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Are farmer perceptions among significant determinants of adoption of agricultural diversity in Malawi? A case of Lilongwe district

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Abstract

Agricultural diversity can strengthen resilience of livelihood of farmers to climate change and market uncertainties while, potentially at the same time, offering better dietary and nutritional prospects for households. Adoption of agricultural diversity in Malawi is low. Policy-makers, researchers, non-governmental organisations (NGOs), and extension staff need to understand dynamics of adoption of agricultural diversity in order to develop appropriate policies and interventions to promote agricultural diversification. This study was conducted in Lilongwe District of Malawi to identify factors influencing adoption of agricultural diversity and particularly to test if farmer perceptions were among significant determinants of adoption of agricultural diversity. A survey of 424 randomly sampled households was conducted in 2016 and 2017. A Tobit model, having 16 possible determinants, was run against a holistic agricultural diversity index that combined number of crop, livestock, and fruit tree species and cropping patterns. The study found that farmer perceptions were among significant determinants of adoption of agricultural diversity. Some farmers perceived that they faced problems to find seeds of preferred varieties, droughts posed problems to farming; some crops produced good yields while other crops did not. Farmers with such perceptions were less likely to practice agricultural diversification. In addition to perceptions, engagement in off-farm sources of income also negatively affected agricultural diversity. Other factors, namely farmers' access to land and credit, irrigation farming, selling of crops, ownership of radios, and farmer group membership fostered adoption of agricultural diversity.

Keywords: Crop production, extension, innovation diffusion, livestock production

1 Introduction

Agricultural diversity entails growing of various crops and rearing various livestock species by a farmer (Tisdell *et al.*, 2019). Agricultural diversity usually promotes human nutrition, raises household incomes, and enables farmers to adapt to challenges posed, for instance, by climate change (Kankwamba *et al.*, 2018). In Malawi, agriculture faces frequent droughts, floods, coupled with erratic rainfall and pests and diseases (Phiri *et al.*, 2012). Agricultural diversity averts many of such challenges where poor performance of some crop or livestock species can be compensated by availability of other species thereby achieving food and economic security (FAO, 2008).

Crop diversity is low in Malawi since maize (*Zea mays*) dominates smallholder agricultural production, thereby exposing farmers and the economy to commodity-specific risks (Government of Malawi, 2016a). For example, results of the 2010/11 Integrated Household Survey (IHS) showed that crop diversity was at 39 % in Malawi (Simpson Diversity Index; SDI=0.39) and thus, 7 % lower compared to the 2004/05 assessment (Jones *et al.*, 2014; Kankwamba *et al.* 2018). This is low compared to an SDI value of 0.54 in northern Ghana (Bellon *et al.*, 2020) and SDI values of 0.5 in two regions of Tanzania (Rajendran *et al.*, 2017). With evidently low and declining agricultural diversity, it becomes necessary to understand determinants of its adoption in order to tailor actions for increasing agricultural diversification.

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Understanding the scope of determinants of adoption of agricultural diversity requires a synopsis of the adoption theory. According to Masangano (2003), three groups of paradigms explain why people decide whether to adopt innovations, namely an economic constraints model, an innovation diffusion model, and an adopter perception model.

The economic constraints model explains that status of inputs, such as access to credit, land, and labour, affects decisions to adopt innovations (Smale *et al.*, 1994; Masangano, 2003). Consistent with the economic constraints model, considerable empirical adoption literature centred on land holding size as the most important determinant of innovation adoption (Daku, 2002; Uaiene *et al.*, 2009). The assumption of the innovation-diffusion model is that while an innovation may be technically and culturally appropriate, its adoption may be affected by access to information (Feder & Slade, 1984). In line with the innovation-diffusion model, Feder *et al.* (1985, cited by Dimara & Skurus, 2003), defined adoption as "*the degree of use of an innovation in the long-run when the farmer has full information about the innovation and its potential*". The adopters' perception paradigm, on the other hand, posits that perceived attributes of the innovation are important. Even with full information, farmers may subjectively evaluate an innovation (Uaiene *et al.*, 2009). Adopters' perception paradigm also focuses on whether farmers perceive that there is a problem which can be solved by using the innovation (Doss, 2006). Perceived use and ease of use of the innovation is also considered as an important factor in adoption under this paradigm (Kakhobwe *et al.*, 2016).

Combining the three paradigms in modelling determinants of adoption improves the model's explanatory power compared to using only one or two of them (Adesina & Zinnah, 1993; Gemeda *et al.*, 2001). Combinations of the different aspects and constructs of adoption models are particularly important when studying multifaceted innovations (Hubert *et al.*, 2019) such as agricultural diversity.

