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Understanding Crop Diversification Among Smallholder Farmers: Socioeconomic Insights from Central Malawi

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Abstract: In Eastern and Southern Africa (ESA), smallholder rain-fed systems are vital, yet they are challenged by land degradation, soil fertility decline, and climate risks. To address these challenges, crop diversification has been promoted as a potential pathway to enhance productivity, improve nutritional security, and offer a viable pathway out of poverty and hunger. This study explores crop diversification among 150 smallholder households in the Kasungu, Mchinji, and Lilongwe districts of Malawi, where the project Sustainable Intensification of Maize Legume Systems in East and Southern Africa (SIMLESA) has engaged the smallholder farmers in conservation agriculture (CA)-based sustainable intensification participatory research and development for seven years since 2010. This study used Simpson's diversity index (SDI) to estimate crop diversification, and a multiple linear regression model (MLRM) to analyze how smallholder farmers' socio-economic characteristics influence adoption. The findings show a prevalence of small farms of less than 1.5 hectares, with most farmers perceiving crop diversification as beneficial for soil fertility. Key adoption constraints include labor shortages and a lack of legume seeds. SIMLESA participants lead in crop rotations, with a 63% higher adoption rate, and show the highest crop diversity, with a 99% increase in farmers growing three crops and a 74% increase in those growing four crops compared to non-SIMLESA farmers. The SDI values were 0.39 for non-SIMLESA, 0.48 for SIMLESA neighbors, and 0.57 for SIMLESA participants. Access to NGO inputs, larger farm sizes, and participation in research programs were positively associated with diversification, while food insufficiency was negatively associated with its adoption. The study highlights the importance of integrating participatory research methods to promote development initiatives effectively.

Keywords: crop diversification; cropping systems; food security; Simpson diversification index; SIMLESA; agriculture support programs

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1. Introduction

In the agrarian landscape of Sub-Saharan Africa (SSA), where smallholder farmers form the backbone of agriculture, fostering the development and promotion of affordable sustainable agricultural systems is crucial. Smallholder farmers are essential contributors to the region's food security. Yet the majority of them grapple with a myriad of challenges, including unpredictable climate patterns [1], land fragmentation due to population pressure [2], high costs of technologically advanced inputs [3], and endemic soil fertility decline [4]. The region heavily relies on climate-sensitive rain-fed systems and lacks resources for complex coping strategies [5]. This limits crop yields and, with the anticipated more erratic precipitation, the situation is expected to worsen. The combined effects of these challenges have contributed to widespread poverty, food insecurity, and malnutrition [5,6]. Consequently, governments face the critical challenge of ensuring food security and alleviating poverty amidst a growing population and climate uncertainties.

The Sustainable Intensification of Maize–Legume Cropping Systems for Food Security in Eastern and Southern Africa program, commonly known as SIMLESA, launched in 2010 and implemented in several countries across Eastern and Southern Africa, sought to address some of these challenges by promoting sustainable intensification practices, particularly through the integration of maize and legume cropping systems [7,8]. The program demonstrated improved productivity, resilience, and resource management through conservation agriculture-based sustainable intensification (CASI) in targeted countries. The adoption of CASI methods enhanced the livelihoods and food security of farm households in both low- and high-potential environments across the region [7–10]. Adoption monitoring in 2013 and 2015 revealed significant variation in the uptake of sustainable practices, such as crop diversification (rotation and intercropping), across the region [8]. These findings underscore the importance of understanding the factors that influence the adoption of such practices at the smallholder level.

In this context, crop diversification, the cultivation of multiple crops, or the adoption of different cropping systems in a given area [11], presents itself as a promising adaptive practice to enhance resilience and improve livelihoods. It has been considered one of the most ecologically feasible, cost-effective sustainable intensification systems to minimize environmental impacts while improving agricultural productivity [12,13]. Crop diversification involves increasing the diversity of crops through crop rotations, multiple cropping, or intercropping and the inclusion of grain legumes into maize-based systems in the case of Eastern and Southern Africa [9,10]. Its promotion in SSA specifically targets the smallholder low-input systems, where practices and adoption may vary to suit local conditions, needs, and challenges.

The promotion of crop diversification is based on its benefits, as it can improve the productivity, stability, and delivery of ecosystem services. A diversified cropping portfolio can suppress pests and disease carryover [14], enhance crop yield [9], buffer climatic shocks [15], boost soil fertility [16], and lowering agrochemical inputs [17] among other benefits. At a household level, where much of the agricultural production is for home consumption, diversification has been consistently associated with enhancing resilience, as evidenced by improvements in household income, food security, and nutrition [12,18].

Despite the potential benefits of crop diversification, a gap remains in the understanding of how smallholder farmers in SSA perceive and adopt these practices. This study explores the factors that influence farmer decision-making, focusing on Malawi, where small farm sizes, erratic rainfall, and reliance on cereal monocrops pose challenges. Building on the work of SIMLESA, this research assesses the long-term impacts of its efforts on the smallholder perceptions of crop diversification. SIMLESA facilitated capacity building and out-scaling by engaging host farmers in hands-on learning experiences, while their neighbors learned through observation [8], creating a cohort with intensive exposure to CASI technologies. This enables comparisons with farmers in the districts who did not directly benefit from this engagement (non-SIMLESA). Thus, this study aims to answer: What are smallholder farmers' perceptions of crop diversification? What factors influence their adoption of these practices? This study offers practical insights to support the promotion of improved farming practices among smallholder farmers.

2. Materials and Methods

2.1. Site Description

The study was conducted in 2024 in Malawi, which has a predominantly agrarian economy, with approximately 65% of the population dependent upon agriculture and engaged in smallholder subsistence farming [19]. Most of the food consumed in the country is produced by small-scale farmers. This stresses the importance of smallholder farmers and agriculture itself in general in Malawi. The majority of smallholder farmers heavily rely on seasonal rainfall, making crop production susceptible to drought and rainfall anomalies.

The study used cross-sectional household data from the semi-structured questionnaires that were administered among the rural households located in three districts, i.e., Kasungu, Lilongwe, and Mchinji districts. The three study districts are located in Central Malawi, with an altitude of 760–1300 m above sea level (Figure 1). Households typically own small farms that are actively cultivated for crop production [2]. The crop-growing season runs from November to April, receiving 600–1000 mm of rainfall and temperatures of 16–28 °C, and is marked by frequent dry spells in January and February.

