Maize Biodiversity and Food Security Status of Rural Households in the Derived Guinea Savannah of Oyo State, Nigeria

Oluwakemi Adeola OBAYELU (✉)
Oluwayemisi Abidemi ONASANYA

Summary

The incidences of food insecurity and loss of crop biodiversity are devastating in the developing countries including Nigeria. The continued loss of genetic diversity of agricultural crops has major negative consequences on food security. This study examined the effects of maize biodiversity on household food security status of rural maize farm households in the southern guinea savannah of Oyo State, Nigeria. A multistage sampling procedure was used to select 200 maize-farm households. The data were analysed using descriptive statistics, recommended daily calorie approach, Logit model, agro-biodiversity indices (Margalef, Shannon and Simpson) and the two-stage least Square. Based on the Food and Agriculture Organization (FAO) recommended daily energy requirement of 2260 Kcal, about 76.5% of the rural households were food secure. The highest proportion of the farmers with abundance of maize cultivars were within 30 to 49 years old, with five to nine household members, had formal education and 10-19 years of farming experience and cultivated five to nine hectares of farmland. Food security headcount increases with maize richness, cultivar evenness and relative abundance. Most of the farmers grow improved varieties such as 'Tsolo', 'NS-1', 'N.S 5', 'TZB', 'TZBP', 'OBA Supper' (Yellow and White) and Popcorn varieties. Farmers growing Tsolo had the highest percentage of abundance, while the least abundant species were 'NS-1', 'N.S 5', 'TZB', 'TZBP', 'OBA Supper' (Yellow and White) and Popcorn varieties. Disaggregation of maize diversity into its components showed that its effect on household food security status was based on the age of the farmer and the annual gross farm income. Maize diversity is positively related and truly endogenous to household food security status without reverse causality.

Key words

maize cultivars, relative abundance, cultivar richness, maize evenness, two-stage least square

University of Ibadan, Faculty of Agriculture and Forestry, Department of Agricultural Economics, Ibadan, Nigeria
✉ e-mail: jkemmyade@yahoo.co.uk

Received: December 12, 2015 | Accepted: March 25, 2017

Introduction

Food security occurs 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 (FAO, 2010). There are four dimensions of food security which are availability of sufficient amount of food that is a function of food production; access to the available food that depends on income levels and its distribution; food utilization that encompasses procurement, ingestion and digestion, all of which are dependent on nutritional quality, education and health; and stability of supply over time that depends on the ability to preserve produced food and supplement available food through imports if necessary (Tollens, 2000). These dimensions largely depend on domestic food production, which, in turn, depends on the amount of agricultural biodiversity available. Agriculture also reduces diversity to increase productivity for a component of biodiversity of particular interest. However, this biodiversity is endangered by socioeconomic and climatic determinants (Rouxel *et al.,* 2005; Faye *et al.,* 2010; Bisseleua and Niang, 2013).

Agricultural biodiversity is the variety and variability of living organisms (plants, animals, microorganisms) that are involved in food and agriculture (FAO, 1999). It can be considered at three main levels: ecological diversity, organismal diversity and genetic diversity (Heywood, 2003). It is not merely a subset of biodiversity but it is an extension of it so as to embrace units (such as cultivars, pure lines, breeds and strains) and habitats (agro-ecosystems such as farmers' fields and fisheries) that are not normally considered or even accepted by some conservation biologists as part of biological diversity. Agricultural biodiversity plays a central role in household food security and income generation, and thus regional and global food security. Diversity can also help to improve productivity by raising yield stability, contributing to pest and disease control, and improving the environment (Flood, 2010).

Over the past two decades, agricultural biodiversity (agrobiodiversity) has regrettably steadily declined, owing to changes in agricultural practices, with a corresponding increase in dependence on a small number of food crops (Jackson *et al*., 2005, Moore, 2010). According to Frison *et al*. (2006), only three plant species (maize, wheat, and rice) currently supply the bulk of protein and energy needs for both developing and developed country populations. The continued loss of on-farm agro-biodiversity has been one of the reasons for the increasing attention to dietary diversity because the rapidly and unsustainable increase in consumption cannot keep pace with a consistent decline in biodiversity (Binayak *et al.,* 2010; Toledo and Burlingame, 2006). Thus, supporting the preservation of crop and variety diversity can meet both the current needs of farmers and future needs of society (Benin *et al*., 2004).

Maize is pivotal to achieving food security in Sub-Saharan Africa, not only on the basis of the number of farmers that are engaged in its cultivation, but also on its economic value (Olaniyi and Adewale, 2012). The demand for maize in developing countries is expected to double by 2015, and by 2025 maize will have become the crop with the greatest production globally (FARA, 2009). This points to the significant role of maize production to sustainable development of rural economy, food security and poverty reduction especially in rural areas of Nigeria. Its predominance in farming systems and diets in most region implies that its yield gains have the potential to jump–start a Green Revolution like for rice and wheat revolution in Asia (Smale *et al*., 2011). Despite the fact that maize remains the most important food security crop for millions of rural households in Nigeria, chronic food insecurity persists and it has not been produced to meet food and industrial needs of the country. The demand for maize sometimes outstrips supply as a result of the various domestic uses (Akande, 1994). This can be attributed to low productivity from maize farms and decline in its biodiversity.

Significant maize genetic diversity decrease is a consequence of development of modern hybrids and agricultural systems (Brush 1995; Drinic *et al*., 2012). The use of a limited number of elite lines and synthetics heightens the risk of genetic uniformity in commercial maize production fields (Hallauer *et al*., 1988). On the other hand, grain yield losses ranging from 0 to 70% have been reported due to some of the major diseases, which depend on factors such as genetic constitution of the cultivars and stage of growth at the time of infections (Bua and Chelimo, 2010). Consequently, cultivation of maize varieties in the Nigeria is characterized by low and instable grain yield, susceptibility to pests and diseases, as well as poor adaptation (Fakorede *et al*., 2011). The dearth of targeted empirical research on on-farm conservation of maize has prevented a considerable explosion of recent recommendations on how to conserve maize biodiversity on-farm. This study assessed the contribution of maize biodiversity to rural household food security. It also investigated if reverse causality exists between maize biodiversity and food security. It contributes to the existing socio-economic literature on agricultural biodiversity and food security in terms of crop (maize) and location (Nigeria) specificity.

