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Effects of perceptions on adoption of climate-smart agriculture innovations: empirical evidence from the upper Blue Nile Highlands of Ethiopia

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Abstract

Purpose – This study aims to examine smallholder farmers' perceptions toward the adoption of climate-smart agriculture (CSA) in smallholder farmers in the Upper Blue Nile Highlands of Ethiopia. Available research focused on profitability and economic constraints alone, disregarding the farmers' perception of the adoption of CSA innovations. There is relatively little empirical work on farmers' perceptions of innovations. Hence, a critical research gap that will strengthen CSA innovation research and practice includes understanding farmers' perceptions about CSA innovations and how these perceptions interact with their adoption.

Design/methodology/approach – A cross-sectional household survey was conducted among 424 smallholder farmers selected from five agro-ecosystems. A structured questionnaire was used to collect primary data and a review of literature and documents was used to collect secondary data. The study used a multivariate probit model to examine perception factors affecting the likelihood of adopting multiple CSA innovations. The dependent variables were eight CSA innovations, while the independent variables were crafted from the three pillars of CSA.

Findings – Major CSA innovations adopted by farmers include improved variety, crop residue management, crop rotation, compost, row planting, soil and water conservation, intercropping and

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agroforestry. Farmers' perception toward CSA innovations includes: CSA innovations sustainably increase productivity and income; enhance soil fertility; diversify livestock feed and energy sources; reduce soil erosion, weed infestation and crop failure; enhance soil organic matter, reduce chemical fertilizer use and rehabilitate land. Farmers' positive perceptions of the benefits of CSA innovations for increasing crop productivity, reducing agricultural vulnerability to climate change and lowering farm greenhouse gas emissions have boosted adoption.

Practical implications – Farmers' perceptions toward CSA innovations must be enhanced to increase the adoption of CSA innovations in the smallholder agriculture system. The CSA innovation scale-up strategies should focus on farmers' perception of CSA innovation benefits toward food security, climate change adaption and mitigation outcomes. Awareness of CSA needs the close collaboration of public extension as well as local institutions such as farmers' training centers.

Originality/value – The study adopts a multivariate probit model that models farmers' simultaneous CSA innovation choices. Hence, this study contributes to the literature in four significant areas. First, it argues for differential treatment of the perception of smallholder farmers about innovations is needed. Second, it recognizes the interdependence of the adoption of innovations. Third, it directly assesses the farmers' perception, while others use proxies to measure it. Finally, there are limited or no studies that address the perception of innovations within the lens of adopter perception theory.

Keywords Climate-smart agriculture, Innovations, Blue Nile Highlands, Crop residue management, Crop rotation, Compost, Row planting, Soil and water conservation, Intercropping, Agroforestry, Adoption

Paper type Research paper

1. Introduction

Perception of climate change has been one of the important factors that enables or hinders the adoption of adaptation strategies among farmers in sub-Saharan Africa (Juana *et al.*, 2013). As consumers, farmers evaluate the innovations they receive and practice based on the benefits that the they provide to the farmers (Adesina and Jojo, 1995; Adesina and Moses, 1993; Workneh and Parikh, 1999). Some farmers may tend to adopt adaptation options to reduce the effect of climate change-induced risks such as droughts and floods, while others may prefer to adopt technologies that increase their productivity and income (Teklewold *et al.*, 2017). The innovations may provide these benefits one by one, or multiple benefits may be obtained from a single innovation (Teklewold *et al.*, 2019).

Climate-smart agriculture (CSA), as an approach to agricultural development, reorients agricultural production systems to ensure food security in the face of climate change by building climate resilience and adapting to climate change, and if possible, reducing or removing greenhouse gas (GHG) emissions (Bazzana *et al.*, 2021). CSA innovations are agricultural innovations that enable farmers to achieve at least two of the three pillars of CSA: food security, climate change adaptation and mitigation.

