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Effects of Crop Diversification on Households' Food Security Among Smallholder Coffee Farmers in Kirinyaga Central and East Sub-Counties, Kirinyaga County, Kenya

Micheni Pauline Kananu[1, *], Gathungu Geoffrey Kingori[2], Dennis Kariuki Muriithi[3]

[1]Department of Agribusiness Management, Agricultural Economics and Agricultural Education and Extension, Faculty of Agriculture, Chuka University, Chuka, Kenya

[2]Department of Plant Sciences, Faculty of Agriculture, Chuka University, Chuka, Kenya

[3]Department of Physical Sciences, Faculty of Science, Engineering and Technology, Chuka University, Chuka, Kenya

Email address:

kananumicheni@gmail.com (Micheni Pauline Kananu)

[*]Corresponding author

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Abstract: Crop diversification strategies are one way for Kenyan households to improve their food security. In Kirinyaga Central and East Sub-Counties, the agricultural sector is dominated by smallholder coffee farmers who suffer seasonal hunger due to low food crop productivity. This has led to what has been labeled as 'lean months' by scientists. Several studies have shown that crop diversification provides smallholder farmers with food and nutrition security. However, smallholder coffee farmers in the study area have minimal information concerning potential and contribution of crop diversification to food security. The study aimed to establish the effects of crop diversification on food security in Kirinyaga Central and East Sub-Counties, Kirinyaga County, Kenya. The study was guided by modern portfolio theory. The study was carried out in three agro-ecological zones (UM1, UM2 and UM3) using descriptive research design to collect household data with structured questionnaires. A target population of 18420 smallholder coffee farmers was used, from which using multistage sampling techniques, a sample of 408 was selected. Descriptive statistics and econometric models were relied on for data analysis. The mean Crop Diversification Index (CDI) was 0.39. Cereals were the most consumed food crop with mean Food Consumption Score (FCS) of 7.50. The total mean FCS of households was 27.46, which may have implied that majority of them fall into borderline food consumption category (52.87%). Further, the findings show that farmers faced seasonal food insecurity with 54.36% of them reporting at least one month of food scarcity. Findings of multinomial logistic model revealed that the expected change in probability for a farmer to fall into borderline FCS level at $p<0.05$, was effected by landscape heterogeneity (33.2%), crop varietal diversity (8.8%), intercropping (13.6%) and crop species diversity (15.2%). For a farmer to fall in acceptable FCS level at $p<0.05$, it was contributed by 0.5% of landscape heterogeneity, crop rotation (0.4%), crop varietal diversity (0.4%), intercropping (2%) and crop species diversity (1.8%). Based on this study findings, we can conclude that crop diversification is one viable option in smallholder farming that can ensure establishment of resilient agricultural systems that can contribute significantly to household food security. There is need for government to support policies and programs that promote adoption of crop diversification strategies for realization of enhanced food and nutrition security.

Keywords: Smallholder Coffee Farmers, Crop Diversification Strategies, Food Security, Food Consumption Score

1. Introduction

1.1. Background and Statements of Problems

In 2022, it was estimated that about 3.1B people in the world were vulnerable to food and nutrition security despite the global efforts towards achievement of the sustainable development goal 2, to end hunger, food insecurity and all forms of malnutrition [1]. It has been reported that in the past decade, the number of people facing chronic and persistent food insecurity and malnutrition has been increasing steadily from year 2014 with 20.8% to year 2018 (22.8%) [2]. Majority of the most affected populace live in Sub-Saharan Africa and South-East Asia, and depend mostly on agriculture for their livelihoods [3]. Africa is predicted to have 200 million undernourished people and to address the issue of food insecurity, the African Union Comprehensive Africa Agriculture Development Programme (CAADP) has boosted yearly national budgetary allocations for agriculture to at least 10% in order to assure a 6% annual rise in agricultural output [4]. Additionally, each country in Africa developed and implemented unique national agricultural policies to support its efforts. Empirical evidence confirms the role of agriculture for the improvement of incomes and food, which provides two capital dimensions of food security: the availability and accessibility of food and reduction of malnutrition [5].

Food security, as declared at the World Food Summit in 1996, is a situation where all people at all times have access to adequate, nutritious and safe food that meets their dietary needs and preference for a healthy life. Kenya faces a lot of challenges including that of attaining food and nutrition security, which is one of the Kenyan Government Big 4 Agenda. The main issues affecting food security in Sub Saharan Africa are climate change (floods and droughts), decreased soil fertility, poor macroeconomic environment, and poor agricultural policy [6]. The prevalence of food insecurity and malnutrition in Kenya, is of concern especially on smallholder farmers since they are vulnerable to climate change, have low access to extension and credit, and low access to production and marketing information, thus lack the availability and accessibility of nutritionally adequate foods. It has been noted that promoting households to transit from mixed livelihoods to relying more on cash crops like coffee without a subsistence safety net increase their vulnerability to food insecurity [7].

Seasonal hunger, a predictable and cyclical pattern of decreased food availability and access, is the very popular type of food insecurity among small-scale coffee farmers (8], despite the 65% global increase in coffee demand due to its high consumption rate in developed nations. Integrating coffee into the food production system in Ghana has been reported to improve food nutrition security in the households [9]. In contrast, Jemal [7] reported that coffee crops in Ethiopia had a detrimental effect on the smallholder farm households' food security in terms of diet diversity, since relying on purchased food due to income from coffee could be hazardous, by the risks and high costs that food marketing systems entail. High food prices, have been reported to increase competition for land, high costs of production and hence climate change has made smallholder coffee farmers' families unable to cover the high costs of living, and hence suffered from seasonal hunger [10]. To reduce food and nutritional insecurity among smallholder coffee farmers, adoption of crop diversification strategies would an impartial technique [11]. Crop diversification has the ability to significantly improve household resilience and nutritional status in a sustainable way [12]. It is possible that crop diversity lowers levels of uncertainty or vulnerability to upcoming disturbances by ensuring food availability, accessibility, utilization, and stability.