Methodology

The study was carried out in the southern guinea savannah of Oyo state, Nigeria. Oyo State is an inland State in southwestern Nigeria with its capital at Ibadan. It lies within latitudes $7^0$3' N and $9^0$12" N and longitudes $2^0$47' and $4^0$23" E. It covers a land area of 32,249 square kilometres and bounded by Kwara state in the North, Osun state in the East, Ogun state in the south and the west partly by Ogun state and Benin Republic. The Local Government Areas that fall within the Southern Guinea Savannah comprises Saki West, Saki East, Irepo, Oorelope, Olorunsogo, Atisbo, Iwajowa, Kajola, Iseyin, Afijio, Ibarapa North, Afijio, Oyo East, Oyo West, Ogo Oluwa, Ogbomoso south, Ogbomoso North, Oriire, Atiba, Atisbo and Itesiwaju (Figure 1).

Primary data for this study were collected in 2014 through the use of a semi-structured interview that was directly conducted among rural maize-based farming households. A multistage sampling procedure was employed to select the sample households for the study. The first stage was the purposive selection of two zones (Oyo and Saki) from the four zones of the Agricultural Development Programme (ADP) zones in Oyo State. ADP is a national programme organized by the Nigerian government to foster agricultural development. The second stage involved the stratification of blocks of each zone. Given

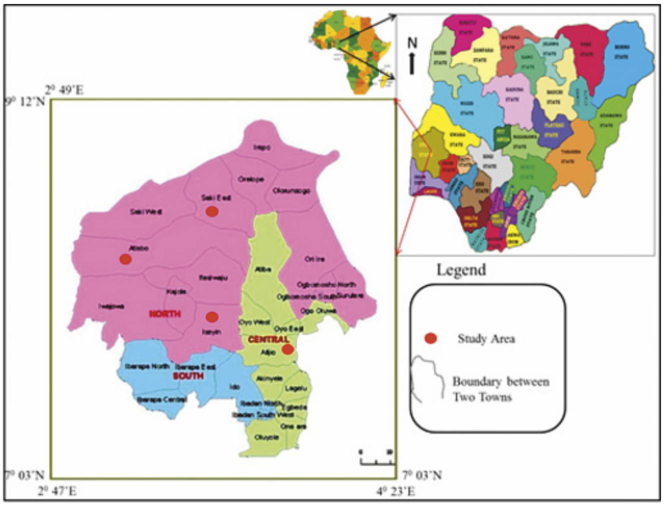

Figure 1. Map of Oyo State showing the study area

the higher population of Saki zone relative to that of Oyo zone, a random selection of three cells from Oyo zone and four cells from Saki zone formed the third stage leading to a total of 14 cells in all. ADP agricultural zones were used because the study was focused on rural households whose primary livelihood is farming. The number of respondents used in each zone was proportionate to the population size of the zone, this constitute the fourth stage of the sampling. In all 80 respondents were sampled in Oyo zone, while 120 respondents were sampled in Saki zone totalling 200 respondents (Appendix).

The primary data collected from each household included the household socio-economic and demographic characteristics, participation in social network, household food consumption and asset ownership and varieties of maize grown and consumed in the study area.

Analytical methods

The analytical tools used to analyse data collected were descriptive statistics: Food Security Index, diversity indices (Shannon, Margalef and Simpson), logit regression model, ordinary least square (OLS) and two stage least square (2SLS). The descriptive statistical technique involves the use of frequency distribution, percentages, mean and standard deviation.

To establish food security status of farming households in the study area, we constructed a Food Security Index (Z_i) and determined the food security status of each household based on the food security line using the Recommended Daily Calorie (RDC) approach as was used by Babatunde *et al.* (2007). Households whose Daily Calorie Intake equals to or higher than RDC (2900 Kcal) were considered food secure households, and those whose Daily Calorie Intake fall below the RDC were considered food insecure households. The Food Security Index is given as:

$$Z_i = \frac{Y_i}{R} \qquad (1)$$

where: Z_i represents Food Security Index of i^{th} household, Y_i is daily per capita calorie intake of i^{th} household and R is the recommended daily calorie requirement of i^{th} household. To obtain per capita daily calorie intake; daily calorie intake of each household were divided by its' household size.

In this study, maize biodiversity is defined and measured on the basis of samples collected from the maize populations grown by a sample of farm households drawn from several communities in a specified environment of the study region. The Shannon, Simpson and the Margalef indices were calculated and used to profile the food security status of the rural households. The most common index used to measure the degree of crop diversity is the Shannon index (H') that accounts for the number of the species or cultivars within the crop (Gozdowski *et al.*, 2008). It measures the average degree of uncertainty, in order to predict what species an individual will randomly choose from the collection of 'S' species and total number of 'N' individual species. This average of uncertainty increases as the number of species increases and as the distribution of individuals among the species becomes constant (Meerman, 2004). The mathematical expression of Shannon's index (*H'*) is described as:

$$H' = \sum_{i}^{S} pi.Inpi \qquad (2)$$

where:

H' = Shannon's index

ni = number of individuals in species i; the abundance of species i.

S = number of species, also called species richness.