Several researchers, e.g. Kankwamba *et al.* (2018) and Sichoongwe *et al.* (2014), have studied determinants of crop, livestock, or crop/livestock species diversity. The studies suggest analytical models and provide possible factors that can be included in assessing determinants of agricultural diversity.

On crop diversity, Kankwamba *et al.* (2018) using a Tobit model, found in Malawi that households headed by females, having more human resources for labour and access to extension services, had a higher diversity. In Zambia, Sichoongwe *et al.* (2014) also using a Tobit model, indicated that diversifiers were located further away from the nearest market, and had larger landholdings. Mofya-Mukuka & Hichaambwa (2016) using bivariate analysis, found that access to extension services such as on minimum tillage, crop rotations, and mixed cropping, had a significant positive effect on adoption of crop diversity in Zambia. In Ethiopia, Rehima *et al.* (2013) using a Heckman two-stage model, found that parameters affecting crop diversification were gender, education, and membership in cooperatives.

On livestock diversity, Dossa *et al.* (2008) using a logistic regression model, found in a study carried out in Benin that women were more likely to keep small ruminants. Owners of small ruminants were less likely to be involved in off-farm activities. Further, perception of risk associated with species was a major factor affecting people's choice of species. In Ethiopia, Mekuria & Mekonnen (2018) using a Tobit model, found that extension contact and irrigation positively influenced the extent of crop-livestock diversity. In Brazil, Gil *et al.* (2016) using a logistic regression model, showed that farmers with higher capital availability and access to information were more likely to adopt crop-livestock diversity. To analyse adoption, Fufa & Hassan (2006) suggest that the Tobit analytical model is more appropriate unlike Logit and Probit models which only analyse factors affecting whether the innovation is adopted. The problem with Ordinary Least Square (OLS) and generalised linear models is high levels of heteroscedasticity (Klein *et al.*, 2016). The Double-hurdle is criticised on the ground that it overlooks the aspect of selectivity bias (Greene, 2012). The Tobit model, however, is a Maximum Likelihood Method and not an OLS according to Gujarati (2004). Nevertheless, Nakhumwa (2004) stated that the weakness of using a Tobit model in simulating a two-step process of decision making by farmers is that it assumes that variables affecting the decision to adopt are the same as variables that affect the level of adoption.

Most studies of determinants of adoption of agricultural diversity did not include adopter perceptions. Yet, according to Chi & Yamada (2002), adopter perceptions are crucial in the decision-making process. Farmers make decisions based on perceptions which are their interpretation of information and their personal situation. Most studies identify determinants of crop and livestock diversity separately, hence their results are not reflective of determinants of adoption of complete agricultural diversity. Therefore, this study included economic constraints, innovation-diffusion and adopters perception model factors as possible determinants of agricultural diversity. The study also employed a comprehensive agricultural diversity index which combined the diversity of crops, livestock, and fruit trees, practices of agricultural diversity-enriching cropping patterns, and backyard gardening into one index. The study was conducted to identify determinants of adoption of agricultural diversity in order to provide information that can guide policy makers, agricultural scientists, extension workers, and non-governmental organisations to accelerate the adoption of agricultural diversity in Malawi and other countries of sub-Sahara Africa with similar conditions. The study aims to answer the following research question: what are the major factors influencing adoption of agricultural diversity among smallholder farmers? It hypothesizes that farmers' perceptions are significant determinants of adoption of agricultural diversity just like the economic constraints and innovation diffusion factors.

2 Materials and methods

2.1 Study design and setting

Repeated cross-sectional field surveys were conducted in 2016 (baseline) and 2017 (end-line) in Malingunde, Chitsime, Mpenu and Chiwamba Extension Planning Areas (EPAs) in Lilongwe district, under Lilongwe Agricultural Development Division (ADD). The district has a semi-arid to sub-humid climate (Anseeuw *et al.*, 2016) and a high population density, at 282 inhabitants km^{-2} higher than the national population density of 186 inhabitants km-2(National Statistical Office, 2019). Figure 1 shows the four EPAs of Lilongwe district in Malawi. The district was chosen purposively, since it is an area where agricultural diversity is minimal, dominated by maize production (Government of Malawi, 2016b).

