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Indigenous or Exotic Crop Diversity? Which Crops Ensure Household Food Security: Facts from Tanzania Panel

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Abstract: Farm crop diversity is often overlooked, predominantly indigenous crops' role in this diversity. The main concentration has been on the contribution or role of exotic crops to household crop diversification. At the same time, the role played by both types of crops in household food security has only been aggregated, failing to show how indigenous crops play a key role in household food security. This research paper uses Tanzanian Panel data from waves 4 and 5 to study the factors influencing indigenous and exotic crop diversification and the role of this diversity in household food security. Using a random effect model, the author found that various factors are crucial in determining household crop diversification. Gender, household size, marital status, and expected harvest quantity are among the key factors influencing indigenous crop diversification. On the other hand, age, education, access to markets, access to irrigation services, and soil quality are the primary factors that affect the diversification of exotic crops. Moreover, the findings show that indigenous and exotic crop diversity significantly influences household food consumption. Thus, policies to increase the production of indigenous crops in order to improve household food consumption should be considered.

Keywords: indigenous crops; exotic crops; panel analysis; food security; Tanzania

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1. Introduction

Food security is a situation in which all people have access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life at all times [1]. Achieving food security is a significant concern for many developing nations and the developed world, albeit with a difference in magnitude [2]. Food insecurity results from a lack of nutritious food resources due to shortages, a significant concern within the sustainable development goals. The first and second objectives of the sustainable development goals for no poverty and zero hunger require exploring ways to increase households' access to food and incomes, especially in developing countries [3,4]. In sub-Saharan Africa, food insecurity is a pressing issue closely linked to extreme poverty [5]. According to a UN report, in 2022, 2.4 billion people, mostly women and people living in rural areas, were moderately or severely food insecure [6]. Particularly in Africa, where the population is growing and the food supply is scarce, the rate of food insecurity is higher compared to other regions [7]. As a result of the population crisis and the adverse effects of climate change on natural resources, an alarming increase in food demand is anticipated. This situation has put many households in a challenging position, struggling to bridge the gap in their food consumption. It is crucial that we take urgent and immediate action to address this issue and ensure that everyone has access to sufficient, nutritious food. By doing so, we can make a significant difference in the lives of millions of people [8].

Agriculture is a key sector and a primary source of livelihood for many African countries, and more than 80% of farmers are smallholders. These smallholder farmers play a crucial role in achieving sustainable rural development and ensuring food and n Yes, the meaning is maintainedutrition security. Agriculture is an important sector in Tanzania, with approximately 45% of its land area dedicated to agriculture, which is the most significant contributing sector to the country's gross domestic product (GDP) at approximately 26% [9,10]. Agriculture also contributes to 85% of exports, provides 65% of raw materials to industries, and is the source of 100% of the country's food [11]. Agriculture also employs 65.6% of Tanzania's growing population, currently at 61 million [12]. Most of the population resides in rural areas and consists mainly of small-scale farmers who produce crops for consumption. Agriculture is considered a strategic sector in achieving sustainable development goal (SGD) 1, which is focused on ending extreme poverty in all forms by 2030. The sector is also critical in achieving SDG 2, which aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture by 2030. Maize is a major cereal crop that is consumed and produced in Tanzania. Although it is viewed as an exotic crop, it has the potential to be diversified with several crops, especially legumes such as beans, cowpeas, pigeon peas, and other pulses.

One unsustainable farming practice that continues to frustrate efforts to improve household food availability is monoculture. Shifting from this to a cropping system that encourages diversification through intercropping and crop rotation is one innovative climate change adaptation strategy [7,13]. Diversification in the country has been seen as a strategy to deal with food shortages and nutrition issues. Diversifying crops can be a crucial factor in improving household food security. Crop diversification can increase farm revenue, create jobs, reduce poverty, and preserve soil and water resources, which are essential for resolving these crises in developing nations. Crop diversification is likely to (i) reduce vulnerability to climate change, pests, and diseases [14], (ii) increase agroecosystem resilience [15], (iii) enhance the quality and diversity of foods and overall food and nutritional security [16], (iv) increase and nutritional security [16], and (v) increase farm households' economic resiliency and autonomy [17–20].

When it comes to crop diversification, there are two main options: indigenous crops (ICs) or exotic crops (ECs). Both have potential benefits and drawbacks. However, indigenous crop diversification can be a great option, as it promotes cultural heritage and ensures community food security. On the other hand, exotic crop diversification might bring in higher yields, but it could also lead to environmental degradation and the loss of local crop diversity. Ultimately, choosing the right crop diversification strategy should be based on a thorough analysis of the local context and the community's needs.

