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An Analysis of The Impact of Agro-Ecological Zones on The Influence of The Key Factors That Affect Food Security: The Case of The Embu County in Kenya

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Abstract— **This paper is based on the results of a study that was carried out to determine the impact of agro-ecological zones (AEZs) on the influence of the key factors that affect household food security through a case study in the Embu County of Kenya. The Embu County was chosen for a case study because it is endowed with most of the various types of AEZs found in Kenya. The three agro-ecological zones covered in the case study were the Sunflower-Zone (UM 4 and LM 3), the Coffee Zone (UM 1-3) and the Tea Zone (LH 1-2), based on [1] categorization of the AEZs in Kenya. The study analyzed and evaluated the food security data collected from 384 farm-households which had randomly been selected from the three AEZs in the Embu County using a 4-stage cluster sampling method. Household caloric acquisition method was used to compute a household food security index (HFSI) that was used to measure the household food security status. Previous studies had established that the key factors that influence food security in Kenya include farm size, access to and use of modern technologies in farming, access to agricultural extension services, farm household size, age and education level (literacy) for the head of household and household dependency ratio. This study found that the AEZs had a significant impact on the effects of the key factors that influence household food security in Kenya. The effect of farm size on food security was found to be positive in the Sunflower and Tea zones, but not in the Coffee Zone. Technology adoption was found to have a significant effect on food security in the Sunflower and Coffee Zones, but not in the Tea Zone. Access to agricultural extension was found to have a significant effect on food security in the Coffee and Tea zones, but not in the Sunflower Zone. Household size was found to have a significant effect on food security in the Sunflower and Coffee zones, but not in the Tea Zone. The dependency ratio was found to have a significant effect on food security in the Coffee and Tea Zones but not in the Sunflower Zone. The age of the household head and/or wife was found to have a significant effect on food security in the Tea Zone, but not in the Coffee and Sunflower Zones. The level of education for the head of the household was found to have a significant effect on food security in the Sunflower Zone but not in the Coffee and Tea Zones. On the basis of the study findings, it is concluded that the effects of the factors that influence food security vary by the AEZs. Therefore, AEZ-specific measures are recommended to enhance household food security in different areas of Kenya.**

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Index Terms- **Agricultural extension, Agro-ecological zones, Farm size, Food security, Technology adoption.**

I. Introduction

A. World and Kenya Food Security Status

Food security exists when all people at all times have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life [2]. As such, food insecurity or undernourishment is said to exist when people's calorie intake is below the minimum dietary energy requirement. The number of undernourished people in the world is estimated at 795 million with about 780 million (98%) of these people living in the developing countries [3]. Of the nearly 780 million people who are undernourished and live in the developing countries, about 220 million of them are found in Sub-Saharan Africa [3].

Since the 1980s, there has been a concerted effort to fight food insecurity in the world. For the first time in the global agenda, the World Food Summit (WFS) held in 1996 set a global target to address food insecurity in the world. The WFS target was to reduce the absolute number of undernourished people to half the 1996 level (say about 800 million people) by 2015 [4]. The WFS commitments were reinforced by the resolutions of the UN Millennium Summit that was held in 2000 and which also set a target of reducing by half the proportion of people who suffer from hunger in the period between 1990 and 2015 [2]. The UN Millennium Summit target on food insecurity formed part of the eight millennium development goals (MDGs).

In Kenya, it is estimated that over 10 million people (which is about 25% of the country's population) suffer from chronic food insecurity and malnutrition, and an estimated 1.5 million of them require emergency food assistance annually [5,6]. To reduce food insecurity in Kenya, the Government of Kenya (GOK) has instituted a number of legal, institutional and policy reforms in the country. Article 43(1c) of the Kenyan Constitution guarantees individuals a right to adequate food of acceptable quality [7]. The policy reforms aimed at addressing food insecurity include National Food Policies of 1981 and 1994, National Plan of Action on Nutrition of 1994 and the National Food and Nutrition Security Policy of 2011 [5]. Kenya is also a member of the Famine Early Warning Systems Network (FEWS-NET) which was established in 1985 by the United States Agency for International

Development (USAID) to monitor and assess food insecurity in the world.