Despite these potential benefits and national and international initiatives that promote adoption of CSA innovations (Kpadonou *et al.*, 2017; Solomon and Manuela, 2015), adoption of CSA innovations has been challenging for the sub-Saharan African agriculture development policy agenda (Lipper *et al.*, 2014; Rao, 2011). Among others, lack of economic and technological capacities, weak institutional settings and lack of awareness of CSA innovations can be largely attributed to the low adoption rate (Abegunde *et al.*, 2019; Bazzana *et al.*, 2021). Thus, several studies have shown that high climate change awareness increases the adoption of climate change adaptation strategies (Babatolu and Akinnubi, 2016; Saguye, 2017; Asrat and Simane, 2018; Tran Van *et al.*, 2015).

Previous research focused on the perception of climate change as well as the impact and adaptation strategies of climate change on smallholder agriculture in Ethiopia (Desalegn and Filho, 2017; Esayas *et al.*, 2019; Kahsay *et al.*, 2019; Israel Rop and Adepoju Ib, 2017).

Nyang'au *et al.* (2021) investigated farmers' perceptions of climate variability and change and the adaptation measures adopted to enhance their resilience toward climate change. Tran *et al.* (2019) examined the determinants of farmers' adoption of CSA technologies and the effects of their adoption on net rice income (NRI) in three provinces. However, these studies lack the ability to address farmers' perceptions of CSA innovation benefits (Nyang'au *et al.*, 2021; Tran *et al.*, 2019). Only some studies have attempted to address the impact of farmers' perceptions and social interactions on CSA innovation adoption (Bazzana *et al.*, 2021; Teklewold *et al.*, 2019). However, this literature focuses on the social context, i.e. social interaction, neighborhood effects and social conformity of CSA innovation adoption rather than the adopters' perceptions of the CSA innovations, which is the research gap that this study aims to fill.

Existing literature on the adoption of agricultural technologies is grounded on three principal theories: economic constraints, diffusion-innovation and the adopter perception paradigm (Ngwira *et al.*, 2014a, 2014b; Prager and Posthumus, 2010).

The first theory, the economic constraint theory, argues that individuals strive for profit or utility maximization, but observed patterns of adoption are determined by the asymmetrical distribution of resource endowments among farmers. Although the economic constraints model recognizes the importance of profitability and economic constraints (access to capital, learning costs associated with innovation, or risk), it fails to conceptualize the social dimensions of knowledge, information, communication and rationality (Ngwira *et al.*, 2014a, 2014b). The diffusion-innovation theory, the second theory, addresses the knowledge, information and communication factors of an individual or societal difference. Thus, the "diffusion of innovations" theory describes how agricultural technologies are adopted over time through communication, information and knowledge. The "diffusion of innovations" theory has five characteristics that determine the rate of adoption of agricultural technologies: relative advantage, compatibility, complexity, trial-ability and observability. In addition, the theory says that the decision to adopt an agricultural technology is a mental process consisting of five stages: knowledge, persuasion, decision, implementation and confirmation. Rogers (2003) suggested that the innovativeness of an individual determines when the individual adopts technology and identified five successive adopter categories: innovators, early adopters, early majority, late majority and laggards. Hence, the diffusion-innovation concern is that access to information is the key to the adoption of agricultural technologies (Rogers, 2003).

The other theory, the adopter perception theory, argues that adoption perception about the perceived benefit of agricultural technology is the key to adoption (Adesina and Jojo, 1995; Adesina and Moses, 1993; Workneh and Parikh, 1999). Smallholder farmers, as consumers, generally have subjective preferences for characteristics of technologies and their demand for the technology is significantly affected by their perceptions of the technology's attributes (Adesina and Jojo, 1995). As far as CSA innovations are concerned, there is relatively little empirical work on the study of farmers' perceptions of CSA innovations (Precious *et al.*, 2018).

The critical research gap of the existing literature is that most researchers focused on the profitability and economic constraints (access to capital, learning costs associated with innovation, or risk) adoption of agricultural technologies, disregarding the farmers' perception of the adoption of CSA innovations. However, perception of the perceived benefit of CSA innovations is the key to adoption by small-scale farmers (Meijer *et al.*, 2015). Exploring perceptions of CSA innovations adoption is thus the first step in unravelling the CSA adoption puzzle, including determining whether there are potential gaps in available knowledge of CSA innovation among smallholder farming households (Fayso, 2018).

