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Influence of Selected Institutional and Technological Factors on the Adoption of Sustainable Agriculture Technologies in Maize Farming in Mzimba South, Malawi

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Abstract

Sustainable Agriculture Technologies (SATs) significantly contribute to addressing the negative effects of land degradation, poor soil health and climate variability in the agriculture sector. Despite efforts made by different stakeholders in promoting SATs to improve maize productivity in Mzimba South in Malawi, the adoption of the technologies among small-scale farmers remains unsatisfactory. As a result, most of the farmers continue to realize low maize yields. A survey was conducted from July to September 2019 to investigate the influence of selected institutional and technological factors on the adoption of SATs in maize farming among the small-scale farmers in Mzimba South. A multi-stage sampling procedure was used to select a representative sample of 132 small-scale maize farming household heads. Data was collected using a researcher-administered questionnaire. Multivariate probit, ordered probit and ordinary least square (OLS) models were applied to determine the influence of the selected factors on the adoption of SATs at α level of .05 using STATA and SPSS. Qualitative data was analyzed by a deductive approach, in which responses were categorized and summarized under the related themes. The study established that the adoption of SATs was significantly influenced by membership in farmer organizations (FOs), access to extension services, and the levels of relative advantage and complexity associated with the SATs. The findings of the study implied that the Government of Malawi and relevant stakeholders in the agriculture sector need to train and recruit more extension field staff to improve coverage and frequency of extension services delivery on sustainable agriculture. The stakeholders should also promote affiliation of the small-scale farmers to FOs to improve access to agricultural extension services and production resources on sustainable farming. In addition, efforts should be made to develop and promote affordable mechanization options for reducing farm drudgery associated with the implementation of SATs. Furthermore, the Government of Malawi should facilitate the formulation, enactment, and enforcement of local by-laws for safeguarding the SATs and their related inputs (or raw materials) against vandalism, livestock damage, and bushfires.

Keywords: Sustainable agriculture technologies (SATs); Adoption; Maize farming; Mzimba south; Malawi.

1. Introduction

Rapid demographic changes have stimulated a global transition of farming practices from traditional organic systems to modernized input-intensive systems to meet the growing demand for agricultural produce for food and industrial raw materials [1]. Despite the increase in overall agricultural output, technological improvements coupled with unsustainable farming methods, have significantly contributed to a reduction in the quality of land and per capita production [2]. Likewise, Malawi's agriculture sector continues to struggle with the effects of land degradation due to unsustainable farming methods [3].

Maize is one of the arable crops in Malawi which experience negative effects of the loss of natural soil nutrients and organic matter content due to unsustainable farming. For example, Mzimba District has experienced a drop in the yield of maize grown without inorganic fertilizer application from 1.5 metric tons per hectare in the 1960s to 0.67 metric tons per hectare in 2013. This decrease in maize yield indicates the effect of high levels of land degradation on the crop in the district [4]. According to Thierfelder, *et al.* [4], the situation is aggravated by the low capacity of the resource-poor small-scale farmers to purchase adequate fertilizers and meet other production costs for sustaining maize production. Sustainable agriculture is one of the effective concepts for addressing land degradation in different agro-ecological zones [5]. The concept applies a wide range of Sustainable Agricultural Technologies (SATs) that work with the natural processes to conserve resources, reduce waste and environmental impacts, and promote resilience and self-regulating mechanisms of agro-ecosystem to sustain agricultural production [6]. The SATs mostly rely on organic farm inputs, agro-ecological processes for fixation and cycling of resources, and natural interdependencies among organisms.

Maize remains an important staple food crop in Malawi and other African countries. The crop relies on a number of SATs to improve soil fertility and productivity. In Malawi, the commonly promoted SATs include reduced tillage, agroforestry, manure making and use, mulching, pit-planting, crop rotation, and crop residues incorporation. These technologies are mostly practiced by small-scale farmers in maize farming in all the three regions of Malawi [7]. Considerable efforts have been made to promote the adoption of SATs by governments and development agencies at all levels. However, the adoption of these technologies among farmers is still low in both developed and developing countries [8, 9]. Similarly, adoption has failed to attain the desired levels in Malawi despite their proven benefits to the farmers. For example, Mzimba South reported a percentage of arable land under SATs of 9.3 in 2016 (Mzimba South District Agriculture Development Office [10].

Research on the adoption of SATs in Malawi has been conducted in only a few districts. These studies have had a relatively narrower scope due to their focus on a few technologies in selected districts [3, 11]. As a result, the level of generalizability of the findings has been relatively low across different agro-ecological zones of Malawi. In addition, few studies have narrowed down their focus on aspects influencing SATs adoption in maize cropping systems. Inadequate understanding of these aspects poses a great challenge among extension agencies, research institutions and farmers in establishing the current status of adoption as well as formulating strategies to scale up the use of SATs in maize farming [4]. Factors which influence farmers' decisions to adopt SATs are multi-dimensional in nature. They include institutional and technological factors [2, 12]. However, there is a lack of information on the extent of the influence of the factors on the adoption of SATs in maize cropping systems in Mzimba South in Malawi.