N = total number of all maize species.

pi = is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N)

Thus, H' has two properties that were made to reflect the popular measure of crop species diversity: (1) H' = 0 if there is one species in the sample, and (2) H' = it is maximum if all S species are represented by the same number of individuals in the sample, that is, a perfectly even distribution of the abundances. When all species in a sample are equally abundant, an evenness index should be maximum and decrease toward zero as the relative abundances of the species diverge away from evenness (Meerman, 2004). The Shannon index (H') increases with an increase in the number of species cultivated within one single crop. Therefore, the Shannon index (H') represents the difference between the farm households who cultivate relatively the same number of crops (Abdalla *et al.*, 2013)

Simpson's index (D') is used to quantify biodiversity of a habitat, takes into account the number of species present, the relative abundance of each species and it represents the probability that two randomly selected individuals from the habitat will not be from the same species. In other words, it gives the probability of any two individuals drawn at random from an infinitely large community belonging to different species. It is therefore expressed as 1-D or 1/D and it is heavily weighted towards the most abundant species in the sample while being less sensitive to species richness. It has been shown that once the number of species exceeds 10 the underlying species abundance distribution is important in determining whether the index has a high or low value. The D value which is standing for the dominance index is used in pollution monitoring studies. As D increases, diversity decreases. Mathematically, Simpson's index is expressed as:

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)} \right) \quad (3)$$

where:
n = the total number of maize of a particular species
N = the total number of maize of all species
D = represents a range between 0 and 1 (1 represents infinite diversity while 0 denotes no diversity).

Margalef index has a very good discriminating ability and it is sensitive to sample size. It is a measure of the number of species present for a given number of individuals. However, it is weighted towards species richness. The advantage of this index over the Simpson index is that the values can be more than 1 and this makes comparing the species richness between different samples collected from various habitats much easier. It is defined as:

$$\text{Margalef index} = (S-1)/lnN \quad (4)$$

where S is number of varieties of maize species; N is total number of samples summed over all classes.

Regression model

A binary logistic regression model was used to determine the effects of some socio-economic and demographic characteristics of the household on-farm maize biodiversity. The estimated variables used consist of age of household head, years of cultivation, quantity of maize production, gender, access to credit, education level of farmer, household size, annual gross farm income, main occupation of farmer, membership of cooperative, farm size, contact with extension agent, annual non-farm income, household food security status, distant of farm to market and the number of distinct farmlands.

Causal relationship between maize biodiversity and food security status was assessed using the Two-Stage Least Square (2SLS) Approach. The adopted 2SLS equation is specified as:

$$Z_s = N\gamma_1 + \lambda_i\gamma_2 + \omega_i \quad (5)$$

where:
Z_s = Per capita food calorie
N_i = Maize diversification index of 'i' farmer
λ_i = Vector of 'i' explanatory variables
γ = Vector of parameters to be estimated
ω_i = Error term

Given that the above system of equations is endogenous, the parameters were estimated using the instrumental variable approach. The 2SLS was applied in order to correct for the endogeneity of N_i in equation (5). A two stage least square (2SLS) instrumental variables regression was used to produce consistent estimates if the maize biodiversity was poorly identified (Davidson and Mackinnon, 1993). A reduced form equation specified as a function of all the exogenous variables in equation (5) and a set of instrumental variable is specified as follows:

$$Ni = \lambda_i\theta_1 + Q_i\theta_2 + \varepsilon_t \quad (6)$$

where: Q_i is the vector of instruments (nearness of farm to input supply shop and nearness of farm to market) that impact maize diversification but do not affect household food security, as used by Di Falco and Chavas (2009). The predicted values from equation (6), defined as $\check{N}_i$, are then inserted into the structural equation (5) to replace N_i. Therefore, the reduced form of the equation (5) is given below:

$$Z_s = \check{N}_i\theta_1 + \lambda_i\theta_2 + \Pi_I \quad (7)$$

The vectors of instrument Q_i are: religion, marital status, nearness of farm to input supply shop and nearness of farm to market as used by Di Falco and Chavas (2009).

Results and discussion

Food security profile and on-farm biodiversity indices of the farmers in the study area

Simpson and Shannon indices incorporate richness and evenness into a single measure. The Simpson index is a function of the probability that two individuals sampled at random will belong to the same species and it has an inverse relationship with biodiversity. Shannon index is a measure of the average degree of "uncertainty" in predicting the species to which a maize crop chosen at random from a collection of maize species and *N* individuals (maize samples) will belong (Ludwig and Reynolds, 1988). Agrobiodiversity increases with this uncertainty. Results of the summary statistics showed that the farmers grew about eight varieties of maize. Simpson index was close to unity and was the highest while was the least index (Table 1).

Table 1. Summary statistics of maize diversity indices

Diversity measure	Mean	SD	Minimum	Maximum
Count index	7.80	0.60	6.21	10.62
Shannon index	0.46	0.68	0.36	1.08
Simpson index	0.99	0.08	0.92	1
Margalef index	2.38	1.31	0.80	3.64

Shannon's index profile of maize crop farmers

Across the Shannon index groups, the highest proportion of the farmers with high richness and diversity per hectare of maize cultivars were within the 30 - 49 years age range (Table 2). This suggests that more able-bodied and active individuals were involved in agricultural production in rural Nigeria. Households with five to nine members also had the highest richness of maize cultivars especially among the male farmers (90%). Farmers who had formal education (73.5%) and those with 10 to 19 years of farming experience (62.5%) were those with the highest richness of maize cultivars. Results further showed that food security headcount increases with cultivar abundance. This implies that the majority of the respondents who were food secure were those who cultivated highly diverse varieties of maize. Farmers with high richness of maize cultivars cultivated five to nine hectares while more than half of the farmers had no access to credit. About 61.5% of farmers in the study area were members of the cooperative society and the majority had no agricultural extension contact.