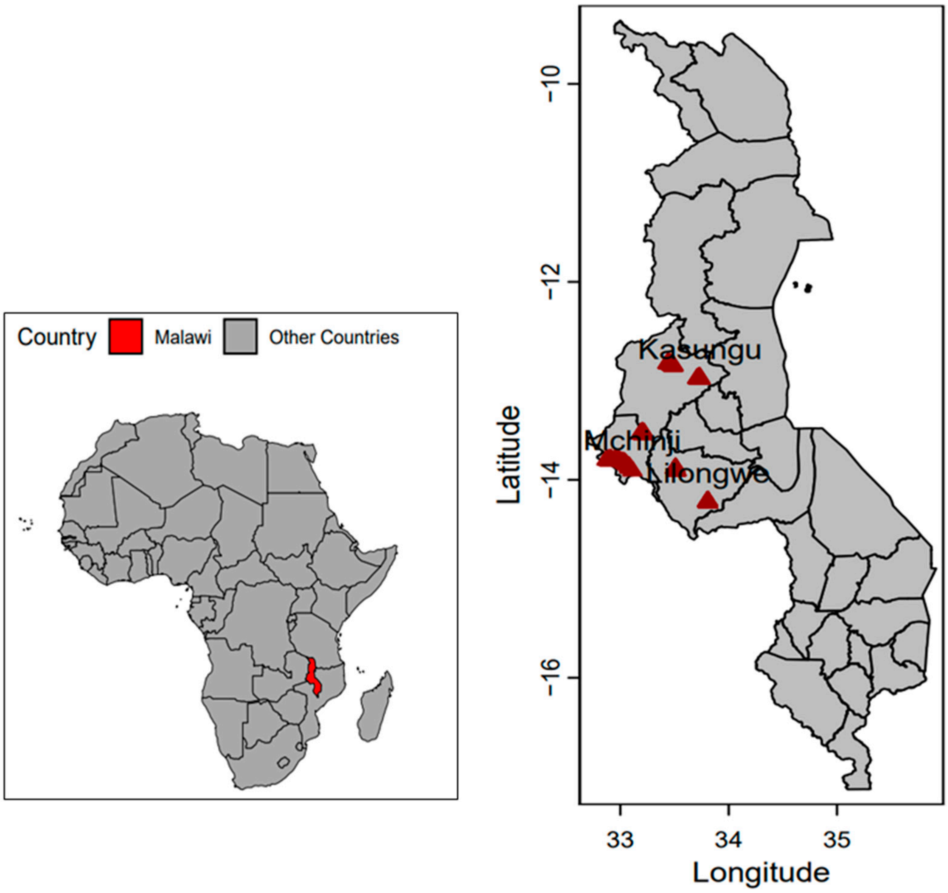

Figure 1. Geographical distribution of rural households sampled in Lilongwe, Mchinji, and Kasungu districts of Malawi.

2.2. Sampling and Data Collection

To capture farmers' perceptions and assess the adoption of crop diversification, we made a follow-up study of on-farm trials that were implemented by CIMMYT. The trials were established with the objective of developing sustainable and resilient cropping systems in Malawi through an Australian Centre for International Agricultural Research (ACIAR)-funded project acronymed SIMLESA, which was implemented between 2010 and 2018 [8]. The SIMLESA project emphasized extension and out-scaling to enhance agricultural productivity among smallholder farmers. The project conducted on-farm trials in target districts, testing crop-diversification systems with various leguminous crops in association with maize (*Zea mays* L.), which was the staple test crop. In Malawi, SIMLESA was implemented in six districts across two agroecological zones, namely the low-altitude and mid-altitude regions, with Lilongwe, Mchinji, and Kasungu located in the mid-altitude zone.

Data collection for the present study involved a household survey, which was carried out from February–March of 2024 through the face-to-face administration of questionnaires with structured and semi-structured questions. The survey used a stratified random sampling method, involving 18 SIMLESA host farmers and 4 neighbors per host, totaling 72 neighbor farmers. To compare crop diversification adoption levels, we also included 20 farmers from SIMLESA non-participating communities from each district, totaling

60 farmers. In total, 150 farmers participated in the survey (Table 1). A SIMLESA farmer neighbor was defined as a household that engages in farming activities and resides in close proximity to the SIMLESA trial-hosting farmer. The survey gathered information on household demographics, socio-economic characteristics, crop production, institutional support, food security status, and other farm- and farmer-specific characteristics. All farming households were geo-tagged.

Table 1. Household sample size across Mzimba, Kasungu, and Lilongwe district.

Household Description	Sample Size
SIMLESA farmers	18
SIMLESA farmer neighbors	72
Non-SIMLESA farmers	60
Total	150

2.3. Data Analysis

2.3.1. Measuring Crop Diversification

In order to measure crop diversification, we employed the Simpson diversification index (SDI). The SDI of crop diversification [20] is a composite and commonly used measure of diversification, reflecting both crop species richness (count) and evenness (relative abundance of crop species). It is calculated based on the relative abundance of different categories or species within the dataset, with a higher value indicating greater crop diversification. The index equals one under complete diversification and zero under complete specialization, indicating that higher values represent greater diversity in crop species, while lower values reflect a concentration on fewer species. We used different crops grown by the household and the approximate area allocated to each crop to compute our indices. Information on crop production was collected for the 2022/2023 agricultural season from the Kasungu, Lilongwe, and Mchinji districts.

The Simpson diversification index (SDI) takes the following form:

$$\text{Simpson index (SI)} = SI_J = 1 - \sum_{c=1}^{n} \left(\frac{fsc}{fs}\right)^2 \quad (1)$$

where SI_J is the Simpson index for farmer j, *fsc* is the approximate area devoted to crop c, and *fs* is the total farm size. The Simpson index ranges from 0 to 1, and larger (lower) indices indicate high (low) levels of crop diversification. The index equals one under complete diversification and zero under complete specialization. The diversification status of the households was then determined using classes as defined by [21,22] as low (0 to 0.38), medium (0.39 to 0.63), and high (above 0.63).

In this study, we used fifteen crops that are common in smallholder farming in Central Malawi to calculate the indices. The fifteen crops included cereals (maize, sorghum, millet wheat, and rice), legumes (groundnuts, cowpea, soybean, pigeon pea, and common bean), roots and tubers (sweet potatoes, Irish potatoes, and cassava), and cash crops (cotton and tobacco) [23].

2.3.2. Household Characteristics and Crop-Diversification Adoption

For us to examine the influence of smallholder farmers' socio-economic characteristics on the adoption of crop diversification, we estimated using the following equation with the smallholder farmer as the unit of analysis.

For the multiple linear regression model,

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \epsilon \quad (2)$$

where Y is the dependent variable, $x_1, x_2, \ldots, x_n$ are the independent variables, β_0 is the intercept, $\beta_1, \beta_2, \ldots, \beta_n$ are the respective coefficients (slopes) for each independent variable, and ϵ is the error term.

The multiple linear regression model (MLR) is a statistical technique used to assess the association between two or more independent variables and a single continuous dependent variable [24]. Its primary use is in predicting the value of the dependent variable based on the values of the independent variables. To assess multicollinearity in the regression model, we calculated the generalized variance inflation factor (GVIF) for each predictor. The GVIF values, adjusted for degrees of freedom ($GVIF^{(1/(2*df))}$), were examined, with values above 2 indicating potential multicollinearity. This step ensured that the predictor variables did not excessively correlate, maintaining the model's stability and interpretability.

2.3.3. Descriptive Statistics

The descriptive analysis of households' socioeconomic characteristics, crop diversification, and food security levels involved utilizing household survey data from the 2024 household interview survey. Quantitative categorical types of data were analyzed using percentages and frequency distributions, while continuous data were analyzed using mean and standard deviation (Table 2). This analysis aimed to describe the demographic and socioeconomic characteristics of farmers in the three districts. Additionally, a principal component analysis (PCA) was employed to identify patterns and relationships among farm household variables across the districts.