In sub-Saharan Africa, one option for adapting to a changing climate and reducing damaging farming practices [21,22] is a focus on promoting locally grown crops that can support household food security and income generation. A holistic solution is needed to address issues of food insecurity in Tanzania. Exploring and promoting indigenous crops offers such a potential solution. Indigenous crops (orphan or neglected crops) are traditional plants in a region consumed as part of traditional diets [23]. They are classified into three main categories: grain, vegetable, and fruit crops [24]. Such crops provide opportunities to diversify and improve farming systems [25], improve food security [16], improve nutrition for poorer households [14,16], and increase income generation opportunities as part of addressing poverty alleviation [15]. An added advantage, the potential value, and the benefits of ICs in production are their relatively few financial inputs, with minimal financial losses and risks compared to exotic crops with higher returns. However, efforts need to be made to introduce ICs into household diets by promoting the cultivation of these crops to form part of household diets and become a source of income [20].

Yet, in Tanzania, indigenous crops are rarely considered viable for addressing the food insecurity that continues to bedevil the region. The main focus in Tanzania and other Sub-Saharan African countries has been the shift towards non-indigenous crops by urban and rural dwellers, driven by the perception that indigenous foods are poor people's food [26]. These have led to a fall in the production of these crops, with much emphasis given to exotic crops. Still, little is known about where these crops can potentially perform well, given their climatic or environmental characteristics. Given that food insecurity is the most acute amongst the most vulnerable in subsistence environments, a sample of smallholder farmers in Tanzania was drawn from national panel survey waves 4 and 5 to explore two interlinked research questions: (1) What factors influence indigenous and exotic crop diversification? And (2) what is the influence of indigenous and exotic crop diversification on household food security? This research paper makes a key contribution to the growing importance of indigenous crops in Tanzania, as well as previous research evaluating the impact of crop diversity (in this case, comparing indigenous and exotic crops' diversity) on food security to improve livelihoods [18,27–30]. The rest of the article is organized as follows: the next section outlines the materials and methods, which include the data sources, econometric models, diversity indices, and food security indices. The subsequent section presents the results, including the descriptive statistics and regression analysis results. The final section provides the study's conclusions based on my findings.

2. Materials and Methods

2.1. Data Source

The paper uses data from waves 4, the "Refresh Panel", and 5, the "Extended Panel", of Tanzania's National Panel Surveys (NPSs), conducted in 2014/2015 and 2020/2021. The NPS data mentioned here were gathered by Tanzania's National Bureau of Statistics (NBS) as part of the living standard measurement studies conducted in collaboration with the World Bank (WB). Wave 4 of the study was conducted between October 2014 and November 2015, while wave 5 took place between December 2020 and January 2022. The sample design for NPS is based on a stratified, multi-stage cluster sample design.

In the fourth wave of the study, the sample design was updated from the original NPS sample. An extended panel of 989 households was included, along with an entirely new sample called the "Refresh Panel", consisting of 3352 households. The fifth wave of the NPS followed the Refresh Panel cohort and introduced an additional booster sample of households, giving a total of 5587 households. This study uses data from the last two waves to gain a more current understanding of the contribution of indigenous crops to households.

After the data were merged, appended, and cleaned, the panel dataset was balanced by tracking only those household farmers who had cultivated any indigenous crop during the surveyed period. To ensure the consistent tracking of the same household members across both waves, a sample of 5604 was obtained, which included 2802 from each wave.

2.2. Econometric Model: Random Effect Model (REM)

The paper primarily focuses on investigating the factors influencing households' diversity of indigenous and exotic crops and how this diversity influences household food security. The outcome variables are the different measures of dietary diversity. The author estimated two different regression models using two distinct production diversity measures with a random effect (RE). After running the Hausman test, the model was selected to see which model worked best for the data between the fixed and random effect models. The random effect model assumes that the individual effects are randomly distributed and uncorrelated with the predictor or independent variables. The author made a key assumption that the differences across individuals influence the cultivation of indigenous crops, but this difference is not correlated with the predictors.

The generic form of the model is as follows:

$$y_{it} = \beta X_{it} + \alpha_i + \sigma_{it} + \varepsilon_{it} \quad (1)$$

y_{it} is the dependent variable observed for individual i at time t. X_{it} is a vector of the control variables, β is the parameters, and α_i is time-invariant variables. σ_{it} is time-variant variable and ε_{it} is the error term. The paper applies this model to the panel data collected from the two waves. The model includes time-invariant variables such as gender, which play a role as explanatory variables. In this paper, the regression model in Equation (1) can be an RE panel estimation method. The RE estimator is efficient if the independence assumption is valid but inconsistent otherwise. The paper applies an estimation method to obtain standard errors that are robust to heteroscedasticity and within-panel autocorrelation in the error term.

Model Equation (1) uses various dependent variables. One of the dependent variables is the diversity-dependent variable, which measures the diversity of crops using the number of crops grown by a household. The second dependent variable is the household food consumption score (FCS) indicator to measure dietary diversity. The diversity-dependent variable includes two measures of crop diversification: indigenous crop and exotic crop diversification. The model includes four dependent variables that measure diversification: an indigenous crop binary, an exotic crop binary, IC count diversity, and EC count diversity. These two dependent variables are further explained in Sections 2.3 and 2.4.