B. Problem Statement

Food insecurity is still rampant despite the concerted efforts that have been made to fight it at both the global and national levels. About 23% of the total population in Sub-Saharan Africa still suffers from undernourishment [3] while about 25% of Kenya's population is undernourished with about 15% of them requiring emergency food assistance annually [5]. Kenya's strategies to address food insecurity are broad-based and their implementation would benefit from reliable and research-based information on food security that is specific to a particular agro-ecological zone. Much of the research done on food security has not focused on the impact of agro-ecological zones (AEZs) on the effects of the major factors that influence food security, and this is the knowledge gap that this study attempted to fill.

Agro-Ecological Zoning refers to the division of an area of land into smaller units, which have similar characteristics that are related to land suitability, potential production and environmental impact [8]. An Agro-ecological Zone (AEZ) is thus a land resource mapping unit, defined in terms of climate, landform and soils, and/or land cover, and having a specific range of potentials and constraints for land use [8]. The agricultural land in Kenya is classified into zone groups based on maximum temperature limits and water requirements within which the main crops grown in Kenya can flourish [1]. The lowland (LL) zones are based on cashew and coconut production, the lower midlands (LM) zones are based on cotton, sunflower and sugarcane production, while the upper midland (UM) zones are based on tea and coffee production. The low highlands (LH) zones are based on tea production, while the upper highlands (UH) zones are based on pyrethrum production. Many other types of crops could be produced in each of the given zones, depending on a particular crop's agro-ecological suitability.

C. Objectives of the Study

The study attempted to identify the major factors that influence household food security in Kenya and then analyzed how the effects of these factors on food security vary across different agro-ecological zones (AEZs), by examining the situation in the Embu County of Kenya. The Embu County was chosen as the case study area because the county is endowed with most of the agro-ecological zones in Kenya, right from the Upper Highland (UH) and Upper Midland (UM) Zones to Low Midland (LM) and Low Land (LL) Zones following categorization of the AEZs in Kenya [1]. Further, Embu County is among the most densely populated areas in Kenya. Thus the case study in Embu County was not only expected to bring in the AEZ factor but also the farm size factor in the study of the determinants of food security. The identification of the major or key factors that influence household food security was based on the findings from the review of previous studies (e.g.,[9],[10],[11],[12],[13],[14], [15],[16]

Based on the findings from the review of previous studies, the major or key factors that influence food security at the household level include the gender, age, education, and income of the head of the household, the household (family) size, the household dependency ratio, access to extension services, access to credit services, technology adoption and farm-size. The research gap identified through the review of the previous studies is their failure to examine the impact of agro-ecological zones (AEZs) on the effects of the major factors that affect food security. In this study, the AEZs are hypothesized to cause variations in the extent to which the factors that have been identified as influencing food security are able to impact on food security in a given AEZ. Therefore, this study attempted to contribute to knowledge by evaluating and documenting how the effects of the major factors that affect food security vary across different AEZs. The findings from this study are expected to contribute to the development of appropriate agro-ecological zone specific interventions for improving food security in Kenya.

II. RESEARCH METHODOLOGY

A. Sample Size

The data used in this study were collected from a sample comprising 384 households drawn from three AEZs: Sunflower, Coffee and Tea zones. The sample size was determined using the following formula [17]

$$N = \frac{z^2 p(1-p)}{d^2} \quad \text{(Equation 1)}$$

Where:

N = the desired sample size

Z = the standard normal deviate at the required confidence level

P = the proportion of the target population estimated to have the characteristic being measured