Table 2. Description of independent variables.

Variable	Description	Measurements
Location	District	Mchinji Lilongwe Kasungu
Gender	Gender of the household head (HH.Sex)	1 for Male and 0 for Female
Age (Years)	Age of the household head (HH.Age)	Continuous
Family size (persons)	Number of people in the household (HH.size)	Continuous
Education	Household head level of education (HH.education)	1 for primary and 0 else 1 for secondary and 0 else 1 for Tertiary and 0 else
Farmer type	Farmer type	Non-SIMLESA SIMLESA Participant SIMLESA Neighbors
Labor (persons)	Number of people who are involved in farm work	Continuous
Market (km)	Distance to the nearest market	Continuous
Extension (km)	Distance to the nearest extension officer working place	Continuous
Government inputs	Whether farmer received inputs from the government	1 for Yes and 0 for No
NGOs inputs	Whether farmer received inputs from the NGOs	1 for Yes and 0 for No
Farm size (ha)	Size of the household farm	Continuous

HH: household head, SIMLESA: sustainable intensification of maize legume in East and Southern Africa.

3. Results

3.1. Descriptive Statistics Results

The statistics are derived from a sample of 150 farming households from Kasungu, Mchinji, and Lilongwe in Central Malawi (Table 3). On average, the respondents are relatively mature, with a mean age of 43 years. Family sizes varied, with an average of 6 members, while labor availability showed some variability among households, with a mean of four people. The distance metrics reveal disparities in access to the market and extension services, with an average distance of 4.070 km to the market and 11.195 km to extension services. The farm sizes were small but also varied, averaging 1.176 ha. The gender distribution is slightly skewed towards males, with a mean of 0.563, implying a predominance of male-headed households. Furthermore, the data highlight limited but varying levels of support from external sources, with mean values of 0.185 and 0.225 for inputs from NGOs and the government, respectively.

Table 3. Descriptive statistics.

Variable	Mean	SD
Age (Years)	43.245	11.833
Family size (Persons)	5.616	1.788
Labor (Persons)	3.636	1.472
Distance to market (km)	4.070	2.600
Distance to extension (km)	11.195	9.020
Farm size (ha)	1.176	0.676
Gender	0.563	0.498
NGOs inputs	0.185	0.390
Government inputs	0.225	0.419

3.2. PCA Biplot Analysis of Farm Household Variables Across Districts

Figure 2 visualizes factors influencing farm households and highlights important relationships among variables. PC1 shows a strong positive association with extension, indicating that better access to extension services enhances productivity. Food security and household-head education are also positively correlated, suggesting that higher education levels improve food security outcomes. However, a negative relationship between location and extension implies that some areas have limited access to extension services. Farm size and labor align with PC2, indicating that larger farms and more labor resources influence agricultural strategies. Additionally, household-head age clusters with farm size, suggesting that older household heads tend to have larger farms.

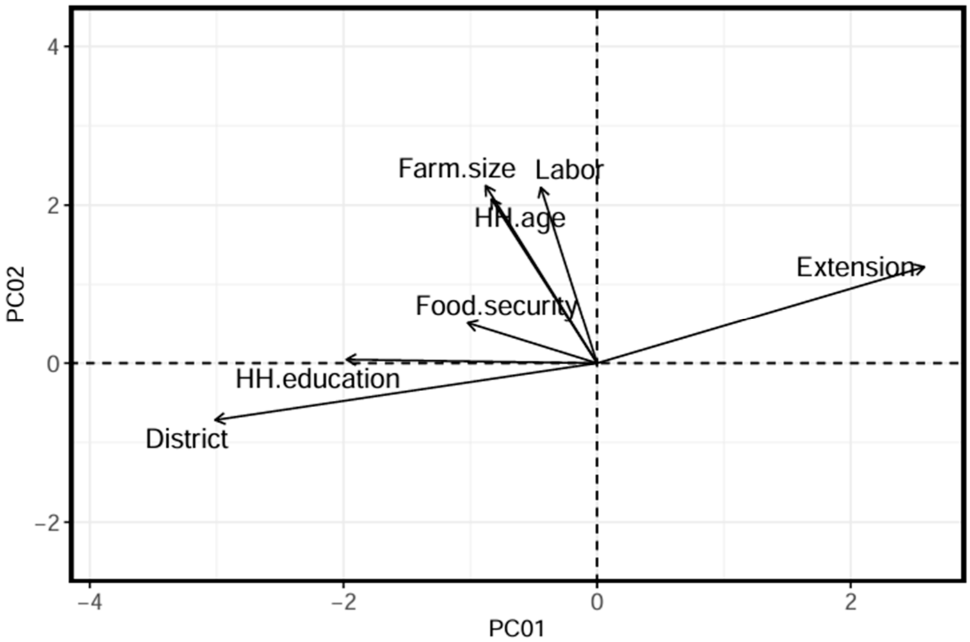

Figure 2. PCA biplot shows the relationships among household and farm characteristics in Kasungu, Mchinji, and Lilongwe.

3.3. Farm Size

Figure 3 shows that small farms are prevalent among the surveyed communities. Over half of the non-SIMLESA farmers (52.5%) and SIMLESA neighbors (53.6%) own extremely small plots of less than 1 ha, while only 27.3% of the SIMLESA participants fell into this category. Conversely, 40.9% of the SIMLESA participants reported owning average farm sizes ranging from 1 to 2 ha, while their neighbors and non-SIMLESA farmers reported 39.1% and 32.2%, respectively. Relatively few households owned larger farms exceeding 2 ha, with 31.8% of the SIMLESA participants in this category, compared to only 7.2% of the SIMLESA neighbors and 15.3% of the non-SIMLESA farmers.