The study drew its basis from the Random Utility Theory (RUT) and the Diffusion of Innovation Theory (DOI) to determine the influence of selected institutional and technological factors on the adoption of SATs [13, 14]. It narrowed down its focus on the institutional factors of membership in farmer organizations (FOs) and access to extension services on sustainable agriculture. In addition, the technological factors comprised farmers' perceptions towards relative advantages, complexity and compatibility of the technologies. The selected SATs were manure making and utilization, agroforestry, pit-planting, mulching, reduced tillage, crop rotation (with the inclusion of leguminous crops), and crop residues incorporation. The determination of the influence of the selected factors on SATs adoption was done through the testing of the following three null hypotheses:

(i) There is no statistically significant difference in the characteristics of adopters and non-adopters of SATs among the small-scale maize farmers in Mzimba South, Malawi.
(ii) There is no statistically significant influence of selected institutional factors on the adoption of SATs among the small-scale maize farmers in Mzimba South, Malawi.
(iii) There is no statistically significant influence of selected technological factors on the adoption of SATs among the small-scale maize farmers in Mzimba South, Malawi.

2. Research Methodology

2.1. Description of the Study Location

The study was conducted in the southern part of Mzimba district in Malawi. Mzimba is the largest district which covers an area of 10,430 square kilometres in the Northern Region of Malawi. The district lies at coordinates -11°29'59.99" S 33°29'59.99" E.

Figure-1. A Map of Mzimba South in Malawi

In the agriculture sector, the areas of the district are administratively divided into Mzimba North and Mzimba South; under Mzimba North District Agriculture Development Office (MZNDADO) and Mzimba South District Agriculture Development Office (MZSDADO) respectively. Mzimba South is agro-ecologically divided into 11 Extension Planning Areas (EPAs). On the basis of the area and population of the EPAs, each EPA is broken down into a number of Sections. In total, Mzimba South has 106 Sections [15].

Mzimba district shares boundaries with Zambia to the West, Rumphi District to the North, Nkhatabay District to the East, Kasungu District to the South and Nkhotakota District to the South East. Approximately, 70% of the population of the district are small-scale farmers who depend on maize as the main staple crop. During some years, the district experiences inadequate and unevenly distributed rains. This condition, coupled with degraded soils, has led to an increase in the number of agriculture sector stakeholders promoting SATs in the district [15].

2.2. Sampling Procedure and Sample Size

The study used a multi-stage sampling procedure in which Mzimba South was purposively selected on the basis of the level of arable land degradation [4]. Simple random sampling was employed to select six EPAs from a total of 11 EPAs in Mzimba South. The identification of 132 small-scale maize farming households from the population of 156,670 households was carried out using simple random sampling technique [16]. The sample size of 132 household heads was proportionately distributed across the six sampled EPAs (Table 1).

Table-1. Sample distribution of the household heads by EPA

EPA name	Sample size
Luwerezi	17
Champhira	29
Mbawa	27
Manyamula	25
Eswazini	22
Mjinge	12
Total	**132**

2.3. Data Collection

A researcher-administered questionnaire was used to collect qualitative and quantitative data from the 132 small-scale maize farming household heads. The questionnaire was pretested and subjected to a reliability test to determine the degree of consistency using Cronbach's alpha method [17]. The Cronbach's α coefficient for the instrument was estimated at 0.71.

2.4. Data Analysis

Data was analyzed using SPSS and STATA at the maximum α level of 0.05. Specifically, means, percentages and standard deviations were used to describe the institutional and technological characteristics relating to the sample. T-tests and chi-square tests were applied to compare the adopters and non-adopters. Multivariate probit model was used to establish probabilities of adoption of specific types of the SATs among the farmers. An ordered probit model was used to determine the influence of the independent factors on the level of adoption (based on the number of SATs adopted by the farmers). The respondents were categorized into different adoption levels based on the number of adopted SATs as (i) low adopters (for zero to two SATs), (ii) average adopters (for three to four SATs) and (ii) high adopters (for five to seven SATs). This categorization was based on the strategy used by Mzuzu Agricultural Development Division (MZADD) in Malawi for characterizing small-scale farmers involved in sustainable agriculture projects and programmes (MZSDADO, 2016).

An OLS model was used to establish the influence of the explanatory factors on the area of arable land under the seven technologies. Furthermore, a deductive approach was used to analyze qualitative data whereby responses from the respondents were grouped and subsequently coded under specific themes relating to the items of the instrument. Then, the data was summarized by examining similarities, differences and trends across the responses.

2.4.1. Description of the Statistical Models

2.4.1.1. Multivariate Probit Model

Farmers adopt a combination of technologies to address a number of problems they face and maximize benefits from their enterprises. Adoption decisions are intrinsically multivariate as farmers are required to select practices or technologies from an interrelated set of options available within their environment [18].