1-p = the proportion of the population without the characteristic being measured

d = the level of statistical significance set

The standard normal deviate was set at 1.96 which corresponds to 95% confidence level. Since there was no available estimate of the proportion of the target population with the characteristic of interest, 50% is assumed to have that characteristic. The level of statistical significance corresponding to 95% confidence level is 0.05. The sample size was therefore calculated as follows:

$$N = \frac{(1.96)^2(0.5)(1-0.5)}{(0.05)} = 384 \quad \text{(Equation 2)}$$

B. Sampling Procedure

A four-stage cluster sampling and probability proportionate to size sampling procedures were used to identify the households to be interviewed. The study first selected 4 administrative divisions from each of the three AEZs, followed by random selection of 4 administrative locations from each division. One administrative sub-location was randomly selected from each location, followed by random selection of one administrative village from each sub-location. In total 12 villages were selected. The probability proportionate to size sampling was used to determine the number of households to be interviewed in each selected village, using the following formula:

$$M = \frac{n_i}{N_V} * N \qquad \text{(Equation 3)}$$

Where:
M = number of households to be interviewed
n_i = No. of households in the i[th] village (i=1,2,3,…,12)
N_V=Total number of households in the selected villages
N= desired sample size (=384)

In total 134 households were selected for interview in the sunflower zone, 133 in coffee zone and 117 in the tea zone making a total of 384 households.

C. Data Collection

The study collected food security data during the long-rain (LR) and short rain (SR) seasons in order to capture seasonal variations in food intake. The food security data included the different types of food items taken by each of the households in the sample and their quantities, using a 7-day recall period. The data on the household socio-economic characteristics and their access to institutional services were also collected using semi-structured questionnaires.

D. Empirical Models

The study used the household caloric acquisition method based on [18] to determine the level of household food security. Household caloric acquisition is the total amount of energy (in calories) in the food acquired by the household over a defined period of time, usually 7 or 14 days [19],[20]. The caloric acquisition method measures the household food security index as a ratio of the total energy available in the food items taken by the household per day to the recommended daily energy requirement for the household. This is expressed as [16]:

$$HFSI = \frac{HDCI}{HDCR} \qquad \text{(Equation 4)}$$

Where: HFSI= household food security index
HDCI= Household daily calorie intake
HDCI= Household daily calorie requirement

In determining the household calorie acquisition for each household in the sample, the quantities of food items taken by the household were all converted into a common unit, kilograms. The food quantities were then converted into calories using the Food Composition Table provided by Technical Centre for Agricultural and Rural Cooperation/ East, Central and Southern Africa Food and Nutrition Centre [21].

To determine the household dairy energy requirement, the members of a household were categorized into their respective genders, and further into age brackets which are used by FAO [22] to provide the recommended human energy requirements. The household daily calorie requirement was determined by summing the daily energy requirements of all household members as recommended by FAO [22].

The HFSI was determined for each of the household in the sample using (4). The sample was categorized on the basis of the three agro-ecological zones (AEZS): the Sunflower, Coffee and Tea zones. The households in each AEZs were further classified into four food security categories on the basis of HFSI: low food security category (HFSI<0.5), moderately low food security (0.5 -<0.75), moderately high food security (0.75 - <1.00) and high food security (HFSI ≥1.00). To analyze the factors that significantly affect household food security in each agro-ecological zone, the four food security categories were regressed against the hypothesized explanatory variables using Multinomial Logit Regression (MLR) algorithm in the computer programme SPSS. All the four food security categories were regressed against the explanatory variables at the same time.

The multinomial logit model is a generalization of binary logit model and is based on a random utility model. The model is used to analyze relationships involving dependent variables which are classified into more than two categories [23]. The β-coefficient of the Multinomial Logit Regression indicates the contribution that an independent variable makes to change the odds (probability) of a household being in one food security category in favour or rather than the preferred category. In this study, the category of high food security (HFSI ≥1.00) was used as the preferred category. If an independent variable increases the probability of a household being in the lower food security category rather than the preferred one, the variable has a positive β-coefficient, implying a negative effect on food security. If a variable decreases the odds of a household being in the lower food security category in favour of the preferred category, then the variable has a negative β-coefficient, implying a positive effect on food security [14].

