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The role of crop diversification in improving household food security in central Malawi

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Abstract

Background: This paper concerns the role of crop diversification in improving household food security in central Malawi. In this country, the agricultural sector is dominated by smallholder farming and rain-fed food production systems that are facing increasing challenges from land degradation and declining soil fertility. Maize is the staple food crop, and as such, the majority of farmers grow it regardless of land suitability. This has led to what scientists have labeled as "maize poverty trap." In the event of prolonged drought, maize fails thus leaving farmers food insecure. However, research in Sub-Saharan Africa has shown that crop diversification provides smallholder farmers with a diversity of diet, improves their income, and nutrition security. Due to increased cases of malnutrition and food insecurity, in the wake of climate change, government of Malawi has in the past few years intensified extension efforts for crop diversification.

Methods: The study is based on a sample of 271 randomly selected smallholder farming households from central Malawi. It investigates the influence of crop diversification and other household socioeconomic characteristics on the household Food Consumption Score and Household Food Insecurity Access Score. In our analysis, we rely heavily on a combination of ordinary least squares techniques and some descriptive statistics.

Results: Our results show that crop diversification, cattle ownership, access to credit and attaining of education have a positive and significant effect on the household Food Consumption Score. Precisely, crop diversification, cattle ownership and access to credit are all significant at 5% level, while education is significant at 10%. In addition, crop diversification and attaining of formal education by household head were found to have a negative and significant effect on Household Food Insecurity Access Score and were all significant at 1% level.

Conclusion and policy recommendation: Based on our study findings, we 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. In terms of policy, the results imply that the current efforts by government of Malawi to intensify promotion of crop diversification should remain a priority policy direction due to the continued malnutrition and food insecurity threat. This is particularly so in this era of climate variability that poses an extra burden to farmers.

Keywords: Household food security, Crop diversification, Food Consumption Score, Smallholder farmers, Malawi

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Background

Introduction

Malawi is largely an agricultural country. An estimated 84% of Malawians live in rural areas where about eleven million people (which is approximately 65% of the population) are engaged in smallholder subsistence farming. Agriculture contributes significantly to the economy. It accounts for more than 33% of gross domestic product (GDP), 90% of exports, over 80% of employment and approximately 65% of raw materials to the manufacturing industry [1]. Furthermore, over 75% of the food consumed in the country is produced by small-scale farmers [1, 2]. This stresses the importance of smallholder farmers and agriculture itself in general in Malawi. Although agriculture is the most important sector of the economy in Malawi in terms of contribution to livelihoods, GDP, employment creation and export earnings, the country is still on the list of the world's poorest countries [3]. According to the UNDP [4] human development report, about 74% of the population in Malawi still lives below the income poverty line of US$ 1.25 a day and 90% below the US$2 a day threshold.

Malawi faces a lot of challenges including that of attaining food security which is one of the objectives of the Agriculture Sector Wide Approach (ASWAP) of 2011 [1]. Most of the challenges, however, are caused by climate change (droughts, floods), declining soil fertility, poor agricultural policies and bad macroeconomic environment. Due to these challenges, smallholder farmers in Malawi are poverty stricken. These challenges affect individual farmers and they put the household food security status at risk. Moreover, farmers are more vulnerable to the overall effects of climate change since they have limited resources to invest in expensive coping strategies [5, 6].

Consequently, this risk encourages smallholder farmers to diversify in crop production in order to stabilize their food stocks and incomes. Crop diversification is based on cultivating more than one variety of crops belonging to the same or different species in a given area. Crop diversification is one way of developing a resilient agricultural system, especially where communities depend largely on agricultural products (food and fodder) for their livelihoods [7, 8]. Crop diversification is also one of the most ecologically, feasible, cost-effective and rational ways of reducing uncertainties in agriculture, especially among small-scale farmers. In addition, crop diversification brings about higher and spatial temporal biodiversity on the farm and increases resilience, i.e., the ability of an ecosystem to return to its original productive state after being disturbed [7]. According to Di Falco and Chavas [9], cultivating several crop species can also help smallholder farmers to manage price and production risks. In moisture-stressed, ecologically fragile agriculture systems crop diversification can also be a viable strategy to increase farm-level crop productivity [9]. All these benefits of diversification contribute to improved yield for the smallholder farmer which will translate to more and a variety of food for consumption and marketable surpluses from production.