The model concurrently determines the influence of a set of predictor variables on each of the specific technologies; while accounting for the correlation of the variables on each of the different SATs. A utility formula can be used to determine the observed benefits of adopted SATs by the farmers. The formula depicts the condition that farmers adopt SATs whose perceived advantages outweigh those of the other options (1):

$$\mathrm{Y}_{\mathrm{is}}^{*} = \mathrm{B}_{\mathrm{s}}^{*} - \mathrm{B}_{\mathrm{o}} > 0 \quad (1)$$

Where ***i*** represents small-scale maize farming households and ***s*** are the specific SATs of manure making and utilization *(MMU)*, mulching *(MC)*, pit-planting *(PP)*, agro-forestry *(AGF)*, crop rotation *(CR)*, crop residues incorporation *(CRI)*, and reduced tillage *(RT)*. $\mathbf{B}_{\mathbf{s}}^{*} - \mathbf{B}_{\mathbf{o}}$ represents the net benefits of the SATs over their alternatives. The net advantages that a household realizes from SATs is a latent variable determined by observable household characteristics ($\boldsymbol{X_i}$) as well as unobservable aspects (ε_{i}) as summarized in equation (2).

$$Y_{is}^{*} = X_i^{'}\beta_s + \varepsilon_i \quad (2)$$

(s = MMU,MC,PP,AGF,CR,CRI,RT)

The unobserved adoption decisions in equation (2) can be translated into an observed binary result function for the adoption of each of the available SATs as shown in (3).

$$\mathrm{Y}_{\mathrm{s}} = \begin{cases} 1 \text{ if } Y_{is}^{*} > 0 \\ 0 \text{ otherwise} \end{cases} \quad (3)$$

This implies that the probability of adopting a particular SAT was realized only when the value of expected net benefits Y_{is}^{*} was greater than 0. A multivariate probit model for possible adoption of several SATs provided a situation in which there was a multivariate normal distribution (MVN) of disturbance terms with a mean of zero and a normalized variance. The resultant multivariate probit model is shown as:

$$P(Y_{is} = 1|X_i) = P(X_i^{'}\beta_s + \varepsilon_i > 0|X_i) \quad (4)$$

2.4.1.2. An Ordered Probit Model

Multivariate probit model is limited to the determination of adoption probabilities of each of the available technological options. The model could not predict the likelihood of farmers' inclusion in any of the adoption categories on the basis of the number of SATs adopted. In reality, not all farmers could adopt the whole set of available SATs; their choices of the number of SATs were significantly influenced by the personal preferences of the technologies. Therefore, it was imperative to use ordered probit model to predict the adoption level (as an ordinal dependent variable) by the farmers.

Similar to the multivariate probit model, the ordered model includes a latent variable for the adoption level function **(L*)**. Based on the utility maximization function, the function can be presented as:

$$L_i^{*} = \beta X_i^{'} + \varepsilon_i \quad (5)$$

Where $\mathbf{X_i}$ represents a vector of household characteristics, $\boldsymbol{\beta}$ is a vector of predicted parameters, and $\boldsymbol{\varepsilon_i}$ represents unobserved factors. In this case, farmers would adopt extra SATs (thus moving towards higher adoption level) if the benefits realized from adopting more of these SATs are more than those associated with adopting fewer technologies [19]. The resultant ordered probit model is shown as:

$$P(L_i = 1|X_i) = P(X_i^{'}\beta + \varepsilon_i > 0|X_i) \quad (6)$$

2.4.1.3. Ordinary Least Squares Model

An OLS model was used to establish the influence of selected institutional and technological factors on the acreage of arable land under SATs. The OLS regression equation for the sample of 132 households is shown as:

$$\hat{y}_i = \hat{\alpha} + \hat{\beta}_i x_i + \hat{\varepsilon}_i \quad (7)$$

Where:

$\hat{\mathbf{y}}_\mathbf{i}$ is a change in the area of arable land (in acres)

$\hat{\boldsymbol{\alpha}}$ is OLS estimator of the intercept coefficient

$\hat{\boldsymbol{\beta}}_\mathbf{i}$ is OLS estimator of the slope coefficient

$\mathbf{x_i}$ is the independent variable of the ith household

$\hat{\boldsymbol{\varepsilon}}_\mathbf{i}$ is the OLS residual for ith household

3. Results and Discussion

3.1. Comparison of the Characteristics of Adopters and Non-Adopters of SATs

The sampled households were characterized on the basis of the selected institutional and technological factors in relation to being an adopter or non-adopter of each of the seven SATs. The results of the statistical analyses rejected the null hypothesis that there is no statistically significant difference in the characteristics of adopters and non-adopters of SATs among the small-scale maize farmers ($p < .05$). The two categories of farmers were different in terms of access to extension services, membership in FOs, and perceptions towards relative advantage, complexity and compatibility of the seven SATs.