Therefore, the study contributes to the literature in four significant areas. First, it acknowledges the contribution and differential treatment of the perception of smallholder farmers toward adopting CSA innovations. Second, it also highlights the interdependence between different CSA innovations and jointly analyzes the decision to adopt the technologies. Third, it assesses directly the perception of CSA innovations rather than using proxies to measure it, unlike the previous studies. Therefore, the objective of this study is to analyze how farmers' perceptions of CSA innovations affect their decision to adopt CSA innovations in the upper Blue Nile Highlands of Ethiopia.

2. Research methodology

2.1 The description of the study area

The study was conducted in the Choke Mountain Watershed of the Blue Nile Highlands of Ethiopia. The lifeline of the watershed is the Choke Mountain, which is a biodiversity-rich hotspot area with unique flora and fauna and is referred to as the "water tower" of the upper Blue Nile Basin, where 60 rivers and 270 springs originate from; 29 of these rivers are responsible for a significant amount of water flowing into the upper Blue Nile (Simane *et al.*, 2013).

Geographically, the Choke Mountain Watershed is located approximately between 90 38' 00" and 10055' 24" North latitude and 370 07' 00" to 380 17' 00" East longitude. It lies in the altitude range of 2,100 to 4,113 m.a.s.l. The watershed has a total land surface area of approximately 15,950 km^2. The average annual rainfall in the watershed varies between 200 and 2,200 mm (Simane *et al.*, 2013). The average annual temperature ranges between 11.50 and 27.50°C, and the slope gradient of the watershed varies from flat to steep slopes. There are eight dominant soil types found in the watershed, i.e. Alisols andosols, Cambisols, Leptosols, Luvisols, Nitosols, Phaeozems and Vertisols. The climate of the watershed ranges from the hot, arid climate of the Abay (Blue Nile) Gorge to the cold, moist climate of the peak of the Choke Mountain Simane (2013).

The watershed is part of the north-western highlands that are known to be surplus producing regions and the water tower of the Blue Nile (Benjamin *et al.*, 2012). However, it is threatened by land and water resource degradation and an impending food shortage because of overexploited soils and overgrazing (Ermias *et al.*, 2013).

The Choke Mountain watershed is divided into six distinct agro-ecosystem zones (Simane *et al.*, 2013). The lowland and valley fragmented agroecosystem zone (AESZ1), the midland with black soil agroecosystem zone (AESZ2), the midland with brown soil agroecosystem zone (AESZ3), the midland sloping land agroecosystem zone (AESZ4) and the hilly and mountainous highlands agroecosystem zone (AESZ5) and the afro-alpine (AES6) (Figure 1).

2.2 Data type and sources

A quantitative cross-sectional survey in the East Gojjam zone's Dejen, Awobel, Basoliben, Machakel and Sinan districts was conducted to collect the household data. The districts have been selected to represent the agro-ecosystems. Data was gathered at the household level on perceptions of CSA innovations. Secondary data was collected from each district agricultural office through desk review.

2.3 Sampling design

The sample size determination was calculated based on finite population sample size calculation (Cochran, 1977). As there is no prior data on the current level of awareness of CSA innovations in the study area, the proportion of smallholder farmers who perceived