The independent variables in the model include the gender of the head of the household, their age (in years), the household size, their occupation (whether involved in agricultural activities or not), their education (no schooling, primary, or higher education), their marital status, their access to extension officers (whether the household head has access to extension services or not), a rural or urban area (1 = rural, 0 = urban), their own farm area (in acres), the logarithm of the IC quantity harvested (Ln IC harvest), the logarithm of the IC value in monetary terms (Ln IC value), the logarithm of the EC quantity harvested (Ln EC harvest), the logarithm of the EC value in monetary terms (Ln EC value), the wealth index, their access to credit, their access to irrigation, their access to a market, the soil quality, and the distance from the farm to a market (in kilometers). These variables are used interchangeably, depending on the model being analyzed.

2.3. Diversity Index

Crop diversification in this regard is the cultivation of more than one crop species and/or variety [31]. Measuring diversity is intuitively challenging since the science of analyzing and describing is said to be balkanized, with different conceptualizations among disciplines [32]. Social scientists draw on the classification used by farmers [33]. Ecologists characterize diversity as (1) the number of species found in a given area, or "richness", and (2) the relative distribution of species within a given space, or "evenness" [34]. While some measurements combine the two dimensions into a single value, others only capture one [33]. Indexes that integrate the two characteristics into a single measure tend to confuse the relative importance of each dimension. Still, measures that concentrate on a single dimension cannot convey the complexity of variety [33]. Thus, there is not one ideal diversity measure.

For the measurement of indigenous and exotic crop diversity, the author used the count index and a binary variable (for the diversity of households with more than one indigenous crop and 0 = otherwise). The count index is based on the counts of the number of crop species, indicating the number of crop species cultivated by the household during the 12-month reference periods. The common agricultural system in the study area comprises mixed farming with crops. The simplest measure of diversity is the count index (D^C) (the number of crops cultivated by the household), which measures the richness of cultivated crops and assumes that different crops contribute equally to the household crop portfolio. However, this is not always the case [35]. The count index is, thus, expressed in Equation (2):

$$D^C = J \tag{2}$$

where J is the number of crops cultivated by the household. Additionally, the paper uses a dummy diversity variable defined as 1 for households with more than one crop and 0 for households with only one crop.

2.4. The Food Security Index

In the analysis, the household food consumption score (https://inddex.nutrition.tufts.edu/data4diets/indicator/food-consumption-score-fcs (accessed on 15 January 2024)) (FCS) indicator measures dietary diversity. The FCS is used as a proxy indicator of the nutritional adequacy of households' diets in studies of production diversity and dietary diversity [36]. Validation studies suggest that the FCS is a useful measure that captures the quality and quantity aspects of household food consumption [37].

To construct the FCS, information on a household's food consumption frequency over a recall period of seven days before the survey was used. The FCS was constructed using weightings based on estimated nutrient content at the food category level. The weightings are crude estimates of the nutritional value of different food groups. Finally, the FCS is constructed by summing the weighted food group scores [38].

In addition to indigenous and exotic crop diversity, a number of other explanatory variables may affect household food security. Based on the existing literature [39], a number of variables were included in the analysis to account for socioeconomic influences. This includes the age, gender, marital status, occupation, and educational level of the head of the household, access to extension services, wealth, total agricultural land area, crop value, and rural or urban areas for differences in production areas. The estimated model for food consumption and household crop diversity is as follows:

$$FCS_{it} = \beta D_{it} + \beta X_{it} + \alpha_i + \sigma_{it} + \varepsilon_{it} \quad (3)$$

where FCS is the measure of household food consumption i at the time t; i i is an index for the household; t is time; D_{it} is the measure of the household crop diversity (indigenous and exotic crop); X_{it} is a set of the head of household characteristics and other key variables; α_i is time-invariant variables; σ_{it} is time-variant variables and ε_{it} is the error term.

3. Results

3.1. Descriptive Statistics

Table 1 presents summary statistics for the variables. On average, 13% of households in Tanzania diversify with indigenous crops, while 55% diversify with exotic crops. Most households grow one indigenous crop in their farmland, with a maximum of three indigenous crops. Similarly, for exotic crops, households grow one exotic crop with a maximum of four in their farmland. FCS captures the frequency of consumption of different food groups within seven days.

Table 1. Summary statistics.

Variable	Obs.	Mean	Std.	Min	Max
Dependent variables					
Indigenous crop binary	5604	0.137	0.344	0	1
Exotic crop binary	5604	0.553	0.497	0	1
IC count diversity	5604	0.152	0.402	0	3
EC count diversity	5604	0.718	0.752	0	4
Food consumption score	5604	3.345	3.481	0	7
Independent variables					
Head of the household (male = 1)	5604	0.722	0.448	0	1
Age (years)	5604	47.151	14.195	16	95
Household size (continuous)	5604	4.710921	2.52143	1	15
Occupation (agriculture main = 1)	5604	0.539	0.499	0	1
Education (no schooling, primary, or higher education)	5484	1.445	0.597	1	3
Marital status (married = 1)	5573	0.620	0.486	0	1