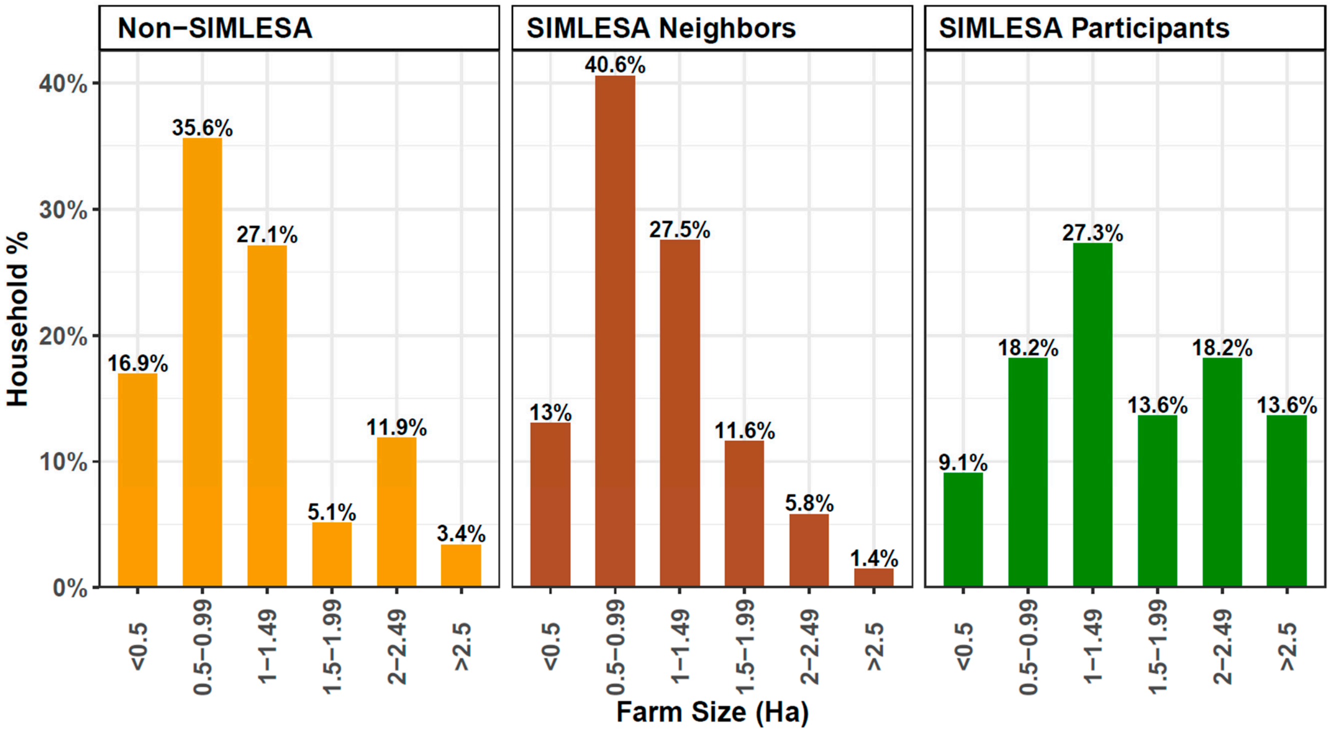

Figure 3. Farm size distribution within our sample of smallholder farmers in Kasungu, Mchinji, and Lilongwe.

3.4. Farmer Perceptions

Table 4 presents the percentages of surveyed households' perceptions regarding the expected benefits and constraints of adopting crop-diversification systems. The SIMLESA participants perceived the highest benefits, particularly in terms of soil fertility improvement (100%) and enhancement of crop yield (90.9%). They also perceived significant gains in food diversity (63.6%), indicating a strong positive impact of the program on dietary diversity. In contrast, the SIMLESA neighbors and non-SIMLESA respondents recognize these benefits to a lesser extent, with soil fertility improvement at 94.2% and 86.7%, respectively, and enhanced crop yield at 81.2% and 68.3%. This highlights a noticeable disparity in perceived benefits among the groups.

However, all groups face notable constraints, with labor shortages being a significant concern. This issue is slightly more pronounced among the non-SIMLESA farmers (76.3%) compared to the SIMLESA participants (72.7%) and the SIMLESA neighbors (69.6%). A critical challenge for the SIMLESA participants is the lack of high-quality legume seed, which affects 81.8% of them, while this constraint is lower for the other two groups (60.9% for neighbors and 60% for non-participants). Additionally, the SIMLESA participants and the neighbors report similar concerns regarding the lack of sufficient land to practice (59.1% and 56.5%, respectively), whereas this concern is less pronounced among the non-SIMLESA respondents (46.7%).

Table 4. Benefits and constraints to crop diversification as perceived by different categories of surveyed farmers in Malawi.

Benefit or Constrain Type	Non-SIMLESA	SIMLESA Neighbors	SIMLESA Participants
Benefits			
Soil fertility improvement	86.7%	94.2%	100%
Enhances crop yield	68.3%	81.2%	90.9%
Soil conservation	58.3%	76.8%	68.2%
Water conservation	36.7%	60.9%	59.1%
Food diversity	25.0%	50.0%	63.6%
Nutritional consumption	8.3%	30.0%	22.7%
Fodder provision	3.3%	2.9%	4.55%
Constraints			
Labor shortages	76.3%	69.6%	72.7%
No quality legume seed	60.0%	60.9%	81.8%
No spare land to practice	46.7%	56.5%	59.1%
Limited information	33.3%	44.9%	27.3%
Low price	21.7%	29.0%	13.6%

3.5. Food Sufficiency as an Indicator of Household Food Security

Food sufficiency is a dire situation in the communities interviewed. Figure 4 shows a varied picture of food security among the surveyed households. Half of the SIMLESA participants (50%) had enough or surplus food. Meanwhile, their neighbors recorded only 33.3% and the non-SIMLESA farmers recorded 42.4% in the same category. Among the SIMLESA neighbors, 66.7% reported severe food insufficiency, categorized as either insufficient or sometimes sufficient. Meanwhile, 57.6% of the non-SIMLESA farmers fell into the same categories, and 50% of the SIMLESA participants reported similar levels of food insufficiency.

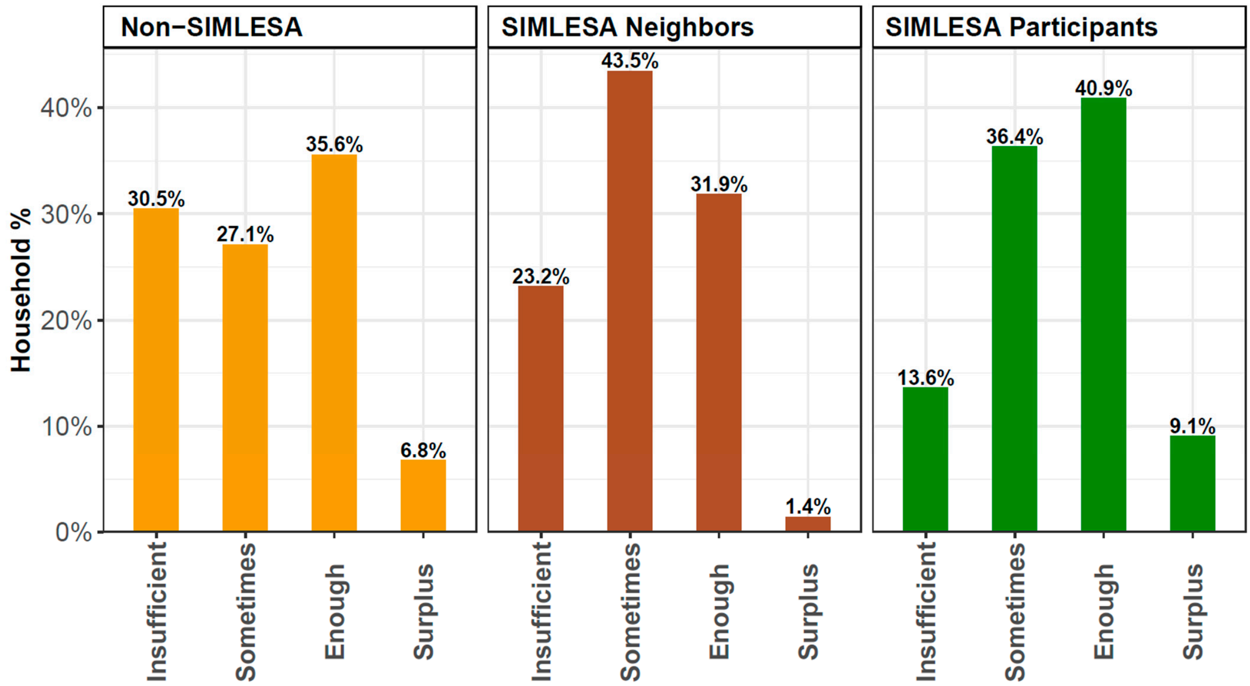

Figure 4. Year-round food sufficiency among households by SIMLESA participation. Surplus—households with more than enough food year-round, not at risk of hunger. Enough—households with sufficient food, with occasional shortages manageable without severe consequences. Sometimes—households with irregular food access, facing both sufficiency and shortages. Insufficient—households lacking enough food to meet basic needs, often experiencing hunger.