The existence of multicollinearity among the explanatory variables was ruled out through testing using the Variance Inflation Factor (VIF) for continuous variables and Contingency Coefficients (CC) for discrete variables. The following formulae were used in the tests [9],[24] :

a) $$VIF(X_i) = \frac{1}{1 - R_i^2} \qquad \text{(Equation 5)}$$

Where:
X_i = the i[th] quantitative explanatory variable regressed on the other quantitative explanatory variables
R_i^2 = the coefficient of determination when the variable X_i is regressed on other variables

As a rule of thumb, a value of VIF exceeding 10 is a signal for the existence of strong multicollinearity between continuous explanatory variables [9],[24].

b) $$CC = \sqrt{\frac{X^2}{n + X^2}} \qquad \text{(Equation 6)}$$

Where:

CC= Contingency Coefficient
X^2= a Chi-square random variable
n = total sample size.

The CC value ranges between 0 and 1 and, as a rule of thumb, a variable with Contingency Coefficient below 0.75 shows a weak multicollinearity and a value above it shows a strong one [9],[24].

III. RESULTS AND DISCUSSIONS

A. Results

Factors Affecting Household Food Security in the Sunflower Zone

Based on the results of multinomial logistic regression (MLR) analysis, the socio-economic factors that were found to significantly affect HHFSI in sunflower zone at levels of 5% and below are farm-size, household size and the adoption of tissue culture bananas. The other factors are the levels of education of the wife. The results of MLR analysis in the Sunflower Zone are given in Table 1 and discussed thereafter. Based on the MLR results given in Table 1, the following are the individual factors that significantly affect HFSI in the Sunflower Zone:

Table 1: The results of MLR analysis of factors that affect HFSI in the Sunflower Zone

	FS Categories' B-coefficients		
Independent Variables	**Low**	**Moderately Low**	**Moderately High**
Farm-size	-2.890 (0.032)*	0.466 (0.453)	-0.044 (0.957)
Distance from market	0.236 (0.231)	0.142 (0.438)	0.322 (0.057)
Wife's age	0.063 (0.166)	0.01 (0.793)	0.054 (0.126)
Wife's education level	-2.030 (0.015)*	0.06 (0.932)	0.986 (0.137)
Access to electricity	-0.335 (0.212)	1.443 (0.238)	0.312 (0.813)
Land tenure	-0.165 (0.866)	-0.833 (0.338)	-1.038 (0.189)
Head of house's educ. level	-0.741 (0.477)	-1.012 (0.094)	0.061 (0.915)
Household size	0.838 (0.019)*	0.707 (0.027)*	0.479 (0.118)
Adoption of TC bananas	-2.220 (0.042)*	0.591 (0.482)	-0.732 (0.325)
Irrigation access	0.641 (0.535)	1.201 (0.188)	1.482 (0.087)
Pseudo-R^2	0.552		

Source: Survey data, 2016. Legend: ** 1% level of significance, * 5% level of significance

Farm-size: The β-coefficient associated with farm-size was significant for the low food security category (*p=.032*) in the Sunflower Zone. The β-coefficient in the low food security category was negative 2.433, implying that a one unit increase in farm-size decreases the probability of a household being in the low food security category by a factor of 2.433, in favour of the household being in the preferred food security category (the reference category). The possible explanation is that an increased farm-size increases the area under food crop production, and thus increasing food availability in the household. An increased farm-size also increases food access by increasing household income through increased cash crop production.

Education level: The β-coefficient for the wife's education level in the low food security category was significant (*p=.015*). The β-coefficient in the low food security category was negative 2.030, thus implying that an increase in the education level of the wife decreases the probability of the household being in the low food security category by a factor of 2.030, in favour of the preferred food security category. The possible explanation is that education increases the wife's capacity to increase farm production through better management of farm resources and adoption of modern technologies. In addition, the education status of the wife increases her ability to make food choices that improve the household's food utilization.