Access to extension officers (having access = 1)	5604	0.056	0.230	0	1
Rural or urban area (rural = 1)	5604	0.660	0.474	0	1
Own farm area (acre)	5604	2.585	2.162	0.100	15.000
Ln IC harvest	1289	5.303	1.425	0	11.736
Ln of IC Value	1288	11.420	1.349	4.898	15.811
Ln of EC harvest	2946	6.290	1.431	0.693	11.513
Ln of EC value	2946	12.356	1.471	2.708	18.089
Wealth index (1 = poor, 2 = not very poor, 3 = average 4 = not very wealthy, and 5 = wealthy)	5598	3.076	1.337	1	5
Access to credit	5604	0.108	0.310	0	1
Access to irrigation	5604	0.483	0.500	0	1
Access to market	5604	0.270	0.444	0	1
Soil quality (1 = good, 2 = average, and 3 = bad)	5604	2.320	0.782	1	3
Distance from farm to market (km)	3520	7.257	11.581	0	250

Source: Author's calculation.

The socioeconomic characteristics of households in Tanzania show that 72% are male-headed, with an average age of 47 years. Most households have an average size of five and rely on family labor to work on their farms, making a larger household an asset for farm work. On average, 53% of households identify agricultural activities as their main occupation. Most household heads have received no schooling (61%), with only 33% having completed primary education and only 5% with secondary education and above. Most of these households' members are married (62%) in either a monogamous or polygamous marriage.

Socio-demographic factors such as age, gender, and education level are critical determinants that affect the household adoption of various technologies. Gender plays a crucial role in agricultural issues, in which male and female individuals are involved in household decisions. In contrast, with indigenous crops, it is believed that the older the household head, the more informed they will be with traditional crops such as indigenous crops. Furthermore, education is expected to impact the knowledge one has about the significance of these two types of crops. Extension services in Tanzania remain a major challenge, with a ratio of 1:1172 for crops and 1:500 for livestock farmers. The statistics show that only 5% of households can access extension services. Access to household extension services is measured by seeking or receiving information from extension officers on seeds/planting, fertilizer, land management, agro-processing, marketing, fishing, crop or livestock production, and disease prevention.

Most agricultural households (57%) live in rural areas, where they cultivate an average of 3 acres of land, while 43% live in urban areas. The household's wealth index is determined through principal component analysis [40], which combines all household assets to create an index that is then classified into five groups, from poor to wealthy. The household ownership of physical assets such as motorcycles, bicycles, radios, televisions, refrigerators, mobile phones, and livestock is considered. Most households are less wealthy, with more than 50% in the poor quartile.

It was found that only 10% of household heads had access to credit, 26% had access to markets for selling their produce, and 48% had access to irrigation schemes during the short and long rainy seasons. The soil quality was a crucial factor in deciding which crops to cultivate. In this case, soil quality was assessed based on household self-evaluation, with good, bad, or average options. Most households had bad soil, with only about 20% considering their soil good for crop cultivation. The distance from the farm to the market, home, or road played an essential role in the sale of crops and the type of crop they grew. The farthest distance from the farm to the market was 7 km.

3.2. Indigenous and Exotic Crops

ICs, also known as orphan crops, are traditional plants in a region consumed as part of traditional diets [23]. These crops are classified into three main categories: grains, vegetables, and fruits [24]. In Tanzania, 28 indigenous crops have been identified, including cowpea, sorghum, pigeon pea, and okra, which are commonly grown crops. Other crops like baobab, jack fruit, jute mallow, bitter lettuce, chili pepper, monkey orange, finger millet, moringa, blackjack, spider flower, crotalaria, lablab, or locust bean are also grown. Table 2 lists all indigenous and exotic crops identified in the panel data that were used for the analysis. Figure 1 shows the panel results that only identified seven crops, including cassava, sorghum, bambara nuts, sweet potatoes, pigeon peas, finger millet, and cowpeas. The most commonly grown crops were cassava, sorghum, bambara nuts, cowpea, and sweet potatoes. Some crops, such as okra, amaranths, and pumpkins, were identified as being grown by households but with the least number of people.

Table 2. List of indigenous crops (ICs) and exotic crops (ECs) with their botanical names.

	Crop Name	Botanical Name	Category
1	Cassava	*Manihot esculenta*	IC
2	Sorghum	*Sorghum bicolor* (L.) *Moench*	IC
3	Bambara nuts	*Vigna subterranea*	IC
4	Sweet potatoes	*Ipomoea batatas*	IC
5	Pigeon pea	*Cajanus cajan*	IC
6	Finger millet	*Eleusine coracana*	IC
7	Cowpeas	*Vigna unguiculata*	IC
8	Okra	*Abelmoschus esculentus*	IC
9	Amaranths	*Amaranthus cruentus*	IC
10	Pumpkins	*Cucurbita pepo*	IC
11	Maize	*Zea mays*	EC
12	Paddy	*Oryza sativa*	EC
13	Banana	*Musa acuminata*	EC
14	Beans	*Phaseolus vulgaris*	EC
15	Cashew nut	*Anacardium occidentale*	EC
16	Cotton	*Gossypium* spp.	EC
17	Sesame	*Sesamum indicum*	EC
18	Sunflower	*Helianthus annuus*	EC
19	Mango	*Mangifera indica*	EC
20	Coffee	*Coffea arabica*	EC
21	Timber	*Diospyros ebenum.*	EC
22	Irish potatoes	*Solanum tuberosum*	EC
23	Tomatoes	*Lycopersicon esculentum*	EC
24	Chickpeas	*Cicer arietinum*	EC