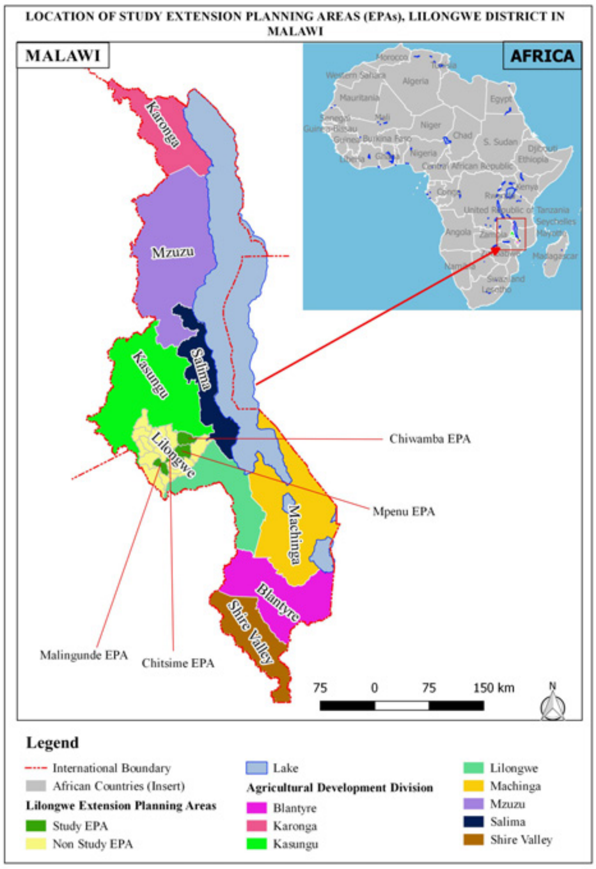

Fig. 1: *Maps of Africa and Malawi showing study sites. Source: Government of Malawi*

2.2 Sampling

Proportional probability sampling was conducted to select three sections per EPA and three villages per section. A list of all households in the sampled 36 villages was obtained from the Lilongwe District Agriculture Office. Simple random sampling was used to sample 424 households at baseline. From the baseline sample, 381 also participated in the end-line survey.

2.3 Instrumentation and data collection

A pre-tested, semi structured questionnaire translated into Chichewa language was used to collect categorical and continuous data on possible determinants of agricultural diversity such as age, level of education attainment, household size, occupation, access to farming land; credit and extension services, group membership, crop selling, time taken to access nearest market, and perceptions on agricultural diversity and farming problems. Farmers were asked to state whether they agreed to statements which represent widely held opinions of farmers on agricultural diversity in order to gauge their perceptions.

Moreover, data used to measure the level of agricultural diversity were collected. This included the number of farmers conducting agricultural practices such as crop rotation, intercropping, backyard gardening, and number of field crop, fruit tree and livestock species grown and kept, respectively. Choice of the type of data collected was informed by the results of agricultural diversity studies in line with the adoption models cited in the introduction section of this paper.

2.4 Analytical methods

Categorical data were analysed using frequencies and percentages as well as cross tabulation of baseline and end-line results. Statistical significance of the differences between baseline and end-line categorical data was analysed using McNemar Chi-square test. For continuous data, means and standard deviations were generated. Two tailed t-tests were conducted to test significant differences between baseline and end-line means. IBM SPSS Statistics for Windows version 22.0 and Stata version 13 were used to conduct the analysis. In this study, a Tobit Model was used to determine the factors influencing the adoption of agricultural diversity. The Tobit model and estimators have variations of the structure below. It expresses the observed level of y in terms of an underlying latent variable y^*as below:

$$y^* = \beta_0 + \beta_i x_i + \mu \qquad \sim(N[0, \sigma^2]) \tag{1}$$

y_i^* is observed if $y_i^* > 0$ and is not observed if $y_i^* < 0$. Thus the observed y_i is defined as:

$$\begin{cases} y_i^* = \beta x_i + \mu_i & \text{if } y_i^* > 0;\ \textit{diversified agriculture adopters} \\ 0 & \text{if } y_i^* = 0;\ \textit{non diversifiers} \end{cases} \tag{2}$$

$$\mu \sim \ln(0, \sigma^2) \tag{3}$$

Since this model cannot be estimated using the OLS method, it uses the maximum likelihood function which is presented below.

$$\log L = \sum\nolimits_{y>0} -\frac{1}{2}\left[\log(2\pi) + \log\sigma^2 + \frac{(Y_i - \beta x_i)^2}{\sigma^2}\right] + \sum\nolimits_{y_i-0} \log\left[1 - F\left(\frac{\beta x_i}{\sigma}\right)\right] \tag{4}$$

$$\begin{cases} y_i = \beta x_i + \mu_i & \textit{diversified agriculture} \\ 0 & \textit{universified agriculture} \end{cases} \tag{5}$$

The dependent variable, y_i, was the Holistic Agricultural Diversity Index for each farm. The independent variables for the Tobit model were:

Continuous variables: x_1 = land access, acres; x_2 = labour availability (number of household members in age of 16 to 49); x_3 = age of caregiver, number of years. Dummy variables 0 for no 1 for yes: x_4 = credit access; x_5 = irrigation; x_6 = attendance of school by caregiver; x_7 = selling of crop produce; x_8 = use of off-farm income sources; x_9 = farmer group membership; x_{10} = extension access; x_{11} = radio possession.