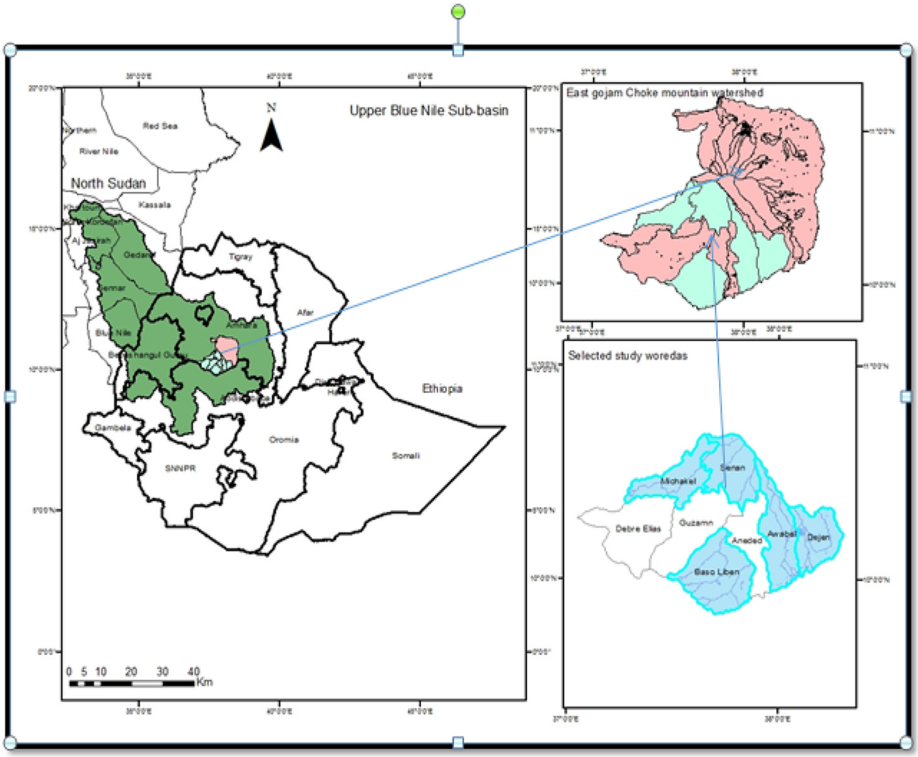

Figure 1.
Map of the study area

CSA innovations as important innovations were assumed to be half of the population in the study area. Using the formula:

$$
\begin{aligned}
n_1 &= \frac{Z^2_{1-\alpha/2}}{d^2} P(1-P) \\
&= \frac{(1.96)^2 (0.5)^2}{(0.05)^2} \\
&= 385
\end{aligned}
$$

where n_1 is sample size; $z_{\alpha/2} = 1.96$ for 95% confidence interval; P is the proportion of the population who said CSA innovations are important for climate change adaptation, P = 0.5; and d is the error margin, taking d = 0.05. The study also assumed a 10% non-response rate, which equates to 39 households. The sample size then becomes 424 smallholder households.

A multi-stage sampling technique was used to randomly select 424 households from the five districts. The selection of the districts was through purposive sampling taking into consideration the agroecosystem zone they represent. The sampling frame was a one-to-five mobilization register obtained from the kebele extension officers. Second, one kebele from each woreda were randomly selected. The selected kebeles are Gelegele from Dejen, Enebi from Awobel, Limichim from Basoliben, Debere klemu from Machakel and Yeted from Sinan. In the second stage, systematic random sampling technique was used to select households from each of the five kebeles using a sampling frame of a one-to-five community mobilization group register. Finally, 424 households were randomly drawn from the sample kebeles on the basis of probability proportional to size (PPS) sampling procedure (Table 1).

2.4 Methods of data collection

The household survey data was administered by well-trained and experienced enumerators using android tablets on a one-to-one interview basis. Through this instrument, information on the adoption of CSA innovations and farmers' perceptions of CSA innovation was collected from household heads. In collecting the data, each respondent was briefed about the purpose of the survey, information confidentiality and the average length of time that the interview would take and the actual interview was conducted following the respondent's willingness to participate in the interview. Secondary data was collected through desk review and review of empirical literature and documents.

2.5 Methods of data analysis

Data analysis was carried out using descriptive statistics and econometric models accompanied by SPSS and Stata statistical packages. Descriptive statistics tools such as mean, standard deviation and percentages were used to analyze and present perception of CSA innovations and its adoption. T-test, χ^2 test and mean comparison tests were run to compare adopter and non-adopter groups with respect to farmers' perception of CSA innovations.