3.1.1. Access to Extension Services on SATs

In relation to the access to extension services, the study revealed that the mean of total extension visits that the respondents were exposed to from April to June 2019 (three months prior to data collection) for all the seven technologies was 12 (SD = 9). Particularly, the means of extension contacts for adopters and non-adopters were 13 and 2 respectively. The findings showed that the adopters were exposed to more extension contacts than the non-adopters, $p < .05$ (Table 2). The results are in agreement with those by Beshir [20] in which households with higher frequencies of extension contacts had higher chances of adopting SATs as a result of acquisition of knowledge and skills related to sustainable agriculture.

Table-2. Frequencies of extension contacts and SATs adoption

SATs	Means of SATs-related extension contacts		t-value	Sig.
	Adopters	Non-adopters		
Manure making and utilization	14.721	3.740	9.609*	.000
Agroforestry	16.843	7.118	7.424*	.000
Pit-planting	17.239	7.827	6.983*	.000
Mulching	17.733	10.111	5.132*	.000
Reduced tillage	18.911	10.713	5.010*	.000
Crop rotation	15.338	5.544	7.958*	.000
Crop residue incorporation	15.916	8.734	4.980*	.000

Note: * indicates the statistical significance at 1%

3.1.2. Membership in FOs

With respect to membership in FOs, the results showed that the percentage of FOs members (58%) was higher than that of non-members (42%). The members were distributed across clubs, associations and cooperatives in the percentages of 52, 7 and 5 respectively. The membership distribution was mutually inclusive across some FOs. Thus, there was a possibility for a household to be a member of at least two different types of FOs. Statistical tests of association revealed that there were more FOs members among the adopters than there were among the non-adopters in all the technologies, $p < .05$ (Table 3). FOs serve as social systems that facilitate rapid transfer of knowledge and skills relating to SATs among farmers. As supported by previous studies on SATs adoption, members of the organizations were likely to take up the technologies as compared to non-members [3, 21].

Table-3. Association between FO membership and SATs adoption

SATs	Percentages of members		$\chi 2$ value	Sig.
	Adopters	Non-adopters		
Manure making and utilization	13.112	4.220	11.484*	.000
Agroforestry	14.509	7.309	7.985*	.000
Pit-planting	14.944	7.713	7.981*	.000
Mulching	16.512	9.211	5.965*	.000
Reduced tillage	19.233	9.607	6.134*	.000
Crop rotation	13.624	5.641	8.965*	.000
Crop residue incorporation	14.831	7.734	7.658*	.000

Note: * indicates the statistical significance at 1%

3.1.3. Perceptions towards Relative Advantages of the SATs

The respondents rated each of the seven SATs on the basis of the degree to which the technologies were perceived as important or beneficial. The rating was done using a 5-point Likert scale which was later collapsed into a 3-point scale during analysis. The results showed that more adopters than non-adopters perceived all the SATs as highly beneficial, $p < .05$ (Table 4).

Table-4. Association between relative advantage and SATs adoption

SATs	Category	Percentages of respondents			$\chi 2$ value	Sig.
		Low	Moderate	High		
Manure	Adopters	0	0	72	64.120*	.000
	Non-adopters	8	8	12		
Agroforestry	Adopters	1	7	38	73.613*	.000
	Non-adopters	34	13	7		
Pit-planting	Adopters	1	0	40	93.158*	.000
	Non-adopters	32	20	7		
Mulching	Adopters	0	2	18	68.698*	.000
	Non-adopters	58	14	8		
Reduced tillage	Adopters	1	0	10	50.473*	.000
	Non-adopters	68	10	11		
Crop rotation	Adopters	5	3	54	49.275*	.000
	Non-adopters	17	11	10		
Crop residues incorporation	Adopters	4	5	32	31.842*	.000
	Non-adopters	23	19	17		

Note: * indicates the statistical significance at 1%

According to Rogers [14], individuals tend to adopt an innovation that they value advantageous based on economic, social prestige, convenience or satisfaction terms. For instance, manure was rated highly beneficial by 84% of the respondents due to its high yielding effect and low cost attribute (as compared to inorganic fertilizers). In contrast, 16% of the respondents rated manure as lowly to moderately advantageous due to its relatively longer time lag before yielding results, dependency on the livestock fecal matter and high cost of transporting manure to farm plots. Agroforestry was ranked as a highly beneficial SAT by 45% of the households on the basis of the soil fertility improvement and relatively low cost attributes of the technology. Nevertheless, the SAT was perceived as lowly advantageous by 35% of the respondents on the assertion that the practice was prone to livestock-caused damage (in cases where agroforestry trees were used as livestock feed), longer time lag before yielding results, high labour requirement and shading of maize plants; thereby causing light interception. The challenges associated with agroforestry are similar to those that are hindering the scaling up of the technology among small-scale farmers in Southern Africa. Therefore, significant efforts need to be made by relevant stakeholders in exploiting sustainable solutions to address the challenges [22].

Pit-planting was ranked highly beneficial SAT by 47% of the households. Similar to the findings of a study by Mafuse, *et al.* [23], the respondents attributed their preference of the technology mainly to its high yielding results and water retention capacity.