Table 2. Shannon's index profile of maize crop farmers in percentages

	0–0.4 (N = 156)	0.41–0.7 (N = 34)	0.71–1.08 (N=10)	Total (N=200)
Age of HH				
10 – 29	0.64	0	10	1
30 – 49	50.64	35.3	50	49
50 – 69	44.87	61.76	40	47.5
70 and above	3.85	2.94	0	2.5
Total	100	100	100	100
Religion				
Christianity	69.23	58.82	50	66.5
Islam	30.77	41.18	40	33.0
Others	0	0	10	0.5
Total	100	100	100	100.0
Household Size				
Less than 5	3.85	0	0	3.0
5 - 9	50.64	47.06	60	50.5
10 – 14	27.56	29.41	10	27
15 and above	17.95	23.53	30	19.5
Total	100	100	100	100.0
Gender				
Male	87.82	88.24	90	88
Female	12.18	11.76	10	12
Total	100	100	100	100
Marital Status				
Single	3.85	2.94	10	4
Married	91.03	82.35	90	89.5
Divorced	1.92	2.94	0	2
Widowed	3.21	11.76	0	4.5
Total	100	100	100	100
Education				
None	19.87	44.12	30	24.5
Primary School	46.79	38.24	30	44.5
Secondary School	32.05	17.65	30	29
Tertiary School	0	0	0	0
Others (Islamic School)	1.92	0	10	2
Total	100	100	100	100
Years of Farming Experience				
1 – 9	25.64	26.47	40	26.50
10 – 19	63.46	61.76	50	62.50
20 and above	10.90	11.76	10	11.00
Total	100	100	100	100
Food Security Status				
Food Secure	17.95	56.82	65	76.5
Food Insecure	82.05	43.18	35	23.5
Total	100	100	100	100
Farm Size				
Less than 5	43.59	14.71	30	78
5 – 9	45.51	64.71	50	17
10 - 14	10.90	20.59	20	5
Total	100	100	100	100
Access to Credit				
Yes	24.34	41.18	30	27.5
No	75.64	58.82	70	72.5
Total	100	100	100	100
Membership of farmers' association				
Yes	64.10	58.82	30	61.5
No	35.90	41.18	70	38.5
Total	100	100	100	100
Extension Contact				
Yes	25	67.65	40	33
No	75	32.35	60	67
Total	100	100	100	100

Table 3. Simpson's index profile of maize crop farmers in percentages

	0-0.92 (N = 10)	0.93-0.97 (N = 34)	0.98-1.00 (N = 156)	Total (N = 200)
Age of HH				
10 – 29	10	0	0.64	1
30 – 49	50	35.29	50.64	48
50 – 69	40	61.76	44.87	47.5
70 and above	0	2.94	3.85	3.5
Total	100	100	100	100
Religion				
Christian	50	58.82	69.23	66.50
Islam	40	41.18	30.77	33.0
Others	10	0	0	0.50
Total	100	100	100	100
Household Size				
Less than 5	0	0	3.85	3.00
5 – 9	60	47.06	50.64	50.5
10 - 14	10	29.41	27.56	27
15 and above	30	23.53	17.95	19.5
Total	100	100	100	100
Gender				
Male	90	88.24	87.82	88
Female	10	11.76	12.18	12
Total	100	100	100	100
Marital Status				
Single	10	2.94	3.85	4
Married	90	82.35	91.03	89.5
Divorced	0	2.94	1.92	2
Widowed	0	11.76	3.21	4.5
Total	100	100	100	100
Education				
None	30	44.12	19.87	24.5
Primary School	30	38.24	46.79	44.5
Secondary School	30	17.65	32.05	29.5
Tertiary School	0	0	1.28	1
Others(Islamic School)	10	0	0	0.5
Total	100	100	100	100
Years of Farming Experience				
1 – 9	40	26.47	25.64	26.5
10 – 19	50	61.76	63.46	62.5
20 and above	10	11.76	10.90	11.0
Total	100	100	100	100
Food Security Status				
Food Secure	40	78.42	78.42	76.5
Food Insecure	60	21.58	21.58	23.5
Total	100	100	100	100
Farm Size				
Less than 5	30	14.71	43.59	5
5 – 9	50	64.71	45.51	17
10 - 14	20	20.59	10.90	78
Total	100	100	100	100
Access to Credit				
Yes	30	41.18	75.64	27.5
No	70	58.82	24.36	72.5
Total	100	100	100	100
Membership of Cooperative				
Yes	70	58.82	35.90	21.15
No	30	41.18	64.10	78.85
Total	100	100	100	100
Extension Contact				
Yes	40	67.65	25	33
No	60	32.35	75	67
Total	100	100	100	100

Table 4. Margalef's profile index of maize crop farmers in percentages

	0-0.8 (N = 57)	0.81-1.42 (N = 41)	1.43-3.64 (N = 102)	Total (N = 200)
Age of HH				
10 – 29	0	0	1.96	1
30 – 49	42.11	26.83	59.8	16
50 – 69	50.88	63.41	37.25	48
70 and above	7.01	9.76	0.99	35
Total	100	100	100	100
Religion				
Christian	75.44	58.54	64.71	66.5
Islam	24.56	41.46	34.31	33
Others	0	0	0.98	0.5
Total	100	100	100	100
Household Size				
Less than 5	3.51	7.32	0.98	3
5 – 9	59.65	43.90	48.4	50.5
10 - 14	22.81	14.63	34.31	27
15 and above	14.03	34.15	16.31	19.5
Total	100	100	100	100
Gender				
Male	84.21	95.12	87.25	88
Female	15.79	4.88	12.75	12
Total	100	100	100	100
Marital Status				
Single	3.51	4.88	3.92	4
Married	89.47	92.68	88.24	89.5
Divorced	1.75	2.44	1.96	2
Widowed	5.26	0	5.88	4.5
Total	100	100	100	100
Education				
None	12.28	26.83	22.55	20.5
Primary School	31.58	51.22	53.92	47
Secondary School	49.12	17.07	22.55	29
Tertiary School	7.02	2.44	0.98	3
Others (Islamic School)	0	2.44	0	0.5
Total	100	100	100	100
Years of Farming Experience				
1 – 9	22.81	14.63	33.33	26.5
10 – 19	61.40	68.29	60.78	62.5
20 and above	15.79	17.07	5.88	11
Total	100	100	100	100
Food Security Status				
Food Secure	26.32	75.61	78.43	76.5
Food Insecure	73.68	24.39	21.57	23.5
Total	100	100	100	100
Farm Size				
Less than 5	43.86	24.39	40.20	38
5 – 9	36.84	53.66	53.92	49
10 - 14	19.30	21.95	5.88	13
Total	100	100	100	100
Access to Credit				
Yes	33.33	24.39	25.49	27.5
No	66.66	75.61	74.51	72.5
Total	100	100	100	100
Membership of Cooperative				
Yes	57.89	53.66	66.67	61.5
No	42.11	46.34	33.33	38.5
Total	100	100	100	100
Extension Contact				
Yes	19.30	19.51	19.61	80.5
No	80.70	80.49	80.39	19.5
Total	100	100	100	100