Household size: The β-coefficient for household size in in the low and moderately low food security categories were significant (p=.019, p=.027). The β-coefficients were 0.838 and 0.707 in the low and the moderately low food security categories respectively. This indicates that an increase in the household size by one member increases the probability of a household being in the low and the moderately low food security categories by about 84% and 71% respectively, rather than the preferred category. The possible explanation is that an increase in the number of household members increases the number of people to be fed and thus decreases the individual energy intake, especially for the households in which the increased household size does not translate into more food production and farm income.

Adoption of tissue culture (TC) bananas: The β-coefficient associated with adoption of TC bananas in the low food security category was significant (p=.042). The β-coefficient in the low food security category was negative 2.22, implying that adoption of tissue culture banana production in the farm decreases the probability of a household being in the low food security category by a factor of 2.22, in favour of the household being in the preferred food security category. The possible explanation is that the adoption of the disease-free tissue culture bananas increases farm production, and thus increasing the available food and income in the household. In this study, adoption of tissue culture bananas was used as a proxy for technology adoption in the study area.

Factors Affecting Household Food Security in the Coffee Zone

Table 2 presents the results of the MLR analysis of the factors that affect HFSI in the Coffee Zone. Based on the results from the MLR analysis, it was found that the number of households in the poor food security category in the coffee zone was insignificant. The socio-economic and institutional factors that were found to have a significant effect on HFSI in the coffee zone are access to agricultural extension, adoption of improved coffee varieties, dependency ratio and household size. The effect of farm size on food security was not found to be significant in the coffee zone.

Table 2: The results of MLR analysis of factors that affect HFSI in the Coffee Zone

	FS Categories' B-coefficients	
Independent Variables	**Moderately Low**	**Moderately High**
Farm size	-0.639 (0.457)	0.435 (0.51)
Access to extension	-1.993 (0.001)**	-0.555 (0.352)
Dependency ratio	-1.84 (0.242)	3.725 (0.045)**
Household size	0.898 (0.001)**	0.107 0.672)
Adoption of improved coffee varieties	-2.99 (0.002)**	0.197 (0.782)
Pseudo-R^2	0.408	

Source: Survey data, 2016. Legend: ** Significant at 1% level, * significant at 5% level

Drawing on the results from Table 4, the following are the individual factors that significantly influence HFSI in the Coffee Zone:

Access to extension services: The β-coefficient associated with access to extension services was significant in the moderately low food security category (*p=.001*). The β-coefficient in the moderately low food security category was negative 1.993, which indicates that access to agricultural extension services decreases the probability of a household being in moderately low food security category by a factor of 1.993, in favour of the preferred food security category. Access to extension services increases the household's food

availability and access by enhancing the transfer and adoption of technologies which increase food and cash crop production in the farm.

Dependency ratio: From the household point of view, dependency ratio or burden is the proportion of household members aged 0 to 15 years and 65 years and above. These age groups are considered to be economically unproductive and dependent on those aged 16-59 years for their livelihood [25]. The β-coefficient associated with the dependency ratio in the moderately high food security category was significant (*p=.045*). The β-coefficient for the dependency ratio in moderately high food security category was positive 3.725, which implies that a one unit increase in dependency ratio increases the probability of a household being in the moderately high food security category by a factor of 3.725, rather than the preferred category. The possible explanation is that an increase in non-working household members increases the number of people to feed without increasing food production, thus decreasing each individual's food availability.

Household size: The β-coefficient associated with household size was significant in the moderately low food security category (p=.001). The β-coefficient for the moderately low food security category was positive 0.898, indicating that a one unit increase in the household size increases the probability of a household being in moderately low food security category by about 90%. The possible explanation is as given in the previous section under the Sunflower Zone.