The study also established that fewer respondents rated mulching as a highly advantageous SAT (26%) than those who perceived it as a lowly beneficial technology (58%). Mulching had a favourable rating among 26% of the respondents due to its contribution to soil and moisture conservation, increase in soil organic matter content, and protection of maize plants from direct sun's heat, hailstorm and strong winds. Mulching received a low rating by 58% of the sampled households based on the reasons of low mulch quantity (due to mulch burning and use for livestock feed), relatively longer time periods before the results are realized by the farmers, increased termites and stalk borer infestation, and poor crop growth. Except for poor crop growth, the other challenges associated with mulching conformed to those that most of the small-scale farmers face in developing countries; hence, they require the use of readily available control measures to address them [24-26]. In contrast to the problem of poor crop growth, [27] reported that mulching had a positive effect on maize germination and growth. Therefore, the basis of the farmers' assertion of the challenge needs to be researched further.

Reduced tillage was rated highly advantageous by 21% of the households based on its low labour cost characteristic (as the SAT involves minimal soil disturbance). However, the technology had a low ranking among 69% of the respondents. Major reasons for the unfavourable rating of the technology were high cost of herbicides (36% of respondents), high cost of farm mechanization implements (16% of respondents) and soil hard-pan effect (13% of respondents). All the three challenges were supported by previous studies on the technology [25, 28]. For instance, the findings of a study conducted in Zambia showed that soils under reduced tillage were more compact at 5cm depth than those under conventional tillage [29]. With regard to mechanization, available farm implements used in reduced tillage (such as direct seeders and rippers) are costly to most of resource-poor small-scale farmers [24]. Therefore, strategies for scaling up of the technologies should incorporate measures to address the identified challenges.

With regard to crop rotation, more respondents (64%) perceived it as a highly beneficial SAT than were those who regarded it as a lowly beneficial practice (22%). Reasons for high ranking of the SAT, on the basis of relative advantage, included the flexibility to diversify farm crops, improvement of soil fertility, and control of pests and diseases. Despite the benefits of the technology, 22% of the farmers reported that the technology required large plots of arable land. The farmers' assertion supported the findings by Kassie, *et al.* [30] that identified land shortage as a limiting factor to crop diversification and rotation.

Crop residues incorporation was ranked as a highly advantageous SAT by more respondents (49%) than the farmers who rated it as a lowly advantageous technology (27%). The major reasons for its favourable ranking was the retention of soil nutrients and organic matter for maize production. Nevertheless, the technology received low rating by 27% of the households because of the competition with livestock for crop residues, shortage of crop residues as a result of burning, increased termites infestation, increased stalk borer infestation and relatively poor seed germination associated with the technology. Despite the availability of relevant literature supporting crop residues depletion through burning and use for livestock feed, there is a lack of scientific evidence supporting the effect of the SAT on increasing termites and stalk borer infestation; as well as on poor seed germination [28, 31]. Therefore, there is a need for further studies to substantiate the farmers' claims about the technologies.

3.1.4. Perceptions Towards Relative Complexity of the SATs

The study also assessed the extent to which the respondents perceived each of the seven SATs as difficult to understand and implement using a 5-point Likert scale (which was collapsed into a 3-point Likert scale during analysis). In conformity with Rogers [14], the findings revealed that adoption was associated with low perception level regarding the complexity of all the SATs. Thus, more adopters were among the farmers who perceived the technologies as relatively simple to understand and use, $p < .05$ (Table 5). A significant proportion of farmers rated specific SATs as highly complex due to the confusion caused by unstandardized messages on pit-planting from different extension agencies (agencies promoted different types of pit-planting), limited technical capacity to implement the technologies and increased farm drudgery (as a result of high labour requirements and limited mechanization options). As regards limited technical capacity in the use of SATs, the results of the study showed that the households which rated the SATs as highly complex had fewer extension contacts ($M = 5$, $SD = 4$) than the contacts of the households which associated the SATs with low level of complexity ($M = 18$, $SD = 9$); $p < .05$. Therefore, the situation could imply that limited knowledge and skill in the use of the technologies contributed to making the farmers view the SATs as difficult.

Table-5. Association between the perceived complexity and SATs adoption

SATs	Category	Percentages of respondents			χ2 value	Sig.
		Low	Moderate	High		
Manure	Adopters	57	9	6	67.029*	.000
	Non-adopters	2	5	21		
Agroforestry	Adopters	33	8	5	68.777*	.000
	Non-adopters	5	4	45		
Pit-planting	Adopters	23	10	8	68.664*	.000
	Non-adopters	2	3	54		
Mulching	Adopters	12	6	2	35.224*	.000
	Non-adopters	13	7	60		
Reduced tillage	Adopters	6	3	2	17.487*	.000
	Non-adopters	16	10	63		
Crop rotation	Adopters	58	1	3	56.014*	.000
	Non-adopters	13	16	9		
Crop residue incorporation	Adopters	39	1	1	40.565*	.000
	Non-adopters	25	17	17		

Note: * indicates the statistical significance at 1%

A significant percentage of the households (65%) attributed a high degree of complexity of the SATs to labour intensiveness and limited mechanization options for the technologies. In line with the findings by Mafuse, *et al.* [23], a hand-hoe remains a tool used in the implementation of most of the SATs in maize farming in Mzimba South. This situation confines the farmers with the intent to mechanize farm operations to perceive the technologies as labourious. In addition, available farm implements used for mechanization (such as direct seeders and rippers) are costly to most of resource-poor small-scale farmers [24]. Therefore, strategies for scaling up of the SATs should also incorporate measures to effectively reduce farm drudgery associated with the technologies.