Although crop diversification can be a viable option in reducing the risks associated with food insecurity, low incomes from agricultural production and nutrition insecurity among other challenges, only limited research on this subject has been conducted in Malawi to date. However, there is renewed global interest in crop diversification, mainly ascribed to the present rising concerns about loss of biodiversity, environmental and human health [7]. This therefore calls for scientific expertise in carrying out research of the various aspects of crop diversification that could provide alternative and more viable tactics for crop production. However, efforts to promote crop diversification in Malawi are evident from the past and recently. A recent, sound example is the Agricultural Sector Wide Approach (ASWAP) of 2011 which targeted vertical and horizontal crop diversification among other strategies to improve productivity, income, food, and nutrition security in Malawi. Non-governmental organizations (NGOs) and research organizations have been promoting crop diversifications directly and indirectly for the same reasons as well in Malawi. Examples include the International Food Policy Research Institute (IFPRI), Food and Agriculture Organization of the United Nations, United Nations Development Program, Irish Aid, and many other institutions. Most of these institutions contributed to the crafting of the ASWAP and funding it.

This work examines the role of crop diversification in improving food security. It specifically examines the role of crop diversification intensity in smallholder farming in Malawi on food consumption (volume and diversity) and food insecurity coping strategies severity. The study tests the hypothesis that crop diversification has no significant influence on the household Food Consumption Score (FCS) and Household Food Insecurity Access Score (HFIAS). To the best of our knowledge, there is no study that has examined the effects of crop diversification in smallholder farming in central Malawi, especially targeting food consumption and severity of food insecurity coping strategies. This study makes an important addition to the literature on the influence of crop diversification efforts in smallholder farming in Malawi in terms of household food security.

The rest of the paper is organized as follows: Upcoming subsection gives the literature on the role of crop diversification in improving household food security. The second section outlines the research methodology adopted

by this study. Third section presents the results and discussions, and the fourth section presents the study conclusions and policy recommendations.

Role of crop diversification in improving yield stability, nutrition diversity and hence food security

Yield stability is one fundamental component targeted by smallholder farmers. Most of the smallholder farmers rely on seasonal yields for food and economic returns. Thus, the implication of fluctuating and/or poor yields can be very profound since it means less food for the family and less income for other household basic needs. Yield stability is an important step toward attaining household food security. To be food secure, a household must have access to adequate food at all times. The household should not risk losing access to food as a consequence of sudden shocks, e.g., economic or climatic crisis. If smallholder farmers invest in crop diversification, this will help them cushion the problem of food insecurity due to the most likely increase in yields, as reported by several previous studies (such as [8, 10]), and bring the yield stability and insurance effect [7] since if one crop fails they can still depend on the other crop. Smithson and Lenné [11] reviewed a total of 100 studies of intra-specific crop mixtures in smallholder farming (mostly grains and legumes) and concluded that yields were often slightly higher compared to pure stands of component cultivars. Moreover, increasing crop diversity by intercropping tobacco, maize, sugarcane, potato, wheat, and broad bean was reported to increase yields for the same season between 33.2 and 84.7% for some combinations [5]. In addition, a meta-analysis study on cereal mixtures by Kiær et al. [12] reported an increase in grain yields of cereals. Thus, with increasing pressures from climate change and other problems constraining smallholder farmers, strategies need to be developed to make our food and farming systems more resilient to the devastating challenges.

The combination of various crops in agro-ecosystems in smallholder farming not only permits more efficient utilization of agro ecological processes, but also provides diversity of human diet and/or improves household income, nutrition, and security. Improving income further improves the purchasing power of the household thereby allowing purchase of other food products. Thus, crop production diversification and consumption habits should include a broader range of crop plant species, in particular those identified currently as underutilized and/or scarce in household food diets ceteris paribus. Crop diversification can as a result contribute significantly to livelihoods, improved health and nutrition, household food security, climate resilience, and ecological sustainability.

Methods

The study aims to attribute food security outcomes of farmers to crop diversification particularly extent of diversification. The study is based on an extract of 271 households interviewed during a baseline survey in Malawi in 2011. The data were collected through questionnaire survey from a stratified random sample of farmers in central Malawi. This section briefly describes sampling methods used to measure food security, crop diversification, and the econometric approaches used to establish causality between food security and crop diversification.