Improved coffee variety: The recommended coffee varieties in the study area were *Ruiru 11* and *Batian*, names given by Kenyan research institutes that developed the varieties. The β-coefficient for farm's adoption of the improved coffee varieties was significant in the moderately low food security category (*p=.002*). The β-coefficient in the moderately low food security category was negative 2.99, implying that the farm's adoption of the recommended coffee varieties reduces the probability of the household being in the low food security category by a factor of 2.99. A possible explanation is that the improved coffee varieties have higher yields and decrease the cost of production because the farmers apply less spray chemicals against diseases. This study actually found a significant and positive correlation between the value of coffee output and the adoption of improved coffee varieties. In this study adoption of improved coffee varieties was used as a proxy for technology adoption.

Factors Affecting Household Food Security in the Tea Zone

Table 3 presents the results of the MLR analysis of the factors that affect HFSI in the Tea Zone. Based on the multinomial logit regression (MLR) results, the socio-economic factors that were found to have significant effect on HFSI in the tea zone are farm-size, head of household's age, and the age of the wife. Other significant factors were access to agricultural extension and dependency burden. The individual variables are discussed separately after the presentation of the MLR results as given in Table 3.

Table 3: The results of MLR analysis of factors that affect HFSI in the Tea Zone

	FS Categories' B-coefficients	
Independent Variables	**Moderately Low**	**Moderately High**
Farm-size	-1.853 (0.026)*	-2.171 (0.035)*
Head of household's age	0.026 (0.832)	0.288 (0.003)**
Access to extension services	-3.317 (0.012)*	-0.423 (0.732)
Adoption of certified seeds	0.719 (0.374)	1.545 (0.028)*
Household's road distance	0.007 (0.663)	-0.222 (0.175)
Dependency ratio	-2.491 (0.436)	6.726 (0.019)*
Pseudo-R^2	0.506	

Source: Survey data, 2016. Legend: ** Significant at 1% level, * significant at 5% level

Farm-size: The β-coefficients associated with farm size in both the moderately low and moderately high food security categories were significant (*p=.026, p=.035*). The β-coefficients in the moderately low and moderately high food security categories were negative 1.853 and negative 2.171 respectively, implying that a one unit increase in farm size decreases the probability of a household being in the moderately low food security category by a factor of 1.853 and by a factor of 2.171 in the moderately high food security category in favour of the preferred food security category. As discussed in the previous section under the Sunflower Zone, increased farm-size enables the household to produce more food and to generate more farm income, thus increasing the household food security.

Head of household age: The β-coefficient for head of household's age in the moderately high food security category was significant (*p=.003)*. The β-coefficient in the moderately high food security category was positive 0.288, implying that a one unit increase in the age of the head of household increases the probability of being in the moderate food security category by about 29%. A possible reason could be that the younger household heads are more educated and have more opportunities for off-farm employment.

Access to agricultural extension services: The β-coefficient for access to agricultural extension services in the moderately low food security category was significant (*p=.012*). The β-coefficient in the moderately low food security was negative 3.317, implying that a household's access to extension services decreases the probability of the household being in moderately low food security category by a factor of 3.317. Agricultural extension provides the farmers with information on technologies that can increase farm production. As supporting evidence, this study found a significant positive correlation between agricultural extension and total value of food crops produced in the farm

Dependency ratio: The β-coefficient associated with the dependency ratio in the moderately high food security category was significant (*p=.019*). The β-coefficient in the moderately high food security category was positive 6.726, implying that a one unit increase in dependency ratio increases the probability of the household being in the moderately high food security category by a factor of 6.726. A possible explanation is that an increase in the dependency ratio increases the household daily energy requirement without increasing its capacity to acquire more food, thus decreasing the per capita energy intake.

The results presented in Table 4 show that the VIF for the continuous variables were less than 10; thus the study ruled out the existence of serious multicollinearity among these variables.

Results of Multicollinearity Tests

The results presented in Table 4 shows the results of multicollinearity test for continuous variables affecting food security using Variance Inflation Factor (VIF).