3.1.5. Perceptions Towards Relative Compatibility of the SATs

The sampled households also rated the seven SATs basing on the degree to which the technologies were considered to be compatible with the existing cultural values. In the study, the cultural values comprise traditional principles, standards and ideals that govern the way farming is undertaken in Mzimba South. With the exception of manure, the results showed more adopters in the category of the farmers who perceived the rest of the SATs as highly compatible with the cultural values, $p < .05$ (Table 6). The study also established that there was no significant difference in the proportions of manure adopters and non-adopters across the three compatibility levels, $\chi2$ (1, N = 132) = 0.043, p = 0.836 (Table 6); since 98% of all the households rated manure as highly compatible.

In agreement with Rogers [14], high levels of technology compatibility to the values of a particular social system reduce uncertainty relating to the acceptance and use of the technology; hence contributing to its adoption among individuals. Therefore, strategies for the dissemination of SATs should conform to and enhance cultural values that optimize returns from sustainable agriculture.

Table-6. Association between the perceived compatibility and SATs adoption

SATs	Category	Percentages of respondents			χ2 value	Sig.
		Low	Moderate	High		
Manure	Adopters	0	1	52	0.043	.836
	Non-adopters	0	1	46		
Agroforestry	Adopters	5	8	33	32.673*	.000
	Non-adopters	30	9	15		
Pit-planting	Adopters	3	6	32	45.629*	.000
	Non-adopters	35	11	13		
Mulching	Adopters	4	5	11	26.715*	.000
	Non-adopters	58	4	18		
Reduced tillage	Adopters	3	5	9	15.499*	.000
	Non-adopters	55	8	20		
Crop rotation	Adopters	1	1	60	15.255*	.000
	Non-adopters	4	5	29		
Crop residue incorporation	Adopters	2	1	38	22.247*	.000
	Non-adopters	8	17	34		

Note: * indicates the statistical significance at 1%

3.2 Determination of the Influence of Selected Institutional Factors on the Adoption of SATs

The outputs of the models showed a statistically significant influence of the two institutional factors on SATs adoption ($p < .05$). Therefore, the null hypothesis that there is no statistically significant influence of the selected institutional factors on the adoption of SATs among small-scale maize farmers was rejected at 5% significance level. The results of the multivariate probit analysis on the FO membership and access to extension services indicated a positive influence of the two factors on the adoption decisions of specific types of SATs, $\chi2(14) = 122.37$, $p = .000$ (Table 7). Specifically, the findings indicated that being a member of any FO increased the probability of a household to adopt manure (MMU), agroforestry (AGF) and crop residues incorporation (CRI) (Table 7). In addition, having membership in any FO made it less likely for a household to be in the low adopters category by 23%, and made it more like for the household to be in the average adopters group and the high adopters group by 11% and 12% respectively, $\chi2(2) = 57.07$, $p = .000$ (Table 8). The study also established that being an FO member increased area of arable land under SATs by 0.8 acre, $F(2,129) = 63.92$, $p = .000$, $R^2 = .50$ (Table 9).

As reported by Ngwira, *et al.* [3], sustainable cropping benefits significantly from FOs through collective sharing of knowledge and skills on different technologies, and improvement of access to extension services and production resources among the members. Furthermore, the collective marketing functions undertaken by the organizations help the members increase their financial capacity to invest in sustainable farming [2, 32].

Table-7. Multivariate probit model results for the institutional factors

Factors	MMU Coef (RSE)	AGF Coef (RSE)	PP Coef (RSE)	MC Coef (RSE)	RT Coef (RSE)	CR Coef (RSE)	CRI Coef (RSE)
FO member	.994* (.320)	.599** (.284)	.015 (.308)	.335 (.369)	.276 (.459)	-.088 (.323)	.536** (.303)
Ext contacts	.104** (.045)	.092* (.020)	.091* (.023)	.049* (.018)	.056** (.022)	.118* (.027)	.045** (.019)
Sample size = 132 Prob. > $\chi2$ = .000	Wald $\chi2(14)$ = 122.37			Log likelihood = -404.82			

Note: RSE are the Robust Standard Errors (presented in parentheses). MMU=Manure making and utilization, AGF=Agroforestry, PP=Pit-planting, MC=Mulching, RT=Reduced tillage, CR=Crop rotation and CRI=Crop residue incorporation. * and ** indicate the statistical significance at 1% and 5% respectively

The findings implied that manure, agroforestry and crop residues incorporation benefited significantly from the operations of FOs. Therefore, strategies for promoting the three technologies in Mzimba South should be complemented by increasing affiliation of the small-scale farmers to FOs.