Sampling and data collection

This study uses cross-sectional household data from the baseline survey collected through structured interviews under the auspices of "Increasing smallholder farm productivity, income, and health through widespread adoption of Integrated Soil Fertility Management (ISFM) in the Great Lakes Region and Southern Africa" project—a case study of Malawi. A total of four districts (Lilongwe, Salima, Dowa and Mchinji) from central Malawi were included in gathering this data. The study population was composed of inhabitants in the communities that were selected for the project. In Lilongwe and Salima districts, these included Extension Planning Areas (EPAs) under the Ministry of Agriculture, Irrigation and Food Security, in Dowa these included Area Development Programs (ADPs) under World Vision, and in one part of Lilongwe and one part of Mchinji these included Farmer Associations under National Association of Smallholder farmers of Malawi (NASFAM). Since this was a household level and community survey, the selected participants for the survey were households. Simple random sampling technique was used to select villages from lists obtained from resident district agricultural development officers. Within selected villages interviewed, households were randomly chosen from households lists provided by representative extension personnel using simple random sampling techniques as well. A total of 599 households were then selected for the survey. However, some households were dropped during data cleaning prior to analysis as they did not have sufficient data thereby reducing the sample to 271 households. Data collection for this study was done in December 2011 through face-to-face administration of questionnaires. Data collection involved a household survey using a questionnaire with structured and semi-structured questions. The survey collected information on household demographics, socioeconomic characteristics, crop production and marketing, crop diversification, crop management, input use, food consumption, food insecurity coping strategies, and other farm- and farmer-specific characteristics.

Measuring food security

According to the FAO [13] and Coates et al. [14], food security is a state in which all people at all times have both physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life. Households are food insecure when they have uncertain or limited access to food through socially acceptable channels—a problem affecting many households worldwide, Malawi included. In this paper, we use FCS as a measure of household food security in the study sites.

Food Consumption Score (FCS)

To estimate food security, the study employed FCS approach and computed in accordance with guidelines provide by EFSA [15]. FCS was measured based on dietary diversity, food frequency, and the relative nutritional importance of nine different food groups. The FCS is designed to reflect the quantity and quality of people's diet at household level. A composite score is derived from a weighted sum based on the food type and frequency of consumption during a 7-day period. Precisely, dietary recalls questions were used to collect information on the consumption of selected food groups common in Malawi. The interviewees were asked about frequency of consumption over a recall period of past 7 days. FCS was calculated using the formula proposed by EFSA [15]. In the formula, FCS is derived by multiplying the weight for each food group/type by the frequency (number of days) these food groups/types were consumed; the values for all food types consumed during the 7 days recall period were summed up to give the FCS. The formula can be expressed as follows:

$$\begin{aligned} \mathrm{FCS} = {} & a \times f(\text{cereal and or tubers}) + a \\ & \times f(\text{pulse}) + a \times f(\text{milk}) + a \\ & \times f(\text{fruit}) + a \times f(\text{meat and or fish}) \\ & + a \times f\big(\text{sugar}\big) + a \times f\big(\text{vegetables}\big) \\ & + a \times f(\text{oil}) + a \times f(\text{condiments}) \end{aligned} \quad (1)$$

where FCS = Food Consumption Score, f = frequency of food consumption (number of days for which each food group was consumed during the past 7 days), and a = weighted value representing nutritional value of selected food groups [15]. Food groups were assigned different weights reflecting their nutritional density. The FCS has thresholds consumption categories of poor food consumption (0–21), borderline food consumption ($21 < \mathrm{FCS} \leq 35$), and acceptable food consumption (FCS > 35) [15]. The FCS was adopted as it provides a more accurate measure of the quality of the household diet. Moreover, it accounts for the nutritional value of food in addition to the number of different types of food consumed. However, the FCS bears some weaknesses, mainly because the measure does not consider foods consumed outside the household and it does not provide any information of intra-household food distribution. To some extent, the 7-day recall makes it impossible to consider quantity of food eaten. Despite its weaknesses, FCS is still considered one of the very useful measures of household food security.

Household Food Insecurity Access Score (HFIAS)

The HFIAS is a continuous measure of the degree of food insecurity (access) in the household in the past 30 days. According to Deitchler et al. [16], the HFIAS reflects the three universal domains of household food insecurity that is anxiety about household food insecurity, insufficient quality and insufficient quantity of food supplies. This indicator captures the household's perception about their diet regardless of its nutritional composition [17, 18]. This food insecurity measure focuses on consumption-related strategies and captures the household's behavioral and psychological responses to food insecurity or perceived food insecurity. The HFIAS is based on the assumption that households' experiences of food insecurity cause predictable reactions and responses that can be captured and quantified through a survey and then summarized into a score.