Simpson's index profile of maize crop farmers

Furthermore, across the Simpson index group, farmers within the age range of 30 to 49 years had the highest proportional abundance and dominance of maize cultivars and a majority of these farmers were male (88%), married (89.5%) and had five to nine members (Table 3). However, farmers who had formal education and 10 to 19 years of maize farming experience had the greatest diversity of maize cultivars. Similar to Shannon index, food security increased with relative abundance of maize cultivars suggesting that majority of the respondents who were food secure were those who cultivate highly diverse varieties of maize. However, farmers who cultivated five to nine hectares of land and had access to credit had evenly and highly diverse maize cultivars. About three-quarters of the farmers who planted highly diverse maize varieties had access to credit.

Margalef's Profile index of maize crop farmers

The Margalef index profile showed that 59.8% of the respondents with high index were in the age range of 30 - 49 years (Table 4). This implies that majority of the farmers who cultivate highly diverse varieties of maize were in their active age. The majority (88%) of the male farmers, with five to nine household members, had the highest richness and diversity per land unit of maize cultivars on their farms. About a quarter of those with maize cultivar richness had no education while 62.5% of the respondents had 10 – 19 years of farming experience and 89.5% of these farmers had the highest maize cultivar richness were married. About 78.43% of respondents in the 3.64 Margalef range were food secure. Farmers who cultivated between five to nine hectares of farmland with access to extension contact had the greatest diversity of maize cultivars.

Relative abundance of maize varieties in the farmers' fields

Table 5 shows that the relative abundance of maize varieties on-farm was measured by the percentage of the households growing that variety. Farmers growing 'Tsolo' had the highest percentage of abundance greater than 50, while those who grow 'Swan Yellow' were between 10 – 20%. The least abundant varieties were 'NS-1', 'N.S 5', 'TZB', 'TZBP', 'OBA Supper' (Yellow and White) and Popcorn varieties.

Distribution of respondents by abandoned varieties

About 21 - 30% of the farmers had abandoned the local white maize variety and less than 10% of the the farmers had abandoned improved varieties like 'Western Yellow', 'NS -1', 'N.S. 5', 'TZB', 'Sagari' (White and Yellow), Popcorn, 'TZSR', Hybrid and 'Boluyo' (Table 6). Farmers claimed that most of these abandoned varieties were not acceptable in the market, has lower yield and late maturity.

Determinants of on-farm maize biodiversity

The results of the regression analysis are presented in Table 7. The model produced a good fit because the chi-square of the computed log likelihood is statistically significant for Margalef, Shannon and Simpson model, respectively. Regression analysis to examine the determinants of on-farm maize biodiversity found that the number of species on the farm is determined by the main occupation of farmer, annual gross farm income and contact with extension agents under the Margalef index.

Table 5. Relative abundance of on-farm maize

Relative abundance (%)	Name of the variety	No of varieties
Greater than 50	Tsolo	1
41 – 50	none	0
31 – 40	none	0
21 – 30	none	
10 – 20	Swan Yellow	1
Less than 10	NS – 1, N.S. 5, TZB, TZBP, OBA Supper (Yellow), Popcorn, OBA Supper (White)	7

Table 6. Distribution of respondents by abandoned species

Respondents (%)	Name of the variety	No of varieties
Greater than 50	none	0
41 – 50	none	0
31 – 40	none	0
21 – 30	Local white maize	1
10 – 20	none	0
Less than 10	Western yellow, NS – 1, N.S. 5, TZB, Popcorn, Sagari (White), Sagari, (Yellow), TZSR, Hybrid, Boluyo	8

The outcome of the regression shows that contact with extension agent had a positive relationship with on-farm richness of maize (Margalef index), which agrees with the outcome from the study of Cromwell and van Oosterhout (2000) that contact with agricultural extension services has a positive influence on crop diversity at the on-farm level in Zimbabwe. The regression coefficient of annual gross farm income showed a positive and significant impact on on-farm maize diversity. This implied that maize diversification is enhanced with increasing annual gross farm income of the farmers, because the purchasing power of the farmers is augmented and they could purchase more maize seeds.

Results of the regression analysis under the Shannon index revealed that access to credit, farm size, and contact with extension agent are significant factors affecting on-farm maize biodiversity. The outcome of the regression in Table 7 shows that an increase in the total land cultivated by maize farmers will lead to an increase in the degree of maize diversity. The marginal effect of total land cultivated by maize crop was about 0.032 implying that as the total land cultivated by maize crop expands by 1%, the level of crop diversity will increase by 0.10%, all other variables remaining constant. This finding agrees with the outcome from the study of Cromwell and van Oosterhout (2000) that found a positive and significant relationship between the area cultivated by cash crops and the degree of crop diversity at the farm level. The result also showed that access to credit has a positive and significant effect on on-farm maize diversity. This is consistent with *a priori* expectations and agrees with the findings of Feder *et al,* (1985) that lack of access to credit significantly inhibits the adoption of high yielding varieties.

The result under the Simpson index revealed that membership of cooperative, farm size and household food security status were significant determinants of on-farm maize diversity. Membership of cooperative had a positive effect on the number of species on the farm. This agrees with the findings of Amaza *et al.* (2007) that membership of a social group, farming experience and use of fertilizer were positively related to on-farm maize diversity.