Categorical variable: x_{12} =gender of household head 0 for female 1 for male.
Perception of diversity: x_{13} = yields are bad for some crops good for others, strongly agree=1, agree=2, neither agree nor disagree=3, disagree=4, strongly disagree=5.
Perception of farming problems variables: no problem=1, medium=2, serious=3, very serious=4; x_{14} = access to preferred varieties or seed; x_{15} = erratic rain; x_{16} = drought; ε = Error term
Since the 16 dependent variables were both discrete and continuous, the pseudo-R^2 could give answers > 1 or < 0 in the Tobit model. According to Sribney (2020), the pseudo R^2 is calculated as:

$$pseudo\,R^2 = 1 - L_1/L_0 \tag{6}$$

where $L0$ and $L1$ are the constant-only and full model log-likelihoods, respectively. For discrete distributions, the log likelihood is the log of a probability, so it is always negative (or zero). This is explained as:

$$0 \geq L_1 \geq L_0 \tag{7}$$

$$0 \leq L_1/L_0 \leq 1 \tag{8}$$

$$\text{hence } 0 \leq pseudo\,R^2 \leq 1 \text{ for discrete distributions} \tag{9}$$

For continuous distributions, the log likelihood is the log of a density. Since density functions can be greater than one, the log likelihood can be positive or negative (Sribney, 2020). Hence, whether the pseudo R^2 is positive or negative does not reflect the direction the relationship between the dependent or independent variables, but rather the presence of discrete distributions and the log of density of continuous distributions.

Construction of an index to measure agricultural diversity was done following a concept which is used to construct a wealth index for the Demographic and Health Surveys as reported by Rutstein (2008). It assigns weights to different assets owned by households, using a Principal Component Analysis (PCA), to compute the index. Such an approach helps to deal with the limitation of existing diversity indices which fail to combine data on species which fall under different kingdoms of organisms such as plants and animals. An aggregated index, which combines information on crops, trees, livestock, and diversity related cropping patterns unlike the conventional indices for diversity is thus proposed. The choice of components of the index was informed by the general definition of agricultural diversity which entails diversity of different species of crops and categories of livestock as suggested by Tisdell *et al.* (2019). Crop rotation and intercropping were included because these practices promote crop diversification, according to Bybee-Finley & Ryan (2018).

We used PCA to obtain component loadings of the index. The component loadings were used as weights for factors that were used to calculate the holistic agricultural diversity index for each farmer. The process was conducted as follows:

a) Running PCA of status of practice of diversity cropping patterns (crop rotation and intercropping), backyard gardens, number of fruit tree species, number of field crop species for rainy season and dry season, and number of livestock species.

b) Multiplying the PCA loadings by the numbers of crops, livestock and fruit tree species, and multiplying by one in a case where a farmer practices crop rotation, intercropping, or backyard gardening and zero for no practice. The sum of the multiplied loadings and diversity factors was the raw index for each farmer.

c) Normalizing the raw index into a range of zero to one by using the following formula (Source: Ginevičius, 2008):

$$Z_i = \frac{x_i - \min(x)}{\max(x) - \min(x)} \quad (10)$$

where Z_i is normalized index score for farmer i , x_i is raw index for farmer i, $\min(x)$ is the raw index for the lowest scoring farmer and $\max(x)$ is the raw index for the highest scoring farmer.

2.5 *Ethical consideration*

Ethical approval was obtained from the Institution Review Board of the University of Giessen in Germany (approval number 56/18) and the National Health Sciences Research Committee in Malawi (approval number 1686). This was prior to the start of the overall study titled "Crops for Healthy Diets: Linking Agriculture and Nutrition (HealthyLAND)".

3 Results

3.1 *Description of the households*

Table 1 presents household characteristics reported during the baseline study of 2016. The studied sample appeared less educated, with crop farming and off-farm activities supporting the households.

3.2 *Access to agricultural services*

Results on access to agricultural services are presented in Table 2. Farmers' access to land was low and dropped from baseline to end-line (means: 1.4 acres at baseline versus 1.07 acres at end-line). The time taken to access the nearest market was approximately one hour. Access to extension services was significantly higher at end-line than at baseline.

Table 1: *Household characteristics at baseline in 2016.*

Aspect	*n*	*Mean (± SD)*
Age of caregiver (years)	405	29.59 (8.41)
Household size (number of people)	423	5.19 (1.77)
		Percentage (n=424)
Gender of household head		
Male		76.7
Female		23.3
Education		
Did not attend school		12.3
Did not complete primary		70.5
Completed primary		6.8
Did not complete secondary		9.4
Completed secondary		0.9
Main occupation of household head		
Farming - crops		53.8
Business		17.7
Casual labour		13.0
Wage employment		8.5
Trades/vocational skills		5.4
Mixed farming - crops and livestock		0.7
Engagement in off farm income generating activities		51.2
Possession of radio by household		33.9

3.3 *Farmers' perception on agricultural diversity*

Table 3 shows farmers' perceptions on agricultural diversity based on a Likert scale. There were variations in perceptions among farmers on various statements that reflected perceptions on agricultural diversity. The overall situation of the perceptions is presented in the mean scores of perceptions.