During the survey, the respondents were asked nine occurrence questions that consist of a generally increasing level of food insecurity. The occurrence questions can be summarized as follows: (Q1a) worrying about food adequacy; (Q2a) eating the kinds of less preferred foods; (Q3a) eating limited variety; (Q4a) inability to eat less preferred foods; (Q5a) eating smaller meal than needed; (Q6a) eating fewer meals in a day; (Q7a) failing to get food of any kind; (Q8a) sleeping at night hungry; and (Q9a) going the whole day or night without eating anything. Specifically, the respondents were asked whether a specific condition (Q1a–Q9a) associated with the experience of food insecurity *ever* occurred during the past 30 days. Respondents were asked to either say yes = 1 if event occurred or no = 0 if the event did not occur. Each severity question is followed by a frequency-of-occurrence question, which asks how often a reported condition occurred during the previous 4 weeks. There are three response options representing a range of frequencies (1 = rarely, 2 = sometimes, and 3 = often). The minimum HFIAS is zero and occurs when a household responds 'no' to all questions on the household food insecurity access scale. Alternatively, 27 is the maximum HFIAS and is obtained by summing up of all frequencies on the frequency-of-occurrence questions when a household responds yes to occurrence question and 'often' as frequency of occurrence to the nine frequency-of-occurrence questions. Following the guidelines by Coates et al. [19], the HFIAS is computed as follows:

HFIAS (0–27) = summation of the frequency-of-occurrence during the past 30 days for the nine food insecurity-related conditions

$$\begin{aligned}\text{HFIAS}\,(0-27) = {} & Q1a*F1 + Q2a*F2 + Q3a*F3 \\ & + Q4a*F4 + Q5a*F5 + Q6a*F6 \\ & + Q7a*F7 + Q8a*F8 + Q9a*F9\end{aligned} \tag{2}$$

At a household level, a high HFIAS shows that a household is very food insecure, while a low score shows that a household is less food insecure.

Measuring crop diversification

In order to measure crop diversification for the particular crops of interest, we employed the Crop Diversification Index (CDI). The CDI is an index of concentration and has a direct relationship with diversification such that a zero value indicates specialization and a value greater than zero signifies crop diversification. With the CDI index, it was then easy to identify those farmers that are practicing crop diversification and those not practicing diversification. The CDI is obtained by subtracting the Herfindahl index (HI) from one (1-HI). Precisely, the CDI is calculated as follows:

$$S_i = \frac{A_i}{\sum_{i=1}^{n} A_i} \tag{3}$$

where, S_i = proportion of ith crop; A_i = area under ith crop; $\sum_{i=1}^{n} A_i$ = total cropped area; and $i = 1, 2, 3, 4,\ldots, n$ (number of crops)

$$\text{But HI} = \sum_{i=1}^{n} S_i^2 \tag{4}$$

$$\text{Therefore CDI becomes } 1 - \sum_{i=1}^{n} S_i^2 = 1 - \text{HI} \tag{5}$$

In this study, we used nine crops common in smallholder farming in central Malawi to calculate the index. The nine crops included cereals (maize, barley, and rice), pulses (groundnuts, cowpea, soybean, and common bean), root and tubers (sweet potatoes) and vegetables. On vegetables, the household considered vegetable growers were the ones growing at least one vegetable crop per season.

Measuring influence of crop diversification on food security

To ascertain causality between crop diversification and food security outcomes, the study adopts an ordinary least squares (OLS) regression. Since we have CDI (a continuous variable and food security outcomes FCS and HFIAS as dependent variables (all continuous variables), we decided to use OLS regression. According to Isik-Dikmelik [20], it is very sound and correct to use OLS to ascertain influence of a continuous variable on another continuous variable like in our case. The OLS model is specified as

$$Y_i = \alpha_0 + \alpha_1 X_{i1} + \cdots + \alpha_7 X_{i7} + e \tag{6}$$

where, Y_i = household food security outcome (either FCS or HFIAS), X_{i1} = crop diversification, X_{i2} = cattle ownership (1 = yes; 0 = no), X_{i3} = household size, X_{i4} = access to credit (1 = yes; 0 = no), X_{i5} = education of household head (1 = at least primary education; 0 = otherwise), X_{i6} = age of household head and X_{i7} = ownership of a grain storage facility, α_0 = intercept, α_1 to α_7 are coefficients, and e is the error term. Table 1 shows the description of variables used in our analysis.