Figure 1 shows a significant rise in the percentage of households cultivating sorghum, bambara nuts, sweet potatoes, pigeon pea, cowpea, and millet in wave 5. This indicates a significant shift from wave 4 to wave 5 towards leguminous crops such as cowpeas, which experienced a significant increase compared to other crops. However, the number of households cultivating cassava decreased significantly. This can be attributed to price fluctuations in the country between wave 4 and wave 5, in which massive production in 2018 led to a significant price fall, impacting production in 2019 [41].

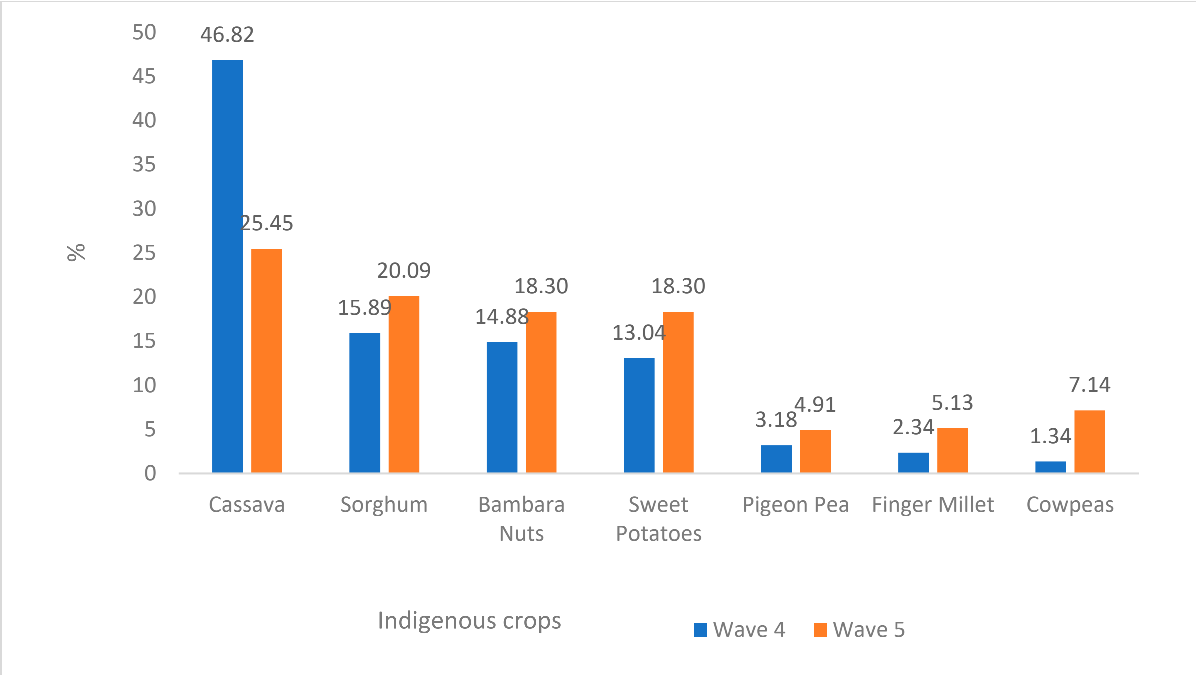

Figure 1. Indigenous crops cultivated in the long and short rainy seasons for wave 4 and wave 5.

Figure 2 shows some of the key exotic crops identified in the study, with maize being the most exotic crop grown by households. Paddy, banana, beans, and cashew nuts followed this. These exotic crops are recognized as non-native crops that are not traditionally grown in the production area [42] They are non-indigenous, meaning they are not traditional. These crops may survive and reproduce but can also displace native species and change natural systems [43,44]. In the country, there are many exotic crops, classified into groups of food and cash crops [45]. The findings confirm the results of other researchers that some of the main exotic food crops grown in the country are maize, paddy, wheat, bananas, beans, and sugar cane [41,45,46]. Cassava, millet, sorghum, and sweet potatoes are indigenous crops in the country's main food crop categories (Figure 1). Cash crops include coffee, cotton, cashew nuts, tobacco, tea, and sisal.

More exotic crops not in Figure 2 that were identified as grown by the farmers included coconut, tobacco, cocoyam, orange, pineapple, sugar cane, onion, green gram, yam, clove, avocado, papaw, fiwi, wheat, seaweed, carrot, tea, cardamom, guava, cucumber, ginger, cocoa, passion fruit, mandarin, chili, watermelon, custard apple, firewood/fodder, lime, and lemon. Some tracking results show an increase in the production of maize from wave 4 to wave 5, with a significant fall in the number of households cultivating mangoes, coffee, timber, and cashew nuts.