3.4 *Farmers' perception on farming challenges*

Table 4 indicates farmers' perceptions on problems faced in farming activities. The mean scores show the trend of perceptions at baseline and end-line.

3.5 *Factors determining agricultural diversity*

Levels of the components of holistic agricultural diversity index measured at the baseline are presented in Figures 2 and 3. Numbers of crop, livestock and tree species, and share of farmers practicing crop rotation, intercropping, and backyard gardening were low.

The weights given to the different components of the agricultural diversity index are presented in Table 5. After standardizing the index, the overall mean holistic agricultural diversity index for the farmers was 0.2822, in a scale ranging

Table 2: *Access to agricultural services at baseline (2016) and end-line (2017).*

Aspect	*Baseline n=424 Mean (Std Dev)*	*End-line n=381 Mean (Std Dev)*	*t (p-value)*
Land accessed, acres	1.68 (1.37)	1.31 (1.07)	6.102 (0.000***)
Number of plots owned by farmers	2.20 (1.44)	3.07 (1.18)	-4.190 (0.000***)
Time in minutes farmers take to access the market	66.3 (33.4)	63.1 (33.1)	1.032 (0.303)
	%	*%*	*$X^{2\dagger}$ (p-value)*
Farmers who accessed credit	28.1	32.3	2.103 (0.176)
Farmers who practiced irrigation	18.4	21.8	0.842 (0.422)
Farmers who belonged to farmer groups	12.3	18.1	3.368 (0.085)
Farmers who accessed extension services	31.3	72.4	119.093 (0.000***)
Farmers who sold crop produce	65.8	60.3	6.728 (0.012*)

* = significant difference at $p \leq 0.05$, ** = $p \leq 0.01$ and *** = $p \leq 0.001$; † McNemar Chi Square

Table 3: *Farmer perceptions on agricultural diversity at baseline (2016) and end-line (2017).*

Perception	*Baseline (B) or End-line (E)*	*SA (%) Score=1*	*A (%) Score=2*	*NDA (%) Score=3*	*DA (%) Score=4*	*SDA (%) Score=5*	*Mean score† (Std Dev)*	*t (p-value)*
Many crops can provide food for the whole year	B (n=418)	54	42	2	2	1	1.53 (0.68)	0.217 (0.828)
	E (n =377)	53	52	12	1	1	1.54 (0.66)	
Bigger farms can plant more kinds of crops	B (n =420)	43	44	3	7	3	1.83 (0.98)	0.646 (0.519)
	E (n =378)	42	43	3	8	1	1.81 (0.92)	
More crops attract pests and diseases	B (n =377)	26	43	9	17	5	2.32 (1.18)	-0.648 (0.517)
	E (n =352)	26	36	11	25	2	2.41 (1.19)	
More crops need fewer chemicals and fertilizers	B (n =392)	21	35	12	25	8	2.64 (1.27)	0320 (0.182)
	E (n =352)	19	40	13	22	6	2.57 (1.21)	
Higher number of crops bad for soils	B (n =400)	13	38	10	30	10	2.86 (1.26)	-0.271 (0.786)
	E (n =363)	17	28	14	37	4	2.82 (1.21)	
Yields are good for some crops and bad for others	B (n =411)	26	52	12	10	1	2.07 (0.92)	2.529 (0.012*)
	E (n =369)	30	55	(7	7	1	1.93 (0.84)	

SA=strongly agree; A=agree; NDA=neither agree nor disagree; DA=disagree; SDA=strongly disagree
* = significant difference at $p \leq 0.05$; † Mean score 1-5 Likert scale

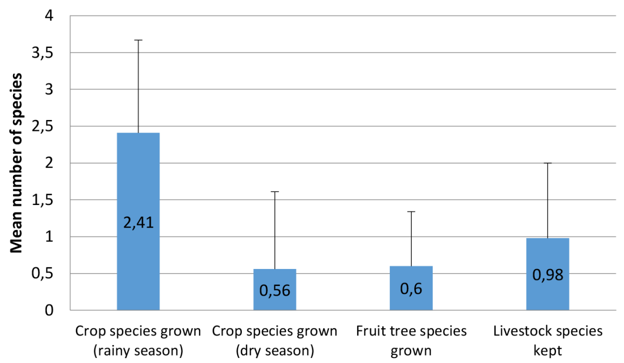

Fig. 2: *Mean number of species of crops, fruits and livestock in farms in Lilongwe district, Malawi (with SD).*
Note: Data were collected during the baseline study in Lilongwe district, 2016.