The linear, double-log, and semi-log functional forms were tried, and the best model was chosen based on the R^2 value, F-value, sign and statistical significance of the variables. The semi-log model was the one chosen because of a superior R^2 value, F-value, sign and statistical significance of the variables. This implies that all the dependent variables were used in log form.

Results and discussion

Descriptive statistics

The descriptive statistics of variables used in our analysis are shown in Table 2. The statistics are based on a sample of 271 farming households from central Malawi.

Food Consumption Score (FCS) and Household Food Insecurity Access Score (HFIAS)

Statistics show that household FCS on average was at 37.01 indicating borderline food consumption. Minimum and maximum FCS was found to be 14 and 87.5, respectively. The distribution of households based on the FCS is shown in Fig. 1.

Table 1 Description of variables used

Variable	Description
FCS	Household's Food Consumption Score
HFIAS	Household Food Insecurity Access Score
CDIIndex	Crop Diversification Index ($0 \leq \text{CDI} \leq 1$)
Cattle	Cattle ownership (1 = yes; 0 = no)
Hsize	Size of the household
Credit	Access to credit (1 = yes; 0 = no)
Educ_hh	Education level of household head (1 = at least primary education; 0 = otherwise)
Agehh	Age of household head (in years)
Storagefacility	Ownership of a grain storage facility (1 = yes; 0 = no)

Table 2 Summary statistics of variables used for analysis

Variable	Variable description	Mean	SD	Min	Max
FCS	Food Consumption Score of the household	37.01	15.78	14	87.5
HFIAS	Household Food Insecurity Access Score	8.18	5.63	0	27
CDIIndex	Crop Diversification Index ($0 \leq CDI \leq 1$)	0.61	0.16	0	1
Cattle	Dummy variable for cattle ownership (1 = yes; 0 = no)	0.10 (*27*)	0.30	0	1
Hsize	Family size	5.95	2.28	1	13
Credit	Dummy for access to credit (1 = yes; 0 = no)	0.30 (*81*)	0.46	0	1
Educ_hh	Dummy variable for attaining at least primary education (1 = yes; 0 = no) for the household head	0.86 (*233*)	0.06	0	1
Agehh	Age of household head in years	43.60	12.56	20	78
Storagefacility	Dummy variable for ownership of a grain storage facility (1 = yes; 0 = no)	0.99 (*268*)	0.09	0	1

Given in parenthesis are frequencies corresponding to average mean proportions of all dummy variables, i.e., mean proportion for cattle ownership 0.10 corresponds to 27 out of 271 farmers who owns cattle in the sample

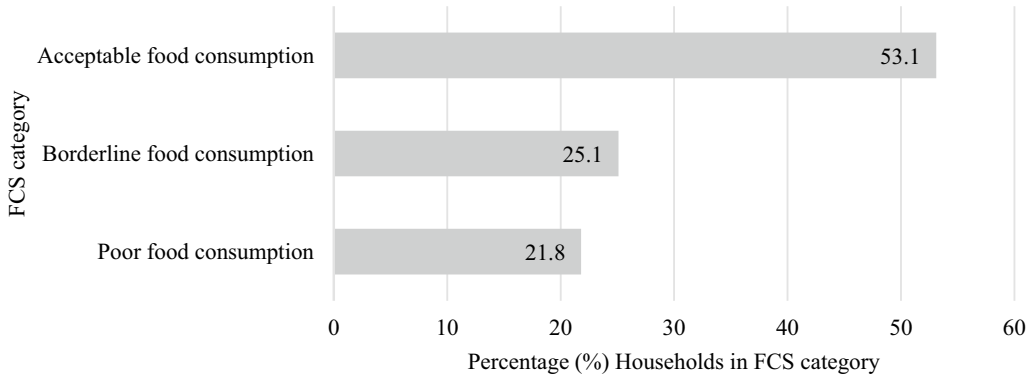

Fig. 1 Distribution of households in central Malawi based on Food Consumption Score

Based on FCS, the distribution shows that the majority of the household (53.1%) are food secure, 25.1% have borderline food consumption, and only 21.8% have poor food consumption. In terms of HFIAS, results show that 22.9% of the households are food secure, 70.5% are mild to moderate food insecure, and only 6.6% are severely food insecure. Distribution of households based on the HFIAS is shown in Fig. 2.