3.6. Cropping Systems Adoption

Figure 5 shows that cereal sole cropping is dominant across all groups, with the highest implementation among SIMLESA neighbors (91.2%), followed by SIMLESA participants (87.0%) and non-SIMLESA households (83.3%). Notably, the SIMLESA participants lead in crop rotations at 65.2%, indicating a 63% percentage increase compared to the non-SIMLESA (40.0%). Intercropping is the least common, particularly among SIMLESA participants (13.0%), which is a 29% decrease compared to the non-SIMLESA (18.3%).

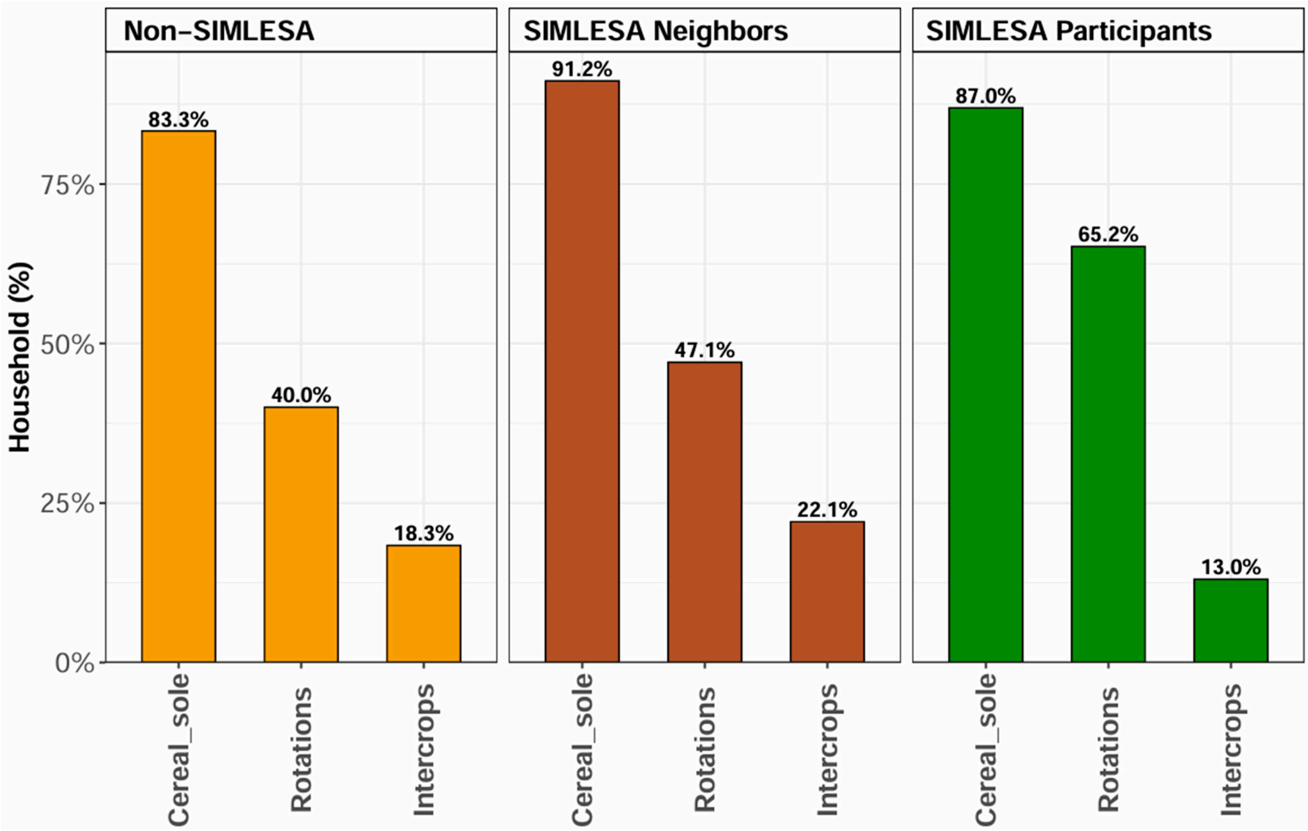

Figure 5. Cropping systems adoption among non-SIMLESA, SIMLESA neighbors, and SIMLESA participants farmers.

3.7. Number of Crops Grown Across Different Farmer Types

Crop diversity analysis based on the number of crops grown (Figure 6) revealed distinct patterns among different farmer types. The non-SIMLESA farmers exhibit the least diversity, with 21.7% growing only one crop, 45.0% growing two crops, 28.3% growing three crops, and 5.0% growing four crops. The SIMLESA neighbors show improved diversity, with a 20% increase in the proportion of farmers growing three crops (33.8%) compared to the non-SIMLESA farmers (28.3%) and 2.9% growing four crops. The SIMLESA participants demonstrate the highest diversity, with a 99% increase in those growing three crops (56.5%) and a 74% increase in those growing four crops (8.7%) compared to non-SIMLESA farmers.

3.8. Level of Crop Diversification by SDI

The analysis of the SDI categories across different farmer types reveals distinct patterns (Table 5 and Figure 7). SIMLESA participants predominantly fall into the medium SDI category at 77.3%, which is 13.5% higher than the SIMLESA neighbors (63.8%) and 26.5% higher than the non-SIMLESA farmers (50.8%). In the high SDI category, the SIMLESA participants have 18.2%, comparable to SIMLESA neighbors at 18.8%, but 4.6% higher than non-SIMLESA farmers (13.6%). Conversely, the low SDI category shows SIMLESA participants at 4.5%, 12.9% lower than SIMLESA neighbors (17.4%) and 31.1% lower than non-SIMLESA farmers (35.6%). Overall, SIMLESA participants exhibit significantly higher levels of crop diversity compared to SIMLESA Neighbors and non-SIMLESA farmers. The results also indicated 0.39, 0.48, and 0.57 mean SDIs for non-SIMLESA, SIMLESA farmer neighbors, and SIMLESA participants, respectively (Figure 7).