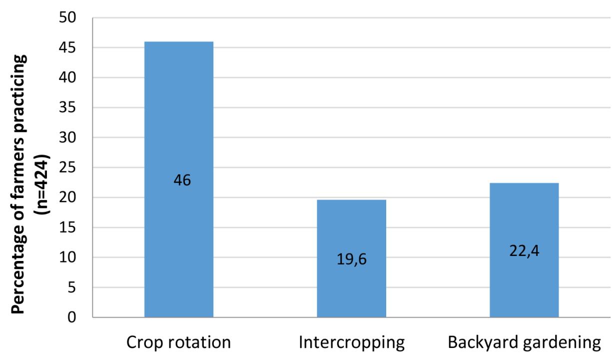

Fig. 3: *Share of farmers practicing crop rotation, intercropping, and backyard gardening*
Note: Data were collected during the baseline study in Lilongwe district, 2016.

from 0 to 1. This implies that agricultural diversity was low, being 28.2 %.

Results in Table 6 identify significant determinants of adoption of agricultural diversity. Out of the 16 possible de-

Table 4: *Farmer perceptions on farming problems at baseline (2016) and end-line (2017).*

Perception of problem	*Baseline (B) or End-line (E)*	*NP (%) Score=1*	*Medium (%) Score=2*	*Serious (%) Score=3*	*VS (%) Score=4*	*Mean score† (Std Dev)*	*t (p-value)*
Ecological factors							
Weeds‡	B (n=420)	16	11	48	25	2.82 (0.98)	
Crop pests and diseases	B (n=424)	28	14	43	16	2.46 (1.06)	-5.199 (0.000***)
	E (n=381)	16	7	50	28	2.91 (0.98)	
Livestock pests and diseases	B (n=412)	40	13	30	18	2.25 (1.16)	-4.847 (0.000***)
	E (n=381)	21	12	45	22	2.69 (1.03)	
Wildlife raiding	B (n=424)	51	12	30	8	1.94 (1.05)	0.302 (0.763)
	E (n=381)	56	6	29	10	1.92 (1.11)	
Low soil fertility	B (n=424)	26	18	38	18	2.48 (1.07)	-3.741 (0.000***)
	E (n=381)	17	14	46	23	2.75 (0.10)	
Soil erosion	B (n=424)	28	16	36	21	2.49 (1.11)	0.973 (0.331)
	E (n=381)	31	13	41	15	2.34 (1.08)	
Natural disaster factors							
Erratic rainfall	B (n=424)	4	6	43	47	3.33 (0.76)	11.711 (0.0000***)
	E (n=381)	22	25	33	21	2.51 (1.05)	
Flooding	B (n=424)	66	9	17	9	1.68 (1.03)	3.660 (0.000***)
	E (n=381)	76	7	12	5	1.47 (0.90)	
Drought	B (n=424)	20	15	34	32	2.77 (1.11)	12.388 (0.000***)
	E (n=381)	51	22	20	7	1.83 (0.98)	
Strong winds	B (n=424)	25	24	37	15	2.42 (1.02)	5.470 (0.000***)
	E (n=381)	44	1	26	11	2.04 (1.07)	
Social factors							
Free roaming livestock	B (n=423)	42	10	38	10	2.16 (1.09)	0.545 (0.586)
	E (n=381)	45	9	34	1	2.15 (1.13)	
Theft	B (n=424)	41	9	29	21	2.30 (1.20)	0.938 (0.349)
	E (n=381)	43	8	28	21	2.28 (1.21)	
Labour shortage	B (n=424)	59	12	24	5	1.73 (0.97)	1.459 (0.145)
	E (n=381)	67	11	16	7	1.63 (0.98)	
Land conflict	B (n=423)	66	3	17	14	1.80 (1.17)	0.539 (0.590)
	E (n=381)	67	3	17	13	1.76 1(.14)	
Market factors							
Lack of seeds	B (n=424)	14	11	45	30	2.92 (0.98)	-1.562 (0.119)
	E (n=381)	11	9	43	36	3.05 (0.95)	
Counterfeit inputs	B (n=423)	44	8	31	17	2.22 (1.18)	2.931 (0.004**)
	E (n=381)	5	10	32	8	1.98 (1.07)	

NP=no problem; VS=very serious; * = significant difference at $p \leq 0.05$, ** = $p \leq 0.01$ and *** = $p \leq 0.001$;
† Mean score 1-5 Likert scale; ‡ End-line data on perception of the problem 'weed' is not included due to an error in programming of the data collection tools which omitted the question.