Reverse causality between on-farm maize biodiversity and household food security status

The logit model treated household food security status as an exogenous variable. However, Food security is also an endogenous variable and it is therefore pertinent to isolate the exogenous effect of food security on on-farm maize biodiversity. The study tested for the existence of a reverse causality effect with

Table 7. Logit regression estimates for determinants of on-farm maize biodiversity

	Poisson regression count index (richness)		Margalef index (richness)		Shannon index (proportional abundance)		Simpson index (proportional abundance)	
	Coeff	dy/dx	Coeff	dy/dx	Coeff	dy/dx	Coeff	dy/dx
AgeHH	0.000 (0.00)	0.001 (0.03)	0.005 (0.03)	0.000 (0.00)	-0.004 (0.02)	-0.001 (0.00)	0.058 (0.06)	0.000 (0.00)
Gender	-0.004 (0.09)	-0.03 (0.67)	-1.068 (0.70)	-0.079 (0.05)	0.372 (0.66)	0.052 (0.09)	-0.383 (1.54)	-0.001 (0.00)
Yearsofcul	0.000 (0.01)	0.001 (0.05)	0.050 (0.05)	0.004 (0.00)	-0.004 (0.46)	-0.001 (0.00)	-0.164 (0.11)	-0.000 (0.00)
QtyofProd	0.000 (7.5e-06)	0.000 (0.00)	0.000 (0.00)	5.5e-06 (0.00)	-0.000 (0.00)	-0.000 (0.01)	0.000 (0.00)	9.9e-07 (0.00)
Accesstocred	0.001 (0.06)	0.008 (0.46)	-0.157 (0.60)	- 0.012 (0.44)	0.813* (0.44)	0.113 (0.06)	-0.183 (1.10)	-0.000 (0.00)
EdulevHH	0.002 (0.03)	0.0141 (0.23)	0.233 (0.32)	0.017 (0.02)	-0.339 (0.24)	-0.047 (0.03)	-0.232 (0.38)	-0.001 (0.00)
HHSize	0.002 (0.01)	0.017 (0.05)	0.000 (0.05)	0.000 (0.00)	-0.021 (0.05)	-0.003 (0.00)	0.191 (0.17)	0.000 (0.00)
AGFincome	0.005 (0.04)	0.039 (0.28)	-0.115 (0.35)	-0.009 (0.03)	-0.124 (0.28)	-0.017 (0.04)	-0.999 (0.63)	-0.002 (0.00)
MOccupHH	0.005 (0.08)	0.045 (0.64)	-1.829** (0.92)	-0.094 (0.03)	0.111 (0.61)	0.015 (0.08)	-2.225 (1.87)	-0.003 (0.00)
MemCoop	-0.002 (0.06)	-0.016 (0.44)	0.605 (0.57)	0.042 (0.03)	0.053 (0.42)	0.007 (0.06)	1.711* (0.91)	0.005 (0.01)
FarmSize	0.011 (0.01)	0.088 (0.08)	-0.075 (0.12)	-0.005 (0.01)	0.233** (0.96)	0.032 (0.01)	-0.381* (0.23)	-0.001 (0.00)
ConExnagent	0.004 (0.04)	0.031 (0.31)	0.978** (0.52)	0.072 (0.04)	0.589** (0.27)	0.082 (0.04)	0.448 (0.68)	0.001 (0.00)
ANFIncome	0.003 (0.05)	0.021 (0.36)	-0.760* (0.43)	-0.056 (0.03)	0.449 (0.36)	0.062 (0.05)	-1.38 (1.05)	-0.003 (0.00)
HHFoodSecSta	0.002 (0.03)	0.013 (0.27)	-0.151 (0.30)	-0.011 (0.02)	-0.452 (0.33)	-0.063 (0.05)	4.296*** (1.63)	0.009 (0.01)
Distoffarmtomkt	-0.000 (0.00)	-0.003 (0.03)	-0.045 (0.04)	-0.003 (0.00)	0.431 (0.03)	0.006 (0.00)	0.013 (0.07)	0.000 (0.00)
Numofdistfarmlands	0.007 (0.02)	0.055 (0.18)	-0.347 (0.22)	-0.026 (0.02)	0.254 (0.18)	0.035 (0.02)	-0.298 (0.58)	-0.001 (0.00)
_cons	1.889		6.16		-1.242		6.833	
Pseudo R square			0.132		0.206		0.394	

Table 8. Correlation values of instrumental variables with food security index

	Religion	Marital Status	Nearness of Farm to Market	Nearness of Farm to Input Supply Shop
Food Security Index	1.000 (P > 0.1)	0.006 (P > 0.1)	-0.122 (P < 0.01)	-0.276 (P < 0.001)
Remark	Not Significant	Not Significant	Significant	Significant

Table 9. 2SLS regression estimates for causal relationship between on-farm maize biodiversity and household food security status.

Variables	OLS		2SLS (Shannon)		2SLS (Margalef)		2SLS (Simpson)	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Logqtyprod	-0.041	0.05	-0.043	0.05	-0.037	0.05	-0.046	0.05
Age	-0.155**	0.06	-0.145**	0.07	-0.173**	0.09	-0.149**	0.06
Gender	-0.122	0.08	-0.109	0.08	-0.130	0.08	-0.107	0.09
Education	0.055	0.15	0.084	0.16	0.076	0.16	0.073	0.15
Hhsize	-0.000	0.01	-0.004	0.01	-0.002	0.01	-0.003	0.01
Dependants	-0.011	0.01	-0.005	0.02	-0.011	0.01	-0.006	0.02
Memcoop	-0.047	0.11	-0.004	0.11	-0.031	0.12	-0.044	0.11
Yrsofcul	0.004	0.01	0.004	0.01	0.006	0.01	0.005	0.01
Memsocnet	0.009	0.03	0.009	0.03	0.008	0.03	0.012	0.03
Annonfarminc	-0.032	0.06	-0.058	0.08	-0.032	0.06	-0.057	0.09
Agfinc	0.228***	0.08	0.027	0.07	-0.182	0.17	-0.225***	0.08
Accesscred	0.038	0.05	0.049	0.06	0.043	0.05	0.045	0.05
Farmsize	0.000	0.01	0.006	0.02	0.002	0.01	0.006	0.02
Conexnagent	0.013	0.03	0.024	0.05	0.019	0.04	0.017	0.04
Occupation	-0.051	0.08	-0.043	0.08	-0.022	0.13	-0.042	0.09
Hhfoodsec	0.029	0.13	0.584***	0.03	0.593***	0.03	0.581***	0.04
_cons	7.530***	0.35	7.664***	0.49	7.36***	0.67	3.74	10.90
R^2	0.74		0.75		0.75		0.75	
Adj R-squared	0.709		0.712		0.713		0.711	
Sample Sizes	200		200		200		200	
Wu–Hausman F test	–		0.018 (p=0.894)		0.018 (p=0.894)		0.018 (p=0.894)	