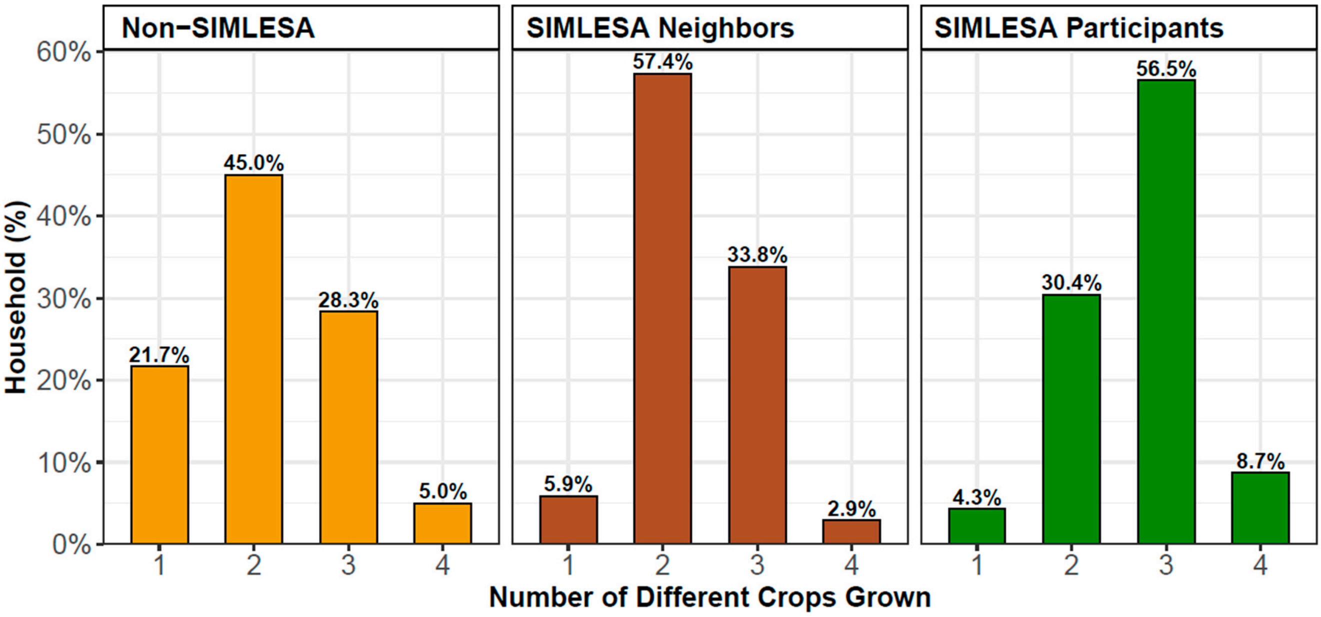

Figure 6. Number of crops grown among non-SIMLESA, SIMLESA neighbors, and SIMLESA participants farmers.

Table 5. Household distribution by level of SDI.

Farmer Categories	Category of SDI	Percentage	Cumulative
SIMLESA Participants	Low (0–0.38)	4.5%	4.5%
	Medium (0.39–0.63)	77.3%	81.8%
	High (>0.63)	18.2%	100%
SIMLESA Neighbors	Low (0–0.38)	17.4%	17.4%
	Medium (0.39–0.63)	63.8%	81.2%
	High (>0.63)	18.8%	100%
Non-SIMLESA	Low (0–0.38)	35.6%	35.6%
	Medium (0.39–0.63)	50.8%	86.4%
	High (>0.63)	13.6%	100%

3.9. Household Socioeconomic Characteristics and Crop Diversification

The multiple linear regression model (MLRM) was used to analyze the effects of household characteristics on crop-diversification adoption (Table 6). Before estimation, the multicollinearity among the explanatory variables was checked using the GVIF, with all $GVIF^{(1/(2*Df))}$ values well below two, indicating no significant multicollinearity (Supplementary Table S1). The MLRM analysis identified several significant factors influencing crop-diversification adoption. Participation in the SIMLESA program, both as a participant and as a SIMLESA farmer neighbor, was significantly associated with increased crop diversification, with estimated increases of approximately 0.195 and 0.133, respectively ($p < 0.001$). Among the demographic factors, including household age, sex, education level, and size, none exhibited significant association with crop diversification. Similarly, the number of laborers and receiving inputs from the government do not significantly influence the levels of crop-diversification adoption. However, receiving inputs from NGOs demonstrates a significant positive association, resulting in an approximate increase of 0.123 in crop diversification ($p = 0.007$). Conversely, households experiencing food insufficiency exhibited lower levels of crop diversification, as indicated by a negative coefficient of −0.092 ($p = 0.023$). Notably, farm size emerges as another significant factor, with larger farm sizes associated with higher crop diversification, indicating a positive effect of approximately 0.068 per unit increase in farm size ($p = 0.009$). Overall, the model explains around 18.65% of the variability in crop-diversification levels, with an R^2 of 0.1865. The overall significance of the model is confirmed by a highly significant F-test result ($p = 8.711 \times 10^{-5}$), underscoring its usefulness in explaining the crop-diversification levels among the smallholder farmers of Central Malawi.

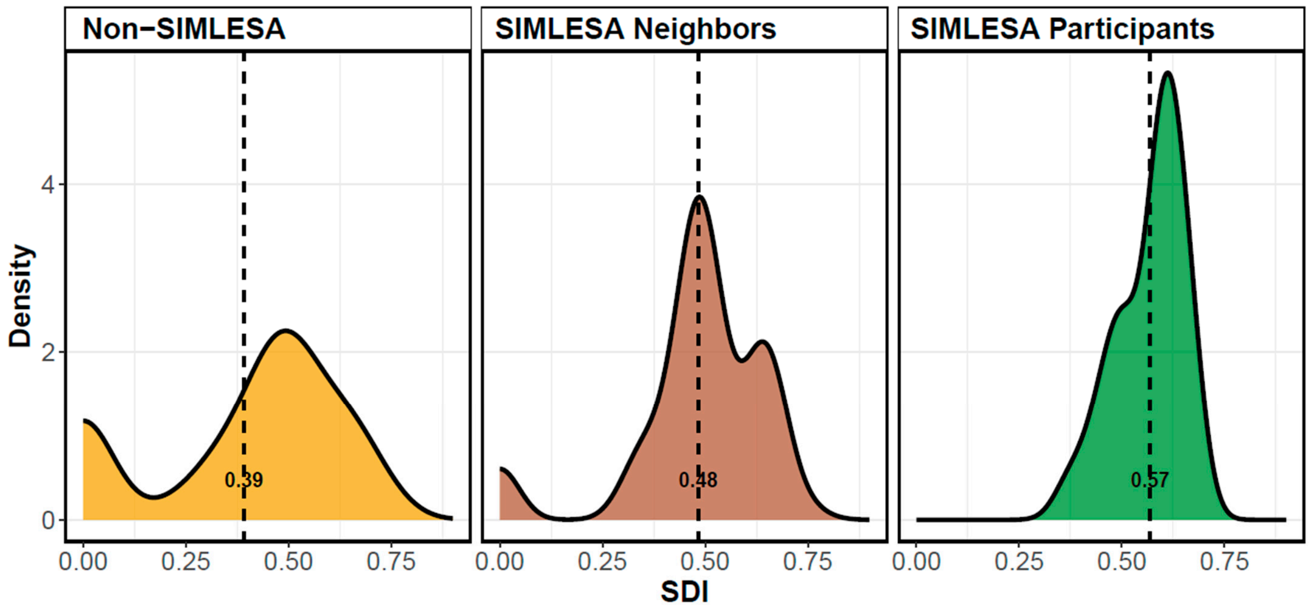

Figure 7. SDI distribution among smallholder farmers in our sample.