Table 5: *Results of the Principal Component Analysis for calculating weights of components for the agricultural diversity index based on the baseline study in the Lilongwe district in 2016.*

Component	*ADIW†*
Crop rotation	0.680
Intercropping	0.044
No. of fruit tree species	0.528
No. of field crop species (rainy season)	0.650
No. of field crop species (dry season)	0.479
No. of livestock species	0.639
Backyard gardening	0.474

†Agricultural Diversity Index Weight (Based on PCA Component Loading)

terminants, ten factors were significant. The positive determinants were land access, credit access, irrigation, selling of crop produce, farmer group membership, and ownership of radio. The negative determinants were use of off-farm income sources, perception that yields are bad for some crops good for others, perception that access to preferred varieties or seeds is a problem, and perception that drought is a problem.

4 Discussion

The study envisaged to identify the major factors influencing adoption of agricultural diversity among smallholder

Table 6: *Tobit regression model for determinants of adoption of agricultural diversity*

Variable	*Variable description*	*β*	*Robust Std Error*	*t*	*p>|t|*	*95% interval*	*Conf.*
LANDACR_B	Amount of land accessed	0.0233	0.0063	3.70	0.000***	0.0109	0.0357
HHMEM49_B	Labour availability (No. of household members in age of 16 to 49)	0.0117	0.0117	1.01	0.315	-0.0112	0.0347
CREDACC_B	Access to credit	0.0421	0.0200	2.11	0.036*	0.0028	0.0815
WATIRR_B	Irrigation	0.1363	0.0219	6.22	0.000***	0.0932	0.1794
AGEMOTHYRS_B	Age of caregiver	0.0003	0.0010	0.27	0.789	-0.0016	0.0021
EDUCMO_B	Attendance of school by caregiver	0.0258	0.0280	0.92	0.358	-0.0293	0.0809
HEADHH2_B	Gender of household head	-0.0185	0.0243	-0.76	0.447	-0.0662	0.0293
DIDSELL_B	Selling of crop produce	0.1361	0.0189	7.20	0.000***	0.0989	0.1732
OFFARMINC_B	Use of off-farm income sources	-0.0429	0.0169	-2.53	0.012*	-0.0762	-0.0096
SOCAPMEMM_B	Farmer group membership	0.0651	0.0290	2.24	0.025*	0.0080	0.1222
ACCEXT_B	Access to extension	0.0115	0.0194	0.60	0.552	-0.0265	0.0496
POSRAD_B	Possession of radio	0.0592	0.0185	3.20	0.001***	0.0228	0.0956
CROYIELD2_B	Perception that yields are bad for some crops good for others	-0.0192	0.0097	-1.98	0.048*	-0.0383	-0.0002
PROBVAR_B	Perception that access to preferred varieties or seed is a problem	-0.0236	0.0089	-2.65	0.009**	-0.0411	-0.0061
PROBRAIN_B	Perception that erratic rain is a problem	0.0183	0.0129	1.41	0.158	-0.0071	0.0437
PROBDRAU_B	Perception that drought is a problem	-0.0171	0.0083	-2.07	0.040*	-0.0334	-0.0008
_cons	Constant	0.1584	0.0668	2.37	0.018*	0.0271	0.2897
/sigma		0.1591	0.0064			0.1465	0.1717
	Other Statistics						
	F (16, 368)	15.27					
	Prob > F	0.000					
	Log pseudolikelihood	121.0					
	Pseudo R^2	-3.9785					

* = significant difference at $p \leq 0.05$, ** = $p \leq 0.01$ and *** = $p \leq 0.001$.

farmers, with particular interest in, but not limited to, farmers' perceptions. Farmers' perceptions on agricultural diversity and on problems hindering farming varied. With regard to farmers' perceptions on agricultural diversity, farmers agreed that a farm with diverse crops can provide food for the whole year. The farmers' admission entails that they perceived agricultural diversity to be important in achieving food security. On average, farmers also agreed that farm-size is important to plant many kinds of crops. Therefore, a smaller farm size is a hindrance to agricultural diversification. Moreover, farmers had mixed perceptions that farms with many crops attract more pests and diseases. This is likely because farmers had contrasting experiences when intercropping several crop species. Farmers need to understand the proper crop species combinations which can be intercropped to avoid infestation of pests and diseases in crop stands. In the absence of that understanding, practice of inappropriate intercropping would be expected to foster pest and disease incidence and therefore farmers would prefer not to intercrop. This explains why only 19.6 % of the farmers practiced intercropping. According to Kalemen *et al.*, (2013), conventional farmers tend to have stronger perceptions on economic value of species diversity than philosophical and more technical importance of species diversity. This explains why in this study, there was general consensus in perceiving agricultural diversity as a determinant for food security but mixed perceptions on role of diversity to manage pests and diseases.