Instrumented: Shannonindex, Margalefindex, Simpsonindex; Instruments: DistMar distfarm; *** - significant at 1% level, ** - significant at 5% level, * - significant at 10% level

the aid of instrumental variable (2SLS) approach. A Pearson product moment correlation between household food security index and proposed four instruments for household food security status was therefore estimated (Table 8). Nearness of farm to market and nearness of farm to input supply shop were significantly related to food security (-0.122 and -0.276, respectively) were therefore used as instrumental variables for food security status in the 2SLS analysis.

In order to test bicausality of maize diversity food security status of households, the instruments chosen were nearness of farm to input supply shop and nearness of farm to market as used by Di Falco and Chavas (2009). This provides the basis for determining the direction of causality between maize diversity and food security status of household members. The result of the instrumental variable is presented in Table 9. Evident from the Table 9 is the improvement in the adjusted R^2 from 0.709 to 0.713 when compared with the use of maize diversity index. Furthermore, the instrumental variable method led to higher coefficient of the food security index in the diversity indices than in the OLS method. A reverse causality could have been accepted if there was no reduction in R^2 as well as in the instrumented regression. Since, there was an improvement on both counts, one can infer the absence of reverse causality and thus substantiate true exogeneity of food security index. A unit increase in the level of instrumented maize diversity indices resulted into 20 percent increase in the percentage of food secure households. This buttresses the findings of M'Kaibi (2014) that agricultural biodiversity is enhanced by food security status of households.

Conclusion and recommendations

The result of the on-farm maize biodiversity farmers profile across the diversity indices shows that the highest proportion of the farmers with high proportional abundance of maize cultivars were within the 30 - 49 years age range, had household size of between 5 – 9 people and 10 to 19 years of farming experience. Farmers with formal education had the highest proportional abundance of maize cultivars and the majority of food secure respondents cultivated highly diverse varieties of maize. Although household food security status had a positive effect on on-farm maize biodiversity, maize biodiversity does not explain household food security status. Thus, intensification of rural food security programmes is a viable policy tool to enhancing on-farm maize biodiversity in the derived guinea savannah.

Farm size, contact with extension agent, membership of a cooperative society and access to credit had positive impacts on on-farm maize biodiversity while annual non-farm income have negative impacts on maize diversity. The study therefore recommends empowerment of maize farmers through increased access to credit and farmland; and improved extension contact.

References

Abdalla, S., Leonhäuser, I., Bauer, S., Elamin, E. (2013). Factors influencing crop diversity in dry land sector of Sudan. *Sky Journal of Agricultural Research* 2(7): 88 – 97.

Akande, SO (1994) Comparative Cost and Return in Maize Production in Nigeria: Nigeria Institute for Social and Economic Research (NISER) Individual Research Project Report, Ibadan: NISER.

Amaza, P, Kwacha A., Kamara A. (2007). Farmers' perceptions, profitability, and factors influencing the adoption of improved maize varieties in the Guinea Savannas of Nigeria. IITA: Research to Nourish Africa.

Babatunde, RO, Owotoki, GM, Heidhues, F., Bucheenrieder, G. (2007). Vulnerability and food insecurity differentials among male and female-headed farming households in Nigeria. *Medwell Journals*, 4(3): 414-418.

Benin, S., Smale M., Pender J., Gebremedhin B., Ehui S (2004). The economic determinants of cereal crops diversity on farms in Ethiopian highlands. *Agricultural Economics* 31 ( ): 197-208.

Binayak, S., Purnima, M.,Akhter, U.A., Fatema, P. C. (2010). Food Utilization and Nutrition Security. Bangladesh Food Security Investment Forum, 26 –27 May 2010, Dhaka.

Bisseleua, H.B.D., A. Ibra Niang 2013. Lessons from sub-Saharan Africa Delivery mechanisms for mobilizing agricultural biodiversity for improved food and nutrition security. Diversifying food and diets: Using Agricultural Biodiversity to Improve Nutrition and Health. Edited by Jessica Fanzo, Danny Hunter, Teresa Borelli and Federico Mattei. Chapter 5 112-121 http://www.b4fn.org/fileadmin/templates/b4fn.org/upload/documents/Diversity_for_Food_and_Diets/Chpt5_Bisseleua.pdf

Brush, S.B. (1995). In situ conservation of landraces in centres of crop diversity. *Crop Science* 35 :346-354.

Bua, B., Chelimo, B.M. (2010). The reaction of maize genotypes to maize streak virus disease in central Uganda: Second RUFORUM Biennial Meeting held from 20-24 September, 2010, Entebbe, Uganda. Pp. 293-297.

Davidson, R., MacKinnon, J. G. (1993).. Estimation and inference in econometrics. 2nd ed. New York: Oxford University Press.

Di Falco, S., Chavas, J. P. (2009). On crop biodiversity, risk exposure and food security in the Highlands of Ethiopia. *American Journal of Agricultural Economics* 91,599 -611.

Drinic, M.V., Andjelkovic, V. and Micic, D.I (2012). Genetic diversity of maize landraces as sources of favorable traits. In the Molecular Basis of Plant Genetic Diversity, Prof.Mahmut Caliskan (Ed.), ISBN: 978-953-51-0157-4, InTech, Available from: http://cdn.intechopen.com/pdfs-wm/33919.pdf

Cromwell, E., van Oosterhout, S. (2000). On-farm conservation of crop diversity: policy and institutional lessons from Zimbabwe. Edited in Stephen B. Brush (2000) genes in the field On-Farm Conservation of Crop Diversity IDRC/IPGRI/Lewis Publishers 2000.