Table 6. Multiple linear regression model of the household characteristics effects on crop diversification.

Variable	Estimate	Std. Error	t Value	Pr (>|t|)
(Intercept)	0.3118969	0.0777117	4.014	9.87×10^{-5} ***
farmer.typeSIMLESA-Participant	0.1954110	0.0517245	3.778	0.000236 ***
farmer.typeSIMLESA Farmer-Neighbor	0.1329435	0.0362593	3.666	0.000353 ***
HH.age	−0.0005881	0.0014140	−0.416	0.678149
HH.SexMale	−0.0380164	0.0339102	−1.121	0.264240
HH.educationSecondary level	0.0098769	0.0336891	0.293	0.769835
HH.educationTertiary level	0.1025643	0.1147354	0.894	0.372955
HH.size	0.0007980	0.0120893	0.066	0.947470
Labor	0.0071060	0.0145688	0.488	0.626514
Inputs.NGOsYes	0.1233301	0.0449798	2.742	0.006937 **
food.securitySometimes	−0.0232030	0.0383787	−0.605	0.546472
food.securityInsufficient	−0.0917912	0.0399613	−2.297	0.023158 *
food.securitySurplus	−0.0550155	0.0762468	−0.722	0.471822
farm.size	0.0677832	0.0254241	2.666	0.008611 **
Inputs.governmentYes	−0.0049105	0.0369595	−0.133	0.894500

Signif. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05. Multiple R-squared: 0.2629, adjusted R-squared: 0.1865. F-statistic: 3.44 on 14 and 135 DF, p-value: 8.711×10^{-5}.

4. Discussion

4.1. Impact of SIMLESA on Crop Diversification and Food Security

The results indicate that SIMLESA has had positive impacts on crop-diversification adoption, with SIMLESA participants exhibiting a mean SDI of 0.57, compared to 0.48 for SIMLESA farmer neighbors and 0.39 for non-SIMLESA households (Figure 7). However, the dominance of sole cereal cropping is still apparent (Figure 5), and the overall response regarding food security remains concerning (Figure 4). The combined percentage of non-SIMLESA households lacking sufficient food to meet basic needs ('Insufficient') or experiencing irregular food access ('Some-times') is 57.6%, compared to 50% for SIMLESA households. This suggests a small improvement in food security among the SIMLESA households, yet the situation remains concerning, with at least 50% of all households still facing irregular food access.

The dominance of cereal mono-cropping suggests that many farmers remain entrenched in traditional practices and have not adopted more diverse cropping systems. This limited adoption of the SIMLESA-promoted crop-diversification initiatives may stem from the applicability of the technologies introduced. While the initiative promoted improved crop management practices and diversification strategies, the adoption of these innovations may have been constrained by factors such as inadequate access to high-quality legume seeds, labor shortages, and limited land, as noted in Table 4. These constraints can undermine the effectiveness of the promoted technologies, limiting their potential to significantly improve yields and food security outcomes. Labor shortages are a significant barrier, as labor is essential in the low-input farming systems typical of SSA. And most farmers lack access to labor-saving technologies [25]. In SIMLESA Malawi trials, labor shortages have also been cited as a major reason for the dis-adoption of CASI technologies [8]. Another major limitation is the inadequate access to high-quality legume seeds, which are critical for diversifying cropping systems. ACIAR [8] also noted that the primary reasons for the dis-adoption of SIMLESA initiatives were shortages of inputs and financial constraints. Due to these financial constraints, many smallholder farmers depend on informal seed systems [26], frequently using recycled seeds from previous seasons. However, these seeds tend to be of lower quality and less productive, limiting the full potential of crop-diversification systems. A study by Breen [27] has highlighted further challenges, such as the high cost of legume seeds, inadequate seed availability, and limited access to information on new, high-yield pest- and disease-resistant varieties.

Additionally, farmers in SSA, particularly in Central Malawi, cultivate small farms of typically less than 1.5 hectares (Figure 3), and this constrains their ability to diversify. Limited access to land forces them to focus on a narrow range of crops, primarily cereal staples like maize, to meet their immediate food needs. Given their dependence on seasonal crop yields, they often prioritize intensifying cereal production with fertilizers, which provide immediate benefits, such as improved soil nutrients and higher yields [28,29]. In contrast, the benefits of crop diversification, like improved soil fertility and yield stability, accumulate more gradually and depend on several unpredictable factors, including rainfall and soil condition [9,30]. This unpredictability, combined with smallholders' needs for immediate food security, often discourages them from adopting diversification practices, despite their long-term advantages. As a result, the inability to diversify increases vulnerability to food shortages, perpetuating a cycle of food insecurity among smallholder households.

Lastly, the persistent challenges faced by smallholder farmers in SSA should not be underestimated. The issues listed in Table 4 highlight the complexity and intractability of the problems farmers face and also more issues, such as large family sizes and dependency ratio [31], land fragmentation [32], soil fertility decline [4], climate variability [1], and cultural preferences [33], among others. These challenges are deeply rooted and often interconnected, making it difficult for a single intervention to generate transformative change. Moreover, farmers' immediate food security needs and their risk-averse nature, driven by the unpredictability of rainfed systems, likely hindered the adoption of crop-diversification systems.

4.2. Food Security Status and Farm Size Impact Crop on Crop Diversification

Our analysis also revealed that food insecurity and farm size are significantly associated with crop diversification. We found a negative correlation (coefficient: −0.092, $p = 0.023$) between insufficient food and crop-diversification levels, while larger farm sizes were associated with a greater likelihood of adopting diverse cropping practices (Table 6). Small farms often struggle to produce sufficient food to meet family needs, leading to food insecurity. As a result, these farmers may be compelled to devote most, if not all, of their land to staple crops, particularly maize in the case of Eastern and Southern Africa, for the immediate family food security needs. This short-term focus on food security restricts their ability to experiment with or adopt more sustainable practices, reinforcing a cycle of food insecurity and limited incomes.

Larger farm sizes were linked to a higher likelihood of adopting crop diversification, indicating that farmers with more land are more inclined to diversify their crops. This trend may explain the improved uptake of diversification systems among SIMLESA participants. The extent of available land directly impacts the number of crops that can be cultivated given the available resources. Farmers with larger holdings typically have the flexibility to allocate portions of their land to various crops, thereby enhancing their agricultural production diversity. Conversely, limited access to land constrains farmers, forcing them to focus on a narrower range of crops due to spatial and resource limitations. These results are consistent with previous research findings. For instance, a study in Zimbabwe found that a 1-acre increase in land size results in a 15.8% increase in the probability of adopting crop diversification [12]. Similarly, in Zambia, a 10% increase in average land size (approximately 0.5 hectares) correlated with a 29% increase in the probability of adopting maize–legume cropping systems [34]. Therefore, land size is a key determinant of crop-diversification adoption, and it plays a crucial role in shaping the agricultural landscape, influencing both the variety and abundance of the crops grown.