The two measures of food security portray almost a similar trend. The two measures show that at least 75% of the households are moderate to food secure. In trying to relate the two measures of food security, FCS and HFIAS, to crop diversification we found that proportions of crop diversification are higher among borderline food secure to food secure households. However, we found no significant differences in average CDI index by food security category. One notable thing is that average indices by food security status category (both FCS and HFIAS) are above 50% indicating high crop diversification intensity. Table 3 shows the average indices per food security category.

Crop Diversification Index and other socioeconomic characteristics

In terms of diversification, statistics of the CDI show that average within the sample of households is 0.61 with a standard deviation of 0.16. The result implies high crop diversification intensity of the sampled households in central Malawi. In terms of cattle ownership, the sampled households had a very poor ratio of cattle ownership. On average, only 10% of the households owned cattle at the time of the survey. Household sizes at the time of the survey were found to be moderate, about six family members per household. The minimum household size recorded was 1 and maximum of 13 members. Credit access from government and or non-governmental institutions was not common in the group of smallholder farmers sampled in central Malawi. Only 30% of the respondents had accessed credit for use in agricultural production-related activities either from government and/or non-governmental institutions at the time of the survey. The result implies that credit access for financing agricultural

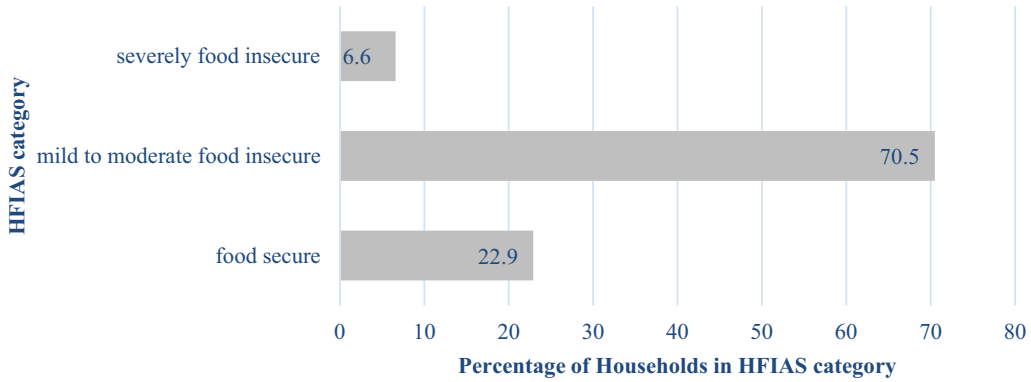

Fig. 2 Distribution of households in central Malawi based on Household Food Insecurity Access Score (HFIAS)

Table 3 Food security status of households and intensity of crop diversification

Food security/insecurity indicator	% of households in category	Average CDI index by category
FCS		
Poor FCS	21.77	0.6
Borderline FCS	25.09	0.61
Acceptable FCS	53.14	0.54
HFIAS		
Food secure	22.9	0.58
Mild to moderate food insecure	70.5	0.58
Severely food insecure	6.6	0.55

activities is still very limited in central Malawi. Education wise, about 86% of household heads had attained at least primary education at the time of the survey. The result implies that the level of education in the study area is good which makes extension messages and any other production- and marketing-related information from various sources easily understood by the smallholder farmers. In addition, the group of farmers was found not to be very old with an average age of 43.6 years. Minimum and maximum age for the group was found to be 20 and 78, respectively. Another characteristic researched on was whether the households own or rent a grain storage facility. Results show that about 99% of the sampled smallholders had access to a grain storage facility at the time of the survey.

Influence of crop diversification on household food security

The ordinary least squares (OLS) regression as mentioned earlier under research methods is used to analyze the effect of diversification on two household welfare indicators, FCS and HFIAS. The results are shown in Table 4. The *F*-statistics for the two models are both significant at 1%, implying that the variables included in the OLS models are jointly significant in influencing the respective dependent variables HFIAS and FCS. The value of R^2 for the FCS and HFIAS model is 19.4 and 20%, respectively. This means that 19.4% of the variation in FCS and 20% of the variation in HFIAS are explained by the variables included in the two respective models.

Results show that CDI, cattle ownership, access to credit, education, positively influence FCS, while CDI and education have a negative influence on HFIAS.