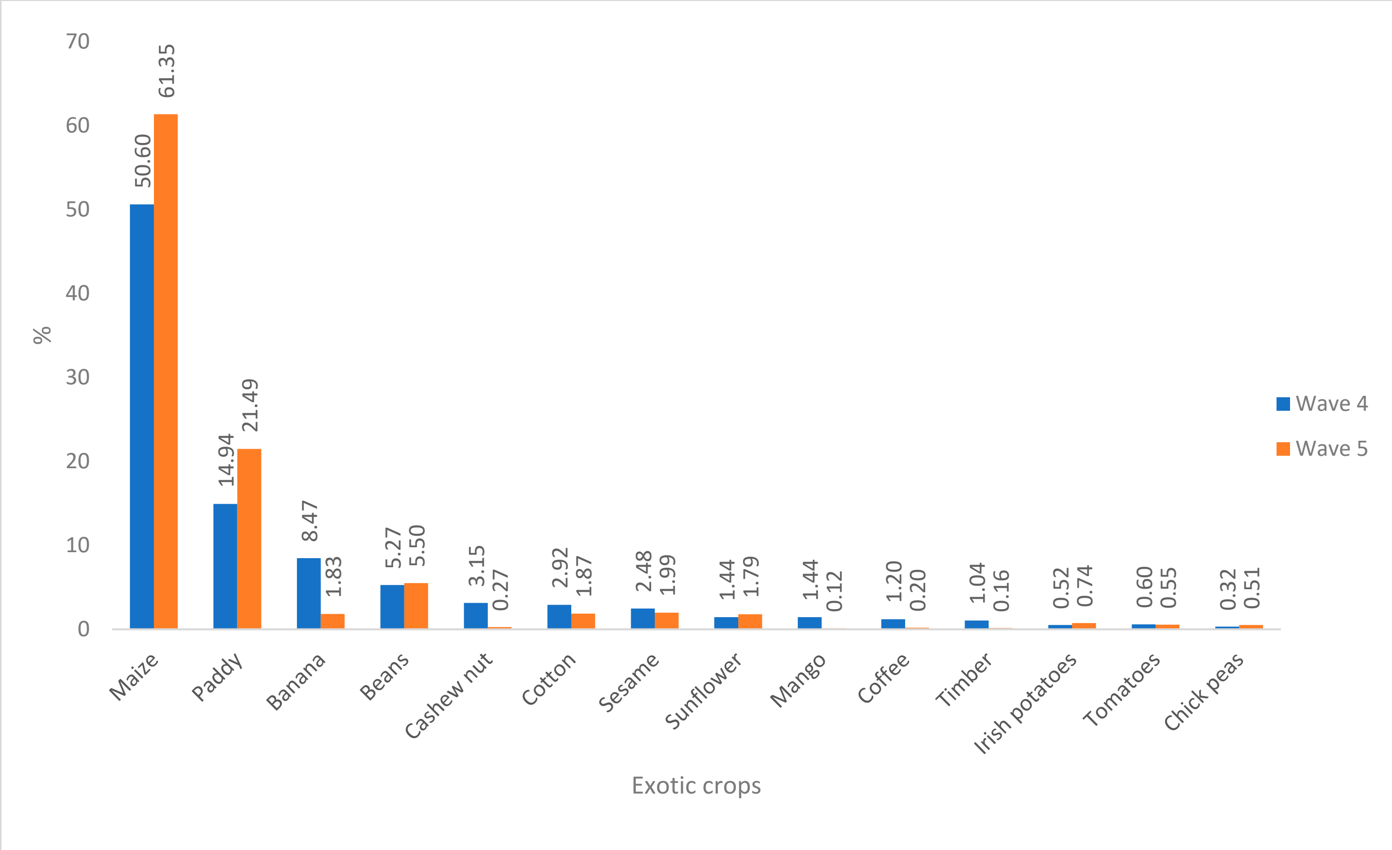

Figure 2. Exotic crops cultivated in the long and short rainy seasons for wave 4 and wave 5.

3.3. The Factors Influencing Indigenous and Exotic Crop Diversity

The paper first presents the results of the key factors that influence diversification with indigenous and exotic crops. The two measures of indigenous crop diversification are used separately in a probit and Poisson model. Table 3 presents the results of the pooled probit model with a binary diversity (indigenous and exotic) dependent variable of the factors influencing diversification.

The findings in Table 3 for indigenous crop diversity indicate that there was a noticeable rise in the correlation between gender (specifically being male), marital status (couples who were married), crop harvest, and the household's decision to diversify with indigenous crops. Additionally, the household size, occupation, land ownership, and wealth level impacted the household's decision to diversify with indigenous crops.

Various factors influenced the diversification of crops towards exotic ones in the household. The age of the household head was found to be a significant factor, with older heads of households being less likely to diversify with exotic crops, meaning younger people highly preferred these crops. This is because crops like maize were more labor-intensive, requiring weeding twice a season, planting, and harvesting. The occupation of the head of the household, especially if they were farmers and had higher levels of education, positively correlated with household diversification with exotic crops. Additionally, access to markets, wealth, and the expected quantity from the harvest positively influenced household diversification with exotic crops. However, marital status, land size, and access to irrigation had a significant association with the diversification of exotic crops, which was observed to decrease such diversity.