Table-8. Ordered probit model results for the institutional factors

Factors	Coefficients		Average marginal effects					
			Prob(Y≤2|X)		Prob(3≤Y≤4|X)		Prob(Y≥5|X)	
	Coef	RSE	Coef	RSE	Coef	RSE	Coef	RSE
FO member	.587**	.272	-.229**	.104	.106**	.054	.123**	.057
Extn contacts	.090*	.021	-.035*	.008	.016*	.005	.020*	.005
Sample size =132			Wald $\chi2(2)$ = 57.07		Prob. > $\chi2$ = .000			
Log pseudolikelihood = -103.410			Pseudo R^2 = 0.263					

Note: RSEs are Robust Standard Errors. Prob(Y≤2|X), Prob(3≤Y≤4|X), Prob(Y≥5|X) show the probabilities for low adoption (1 and 2 SATs), average adoption (3 and 4 SATs) and high adoption (5, 6 and 7 SATs) categories. * and ** indicate the statistical significance at 1% and 5% respectively

The findings also revealed that an increase in the number of extension contacts significantly increased the likelihood of adopting all the seven types of SATs (Table 7). An increase in the extension frequency by one contact reduced the likelihood that a household would be a low adopter by 4%, and increased the probability of being an average adopter and a high adopter by 2% (Table 8). Furthermore, an increase in the frequency of extension by one contact resulted in an increase in the area under SATs by 0.1 acre (Table 9).

Table-9. OLS model results for the institutional factors

Explanatory factors	Coefficients	Standard errors	t-value	P>|t|
FO membership	.761*	.225	3.39	.001
Extension contacts	.084*	.013	6.68	.000
Sample size = 132	F (2, 129) = 63.92		Prob > F = 0.000	
R^2 = 0.498	Adjusted R^2 = 0.490			

Note: * and ** indicate the statistical significance at 1% and 5% respectively

The results conformed to those of previous studies in which adoption of SATs was directly attributed to the acquisition of knowledge and skills by the farmers as a result of increased frequencies of extension contacts [20, 33]. According to Beshir [20], the information acquired through extension services enabled the farmers make informed decisions about the technologies. Therefore, the findings imply that strategies for scaling up SATs in Mzimba South should incorporate measures to increase the frequency and coverage of extension services delivery on sustainable agriculture to small-scale farmers.

3.3. Determination of the Influence of Selected Technological Factors on the Adoption of SATs

The third null hypothesis that there is no statistically significant influence of selected technological factors on the adoption of SATs was also tested. The outputs of multivariate and ordered probit models using maximum likelihood estimation also produced statistically significant Wald test results for relative advantage and complexity of the seven SATs at 5% significance level. The multivariate probit model output showed that the slope coefficients across all the equations were jointly not equal to zero $\chi2(21) = 195.02$, $p = .000$ (Table 10). Likewise, the Wald's chi-squared statistic for the ordered probit model was statistically significant, $\chi2(3) = 81.77$, $p = .000$ (Table 11). In addition, the OLS model had a statistically significant F statistic, $F(3, 128) = 27.01$, $p = .000$, $R^2 = 0.39$ (Table 12). Therefore, the results of the three models implied that the null hypothesis was rejected at 5% significance level. The outputs of the empirical analyses indicated that relative advantage and complexity of the SATs significantly influenced the adoption of the technologies.

The findings established that households were more likely to adopt all the seven types of SATs with increased level of perception regarding their advantages; on the basis of comparisons across the technologies as well as with the conventional practices in Mzimba South (Table 10). The respondents reported that specific SATs were rated highly advantageous mainly because of the low cost, soil fertility improvement, water and nutrient retention, convenience, and absence of adverse effects. The study revealed that a positive change in the perception of a household head towards the advantages of the SATs by one point on a three-point Likert scale (thus, low to moderate or moderate to high) reduced the likelihood of being a low adopter by 45%. Likewise, a change in the perception by the same margin increased the probability of being an average adopter and a high adopter by 23% and 22% respectively (Table 11).

Table-10. Multivariate probit model results for the technological factors

Factors	MMU Coef (RSE)	AGF Coef (RSE)	PP Coef (RSE)	MC Coef (RSE)	RT Coef (RSE)	CR Coef (RSE)	CRI Coef (RSE)
Relative advantage	.552** (.226)	1.079* (.247)	.540** (.237)	.790* (.257)	1.387* (.455)	.696* (.229)	.540** (.219)
Complexity	-.790* (.247)	-.424** (0.208)	-.808* (.250)	.043 (.252)	.067 (.285)	-.571** (.256)	-.112 (.217)
Compatibility	-.072 (.231)	-.081 (.229)	.165 (.287)	.296 (.344)	.134 (.370)	.169 (.223)	.245 (.267)
Sample size = 132	Wald $\chi2(21) = 195.02$		Log likelihood = -389.60			Prob. > $\chi2$ = .000	