Crop diversification

Crop diversification as measured by the index was found to have a positive influence on FCS and a negative influence on HFIAS. The coefficient of CDI is significant at 5% and shows a positive influence on household FCS. Households with higher crop diversification intensities are more likely to have diversity in terms of food crops that can be consumed within the household thus justifying the positive relationship. This implies crop diversification improves food consumption in central Malawi. On

Table 4 OLS regression of the welfare effects of crop diversification

Variables	FCS		HFIAS	
	Coef.	*P* > *t*	Coef.	*P* > *t*
CDIIndex	0.400	0.047**	− 1.028	0.005***
Cattle	0.270	0.011**	− 0.182	0.370
Hsize	− 0.010	0.460	0.008	0.726
Credit	0.166	0.012**	− 0.006	0.960
Educ_hh	0.095	0.089*	− 0.344	0.001***
Agehh	0.001	0.744	− 0.005	0.324
Storagefacility	0.053	0.872	− 0.660	0.260
_cons	1.111	0.004***	3.664	0.000***
R^2	19.4%		20%	
Adjusted R^2	17%		17%	
F	3.33***		2.95***	
N	271		271	

*Significant at 10%; ** significant at 5%; ***significant at 1%

the other hand, the coefficient of CDI is significant at 1% and shows a negative influence on HFIAS. This means that household with higher crop diversification intensities is less food insecure as compared to those with relatively lower crop diversification intensities. The result implies that crop diversification reduces the severity of food insecurity in central Malawi. Households which have relatively higher number of crop species grown per season are less likely to adopt more desperate food insecurity coping strategies. Therefore, farmers who intensify crop diversification are better off than their counterparts as diversification is positively related to food consumption and negatively related to food insecurity mainly due to the benefits of crop diversification to include, raising farm productivity, income, and reducing production and price risks. Similar studies have found crop diversification to impact positively on food security of the household [5, 7, 8]. More so, the merits of crop diversification in improving food security can manifest through better management of price and production risk [21]. This is possible since growing more than one crop species in a single season gives the farmer options which can ensure him/her manage price and production risks better as compared to less diversified farming enterprises.

Considering that Malawi has a variable climate, crop diversification helps farmers insure against disasters such as floods and drought. Statistics report more than 40 weather-related disasters that occurred in Malawi between 1970 and 2006, including about 16 droughts and flood events [22]. These present serious problems to the smallholder farmer in Malawi since he/she can find difficulties in adopting modern coping strategies to the problem of crop diversification. Furthermore, if smallholder farmers continue to increase acreage of the traditional maize and tobacco at the expense of more drought- and flood-tolerant crops (such as cassava, sweet potato, pigeon peas and other crops) could exacerbate the impact of drought and floods on food security [23]. This therefore justifies the positive influence of crop diversification on FCS and negative influence on HFIAS. Further crop diversification helps farmers exit maize poverty trap in case of adverse weather conditions that do not allow maize to reach maturity stage.

Cattle ownership

Cattle ownership in central Malawi was found to influence the FCS. The coefficient of cattle ownership is significant at 5% and positively related to food consumption. Ownership of cattle is important in improving household food consumption in several ways. The results show that households that own cattle have higher FCSs than those that do not own cattle. First, cattle ownership signifies wealth and in this respect wealthier households have a better purchasing power of a variety of food stuffs unlike poorer households. Secondly, cattle play a vital role as a productivity enhancing input in farming activities as they can provide draft power and farmyard manure. Thirdly cattle also serve as a source of food for the household by producing milk and meat. Cattle ownership is therefore very important in improving food consumption in central Malawi. To support this finding, Bogale and Shimelis [24], found that cattle are an important factor that contributes to food security mainly because: livestock contributes to draft power, subsistence household needs, income and nutritional requirements.

Education

Education of the household head was found to influence both the FCS and HFIAS. The sample of smallholder farmers had 86% of smallholder with at least primary education. The coefficient of education is positively related to FCS and is significant at 5%. The coefficient of education is also negatively related to HFIAS and significant at 1%. These results indicate that households whose heads attained at least primary education have better food security status through better food consumption and their food insecurity status will be less severe compared to those households whose heads never attained school. This is not surprising because educated household heads are more likely to understand extension messages and manage crop diversification efficiently and hence improve their welfare. In addition, education can effectively improve prospects of the farming households to diversify their livelihoods through participation in off-farm formal employment activities. Moreover, education influences access to and use of information. It

develops the capacity of farmers to enhance food security. Makombe et al. [25] and Idrisa et al. [26] noted that household head education's level has a positive effect on food security. That is, learned households are more likely to receive information and use it to make informed decisions compared to the less learned ones. Such households are assumed to have better management techniques that can ensure all-year-round supply of diversified and preferred food.