2.5.1 Econometric model specification. The multivariate probit (MVP) model was used to analyze the perception factors affecting the decisions of farmers to adopt each of the CSA innovations. The dependent variable of the MVP model includes eight specific CSA innovations (improved variety, crop residue management, crop rotation, compost, intercropping, row planting, soil and water conservation and agroforestry) that assume a value of 1 if farmers apply specific CSA innovations, and 0 otherwise. The dependent variables were selected based on an extensive literature review on CSA innovations in sub-Saharan Africa in general and Ethiopia in particular. Although there is overlap in CSA pillar perceptions, the independent variables were crafted from the three pillars of CSA based on reviewed literature. Hence, the inclusion of independent variables in the model specification is also based on past empirical literature on the determinants of adoption of agricultural technologies (Alomia-Hinojosa *et al.*, 2018; Baudron *et al.*, 2015; Giller *et al.*, 2009; Kassie *et al.*, 2015; Kidane *et al.*, 2017; Kumar *et al.*, 2015; Miheretu, 2014; Teklewold *et al.*, 2017, 2019; Thierfelder *et al.*, 2012). The independent variables selected for this study include perceptions: CSA increases productivity, soil fertility, income, soil organic matter, diversifies livestock feed sources and diversifies alternative energy sources; CSA reduces the cost of

Table 1.
Sample woredas/districts and kebeles

District/woreda	Kebele	Population of HHs	Sample size	Agroecosystem zone (AESZ)
Dejen	Gelgele	7,475	77	AESZ1: lowland agroecosystem
Awabel	Enebi	5,416	55	AESZ2: midland with black soil
Basoliben	Limichim	10,147	104	AESZ3: midland with brown soil
Machakel	Debre Kelemu	6,207	63	AESZ4: midland with sloping land
Sinan	Yeted	9,533	125	AESZ5: the hilly and mountainous highland
Total		*38,779*	*424*	

production, the amount of synthetic fertilizer used, soil erosion, seeding rate, weed infestation and crop failure; and CSA rehabilitates land.

The essence of using MVP stems from the fact that, inherently, smallholder farmers consider adopting multiple CSA innovations for different agricultural and livelihood outcomes. Some of these technologies render the synergetic effect (complementary), while others trade off effects (substitutes). Hence, a failure to capture these complementarity and substitutable effects among CSA innovations will lead to bias and inefficient estimates (Greene, 2003).

The MVP econometric model is characterized by a set of binary dependent variables (Y_{ij}), such that:

$$Y_{ij}^{*} = \beta_i' X_{ij} + \varepsilon_{ij}, \tag{1}$$

and

$$Y_{ij} = \begin{cases} 1, \; if \; Y_{ij}^{*} > 0 \\ 0, \; otherwise \end{cases} \tag{2}$$

where i = 1, …, 8 denotes the CSA innovations such as 1 = improved variety, 2 = crop rotation 3 = crop residue management, 4 = compost, 5 = row planting, 6 = intercropping, 7 = soil and water conservation (SWC) and 8 = agroforestry; and j = 1, …, *n* and *n* denotes the sample size.

Equation (1) assumption is that a rational jth farmer has a latent variable, Y^{*}_{ij}, which captures the unobserved preferences derived from the ith CSA innovation. This latent variable is assumed to be a linear combination of observed perception of CSA innovations (X_{ij}) such as CSA increases productivity, soil fertility, income, soil organic matter, diversify livestock feed source and diversify alternative energy source; CSA reduces cost of production, the amount of synthetic fertilizer use, soil erosion, seeding rate, weed infestation and crop failure as well as rehabilitates land, as well as unobserved characteristics captured by the stochastic error term ε_{ij}. The vector of parameters to be estimated is denoted by β_i. Given the latent nature of Y^{*}_{ij}, the estimations are based on observable binary discrete variables Y_{ij}, which indicate whether or not a farmer undertook the ith CSA innovation. If the adoption of CSA innovation is independent of another CSA practice, then equations (1) and (2) specify univariate probit models, where information on farmers' adoption of CSA innovation does not alter the prediction of the probability that they have adopted another CSA practice. As we assumed that adoption of multiple CSA innovations, the error terms in equation (1) jointly follow a multivariate normal (MVN) distribution, with 0 conditional mean and variance normalized to 1. Where ($\boldsymbol{\rho 1}$, $\boldsymbol{\rho 2}$, $\boldsymbol{\rho 3}$, $\boldsymbol{\rho 4}$, $\boldsymbol{\rho 5}$, $\boldsymbol{\rho 6}$, $\boldsymbol{\rho 7}$, $\boldsymbol{\rho 8}$) distributed MVN(0,Ω″) and the symmetric variance-covariance matrix″is given by:

$$\Omega = \begin{bmatrix} 1 & \rho_{12} & \rho_{13} & \cdots & \rho_{17} \\ \vdots & & \ddots & & \vdots \\ \rho_{81} & \rho_{82} & \rho_{83} & \cdots & 1 \end{bmatrix}$$

where ($\boldsymbol{\rho_{im}}$) denotes the pairwise correlation coefficient of the error terms corresponding to any two innovations adoption equations to be estimated in the model.

In the analysis, particular interest is the off-diagonal elements in the covariance matrix, $\boldsymbol{\rho_{im}}$ which represent the unobserved correlation between the stochastic component of the ith and mth innovations. This assumption means that equation (2) gives an MVP model that jointly represents the adoption of a particular innovation. In this model, a positive correlation represents a synergy while a negative correlation represents tradeoff between the ith and mth innovations.

The study identified the important determinants of adoption of CSA innovation measures using MVP model to provide policy information on which CSA pillars to target and how. Before modeling the number of innovations on farmers' perception, the study assessed the pairwise correlation coefficient of the farmers' perception of CSA innovations. The correlation result showed that some of the perceptions are correlated to each other, so the issue of heteroskedasticity of the model was addressed using the robust standard error procedure. Robust standard error could effectively solve heteroskedasticity because it gives relatively accurate *p*-value to ensure the significance of the regression model the study used (Wooldridge, 2013).

3. Result and discussion

3.1 Adoption of climate-smart agriculture innovations

Row planting (76%), compost (66%), SWC (51%), crop residue management (46%), crop rotation (37%), improved variety (31%) and agroforestry (21%) were the most preferred and adopted CSA innovations among smallholder farm households. However, the majority of farmers, or more than half, used row planting, compost and soil and water conservation methods, while crop residue management, crop rotation, improved variety and agroforestry were used by less than half of the households (Table 2).

3.2 Perception of climate-smart agriculture innovations and its effects

Table 3 presented the percent of stallholder farmers that exhibited a particular perception of CSA innovations among agroecosystems. Using 13 indicators of benefits of CSA innovations, the farmer's perception toward adoption of different CSA innovations was assessed. Among smallholder farmers, 91, 86, 80, 64 and 50% replied that CSA innovations increase productivity, increase soil fertility, increase income, increase soil organic matter and reduce soil erosion, respectively. Furthermore, CSA innovations reduce the cost of chemical fertilizer when smallholder farmers use compost in their homestead farms, as well as the cost of production through less fertilizer, less weed infestation and a lower seeding rate, according to 61, 59 and 55% of smallholder farmers, respectively. The χ^2 test revealed that perceptions of CSAI that CSA increases productivity, CSA increases soil fertility, CSA diversifies energy sources, CSA reduces soil erosion, CSA reduces production costs, CSA reduces amount of

CSA innovations	AESZ1 (%)	AESZ2 (%)	AESZ3 (%)	AESZ4 (%)	AESZ5 (%)	Average (%)
Row planting	32	31	97	98	94	*76*
Compost	45	29	89	84	66	*66*
SWC	78	27	34	65	50	*51*
Crop residue management	51	56	67	35	27	*46*
Crop rotation	42	44	41	37	26	*37*
Improved varieties	7	15	64	38	20	*31*
Agroforestry	1	5	42	17	22	*21*
Average	*36.6*	*29.6*	*62.0*	*53.4*	*43.6*	