Mulwa [13] observed that a change in one-unit increase in crop diversification in Namibia resulted in increased dietary diversity score of household (HDDS) by 0.7 points, whereas Douvon [12] found that crop diversity contributed positively to household diet diversity in Mali, which enhanced self-consumption of higher nutrient and higher quality crops. Crop rotation helps to increase or maintain soil fertility by reducing depletion of soil nutrients [14], enhances the total nitrogen, soil organic carbon and improves soil porosity [15] and reduces crop pests and diseases [16] which increase crop yields that eventually enables availability of food supplies. Intercropping allows for a better utilization of resources such as nutrients, water, and sunlight, resulting in higher crop yields from the same area of land [14]. Further, Vernoov [17] noted that crop variety diversity enhanced food and nutrition security by reducing the likelihood of plant failure owing to environmental conditions, since it was possible that some crops would survive and thrive despite environmental stress such as drought, flooding or pests which would ensure stable supply of food. Gotor [18] noted that increasing wheat varietal diversity significantly increased wheat crop productivity and smallholder farmers' food security, since varieties were better able to adapt to their local environment (soil conditions and microclimate) and withstand shocks of natural disasters.

Agricultural landscape heterogeneity has been observed to enhance agrobiodiversity which provided abundant and varied resources for natural enemies and pollinators which supported food systems and increased food security [19]. Shivanna [20] observed that pollination done by bees, birds, beetles and butterflies in diverse agricultural landscapes, was the highest agricultural contributor to crop yields rich in vitamin in India such as vegetables and fruits, which enabled households' diet diversity and reduced malnutrition. Further, agrobiodiversity in Chiapas, Mexico, was reported to be significantly correlated with decrease in number of months of food insecurity among coffee growing communities [8]. Crop species diversity contributes to improved nutrition and dietary diversity due to disruption of pests and disease [21], and further it promotes ecosystem-related services like pollination, fertility of soil, reduced soil erosion as well as water management [22], hence households can access a broader range of essential vitamins, minerals, and phytochemicals. It is possible that growing diverse crop species in farms increase crop resilience where incase one crop fails, another would be able to withstand the stressor and ensure a harvest, thus stable food supply with wide range of essential nutrients in the diets.

It was found that smallholder coffee farmers suffered annual periods of seasonal hunger due to low capacity to grow food crops, low yields of food crops, high food prices and coffee price volatility with payments done annually [8]. Previous studies reported that smallholder farmers in Mesoamerica diversified their coffee production systems with food crops to be food secure–[11, 23-25]. However, little evidence exists to substantiate that high crop diversity is an effective strategy in most or all situations to meet smallholder coffee farmers' diet and nutritional needs in Kirinyaga Central and East Sub-Counties, Kenya. Given the need for sustainable policy efforts to guide Kenya's achievement of the sustainable development goal (SDG 2), which is to end hunger, achieve food and nutrition security and promote sustainable agriculture. This study aimed to establish the effects of crop diversification on food security among smallholder coffee farmers in Kirinyaga Central and Kirinyaga East Sub-Counties. The study tests the hypothesis that there is no statistically significant influence of crop diversification on food security (Food consumption scores) among smallholder coffee farmers.

1.2. Theoretical Framework

The study utilized Modern Portfolio Theory (MPT) which was created by Harry Markowitz, to decide on investment strategies in the face of uncertainty and formalizes the concept of risk-reduction through effective asset diversification [26]. The predicted behavior of crops is that of assets, and risks (variabilities in yield and revenue) are decreased by integrating a variety of crops into a portfolio to increase yields and combat food insecurity, The theory was applied in this study because production and marketing risks smallholder farmers face are reduced when assets (crop diversification strategies) are combined and asset returns (crop yields, food and nutrition security) are not perfectly correlated compared to single asset portfolios (mono-cropping).

2. Methodology

2.1. Description of the Study Area

This study was carried out in Kirinyaga Central and East Sub-Counties in Kirinyaga County, Kenya. Kirinyaga County is bordered to the north and east by Nyeri County, to the west by Murang'a County, and to the east and south by Embu County. It is located between Longitude 37° 10′ 0′′ E and 37° 30′ 0′′ E and latitudes 0° 10′ 0′′ S and 0° 40′0′′ S. Kirinyaga Central and East Sub-Counties are made of three agro-ecological zones, namely; lower highland 1 (LH1), upper midland 1 (UM1), upper midland 2 (UM2), upper midland 3 (UM3) and upper midland 4 (UM4). The many agro-ecological zones have had an impact on the kind of crops planted in the area; the main crops grown there are horticulture, coffee, tea, and rice. Ecological and climatic factors influence settlement in upper zones where land is fertile and receives more rainfall, and also high population is attracted in those areas due to high preference for cash crops than food crops [27].

There is a bimodal rainfall trend, with long rains occuring from March all the way to May with averages of 2,146 mm and short rains between the months of October to November averaging 1,212 mm, thus there is some variation in food production and consumption. Kirinyaga Central Sub-County and Kirinyaga East Sub-County are characterized by high population density, high coffee production levels, favourable agricultural potential, very small land size (mostly below 2 hectares) and high number of agricultural markets [27]. According to the County government [28], population size of the County is 605630, area in square km of 1205.40, with a population density of 502.43 person per Km^2. The average family size is estimated to be 3 with poverty rate of 18%.

2.2. Research Design

Descriptive research design was used in the study. Descriptive research focuses on making specific predictions, narrating facts and features about people, groups, or circumstances, in a short time period [29].

2.3. Sample Size and Sampling Techniques

Smallholder coffee farmers in the Kirinyaga Central and Kirinyaga East Sub-Counties made up the study's target population of 18420. These individuals had farms with less than 2 hectares of land. A probability proportionate to size sampling approach was used together with multistage stratified sampling to choose the sampled respondents. In the first stage, Kirinyaga Central and Kirinyaga East Sub-Counties were purposively selected due to their prominence as significant coffee-growing regions in Kirinyaga County as well as their strong potential for the production of a variety of crops for both consumption and commercial purposes. Additionally, three agro-ecological zones were chosen in Kirinyaga Central and Kirinyaga East Sub-Counties through stratification because they were well-suited for coffee production and have a great potential to grow a wide range of crops.

The three zones included the coffee - tea zone (Upper Midland one -UM_1), the main coffee zone (Upper Midland two -UM_2) and the marginal coffee zone (Upper Midland three -UM_3). There were 12 administrative sites in the study region because for each AEZ, two were chosen at random from each of the two administrative Sub-Counties. There are a total of 12 administrative sub-locations in the research area because one was randomly chosen from each of the 12 locations. The study also employed proportionate to size sampling criteria to randomly and purposively select smallholder coffee farmers from the strata with the assistance of extension officers from the ministry of agriculture and local administrative leaders. Finally, the sample size needed for each stratum was used to determine how many smallholder coffee farmer households were chosen. A sample size of 408 smallholder coffee farmers was obtained through use of 2007 Cochran formula [30].

