** and * indicates significant at 1%, 5% and 10% probability levels, respectively. N=1178

Table 8. Logit model maximum likelihood parameter estimates

Variable	Estimate	Standard Error	Odds Ratio	Wald Chi-Sq	Pr > ChiSq
Age	0.037**	0.017	1.038	5.000	0.025
Household size	0.129**	0.051	1.137	6.319	0.012
Years of education	-0.061*	0.034	0.941	3.284	0.070
Single	-0.763**	0.314	0.467	5.88	0.015
Informal financial loan	-1.614***	0.442	5.024	13.327	0.000
Farming experience	-0.050***	0.016	0.952	9.129	0.003
Membership of farmers organization	-0.125	0.237	0.883	0.278	0.598
Sickness of household	0.533**	0.254	1.703	4.408	0.036
Ownership of plow	-0.065	0.239	0.937	0.074	0.785
Price Shock	0.046	0.231	0.955	0.040	0.841
Crop disease	0.435**	0.212	1.544	4.220	0.040
Assets per adult equivalent	-0.011	0.011	0.989	1.085	0.298
Log of total income	-0.837***	0.115	0.433	52.722	<.000
Participation in contract farming	-0.006	0.216	0.994	0.000	0.979
Weather shock	0.668***	0.225	1.951	8.787	0.003
Constant	2.761	0.594	0.000	21.582	<.000

N.B. Chi-square value = 123.1280***

***, ** and * indicates significant at 1%, 5% and 10% probability levels, respectively.

Number of observations = 1178

Table 9-Probit model maximum likelihood parameter estimates

Variable	Estimate	Standard Error	95% Confidence Limits		Chi-Square	Pr > ChiSq
Age	0.020**	0.009	0.004	0.037	5.65	0.017
Household size	0.068**	0.027	0.015	0.121	6.32	0.012
Years of education	-0.036**	0.018	-0.072	-0.001	3.96	0.047
Single	-0.413**	0.172	-0.751	-0.076	5.77	0.016
Informal financial loan	-0.816***	0.208	0.409	1.223	15.41	<.000
Farming experience	-0.028***	0.009	-0.044	-0.011	10.17	0.001
Membership of farmers organization	-0.062	0.129	-0.315	0.192	0.23	0.634
Sickness of household	0.273**	0.132	0.014	0.533	4.26	0.039
Ownership of plow	-0.049	0.127	-0.297	0.199	0.15	0.697
Price Shock	0.041	0.123	-0.283	0.200	0.11	0.738
Crop disease	0.240**	0.113	0.018	0.461	4.48	0.034
Assets per adult equivalent	-0.007	0.006	-0.019	0.006	1.17	0.280
Log of total income	-0.455***	0.063	-0.577	-0.332	52.66	<.000
Participation in contract farming	0.000	0.115	-0.225	0.226	0.00	0.994
Weather shock	0.324***	0.120	0.089	0.560	7.30	0.007
Constant	1.630	0.314	1.015	2.244	27.03	<.000

N.B. Number of observations =1178
Log Likelihood = -329.095
*** and ** indicates significant at 1% and 5% probability levels, respectively.

6. SUMMARY AND POLICY IMPLICATIONS

This study was intended to identify and analyze the factors influencing the food security of farmers in Madagascar. The main objective was to analyze which, how and how much the hypothesized explanatory variables were related to the food security status of households.

The data used for this study covers six regions of Madagascar. The dataset has 1,178 observations and 158 variables. For the analysis, the linear probability model was employed to investigate the most important explanatory variables affecting households' food security. Also, for the sake of robustness, the logit and the probit models were used to estimate the parameters.

Results of the linear probability model estimation show that among fifteen explanatory variables, which were hypothesized to influence food security, ten were statistically significant while the remaining five were less powerful in explaining or did not explain the variation in the dependent variable. The significant explanatory variables at 1% probability level include: loans from informal financial institutions, household's independent farm experience, total assets per adult equivalent, and the log of total household income. The significant explanatory variables at 5% probability level include: age of household, household size, single or unmarried household head, sickness of household, and shocks caused by weather conditions. While, shocks due to crops diseases was significant at 10%. The estimates of both logit and probit models showed that among others, the variable years of education of the household head was significant, though they revealed that assets per adult equivalent was not significant.

The findings of this study indicate that any plan for intervention in reducing household food insecurity should recognize those significant influencing factors. In this respect, targeting educated farmers with rich farming experiences to promote new farming technologies, such as selected seed varieties, fertilizer, pesticides and modern plow, will help to increase agricultural production and thereby reduce food insecurity. Especially, having experience with education as a social capital could positively impact the household's ability to make good and well-informed decisions on production and nutritional status (Babatunde *et al*., 2007 and Amaza *et al*., 2006). Therefore, policymakers can target those farmers who have experience in farming and education in designing appropriate strategies or projects to reduce food insecurity.

The results of the study also revealed that farmers' log of total income, total income from assets per adult equivalent and informal financial loan were inversely related to food insecurity. Hence, extension workers and policymakers should focus on designing programs and strategies to build the culture of saving through involving farmers in saving and credit schemes and other appropriate mechanisms which enhance the accumulation of wealth to bridge the gaps of hungry periods.

Age of household is positively related to food insecurity. The possible explanation is that as the household is getting older, she/he becomes weaker and less able to contribute power/labor to agriculture. This is supported by Babatunde *et al.* (2007), which stated that young heads of household were stronger and expected to cultivate larger-size farms than older heads. Hence, careful consideration of this variable is required in decision making.

Household size has a direct and negative relationship to food security status of the household. As expected, increasing family size tends to exert more pressure on consumption than the labor it contributes to production. Hence, it is better if food security interventions are integrated with family planning, health extension services, and awareness creation to reduce population growth.

In conclusion, improving smallholder farmers food security calls for enhancing farmers' production through utilization of improved farming practices, increasing access to credit and safety nets, monitoring shocks caused by weather conditions, crops diseases, and human diseases and preparedness to combat catastrophic events.

Finally, this study is conducted considering the limitation of incomplete information on the coping strategies of households.

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