Source: Own computation

Table 2. Adoption of CSA innovations by agro-ecosystem

Perception of CSA innovations	AES1	AES2	AES3	AES4	AES5	Overall average	χ^2
Perception toward food security							
Increase productivity	70	52	99	62	101	91	19.9***
Increase income	58	51	84	51	96	80	6.82
Perception toward adaptation/resilience							
Reduces seeding rate	18	12	76	48	78	55	81.9***
Reduces cost of production	26	32	73	46	71	59	29.3***
Increase soil fertility	60	49	103	56	94	86	26.7***
Reduces soil erosion	55	24	50	30	53	50	19.09***
Diversify energy source	26	9	38	14	35	29	9.3*
Diversify livestock feed source	37	27	41	25	54	44	2.75
Reduces crop failure	9	0	22	11	11	13	17.6***a
Reduces weed infestation	1	3	22	9	9	10	23.05*** a
Perception toward mitigation							
Increase soil organic carbon	42	33	69	46	80	64	5.25
Reduces amount of chemical fertilizer	34	28	77	39	81	61	18.54***
Rehabilitates land	33	22	32	29	54	40	5.93***

Notes: ***, **, * are significant at 1, 5 and 10%, respectively a: a cell containing less than 5, the χ^2 value is not valid

Table 3. Perception of CSA innovations and agroecosystem

chemical fertilizer used, CSA reduces seeding rate and CSA rehabilitates land differ significantly across agroecosystems ($p < 0.001$). Hence, the reason for adoption emanates from the characteristics of the innovations and the agroecosystems in which the farmers' lives.

3.3 Perception determinants of the adoption of climate-smart agriculture innovations

Table 4 shows inherently smallholder farmers adopting multiple CSA innovations for different agricultural and livelihood outcomes. Some of these innovations provide synergetic effects (complimentary) or positive correlation, while others tradeoff effects (substitutes) or negative effects. Hence, out of 28 correlations of CSA innovations, 14 of them are significant. This shows the appropriateness of the MVP model for adoption of CSA innovations among smallholder farmers, which concurs with the studies of Aryal *et al.* (2018), Teklewold *et al.* (2017, 2019).

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho81 = rho32 = rho42 = rho52 = rho62 = rho72 = rho82 = rho43 = rho53 = rho63 = rho73 = rho83 = rho54 = rho64 = rho 74 = rho84 = rho65 = rho75 = rho85 = rho76 = rho86 = rho87 = 0:

$$\chi 2(28) = 129.886; \;\; \text{Prob} > \chi 2 = 0.0000$$

1 = improved variety, 2 = crop rotation, 3 = crop residue management, 4 = compost,5= row planting 6 = intercropping, 7 = soil and water conservation and 8 = agroforestry.

Table 5 showed that the overall relationship between the farmer's probability of adopting specific CSA innovation and explanatory variables is significant at the 1% level based on the values of Wald $\chi^2(104)$ (Prob > χ^2 = 0.0000). Hence, according to the MVP result, farmers who perceive CSA innovations increase productivity are more likely to adopt improved variety, crop residue management, intercropping and agroforestry. However, the perception that CSA innovations increase income did not affect any of the CSA innovations. Farmers who perceive that CSA innovations increase productivity are reluctant to adopt SWC because SWC decreases crop yield as it attracts pests and rodents, is difficult to tillage,

Table 4.
CSA innovations adoption matrix

CSA innovations	Improved variety	Crop rotation	Crop residue management	Compost	Row planting	Intercropping	SWC
Crop rotation	0.224***						
Crop residue management	0.156	−0.021					
Compost	0.127	−0.118	−0.371***				
Row planting	0.493***	0.059	−0.042	0.406***			
Intercropping	0.18	0.291**	−0.185	0.339***	0.375***		
SWC	−0.262***	−0.068	−0.373***	0.360***	0.066	0.019	
Agroforestry	0.191*	0.307***	0.014	0.092	0.390***	0.326***	0.053

Notes: Standard errors in parentheses ***, **, * are significant at 1, 5 and 10%, respectively