The 408 households were chosen according to the population size of each strata selected in order to produce a sample for each agro-ecological zone. According to Mosomtai [31], approximately 25% of the coffee farmers are in UM_1, 50% in UM_2 and about 25% in UM_3.

$$n_1 = n^* p_1 \quad (1)$$

where;

p_1 represents the proportionate of population included in stratum 1, n denotes the size of the entire sample and

$n^{*}p_1$ denotes the number of smallholder coffee farmers chosen from stratum 1. As a result, population size and sample size adopted a proportional allocation for each stratum in region of the study (Table 1), since the study used a sample of 408 smallholder farmers drawn from a population of 18420 which is divided into two Sub-Counties and three strata.

Table 1. *Sample size of smallholder coffee farmers.*

Sub-County	AEZs	Location	Sub-Location	Population	Sample Size
Kirinyaga Central	UM_1	Mutira	Kabari	911	20
		Inoi	Mbeti	500	11
	UM_2	Kerugoya	Kaitheri	1900	42
		Koroma	Nduini	922	20
	UM_3	Kanyekini	Kianjege	2174	48
		Kutus	Kangu	370	08
Kirinyaga East	UM_1	Ngariama	Rungeto	600	13
		Karumandi	Kiaruri	2222	50
	UM_2	Baragwi	Rwambiti	3200	71
		Njukiini	Ngiriambu	2800	62
	UM_3	Kirima	Mutige	1490	33
		Kabare	Rukenya	1331	30
Totals				18420	408

The strata included are the coffee - tea zone (Upper Midland one -UM_1), the main coffee zone (Upper Midland two -UM_2) and the marginal coffee zone (Upper Midland three - UM_3). The proportion will be 102 farmers sampled from UM_1, 204 from UM_2 and 102 from UM_3 where a ratio of 1: 3 was used to obtain sample size for Kirinyaga Central and Kirinyaga East Sub-Counties, respectively. Data was collected using a structured questionnaire which was administered on android phones using the free open-source program Kobo Toolbox (https://www.kobotoolbox.org/). However, some responses were dropped during data cleaning process caused by insufficient data, where the analysis was based on useful observations of 401 households.

2.4. Data Analysis

Data analysis included the use of econometric models, inferential statistics, and descriptive statistics in combination. These tools are outlined and discussed in the following sub-sections.

Econometric Models

To address the objective of the study, in addition to descriptive statistics, Multinomial logit model was employed. Descriptive statistics such as mean, percentage, chi square and t-test was used.

2.5. Multinomial Logit Model

Model Specification

Multinomial logit model analyzed crop diversification strategies that influenced household level of food insecurity (Food Consumption Score) which was categorized into three categories. These alternatives can be best explained by logit or probit model which can also predict the probability that a farmer with certain set of characteristics chooses one alternative or the other. MNL model was used since it allows for measurement of several decision of dependent variable.

An individual farmer has K choices of food security levels and a set of variables for crop diversification strategies. Let vector $X_i = (X_{i1}, \dots, X_{im})$ which contain variables such as intercropping, crop rotation, crop species diversity, varietal diversity and landscape heterogeneity that characterize the i^{th} farmer. Utility of the j^{th} category for farmer i is denoted by U_{ij}. Categorical response variable will be denoted by Y_i

$$U_{ij} = \beta_{jo} + X'_i\beta_j \text{ (Simple linear model for } U_{ij}) \quad (2)$$

where;

$\beta_j = (\beta_{j0}, \dots, \beta_{jm})$ is a parameter vector. That means that the preference for the j^{th} alternative for i^{th} farmer is determined by X_i and a parameter β_j.

The MNL model will be specified as:

$$P(Y_i = \text{j}) = \frac{\exp(\beta_{jo} + X_i'\beta_j)}{1+\sum_{s=1}^{m} exp(\beta_{so}+X_i'\beta_s\text{e})} \quad (3)$$

which can be written as:

$$Log\frac{P(Y_i=j)}{P(Y_i=k)} = \beta_{jo} \quad (4)$$

Therefore, log odds for category j with respect to category k is determined by vector of covariables X_i. The following are FCS categories (Table 5).

The study used the FCS approach to measure food security and computed results in accordance with recommendations made by the World Food Programme. FCS was computed using dietary variety, food frequency, and the relative nutritional value of six major food groups. The FCS was intended to accurately represent the scope and caliber of dietary intake in households. The food groups are weighted based on the energy, protein and micronutrient content. A weighted aggregate depending on the type of food and frequency consumed over the course of seven days yields a combined score. Based on the study area and food consumption habits, the limit for the food consumption gap is determined when the FCS is computed. To be more specific, dietary recall questions were utilized to gather data on the intake of particular food groups that are popular in Kenya.

Table 2. *Household dietary diversity score.*

Household food consumption score (FCS) category (Y_i)	Food security threshold
0-21	Poor food consumption
22-35	Borderline food consumption
>35	Acceptable food consumption

where;

p=1 poor food consumption households; *p=2* Borderline food consumption households and *p=3* Acceptable food consumption households

The respondents were questioned on their consumption habits during the previous seven days. FCS was computed following EFSA [32]. The following is an expression for the formula:

FCS = a × f (leafy vegetables) + a × f (other vegetables) + a × f (fruits) + a × f (legumes or pulses or nuts) + a × f (cereals) + a × f (roots and tubers)

where;

FCS = is the Food Consumption Score, f =is the frequency for food consumption (based on the number of days each food item was consumed over the course of the previous 7 days), and a =is a weighted value indicating the nutritional content of particular categories of food [32].

Different weights were given to food types in accordance with their nutritional densities. Poor food intake (0–21), borderline food consumption (22–35), and acceptable food consumption (>35) are the three consumption threshold groups [32]. The FCS was selected because it offers a more precise assessment of the caliber of the food in the home. In addition, it takes into account the quantity of various food kinds ingested as well as the nutritional content of the meal. The study used more than 30 food commodities grouped into six different food groups based on nutritional importance (Table 5). There is no universal consensus on the types of categories of food to include [33]. The FCS has some flaws, primarily the fact that it does not account for food consumed beyond home and does not offer any statistics on intra-household distribution of food. To some extent, the 7-day recalls makes it difficult to take into account the amount of food consumed. Despite the flaws, FCS is still thought of as one of the most useful measures of family food security, which can also be used to identify areas where interventions may be needed to improve access to nutritious foods.