Etoundi S.M.N., Dia, B.K. (2008). Determinants of the adoption of improved varieties of Maize in Cameroon: case of CMS 8704. Proceedings of the African Economic Conference

Fakorede, M.A.B., Fajemisin, J.M., Ladipo, J.L., Ajala, S.O., Kim, S.K. (2001). Development and regional deployment of streak virus maize germplasm: an overview. pp. 503-516 in Jacqueline d'A Hughes and Babajide O Odu (eds). Plant virology in Sub-Saharan Africa. Proceeding of a conference organized by the International Institute of Tropical Agriculture, Ibadan 4th-8th June, 2001. Forum for Agricultural Research in Africa

FAO (1999). What is agro biodiversity. Available on http://www.fao.org/SD/LINKS/documents_download/FS1W hatisAgrobiodiversity.pdf

FAO (2010). The state of food insecurity in the world: addressing food insecurity in protracted crises. Rome.

FARA, (2009). Patterns of change in maize production in Africa: Implications for maize policy development. *Ministerial Policy Brief Series*, *3*: 1 – 8.

Faye, M.D., Weber, J.C., Mounkoro, B., Dakouo, J.M. (2010) 'Contribution of parkland trees to farmers' livelihoods: a case study from Mali', *Development in Practice,* 20(3):.428–434

Feder, G., Just, R.Eand Zilberman, D. (1985). Adoption of agricultural innovation in developing countries: A Survey. *Economic Development and Cultural Change,* 33(2): 225-298. 2008. 397-413.

Flood, J. (2010). The importance of plant health to food security. *Food Security*, 2:215–231.

Frison, E.A., Cherfas, J., Hodgkin, T. (2011). Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security', *Sustainability* 3(1) :238–253, doi: 10.3390/su3010238.

Gozdowski, D., Roszkowska-Mądra, B., Mądry, W. (2008). Crop diversity at the gmina level and its causes in the Podlasie district of Poland. *Communications in Biometry and Crop Science* 3 (2): 72–79.

Hallauer, A. R., Russell, W. A., Lamkey K. R. (1988). Corn breeding, in corn and corn improvement, edited by G. F. Sprague and J. W. Dudley. American Society of Agronomy, Madison, WI. pp. 463–564.

Heywood, V.H. (2003). Conservation strategies, plant breeding, wild species and land races. In K. Ammann, Y. Jacot and R. Braun, (eds) *Methods for Risk Assessment of Transgenic Plants IV. Biodiversity and Biotechnology*, pp.143–159, Birkhauser Verlag, Basel/ Switzerland.

Iken, J.E., Amusa, N.A. (2004). Maize research and production in Nigeria. *Afr. J. Biotechnol.*, 3(6): 302–307.

Jackson, L.E., Bawa, K., Pascual, U., Perrings, C., 2005. Agrobiodiversity: a new scienceagenda for biodiversity in support of sustainable agroecosystems. DIVERSITAS report.

Ludwig, J.A., Reynolds J.F. 1988. Statistical ecology: A Pprimer on methods and computing. New York, New York: John Wiley.

Magurran, A.E. (1988). Ecological diversity and its measurement'. Princeton, New Jersey: Princeton University Press.

Meerman, J. (2004). Rapid ecological assessment of Columbia River Forest Reserve past Hurricane Iris. A study commissioned by: Ya`axché Conservation Trust and Toledo Institute for Development and Environment. October, 2004. Retrieved on 31 March, 2016 from:http://biological-diversity.info/Downloads/Xate%20in%20the%20Columbia%20River%20Forest%20Reserve.pdf

M'Kaibi, F.K. (2014). The role of agricultural biodiversity, dietary diversity, and household food security in households with and without children with stunted growth in rural Kenya. Unpublished dissertation presented for the degree of Doctor of Philosophy in the Faculty of Medicine and Health Sciences at Stellenbosch University

Moore, G. (2010). Multilateral and national regulatory regimes for agrobiodiversity. In: Lockie, S., and Carpenter, D. (Eds.) (2010). Agriculture, biodiversity and markets: Livelihoods and agroecology in comparative perspective. Washington DC, Earthscan.

Olaniyi, O.A., Adewale, J.G. (2012) Assessment of utilization of agricultural information in maize production among rural youth: panacea for sustainable food security in Nigeria. *International Journal of Sustainable* Developments (2): 75-86.

Rouxel, C., Barbier, J., Niang, A., Kaya, B., Sibelet, N. (2005). Biodiversité spécifique ligneuse et terroirs: quelles relations? Le cas de trois villages de la région de Ségou (Mali). Bois et Forest des Tropiques, 1(283):33–49.

Smale, M., Byerlee, D., Jayne, T. (2011). Maize revolutions in sub-Saharan Africa. Policy Research Working Paper 5659. http://ageconsearch.umn.edu/bitstream/113651/2/Smale_Byerlee_Jayne_Maize_Revolutions_2011.pdf

Toledo, A., Burlingame, B. (2006). Biodiversity and nutrition: A common path toward global food security and sustainable development. *Journal of food composition and analysis* 19: 477-483.

Tollens, F. (2000). Food Security: Incidence and Causes of Food Insecurity Among Vulnerable Groups and Coping Strategies, In, CTA (2000) Food Insecurity in ACP Countries, Proceedings of a CTA Seminar, pp27 -50.

acs81_39

Appendix. Distribution of respondents according to blocks

ADP Zones	Blocks/LGA’s	Cells	Respondents
Oyo	Iseyin	Otiri, Olode and Bale-layo	40
	Afijio	Jobele, Ilora and Iluaje	40
Saki	Saki East	Obudo-Ogbomosho, Sepeteri, Oje-owode and Ogboro	60
	Atisbo	Tede, Ago-are, Wasangari and Sabe	60