The results on farmers' perception on problems hindering farming showed that perceptions on seriousness of natural disaster-related problems as impediments for farming, e.g.

erratic rainfall, drought, floods and strong winds, varied depending on season. Farmers perceived that the intensity of ecological problems such as weeds, pests and diseases for crops and livestock, wildlife raiding crops, soil infertility and soil erosion in farming increased overtime in the area. Perception on social factors such as free roaming livestock, theft, labour shortage and land conflicts were perceived to be medium. Among market factors, failure to obtain preferred crop varieties or lack of seeds, was perceived as serious, hence a potential deterrent for agricultural diversity. According to Huet *et al.*, (2020), a study in Mali showed that in general, farmers tend to have high concern over risks associated with plant health, animal health and climate variability, while low resource-endowed farmers reported more exposure to a variety of risks than high resource-endowed farmers. Results from the smallholder farmers in this study agree with the findings in Mali.

Using a Tobit analytical model, five significant economic constraints model determinants of adoption of agricultural diversity were identified, namely amount of land accessed, access to credit, irrigation farming, selling of crops, and use of off-farm income sources. The positive correlation between land access and agricultural diversity was congruent to the findings by Torres *et al.* (2018), Weiss & Briglauer (2000), and Benin *et al.* (2004), where larger farms were more diverse in terms of number of crops but contrary to the findings by Dube *et al.* (2016). On the other hand, Kankwamba *et al.* (2018), found that landholding size positively influenced crop diversity up to 1.5 hectares after which it had a negative influence. In general, this study shows that availability of land allows farmers to grow adequate amounts of different crops, hence land access was an incentive for diversification of crop production. The positive effect of access to credit on agricultural diversity is similar to the findings by Mwololo *et al.* (2019). They found that farmers who practiced crop and livestock diversity had significantly higher access to credit than non-diversified farmers. Aneani *et al.* (2011), explained that farmers accessing credit have the capability to purchase necessary resources for cultivation of diversified crops.

Irrigation had a positive influence on agricultural diversity, congruent with findings by De Sousa *et al.* (2017). Irrigation may allow farmers to do horticulture and if near a town or city market, this may boost income generation. Irrigation is also important for production through-out the year, thereby achieving sustainable production and supply. Selling of crops was found to be an incentive and, therefore, fostered agricultural diversity. The negative correlation between engagement in off-farm income sources and agricultural diversity is similar to findings by Torres *et al.* (2018), reflecting that these kinds of households lack the labour force required to keep a diversified farm due to the fact that some of their members are engaged in off-farm income activities.

Farmer group membership and radio ownership were significant innovation diffusion model determinants of adoption of agricultural diversity. Farmers who belonged to farmer groups had more diversity than those who did not. According to Dube & Guveya (2016), group membership provides opportunity to learn from each other on how to produce and to market new agricultural commodities. As such, farmers who belong to groups are more likely to diversify and radio ownership facilitates access to information, some of which may be on agricultural diversification.

Perception is going beyond fact. The perception that yields are low for some crops and high for others and perception of problems such as access to preferred varieties or seeds, and drought, were significant negative adopter perception model determinants of agricultural diversity. As farmers are poor and have developed strategies, it is important to know how they perceive risks, options and strategies. For example, farmers' variety-attribute preferences are important factors that can influence and shape perceptions on agricultural diversity (Wale, 2011).

5 Conclusions and recommendations

This study endeavoured to test whether farmer perceptions were among significant determinants of adoption of agricultural diversity. The results affirm to the hypothesis. The study exposed gaps in previous studies on adoption, particularly on agricultural diversity. In adoption studies, demographic and socioeconomic characteristics such as household labour availability, age, education and gender are given much prominence. Considering that such common determinants of adoption were not significant in this study, it can be concluded that most adoption studies are limited in their focus. Further, it is worth noting that all significant perception factors were negative determinants of adoption of agricultural diversity. Thus, while the economic constraints and innovation diffusion model factors are generally positive determinants, there would still be unexplained reasons why adoption of agricultural diversity remains low. Those studying determinants of agricultural diversity should, therefore, include farmers' perception factors to make their studies more complete and accurate. Results of this study imply that policies and programs promoting adoption of agricultural diversity should embrace adopter's perception, economic constraints, as well as innovation diffusion model factors. Practitioners promoting agricultural diversity should understand and address farmers' negative perceptions as they negatively affect adoption. Formulation of agriculture policies on diversity should include an analysis of farmers' negative perceptions. To respond to findings related to economic constraints model, farmers with smaller amounts of land and those having off-farm income sources should be encouraged to diversify. There is need for policies and interventions to improve farmers' access to agricultural credit, irrigation, growing of marketable crops, and establishing novel value chains to improve adoption of agricultural diversity. In line with innovation diffusion model findings, farmers should be stimulated to be members of farmer groups and utilise radios to access information on diverse crop and livestock species.

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Conflict of interest

The authors declare that they have no conflict of interest.

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