Table 3. *Food categories and their respective weights.*

Food groups	Weights
Leafy vegetables	1
Other vegetables	1
Fruits	1
Legumes/pulses/nuts	3
Cereals	2
Roots and tubers	2

The parameters of the model were determined by use of the maximum likelihood estimator Ordinary Least Squares (OLS). OLS regression was utilized since the outcome of FCS is a continuous variable (dependent variable) and CDI is a continuous variable (independent variable). OLS is appropriate to assess the impact of one continuous variable on another continuous variable. Every independent variable (X_i) significance to the outcome Y_i should be indicated by the regression coefficients (equation 5).

$$P(Y_i = \text{j}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon_i \quad (5)$$

where;

$P\ (Y_i = j)$ is the household's probability to fall into a certain level food consumption

β_0 =Intercept and β_1 to β_5 are the model parameters to be estimated

ε_i is an error term.

X_1= Intercropping

X_2= Crop rotation

X_3=Crop species diversity

X_4= Varietal diversity

X_5=Landscape heterogeneity

Therefore, the multinomial logit selection model in the above equation was estimated using mlogit command in Stata statistical software (STATA 15).

3. Results and Discussions

3.1. Descriptive Findings for Crop Diversification Strategies

The main practices used by small-scale farmers in the last ten years were found during the study, to improve food crop productivity and cope with food insecurity included landscape heterogeneity (65.84%), crop rotation (54.36%), crop varietal diversity (78.05%), intercropping (78.05%) and crop species diversity (94.76%) [Table 4]. The practices stated were consistent with those reported by Olson [23] and Njeru [34] who argued that crop diversification strategies such as within field- crop genetic diversity was a fundamental tool for improving stability of yield and crop resilience under dynamic climatic conditions. The findings of this study revealed that cultivar mixtures, cover crops and crop mixtures increased soil fertility, reduced pests and diseases, low-input agroecosystems and eventually stabilized yields which increased nutrition diversity.

Table 4. *Crop diversification strategies.*

Crop Diversification Strategies	Description	Frequency	Percent.
Landscape heterogeneity	No	137	34.16
	Yes	264	65.84
Crop rotation	No	183	45.64
	Yes	218	54.36
Crop varietal diversity	No	88	21.95
	Yes	313	78.05
Intercropping	No	81	20.2
	Yes	320	79.8
Crop species diversity	No	21	5.24
	Yes	380	94.76

Mainali [35] observed that landscape heterogeneity required habitat management which is the most potent strategy for conserving natural enemies that relies on plant resources that provides breeding sites, overwintering, shelter, nectar, alternative food and pollen for natural enemies. Further, Mkenda [36] reported similar findings, stating that planting field margins around smallholder bean fields increased aphid mortality rate implying that field margins acted as biological pest control through offering useful habitat to predators. Therefore, crop rotation can be among the recommended measures to prevent pest damage in Integrated Pest Management (IPM) production through disturbing pest's lifecycle and minimizing environmental impacts. In addition, it has been reported that crop rotation improves soil health which boosts crop development, boosts soil water conservation and improves quality performance of soil-based agricultural products which increase and sustain crop productivity [37].

Crop genetic diversity helps the crop to be more tolerant to different abiotic and biotic stresses, which increases or maintains crop yields that lead to adequate and sustainable food supplies. The findings of this study are in line with those of Yang [38] who revealed that cropping systems with mixed varietal arrangements were found to be more tolerant, particularly to biotic stresses. It has been found that intercropping cereals and legumes stimulates the biological activity of the soil which increases the recycling of soil organic matter and the nitrogen fixing activity provides nitrogen which is utilized by cereals to increase the yields [39]. Additionally, Kumar [40] observed that using legume as an intercrop reduced the impact of crop insect pests and diseases which lead to increased cereal yields by 15–25%. Beillouin [41] found that by increasing diversity of planted crop species in agroecosystems, enhanced crop production by more than 14% and biodiversity (+24%), improved water quality by more than 51%, controlled pests and diseases (+68%) and improved soil quality (+11%), which increased food security.

3.2. Descriptive Statistics of Food Security

3.2.1. Food Consumption Scores

This study sought to determine the measures of food security in terms of food consumption scores (FCS) which is a proxy to assess the food security situation of a household, by measuring the amount of the food consumed in terms of quality and quantity over a certain period of time (7 days). In relation to the outcomes of this study, the household FCS on average was 27.46, which indicated a borderline food consumption level (Table 5). In general, if food consumption score is <35, it indicated the presence of household food insecurity [42]. Based on the FCS, the distribution of households showed that majority of the household (52.87%) had borderline food consumption scores which corresponds to a situation of moderate food insecurity, 23.19% were at acceptable level which shows food secure households, while 23.94% were at poor level indicating severely food insecure (Figure 1).

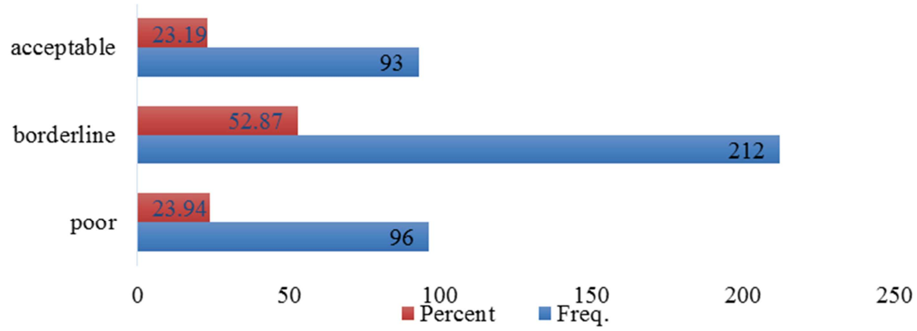


Figure 1. *Distribution of households in Kirinyaga County based on food consumption score.*

In reference to the observations of this study, cereals had the highest mean food intake score across households, at 7.50, followed by legumes and pulses (7.16) [Table 5]. This study's findings are consistent with those of Pal [43] who noted that cereals contribute to a balanced and beneficial diet due to their valuable content values. Diversification may be shown to be a path from agriculture to nutrition because it directly affects the amount and varieties of food available for consumption in families. Douvon [12] revealed that millet and sorghum in Mali contributed to more than 50% of daily diets in rural households, with rice being the main staple meal taken at least every day. However, they further showed that increasing food access and supply does not ensure better nutritional results, as stipulated by FCS, which classifies households as having moderate food security.