Table 4: Variance Inflation Factors (VIF) for Continuous Variables affecting food security

Continuous Variables	1/VIF	VIF
Farm-size	0.893	1.120
Household size	0.811	1.232
Dependency burden	0.668	1.497
Head of household age	0.784	1.276

Source: Field survey data, 2016

Table 5 presents the results of multicollinearity test for discrete variables affecting food security using Contingency Coefficient (CC).

Table 5: The Contigency Coefficient (CC) for discrete variable affecting food security

Discrete Variables	Education level (W)	Education level (HH)	TC bananas adoption	Extension Access	Improved coffee adoption
Education level (W)	1				
Education level (HH)	0.345	1			
TC bananas adoption	0.070	0.098	1		
Extension Access	0.162	0.150	0.103	1	
Improved coffee adoption	0.093	0.202	0.202	0.200	1

Source: Field survey data, 2016

The results presented in Table 5 show that the CC for the discrete factors were less than 0.75 thus the study ruled out the existence of serious multicollinearity among these factors.

B. Discussions

A total of 8 factors were found to significantly affect food security in the study area, namely: farm size, head of household's age, wife's educational level, access to extension, technology adoption, household size and dependency ratio. This study revealed that the effect of the factors on household food security varies with the agro-ecological zone thus indicating a significant impact on the factors that influence household food security in Kenya. The effects of the major factors that influence food security in and across the three AEZs are summarized in Table 6.

Table 6: The effect of major factors that influence food security in across the three AEZs

Factors	Sunflower Zone	Coffee Zone	Tea Zone
Farm-size	**(+)**	**(N)**	**(+)**
Agricultural extension	**(N)**	**(+)**	**(+)**
Technology adoption	**(+)**	**(+)**	**(N)**
Education level of wife	**(+)**	**(N)**	**(N)**
Age of household head	**(N)**	**(N)**	**(-)**
Household size	**(-)**	**(-)**	**(N)**
Dependency ratio	**(N)**	**(-)**	**(-)**

(+) Positive, (-) Negative, (N) insignificant

The effect of farm size on food security was found to be positive in the Sunflower and Tea zones, but not in the Coffee Zone. Technology adoption was found to have a significant effect on food security in the Sunflower and Coffee zones, but not in the Tea Zone. Access to agricultural extension was found to have a significant effect on food security in the Coffee and Tea zones, but not in the Sunflower Zone. Household size was found to have a significant effect on food security in the Sunflower and Coffee zones, but not in the Tea Zone. The dependency ratio was found to have a significant effect on food security in the Coffee and Tea zones but not in the Sunflower Zone. The level of education for the wife was found to have a significant effect on food security in the Sunflower Zone but in the Coffee and Tea zones. Therefore, the effects of the factors that influence food security were found to vary with the agro-ecological zones.

The finding of this study showing that farm size has a positive impact on food security is consistent with the findings of the previous studies by [9],[13],[26],[27],[28]. The findings of this study showing that the farm's access to agricultural extension and adoption of technologies have a positive impact on food security are consistent with the findings of the studies by [15],[29],[30],[31]

The findings of this study showing that household size and dependency ratio have negative effects on food security are consistent with those from the previous studies by [16],[27],[29],[32].

Based on the above findings, it can unambiguously be concluded that the effects of the major factors that had been identified as having significant effects on food security at the household level in Kenya vary by AEZs. And this is a significant contribution to knowledge from the current study. Thus any recommendations on how to improve household food security should be specific to a particular agro-ecological zone.

C. Recommendations

Since this study finds that the effects of the factors that influence food security vary by the AEZs, it is recommended that AEZ-specific measures to enhance household food security in different areas of Kenya be formulated. For example, it is recommended that measures to regulate and control land size be instituted in the Sunflower and Tea zones while measures to improve technology development and dissemination, including an improvement of the access to agricultural extension by the farmers, be instituted in all the three AEZs. To enhance technology adoption, it is also recommended that farm household education be improved in the Coffee and Tea Zones. Promotion of family health education and services is also recommended for all the three AEZs to reduce household sizes and dependency burdens.

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