Additionally, these results emphasize the crucial connection between crop diversification and food security outcomes. Higher crop diversification increases the food available for home consumption, and surplus production can be sold, enhancing cash earnings and mitigating seasonal food shortages [19]. The SIMLESA findings from Malawi and across the region have also supported this, indicating that crop-diversification systems enhance grain and nutritional security [9,10,32]. In contrast, reliance on monoculture or limited crop diversification heightens vulnerability to crop failures, pest outbreaks, and market fluctuations. Crop diversification offers numerous benefits that directly contribute to food security by improving yields and yield stability [9,35,36] and providing a safety net if one crop fails [37]. These results align with the existing research findings that highlight the reciprocal relationship between crop diversification and food security. For example, a study in rural Ethiopia found a positive effect of crop diversification on household food security, underscoring that household access to food largely depends on agricultural output [38]. Furthermore, a study involving 600 households across Kenya, Uganda, and Tanzania revealed that food-secure farming households cultivate a wider variety of crops compared to food-insecure households [39]. In Malawi, Mango [19] found a significant positive relationship between crop diversification and smallholder farm household food security.

This analysis highlights the essential link between food insecurity, farm size, and crop diversification. Small farms facing food insecurity often prioritize staple crops like maize, limiting diversification, while larger farms enable greater diversification, enhancing food security. Promoting crop diversification can improve agricultural sustainability and resilience, but its adoption largely depends on available land size.

4.3. Agriculture Support Programs

The analysis revealed significant insights into the dynamics of agricultural support programs in Malawi, particularly concerning crop-diversification efforts. The positive coefficient (0.1233301) and statistical significance ($p = 0.006937$) associated with inputs from NGOs suggest that households benefiting from NGOs tend to exhibit higher levels of crop diversification. Conversely, the non-significant coefficient (−0.0049105) for inputs from the government implies that government-provided inputs, which primarily focus on subsidizing staple cereal production, may not significantly influence crop diversification. In most Eastern Southern Africa (ESA) countries, including Malawi, although the government promotes diversification, the main policy still focuses on filling the maize basket. This underscores a potential gap in the effectiveness of governmental agricultural policies, as they prioritize maize, which is the primary staple crop. The prioritization of maize subsidization in Malawi's government programs has seen the distribution of maize seeds and fertilizer among smallholder farmers with less focus on other crops, contributing to a decrease in crop diversification. However, NGOs and research institutions have been promoting crop diversification directly and indirectly [19], complementing this focus by providing support through inputs and improved seeds, alongside conducting more research and extension activities targeting sustainable agriculture initiatives. These efforts have been crucial in advancing the diversification of crop production

These results are consistent with [40], who observed that, in Malawi, households that received vouchers for fertilizer and maize seeds allocated 45% more land to maize and 21% less land to other crops (e.g., groundnuts, soybeans, and dry beans). They also observed a significant increase in legumes on the market after the government provision of both maize and legume vouchers for fertilizer and seeds in 2009–2010. Adjimoti [41] also found a negative effect of government input policies on crop diversification in rural Benin, concluding that these led to specialization on one specific crop instead. In Asia, Refs. [42,43] concluded that government incentives on cereal staple production encourage farmers to focus on intensive staple production rather than on crop diversification. Therefore, government efforts to promote diversification should be coupled with the provision of inputs to support the production and commercialization of various crops, rather than primarily focusing on staple crops only [43].

The contrasting outcomes between NGO and government support suggest that diversification needs support, in terms of access to resources (e.g., farming inputs), for it to be feasible. This underscores the importance of collaborative efforts between stakeholders to enhance the effectiveness of agricultural support programs, ultimately fostering greater crop diversification and food security.

4.4. Participation in Agricultural Development Initiatives

The results suggest that SIMLESA participants generally had a better SDI score, indicating better crop diversification compared to both SIMLESA farmer neighbors and non-SIMLESA farmers. A notable increase in crop diversification of approximately 0.195 among participants and 0.133 among farmer neighbors underscores the impact of farmer participation on agricultural development initiatives. While there is evidence of information spillovers from SIMLESA farmers to their neighbors within their communities, the study also finds that increases in crop diversification and adoption are substantially lower for non-SIMLESA communities. This emphasizes the common belief that, in general, people are more likely to accept and practice what they see and try than what they just hear about or what is recommended to them by others [44].

Crop-diversification adoption within the SIMLESA-implementing communities can be attributed to various factors facilitated by SIMLESA, including access to training, resources, and knowledge of the benefits of crop-diversification systems. SIMLESA facilitated capacity building and out-scaling by engaging host farmers in hands-on learning experiences, while their neighbors learned through observation [8]. Peer-to-peer knowledge exchange, which is often referred to as "farmer-to-farmer extension" [45], facilitated by trial-hosting farmers, likely contributed to the diffusion of diversified cropping systems beyond the direct program participants. However, despite SIMLESA's robust emphasis on extension services and out-scaling initiatives aimed at fostering CASI innovation, the non-SIMLESA participants did not directly benefit from these critical support mechanisms. This lack of engagement created a significant gap in awareness and access to tailored resources, thereby slowing adoption beyond host farmers and their neighbors.

Exposure to on-farm demonstrations and to trained farmers can spur broader technology adoption in the community [44,46]. Literature on the effectiveness of decentralized extension models for facilitating innovation and knowledge diffusion has highlighted that trained farmers spur knowledge and adoption among themselves [46,47] and, subsequently, diffuse to other farmers [40,45,46]. This underscores the importance of empowering farmers through participatory programs like SIMLESA, not only for individual farm productivity but also for broader agricultural sustainability and food security in the region. This study, therefore, makes a contribution to the existing literature by reinforcing the importance of increasing the exposure of farmers to new agricultural innovations in enhancing the likelihood and speed of adoption, and the importance of linking research to development efforts through participatory methods.

Therefore, promoting the SIMLESA initiative beyond the hosting communities is essential. These initiatives should be reinforced through sustained efforts and strategic interventions, including supportive policies, improved market access for inputs and improved seed, and intensified research and extension activities. By promoting these initiatives, stakeholders can enhance agricultural resilience, productivity, and livelihoods for smallholder farmers throughout Malawi.

5. Conclusions

This study highlights both challenges and opportunities in the promotion of crop-diversification systems among smallholder farmers. The majority of the households own less than 1.5 hectares of land, and food security is a concern, with at least 50% of all households still facing irregular food access. Despite recognizing the importance of crop diversification in improving soil fertility and crop yields, labor shortages and a lack of legume seeds were cited as major barriers to crop-diversification adoption. A multiple linear regression analysis identified that access to NGO inputs, larger farm sizes, and participation in research programs such as SIMLESA (whether as a participant or neighbor) had a positive influence on diversification levels. Conversely, food insecurity was found to have a negative association with crop-diversification adoption. Crop diversification has the potential to enhance food security, but its success largely depends on the availability of inputs and land, with small farms often constrained by a focus on staple crops to meet household food security needs. This highlights the need for collaborative efforts among stakeholders to promote the adoption of crop-diversification systems, focusing on providing practical support for diverse crop production beyond staple crops.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16209078/s1. Table S1: Generalized Variance Inflation Factor (GVIF) values used to detect multicollinearity in LRM.

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Informed Consent Statement: Informed consent was obtained from all participants through a consent form that ensured they fully understood the nature of the study and agreed to participate voluntarily.

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