Table 3. Factors influencing indigenous and exotic crop diversity (marginal effects–panel probit model).

	Indigenous Diversity		Exotic Diversity	
	dy/dx	Standard Error	dy/dx	Standard Error
Gender of the head	0.1023 **	0.0456	−0.0033	0.0176
Age (years)	0.0000	0.0012	−0.0011 **	0.0005
Household size	−0.0188 ***	0.0063	−0.0037	0.0023
Occupation	−0.1327 ***	0.0493	0.0436 ***	0.0156
Education	0.0152	0.0343	0.0265 **	0.0131
Marital status	0.1361 ***	0.0391	−0.0354 **	0.0156
Access to extension officers	−0.0315	0.0510	−0.0145	0.0210
Rural or urban area	−0.0437	0.0316	0.0033	0.0113
Own farm area (acre)	−0.0715 ***	0.0145	−0.0200 ***	0.0057
Ln of harvest	0.0434 **	0.0184	0.0279 ***	0.0089
Ln of value	0.0167	0.0197	−0.0036	0.0088
Access to credit	−0.0080	0.0470	0.0192	0.0187
Access to irrigation	0.0278	0.0510	−0.0334 *	0.0190
Access to market	−0.0433	0.0314	0.0203 *	0.0119
Soil quality	−0.0209	0.0263	0.0112	0.0101
Distance farm to market	−0.0008	0.0014	0.0000	0.0005
Wealth index	−0.0072 ***	0.0115	0.0132 ***	0.0044

The asterisks represent the following: ***, $p < 0.01$; **, <0.05; and *, <0.1.

Table 3 reveals intriguing insights into household diversification using a binary variable to gauge diversification. The analysis went further in Table 4 and used a count-dependent variable to determine the factors influencing the number of indigenous and exotic crops cultivated by each household. Two models were run using a random effect Poisson model, providing an in-depth understanding of the factors influencing diversification.

The study found that household size was a crucial factor in determining the number of crops cultivated. As the number of crops in the farm field increased, so did the labor required for the farm activities. Additionally, the occupation of the head of the household, their marital status, the size of the land, the expected harvest quantity, and the value of the harvest all impacted the number of indigenous crops grown by the household.

Table 4. Factors influencing indigenous and exotic crop diversity (random effect Poisson model, marginal effects).

	Indigenous Diversity		Exotic Diversity	
	dy/dx	Standard Error	dy/dx	Standard Error
Gender of the head	0.1910	0.1489	−0.0689 **	0.0283
Age (years)	0.0009	0.0040	−0.0001	0.0009
Household size	0.0625 ***	0.0243	−0.0080 *	0.0042
Occupation	−0.2793 *	0.1520	0.1453 ***	0.0348
Education	0.0750	0.1186	0.0152	0.0214
Marital status	0.3575 ***	0.1355	0.0093	0.0241
Access to extension officers	−0.1096	0.1824	−0.0504	0.0339
Rural or urban area	−0.1530	0.1209	0.0039	0.0192
Own farm area (acre)	−0.2701 ***	0.0482	−0.0750 ***	0.0103
Ln harvest	0.1388 **	0.0628	0.0177	0.0164
Ln of Value	0.1111 *	0.0594	0.0904 ***	0.0161

Access to credit	−0.0913	0.1621	−0.0034	0.0304
Access to irrigation	−0.0405	0.1779	−0.0464	0.0369
Access to market	−0.1654	0.1029	0.0438 **	0.0217
Soil quality	−0.0748	0.0867	0.0296 *	0.0175
Distance farm to market	−0.0022	0.0045	0.0000	0.0008
Wealth index	0.0129	0.0397	0.0171 **	0.0082

The asterisks represent the following: ***, $p < 0.01$; **, <0.05; and *, <0.1.

Furthermore, the study found that the number of exotic crops grown by the household was primarily influenced by the occupation, the size of the farmer's land, their gender, the value of the harvest, the type of soil, access to markets, and the household's wealth. This can be attributed to exotic crops being perceived as more profitable and typically growing in larger land areas. The availability of the market also plays a crucial role in determining the number of exotic crops grown. Overall, this study provides valuable insights into the factors influencing diversification. These findings can be used to develop effective strategies to improve crop cultivation, increase household income, and promote sustainable agricultural practices.

3.4. The Effect of Indigenous and Exotic Crop Diversity on Household Food Security

The paper explores the correlation between the diversity of indigenous and exotic crops and household food security. The author measured food security using FCS estimates from Equation (3). Table 5 shows the analysis results of how the diversity of indigenous and exotic crops affects household food consumption. The paper finds a strong correlation between the diversity of households with indigenous and exotic crops and the amount of food consumed. The effects of IC and EC diversification were almost similar, with small significant differences in the coefficients, with ECs having more of an effect, as expected since they have a greater reputation in the market and among households.

Table 5. Household crop diversity on household food consumption (random effect linear model).