This study's findings revealed that the average mean percentage of foods from targeted crops consumed from subsistence was 68.38% per week, with cereals having the highest mean of 77.14%, followed by other vegetables (71.92%), leafy vegetables (64.97%), legumes (64.83%), roots and tubers (64.10%), and lastly, fruits with the lowest mean of 49.33% (Table 5). In accordance to the findings of this study, most of the households produced crops for subsistence, with few supplementing their diets through purchase of food because majority of the households could not grow all selected crops due to land size as the majority had less than 2 hectares. This may suggest that farm households need to diversify crops to improve on diets and nutrition through subsistence production. The study's outcomes are in line with those of Muthini [44] who revealed that smallholder households are known to consume a sizeable part of what they produce at home, although for dietary diversity, it was observed there was need to purchase from market. In contradiction to the findings of this study, Sibhatu [45] asserted that during the lean months in Ethiopia, more than half of all calories consumed at household level were purchased despite challenges of cash income. Ogutu [46] pointed out that food markets need to be made sufficiently efficient and integrated to avoid price fluctuations, to enable access of food.

Table 5. *Summary of food consumption scores per food category and average percent of food consumed from subsistence.*

Description	Mean	Std. Dev.	CV (%)
Leafy vegetables food consumption scores/ week	2.80	0.76	27.14
Other vegetables food consumption scores/week	2.83	0.76	26.86
Fruits food consumption scores/week	2.54	0.56	22.04
Legumes/nuts food consumption scores/week	7.16	1.47	20.53
Cereals food consumption scores/week	7.50	1.89	25.20
Roots & tubers food consumption scores/week	4.66	1.16	24.89
Total mean food consumption scores/week	27.46	6.60	24.03
Leafy vegetables consumed from subsistence %	64.97	17.78	27.37
Other vegetables consumed from subsistence%	71.92	18.22	25.33
Fruits consumed from subsistence%	49.33	12.07	24.47
Legumes/nuts consumed from subsistence%	64.83	13.34	20.58
Cereals consumed from subsistence%	77.14	17.09	22.15
Roots & tubers consumed from subsistence%	64.10	12.03	18.77
Average food consumed from subsistence %	68.38	13.97	20.43

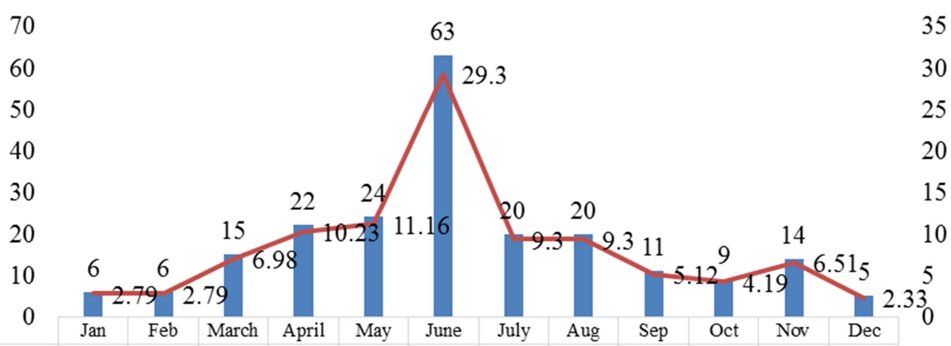
(CV: Coefficient of variation)

The findings of study showed that leafy vegetables, other vegetables and fruits were the least consumed food groups in the study area, with mean FCS of 2.80, 2.83 and 2.54, respectively in a 7-day recall period (Table 5). in relation to the findings of this study, Hlatshwayo [47] found out that in South Africa, cereals were consumed at 98%, vegetables at 38% and fruits at 23% by smallholder farmers. There is a possibility that farmers were diversifying but cereal crops dominated their diets. Maize being the main staple food in Kenya, accounts for 35% of total caloric intake and per capita consumption of 98 kgs per year [48]. Poverty has been observed to cause micronutrient deficiencies in underdeveloped nations, resulting in a heavy reliance on staple crops (typically starchy foods) for energy [49]. During the study it is possible that there were little remaining resources to purchase other essential components to supplement a healthy balanced diet, which resulted to reported poor quality diet deficient in diversity.

3.2.2. Food Security and Lean Months

According to the outcomes of this study, 23.19% of the farmers were at acceptable FCS. Seasonal food insecurity was prevalent among the respondents, with 54.36% reporting at least one month of food scarcity (Figure 2). During the study period, farmers reported that they heavily depended on coffee as their main cash crop, which meant that they were vulnerable to fluctuations in coffee prices and yields. in agreement to this study's findings, Bacon [24] noted that coffee households receive just a yearly salary for the crop, making it difficult to distribute the lump sum over the year to purchase food and cover other expenses. Based on the findings of this study, cultivation of food for consumption by cash crop farmers is essential for food security and should be properly supported by development and food policy in tandem with support of cash crop production.

Further, the study's outcomes of this study revealed that smallholder farmers mainly produce food to sustain their households the entire year, as evidenced by 68.38% mean of food consumed from subsistence production (Table 5). It is possible that seasonal food shortages are caused by low adoption of crop diversification strategies which lead to reduced yields. Similarly, Fernandez [8] noted that some farmers in Chiapas Mexico sell a portion of their subsistence crops immediately after the harvest, when market prices are low and cash demands are strong, and then cannot afford to purchase food during the ensuing lean months, when crop prices are normally higher which results to seasonal hunger.