Access to credit

Access to credit was found to influence the household FCS. The coefficient of credit is significant at 5% level and positively related to the FCS. The result indicates that households that have access to credit had higher FCS compared to those that did not have credit access. This may be because households that had access to credit had additional capital available for the farmers to invest in agriculture including crop diversification and could also obtain more income generated by the farming enterprise which could be channeled to improve household consumption. In another sense, access to credit can also improve crop diversification activities through improved access to productivity enhancing inputs such as seed and fertilizers. Successful crop diversification improves food diversity and income, which therefore improves food security within the household. According to Akaakohol and Aye [27], households with access to credit are more likely to have capital to invest in on-farm and off-farm activities which generates more income for the household which is then used to improve food consumption patterns.

Conclusions and policy recommendations

This study has examined the influence of crop diversification on household food security in central Malawi. The study used two measures of household food security, the FCS and the HFIAS. The OLS results show that crop diversification is positively correlated with the FCS and negatively correlated with the HFIAS. This means that households with higher crop diversification intensities are more likely to have a diverse diet and they are also less likely to adopt desperate food insecurity coping strategies. Farming households with more than one crop grown tend to be more secure in terms of food supplies and income and hence are able to cater for the food requirement of their households. Crop diversification hence improves food security through improving food stocks in terms of quantity and variety and also in improving income through sale of crop produced from a variety of grown crop species which then is used to further improve consumption patterns.

Furthermore, cattle ownership and access to credit have positive significant influence on household FCS, while education of the household head positively influences FCS and negatively influences the HFIAS. The results suggest that education of the household head, access to credit, and cattle ownership are crucial factors for food security in central Malawi. We therefore conclude that crop diversification among other factors is a viable option in building resilient and affordable agricultural systems in smallholder farming that can contribute significantly to livelihoods, improved health and nutrition, household food security, and ecological sustainability. This is mainly because crop diversification improves food availability for the household and also income which translates to improved food consumption through food purchases. Crop diversification benefits the farmer mainly in the sense that cultivating several crop species helps to manage both price and production risks, which in the end ensures more food options for the household and income through market participation from the surpluses. Moreover, crop diversification also benefits the smallholder farmer as it can improve farm-level crop productivity.

In terms of policy, results suggest that the government of Malawi need to intensify promotion of crop diversification in smallholder farming, especially to those currently less diversified to improve the food security status of the rural people. Moreover, policies to ensure smallholder farming households' access to credit, education, and draft power are also recommended. For instance, the government in collaboration with the microfinance organizations can work possibility for offering small loans with low interest rates without collateral to smallholder farmers. The loans can be granted on productivity basis to ensure loan repayment by the farmers.

Abbreviations

ADP: Area Development Program; ASWAP: Agricultural Sector Wide Approach; CDI: Crop Diversification Index; CIAT: International Centre for Tropical Agriculture; EFSA: Emergency Food Security Assessment; EPA: Extension Planning Areas; FCS: Food Consumption Score; GDP: Gross domestic product; HFIAS: Household Food Insecurity Access Score; HI: Herfindahl index; IFAD: International Fund for Agricultural Development; MoAFS: Ministry of Agriculture and Food Security; NASFAM: National Association of Smallholder farmers of Malawi; NGOs: Non-governmental organizations; OLS: Ordinary least squares; UNDP: United Nations Development Programs.

Authors' contributions

NM is the principal researcher who conceived and designed the study, took part in designing the questionnaire, participated in the writing of the paper, and wrote the final manuscript. CM did data entry and analysis, and prepared and drafted the manuscript. LM led the designing of the questionnaire, and writing and reviewing the final manuscript. MS participated in the designing of the questionnaire, led the preliminary surveys, interview schedule design, pretesting, and data collection. All authors read and approved the final manuscript.

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Competing interests
The authors declare that they have no competing interests.

Availability of supporting data
Data for this study can be obtained from CIAT Dataverse. Repository URL https://dataverse.harvard.edu/dataverse/CIAT.

Ethical approval and consent to participate
The study was approved by the International Centre for Tropical Agriculture in collaboration with its partners, Lilongwe University of Agriculture and Natural Resources, Ministry of Agriculture, Irrigation and Food Security and World Vision in Malawi and considered exempt. Informed consent was obtained from all the participants. The authors have all the ethical approval and consent to take and participate in research paper writing and submission to any relevant journal from our organizations where we are working and posted.

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