Note: RSE are the Robust Standard Errors (presented in parentheses). MMU=Manure making and utilization, AGF=Agroforestry, PP=Pit-planting, MC=Mulching, RT=Reduced tillage, CR=Crop rotation and CRI=Crop residue incorporation. * and ** indicate the statistical significance at 1% and 5% respectively

Furthermore, increased perception level on advantages of the SATs predicated an increase in area of arable allocated to the technologies by 0.7 acre (Table 12). The findings supported the conclusions drawn in the previous studies that the higher the level at which new innovations are perceived as more advantageous than the preceding practices, the higher the likelihood of their adoption [14, 34]. Hence, extension methods and messages on sustainable farming should facilitate acquisition of knowledge among the farmers on both advantages and disadvantages of each of the seven SATs. This, in turn, could ensure objective evaluations and informed decision making among the farming households.

Table-11. Ordered probit model results for the technological factors

Factors	Coefficients		Average marginal effects					
			Prob(Y≤2|X)		Prob(3≤Y≤4|X)		Prob(Y≥5|X)	
	Coef	RSE	Coef	RSE	Coef	RSE	Coef	RSE
R. advantage	1.125**	.197	-.448**	.078	.226**	.057	.222*	.054
Complexity	-.542**	.193	.216**	.077	-.109**	.045	-.107*	.041
Compatibility	.049	.217	-.020	.086	.010	.044	.010	.042
Sample size =132		Wald $\chi2$ (3) = 81.77		Prob. > $\chi2$ = .000				
Log pseudolikelihood = -98.888		Pseudo R^2 = 0.296						

Note: RSEs are Robust Standard Errors. Prob(Y≤2|X), Prob(3≤Y≤4|X), Prob(Y≥5|X) show the probabilities for low adoption (1 and 2 SATs), average adoption (3 and 4 SATs) and high adoption (5, 6 and 7 SATs) categories. * and ** indicate the statistical significance at 1% and 5% respectively

With respect to technological complexity, households were less likely to adopt manure, agroforestry and pit-planting with increased level of perception regarding the difficulties associated with understanding and utilizing the technologies (Table 10). The rating of the SATs as highly complex by the households was mainly based on the reasons of labour intensiveness, confusion caused by different messages on the implementation of the same technology (this applied to pit-planting promoted by different agencies) and limited mechanization options for the technologies.

Table-12. OLS probit model results for the technological factors

Explanatory factors	Coefficients	Standard errors	t-value	P>|t|
Relative advantage	.700**	.185	3.77	.000
Complexity	-.463**	.176	-2.63	.010
Compatibility	.165	.201	.82	.413
Sample size = 132		F(3, 128) = 27.01		Prob > F = .000
R^2 = .388	Adjusted R^2 = .373			

Note: ** indicates the statistical significance at 1% and 5% respectively

The findings also revealed that an upward change in the perception towards SATs complexity by one point on a three-point Likert scale (thus, low to moderate or moderate to high) increased the probability of a household to be a low adopter by 22%. However, a change of perception by the same margin and in the same direction reduced the likelihood of the household to be either an overage adopter or high adopter by 11% (Table 11). The results of OLS model analysis predicted a 0.5 acre reduction in the area of arable land for the SATs as a result of a change in the perception from either lowly complex to moderately complex, or moderately complex to highly complex (Table 12). These findings are in agreement with the Diffusion of Innovation Theory (DOI) which includes perceptions towards complexity of an innovation as a major determinant of adoption [14]. Therefore, the findings implied that the extension approaches, methods and messages for promoting SATs should aim at creating favourable perceptions regarding the ease of understanding and implementing the technologies in the farmers' own agro-ecosystems.

4. Conclusion and Recommendations

The study established that the adopters of SATs had more extension contacts on sustainable farming than the non-adopters. The two categories of maize farming households also differed on membership in FOs; in the sense that there were more FOs members among the adopters than there were among non-adopters. The findings of the study also revealed that adoption of the SATs was positively influenced by the membership in FOs, access to extension services and the perceptions towards the relative advantages of the technologies. In contrast, increased level of perceptions towards the complexity of the SATs had a negative influence on the adoption of the technologies.

Therefore, it is recommend that the Government of Malawi and relevant NGOs should train and recruit more extension field staff to improve coverage and frequency of extension services delivery on sustainable agriculture. This strategy should be complemented by the promotion of the small-scale farmers' affiliation to FOs to improve access to agricultural extension services and production resources on sustainable farming. Additionally, efforts should be made by the relevant stakeholders in Malawi to develop and promote affordable mechanization options for reducing farm drudgery associated with the implementation of SATs. With regard to pit-planting, all the relevant agencies in the agriculture sector should also promote effective standardization and harmonization of extension services on the technology to prevent the dissemination of conflicting extension messages to the farmers. Furthermore, the Government of Malawi should facilitate the formulation, enactment, and enforcement of local by-laws for safeguarding the SATs and their related inputs (or raw materials) against vandalism, livestock damage, and bushfires.

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