	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Freq.	6	6	15	22	24	63	20	20	11	9	14	5
Percent.	2.79	2.79	6.98	10.23	11.16	29.3	9.3	9.3	5.12	4.19	6.51	2.33

Figure 2. *Lean months of smallholder coffee farmers.*

Farmers also stated that they experienced shortage of food between months of April and August, with June being the leanest month (29.3%) that was affected by seasons in agriculture and it's when the general availability of food was quite low (Figure 2). During the study period, extension officers reported that in the month of April farmers prepared fields and searched for seeds through using saved seeds, purchase or borrowing from neighbours. During this period, farmers noted that there was high demand for labour (33.67%) in coffee and food crop fields and, it was possible that food availability was low since most money was used to pay for inputs, and also rainfall (38.9%) limited physical access to market to purchase food (Table 6). This may have implied that high level of precipitation caused flooding which limited the physical access to food. The findings of this study are consistent with those of Anderzén [11] who reported an overlap between lean months and annual rainy season in Chiapas, Mexico.

Table 6. *Causes of lean months.*

Cause for low food supply	Frequency	Percentage
High food prices	110	27.43
Rainfall	156	38.9
Demand for labour/ (Harvesting)	135	33.67

During the study, the farmers stated that there was an increased case of food insecurity (11.16%) in the month of May. This was probably because sowing of maize and beans start in May all the way to June depending on the onset of rainfall and seed availability (Figure 2). Also, during this period, farmers stated that most of the proceeds from coffee has already been used and previous season's food reserves are often depleted and market prices of food is at peak (27.43%) [Table 6]. There is a possibility of food unavailability in most households and incapacity (monetary) to purchase food from market, which may leave farmers vulnerable to insufficient diets. Similar to the findings of this study, Muthini [44] noted that own production and market purchase are the two main paths which farmers can acquire food for dietary quality and nutrition.

Furthermore, the outcomes of this study are consistent with those of Bacon [24] who revealed that the leanest months in Nicaragua were June, July and August, which were associated with low income generating activities and due to seasonal scarcity of food, the market price of maize was high which increased the financial pressure on households. Household food security has been linked to on-farm diversity, where leafy vegetables would be obtained from coffee fields to supplement diets [8]. In relation to the findings of this study, it is advisable for smallholder cash crop (coffee) farmers to diversify to food crops that are fast maturing to sustain and supplement diets of households during the lean months.

During the study period, farmers stated that there was food availability from the month of September to February, with December being the most secure at 2.33% (Figure 2). This may have implied that food availability was contributed by harvest and post-harvest season which contributed to increased food supplies and cash flows from coffee sales. The observations of this study are in agreement with those of Sibhatu [45] who found out that the number of lean months (April to August) correlated negatively with corn harvests and fruit trees though from September to February food was available. It is possible that during this study fewer households reported less cases of food insecurity in these months due to accessibility of beans and fresh maize, with low prices of maize. In accordance to the findings of this study, there is a likelihood of farmers who produce their own food crops to do well in the seasonal hunger months and have lower number of lean months than their counterparts, thus cultivating food crops by smallholder coffee farmers provides a safety net for household food security.

3.2.3. Average Crop Diversification Indices Per Food Security Category

The study sought to determine the link between household food consumption scores (FCS) and crop diversification index (CDI). Crop diversification calculated using Herfindahl index (HI), where the average CDI was 0.39. The findings showed that 20 households had CDI between 0 and 0.1, 98 between 0.1 to 0.2, 163 between 0.3 to 0.4, 108 between 0.5 to 0.6, and 12 between 0.7 and 0.8 (Table 7). In accordance to the outcomes of this study, crop diversification proportions were lower among poor FCS level (11, 33, 33) and borderline FCS level households (9, 48, 94) [Table 7]. Although higher levels of crop diversification were seen in borderline (2) and food secure (9) households, the findings of this study may imply that increase in magnitude of crop diversification increases the likelihood of achieving acceptable food consumption.

Table 7. *Food security status of households and extent of crop diversification.*

Food security/Insecurity	Frequency of CDI index by category					
FCS	0-0.1	0.1-0.2	0.3-0.4	0.5-0.6	0.7-0.8	Total
Poor FCS	11	33	33	18	1	96
Borderline FCS	9	48	94	59	2	212
Acceptable FCS	0	17	36	31	9	93
Total	20	98	163	108	12	401

FCS-Food Consumption Scores, CDI- Crop Diversification Index.

Mango [6] reported that crop diversification in Zimbabwe was more prevalent (>50) among borderline showing food secure to food secure households, where more diversification intensities have higher probability to have diet diversity by comparing crops consumed.

Bellon [50] asserted that increasing crop diversity in Ghana increases household own-consumption of food crops. Based on the findings of this study, it can be suggested that for households to improve diet diversity, they need to diversify their crops. Adjimoti [51] noted that households with intense diversification especially those that diversified into root and tuber crops and grains in Benin have high probability to be food secure. It is possible that households' food access and consumption were influenced by the types and number of crops grown. It is possible that more diverse household diets may influence more production systems, which shows that diversification of crops has a direct effect on food access and availability at the household level. In consonance to the findings of this study, Mulwa [13] revealed that a unit change in crop diversity raises monthly per capita expenditure for household by about N$78 (Namibian dollar) and household diet diversity scores (HDDS) by around 0.7 points. In accordance to the findings of this study, it is possible that greater crop diversification can lead to higher incomes which increases the ability of the households to increase more spending on food, resulting in an increased dietary diversity.

Farm family units with higher levels of crop diversification have been reported to be more food secure as compared to their counterparts and that farmers who engage in multiple cropping, and are unlikely to suffer total crop failure due to diversity [3]. This may imply that intensifying crop diversification can result to more productivity, income and risks (production and income) reduction which can assure households of food access and availability. In contrast, Nkegbe [52] reported that households which diversified crops in Ghana had higher probability of facing severe and moderate hunger more and less likely to undergo little hunger which could be because households were unable to manage multiple enterprises of multiple cropping compared to households specializing crop production.

3.3. Multinomial Logistic Regression Model on the Effect of Crop Diversification on Food Security

To assess the relationship between crop diversification and food security the following hypothesis was formulated,

H_{01}: There is no statistically significant influence of crop diversification on food security among smallholder coffee farmers in Kirinyaga Central and Kirinyaga East Sub-Counties, Kenya.

Multinomial logistic regression model analysis was done at a 5% significant level to evaluate the hypothesis. Based on the statistical significance of the model's Chi-square value, the relationship present in the dependent variable and combination of independent factors was established. In this instance, the model Chi-square probability [(10) = 3049.46] was 0.000, which was less than the 0.05 level of significance (Table 8). The null hypothesis that there is no statistically significant influence of crop diversification on food security was not supported in this study. Consequently, there is enough data to conclude that there was a statistically significant relationship between household food security and crop diversification strategies at the 5% level of significance. Hence, all of the independent variables are significant in multinomial logistic regression since the model is good fit. The value of R^2 for the MLR analysis was 0.680 This suggest that 68% of the variation in food security is explained by landscape heterogeneity, crop diversity, intercropping and crop species diversity in multinomial logit model (Table 8).