	Indigenous Diversity		**Exotic Diversity**	
	Coef.	**Standard Error**	**Coef.**	**Standard Error**
Crops diversity	1.0950 ***	0.1652	1.4322 ***	0.2655
Gender of the head	−0.4673 ***	0.1571	−0.4507 ***	0.1559
Age (years)	−0.0322 ***	0.0044	−0.0294 ***	0.0044
Household size	0.0014	0.0214	−0.0039	0.0201
Occupation	0.1823	0.2020	0.1400	0.1958
Education	−0.3001 **	0.1387	−0.3411 **	0.1376
Marital status	−0.1052	0.1558	0.0579	0.1545
Access to extension officers	−0.1900	0.2281	−0.2216	0.2304
Rural or urban area	1.2297 ***	0.0983	1.1886 ***	0.0983
Own farm area (acre)	0.4484 ***	0.0584	0.4192 ***	0.0581
Ln harvest	0.0989	0.1053	0.0044	0.1032
Ln of value	0.1473	0.1040	0.1675 *	0.1014
Access to credit	0.0930	0.2096	0.0762	0.2093
Access to irrigation	0.2679	0.1316	0.2420	0.1304
Access to market	−0.0029 **	0.0045	−0.0030 *	0.0048
Soil quality	−1.2504	0.0468	−1.2609	0.0460
Distance from farm to market	6.3323	1.0454	5.5478	1.0520
Wealth index	−1.2508 ***	0.0468	−1.2614 ***	0.0460
Constant	6.3379	1.0635	5.6230	1.0675

The asterisks represent the following: ***, $p < 0.01$; **, <0.05; and *, <0.1.

The findings reveal a correlation between the availability of food for consumption and the location of the household, i.e., rural or urban. Households in urban areas are more likely to have better access to food than those in rural areas. Similarly, household land size significantly increased the likelihood of food access for consumption compared to households with smaller land sizes. An increasing land size could lead to more land being used to produce diverse crops, increasing households' consumption patterns. This finding also aligns with [36] concerning the fact that land size plays a significant role in expanding the production of diverse crops and improving household food security.

Household characteristics such as gender and age significantly negatively impact FCS. This implies that older people are more likely to experience food insecurity, and men are more food insecure compared to women. Factors such as education level, wealth, and access to markets also have a significant impact on FCS, but they result in a decrease in the likelihood of food access. This means that households with higher education levels and incomes may sometimes experience changes in dietary habits that are less healthy, which can have a negative impact on food security in terms of nutrition and cost. It is possible that the wealth index can negatively influence household dietary patterns, causing them to shift from nutritious traditional foods, such as indigenous crops, to more processed foods. Wealthier people are also more likely to rely on buying food from the market instead of producing it themselves, which can leave them vulnerable to changes in food prices and availability, negatively impacting their food security. Additionally, limited access to markets can further reduce the amount of food available for a household.

4. Conclusions

The main results of this study highlight the significance of indigenous and exotic crops for food security. They illustrate the importance of indigenous crops in influencing food security measured using household food consumption scores, making it important to pay more attention to these crops in the same way exotic crops have been given importance in influencing household diets.

Typically, the current research on crop diversification has focused on exotic crops, particularly maize, with little attention given to indigenous crops, such as cowpea, pigeon pea, millet, sorghum, and even okra, in household food security. The current study's findings show that the factors influencing diversification for indigenous and exotic crops are different. Exotic crops are mainly influenced by market-oriented factors such as market access, irrigation services, and soil quality. On the other hand, socioeconomic factors such as gender, household size, marital status, and expected harvest quantity are more influential in the cultivation of indigenous crops. It should be noted that an increase in male participation had a negative effect on food security. This is because women play a pivotal role in ensuring food security within the household. Limited participation in decision-making, especially in choosing between cultivating indigenous or exotic crops, constrains women's participation in various aspects of food and nutrition security. Gender and food security are linked, and enhancing women's agency in various areas can lead to better food security and nutrition outcomes Therefore, on-farm crop diversification of both indigenous and exotic crops can be achieved by understanding these different farmers that influence their diversification.

Understanding these factors that contribute to the diversification of indigenous and exotic crops is crucial for developing effective policies to promote their production in Tanzania. The targeted policies will support the production and diversification of indigenous and exotic crops in Tanzania. Some policy recommendations include promoting sustainable farming practices, investing in research and development concerning local traditional crop varieties, strengthening market linkages for indigenous crops, and integrating indigenous knowledge into agricultural extension services. By fostering diversification, Tanzania can enhance food security, preserve agricultural heritage, and promote economic development in rural areas.

According to the list of indigenous crops identified in the data, their cultivation varies in magnitude, with more households growing indigenous crops such as sorghum and cassava. Similarly, as expected, maize is grown by the majority of households and is considered the main food crop in most households. These findings suggest that attention should be paid to indigenous crops, and markets for these crops should be improved to boost their production, just as much attention is given to exotic crops. This can help tackle multiple food insecurity issues within households. The findings emerging from this study could serve as a useful background for future research on indigenous crops in Tanzania. The findings of this study could also serve as useful background material for Tanzania and other sub-Saharan African countries concerning the importance of indigenous crops in households.

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