3.3.1. Landscape Heterogeneity and Food Consumption Level

The findings of this study revealed that landscape heterogeneity positively affects the probability of a farmer falling into a borderline and acceptable food consumption level by 33.2% and 0.5%, respectively in favour of poor food consumption at 1% significant level (Table 8). The findings of this study imply that maintaining a heterogeneous landscape through planting of trees, hedges and grass increased pollinator abundance and richness that enhanced crop yields and quality due to sufficient habitat diversity. The findings of this study are consistent with those of Ndakidemi [53], who found that planting field margins in common bean field, increased the number of crop pest natural enemies such as predatory bugs, lacewings, predatory flies, lady beetles and parasitic wasps, probably because higher number of natural enemies would be hosted in the field margins due to a wide range of resources available.

Table 8. *The results of multinomial logistic regression analysis.*

Variables	Borderline			Acceptable		
	coef.	Std. Err	M. eff	Coeff.	Std. Err	M. eff
Landscape heterogeneity	2.019***	0.288	0.332	5.844***	0.830	0.005
Crop rotation	0.158	0.085	0.023	3.568***	0.557	0.004
Crop variety diversity	0.550*	0.018	0.088	4.050**	1.213	0.004
Intercropping	0.912*	0.158	0.136	17.086***	0.456	0.020
Crop species diversity	1.003*	0.366	0.152	16.016***	1.096	0.018
_cons	-6.885***	0.627		-42.917***	2.162	
Poor FCS	Base outcome					

Base outcome=poor food consumption, Astericks *, **, and *** indicate statistical significance at 10%, 5%, and 1% probability levels, respectively. Wald chi^2 (10) =3049.46, Prob > Chi^2=0.000, Pseudo R^2=0.6800, Log pseudolikelihood =-253.110

The findings of this study are in agreement with those of Zamberletti [54] who asserted that semi-natural habitats (SNH) in agricultural landscapes boosts predator populations by diversity of predators and sustaining high density, which controlled and maintained pest density below the threshold for pesticide application. Based on the findings of this study, it is possible that the existence of hedges at the crop- field interface controls pests and limits their growth, strengthening conservation biological control (CBC). Mallinger [55] noted that inclusion of flowering species in full-season cover crop mixtures, season-long floral resources that support both managed and wild pollinators may be attracted thus increasing crop yields through transfer of pollen grain.

In rural Cameroon, Awazi, N. found that agroforestry a climate-smart and agro-ecological practice, improved soil fertility, reduced soil erosion and increased water retention in the soil, which implied that agroforestry increased crop production sustainably to smallholder farmers [56]. Based on the findings of this study, maintenance of landscape heterogeneity promotes biodiversity which is essential for the long-term sustainability of food systems. Diverse landscape with a mix of forested and agricultural land maybe better able to withstand extreme impacts of climate change such as droughts and floods, than monoculture systems. The findings of this study are in line with those of Fernandez [8], who noted that agrobiodiversity boosted food and nutrition security as well as provided crucial ecosystem services like pollination due to sufficient semi natural and natural habitat in agricultural landscapes. Based on the findings of this study, diverse agricultural landscape may increase natural enemies of crop pests and pollinators due to wide range of resources available from both semi-natural and natural habitats, which lead to increased yields that enhanced food consumption levels of households.

3.3.2. Crop Rotation and Food Consumption Level

The findings of this study showed presence of positive and significant effect of crop rotation on food security at acceptable food consumption level at 1% significant level. This indicated that holding all other variables constant, increasing one additional practice of crop rotation increases the likelihood of a farmer being at acceptable food consumption level by 0.4% (Table 8). The findings of this study showed that it is possible to practice crop rotation to reduce crop pests and diseases pressure, provide diversified income streams and increase soil fertility and soil structure. The study's findings are congruent with those of Uzoh [57] who found out that rotating velvet bean the same year with maize increased maize yield by over 100% and improved soil fertility indices compared to maize mono-cropping, which may have implied that legume-maize rotation increased soil nitrogen (N), available phosphorous, exchangeable magnesium (exch Mg) and Effective Cation Exchange Capacity (ECEC). Based on the findings of this study, farmers should therefore practice crop rotation to optimize crop yields and to promote sustainable agriculture.

Rugare [58] noted that rotating short-term maize-red sunnhemp and maize-velvet bean reduced biomass and weed density across seasons at the first weed count. It is possible that cover crops in crop rotation emerge quickly and rapidly to produce a lot of biomass which acts as live mulch leading to reduction of weed emergence and growth. The findings of this study are consistent with those of Saulic [59] who reported that crop rotation was a low input production system which would lower weed density and weed seeds in the soil since it disturbs these niches and prevents weeds from finding their place for establishing. The findings of this study are also in line with those of Dominschek [60] who found out that grassland-cropping rotation reduced weed infestation in the early season of maize growth, which implied that diversification strategy was an economically viable alternative to increase crop yields.

3.3.3. Crop Varietal Diversity and Food Consumption Score

The findings presented by this study revealed that crop varietal diversity positively affected the probability of households falling into borderline and acceptable food consumption at 10% and 5% level in favour of poor level. The findings of this study show that it may be possible that growing an additional variety of food crop increases the likelihood of household being in borderline level and acceptable level at 8.8% and 0.4%, respectively (Table 8). During the study, extension officers stated that when a diverse range of crop varieties are planted, it increases the likelihood that some crops will survive and thrive despite environmental stress such as pests and droughts. The outcomes of this study are in agreement with those of Baniszewski [61] who noted that growing crop mixtures with greater functional trait diversity improved yields due to suppression of pests such as weeds and pathogens.

The observations of this study were also consistent with those of Gotor [18] who found out that durum wheat variety diversification increased and stabilized yields in marginal environments, which improved household food security in Ethiopia. It is possible that increased adaptation of new wheat varieties to specific soil conditions and microclimate enhanced yield stability which ensured a stable supply of food even in the face of environmental challenges. It has been reported that there is need to use new plant breeding technologies (NPBT) such as genetically modified organisms (GMOs) and gene-edited crops which could contribute to higher crop yields, minimized application of pesticides and chemical fertilizers, better crop resilience to climate stress, reduced postharvest losses and more nutritious foods [62]. In relation to the outcomes of this study, farmers should adopt diverse crop varieties to improve food security and increase resilience to climate change with proper training on how to select, plant and manage different crop varieties.

Reinprecht [63] noted that increasing bean cultivar mixture as in-field diversity, increased relative yield of the mixture (RYM) index compared to monoculture. The findings of this study may imply that variety diversity provided greater buffering capacity and resiliency to cropping systems that increased crop yields. In addition, the study's findings concur with those of Horner [64] who opined that cultivar diversification from field pea mixtures increased crop yields due to altered root bacterial and fungal communities which promoted their interactions. Kong [65] also found similar observations where wheat cultivar mixtures had an increased yield of over 4.46% under unfavourable climatic conditions compared to monocultures probably because enhanced crop genetic diversity promotes improved yield for the gains under high temperature and drought which leads towards food security.

During the study, the extension officers reported that a diverse range of crops can provide a wider variety of nutrients, which can improve overall nutritional outcomes for the populations. For example, growing a variety of legumes, grains and vegetables can help to ensure that people have access to a range of vitamins, minerals, and other essential nutrients. The findings are consistent with those of Snynder [66], who found that growing variety of some crop species differ in phytochemical content (functional trait important for insect pest suppression and human dietary diversity) which may imply that varietal mixtures have the capacity to support and improve human nutrition. It has been suggested that to achieve food security there is need for increased production of crops, and farming communities need to collaborate between management of landraces with high genetic diversity [67]. Based on the findings of this study, crop varietal diversity is confirmed to reduce the risk of malnutrition and associated health problems due to greater options for different nutrient profiles.

Furthermore, the researchers from KALRO (CRI), stated that planting a diverse range of crop varieties can help to preserve genetic diversity, which was essential for ensuring the long-term viability of agricultural systems. This can help to guarantee the future generations of access to a wide range of crops that are adapted to local environmental conditions. The findings of this study are in line with those of Qaim [68] who noted that genetic diversity was applied by small-scale farmers to adapt the plants in their farms to current and future climate changes and also provision of raw material of formal breeding. It is possible that diverse crop varieties in cropping system reduces the risks of crop failure that are caused by pests, diseases and environmental factors. Further, in Ethiopia, Cavatassi [69] concluded that genetically diversified crop varieties provide cultivars that respond to new microclimate conditions which reduce production uncertainty that is tied to climate variability and unpredictable weather patterns which reduce food security.

3.3.4. Intercropping and Food Consumption Level

During the study period, it was observed that intercropping practices increased the probability of a household falling into borderline and acceptable categories of food consumption by 13.6% and 2% against being in poor category at 10% and 1% level of significance respectively (Table 8). The outcomes of this study show that it is possible for an additional practice of intercropping to increase the likelihood of a farmer being food secure through uptake of adequate diet since it breaks lifecycles of pests and diseases, suppress weeds and provide microclimate for crops which increase crop yields. Kordbacheh [70] observed that intercropping main crop with flowering cover crops sustained pollinator communities and other beneficial insects within crop fields. The findings of this study may imply that habitat and floral resources for pollinators and predators are provided by cover crops, pests are reduced and crop yields enhanced.

The outcome of this study was consistent with that of Kinyua [71] who found out that farmer adaptation of Mbili-Mbili intercropping system that is, innovation involving two maize rows intercropped with two legume species (beans, cowpeas or pigeon peas) increased maize yields by 56%, which could be used to meet household food security. More also, intercropping maize and peanut in China, increased maize yield by 59.7% and 62.3% in year 2015 and 2016, respectively, compared to sole maize crop which was attributed by maize using N from the soil for growth which is fixed by legume thus improving crop productivity which reduce food insecurity [14]. In accordance to the findings of this study, it is possible that intercropping allows for the efficient use of resources like soil and water, improved soil health as well as fertility, reduced the risks of crop failure caused by weather conditions, crop diseases and pests, eventually leading to increased crop productivity hence better food security.

3.3.5. Crop Species Diversity and Food Consumption Level

The findings provided by this study revealed that crop species diversity positively and significantly affected the probability of a household attaining food security at borderline and acceptable food consumption category at 10% and 1% level. This may have implied that all other variables being constant, an increase in one crop species increased the probability of households to fall into borderline and acceptable food consumption level at 15.2% and 1.8%, respectively (Table 8). In relation to the observations of this study, it is possible for farmers to reduce crop losses due changes in environmental conditions caused by an intra-plot diversification. The observations of this study are in agreement with those of McAlvay [72] who noted that cereal mixtures produced a higher yield compared to their components grown in monoculture which may have implied that growing of crop mixtures was a strategy used by smallholder farmers to ensure increased and stable yields under low soil fertility, pest pressure and inconsistent precipitation. In Accordance to the study outcomes, farmers should be encouraged to grow diverse crop crops, since it reduces incidence of pests and diseases, increase resilience and improve soil fertility which can lead to increased and stable yields that enhances food security.

4. Conclusion and Recommendations

Food consumption score was used to calculate a calorie intake based on the last seven days before the survey. The study revealed that seasonal food insecurity was prevalent among smallholder coffee farmers in Kirinyaga County, since majority of the respondents were found at the borderline FCS level with over 50% of the farmers reporting at least one month of food scarcity. In accordance to the study findings, Farmers also stated that they experienced shortage of food between months of April and August, with July being the leanest month (23.19%) that was affected by seasons in agriculture. Further, a positive link was found between the extent of crop diversification and high food consumption scores and also on average, 68.38% of food consumed by households was produced on-farm. Multinomial logit model findings revealed that landscape heterogeneity, crop rotation, crop varietal diversity, intercropping and crop species diversity showed positive and significant association with food security. To that end, the following recommendations are made based on the findings of the study. Firstly, government should support policies and programs that promote crop diversification strategies to reduce pests and diseases and improve soil fertility, enhance biodiversity and increase crop yields such as crop rotation, landscape heterogeneity and intercropping through supporting and strengthening extension agents. Secondly, the government need to support research and development of new crop varieties and establish community seed banks that promote the use of diverse crops which improve food and nutrition security.

Competing Interests

The authors declare that they have no competing interests related to the publication of this research manuscript.

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