Table 5.
Perception determinants of the adoption of CSA innovations

Explanatory variables	Improved variety	Crop rotation	Crop residue management	Compost	Row planting	Intercropping	SWC	Agroforestry
Perception implication toward food security								
Increase productivity	0.77(0.3)***	0.1(0.2)	1.5(0.3)***	−0.2(0.3)	0. 2(0.4)	1.5(0.5)***	−1.7(0.4)***	0.9(0.3)**
Increase income	0.18(0.20)	−0.01(0.2)	−0.3(0.25)	0.24(0.22)	−0.1(0.3)	0.4(0.4)	0.1(0.2)	−0.2(0.25)
Perception implication toward climate adaptation								
Increase soil fertility	0.0.2 (0.26)	0.8 (0.3)***	1.3 (0.4)***	1.4 (0.3)***	0.18 (0.3)	0.7 (0.5)	0.1 (0.3)	0.4 (0.4)
Diversify livestock feed source	−0.18 (0.17)	−0.3 (0.17)*	0.01 (0.2)	−0.37 (0.2)*	−0.5 (0.2)**	0.2 (0.2)	−0.1 (0.2)	−0.7 (0.2)***
Diversify energy source	0.2 (0.18)	0.3 (0.18)*	0.05 (0.2)	0.03 (0.2)	0.3 (0.24)	0.3 (0.2)	0.5 (0.18)***	1.5 (0.2)***
Reduces soil erosion	−0.1 (0.16)	0.6 (0.17)***	0.45 (0.18)**	−0.002 (0.2)	−0.4 (0.2)*	0.8 (0.25)***	1.8 (0.17)***	0.5 (0.2)***
Reduces weed infestation	0.2 (0.2)	0.8 (0.24)***	0.5 (0.27)*	0.9 (0.3)**	1.3 (0.4)***	1.2 (0.3)***	−0.9 (0.25)***	0.9 (0.3)***
Reduces cost of production	0.18 (0.17)	0.05 (0.17)	0.13 (0.2)	0.05 (0.2)	0.4 (0.2)*	−0.4 (0.2)*	−0.05 (0.2)	−0.2 (0.2)
Reduces crop failure	−0.6 (0.2)**	−0.4 (0.2)*	0.7 (0.2)	0.2 (0.26)	0.5 (0.3)	−0.1 (0.3)	0.5 (0.2)	0.3 (0.2)
Reduces seeding rate	0.4 (0.16)**	0.14 (0.16)	−0.8 (0.2)***	0.3 (0.2)*	2.0 (0.2)***	0.9 (0.26)***	0.1 (0.17)	0.8 (0.2)***
Perception implication toward climate mitigation								
Increase soil organic carbon	−0.2 (0.17)	−0.1 (0.16)	1.96 (0.2)***	0.7 (0.19)***	0.12 (0.2)	−0.1 (0.2)	−0.02 (0.2)	0.1 (0.2)
Reduces synthetic fertilizer use	0.5 (0.17)***	−0.24 (0.17)	0.02 (0.2)	1.17 (0.2)***	0.3 (0.3)	0.2 (0.25)	−0.6 (0.2)***	0.1 (0.2)
Rehabilitates land	−0.15 (0.16)	0.7 (0.17)***	−0.4 (0.2)**	−0.2 (0.2)	−0.02 (0.2)	−0.1 (0.24)	0.25 (0.18)	−0.1 (0.2)
Constant	−1.9 (0.36)***	−1.7 (0.3)***	−3.6 (0.5)***	−1.9 (0.5)***	−0.4 (0.4)	−4.8 (0.8)***	0.7 (0.4)	−3.1 (0.5)***

Notes: Standard errors in parentheses ***, **, * are significant at 1, 5 and 10%, respectively requires much labor and reduces farm size (Simeneh, 2015). However, a good perception of farmers toward the implications of CSA innovations on food security enhances adoption of improved varieties, crop residue management and agroforestry.

Framers who perceive that CSA innovation increases soil fertility are more likely to adopt crop residue management, crop rotation and compost. Farmers who perceive that CSA innovation's increased diversification of fuel sources is expected to create more of an urge to adopt crop rotation, soil and water conservation and agroforestry. Agroforestry and crop rotation have a synergistic effect which increases adoption. Farmers who perceive that CSA innovations reduce soil erosion are more likely to adopt crop residue, crop rotation, intercropping, soil and water conservation and agroforestry. Farmers who perceive that CSA innovations reduce weed infestation are more likely to adopt crop residue, crop rotation, compost, row planting, intercropping and agroforestry. Farmers who perceive that CSA innovations reduce the cost of production cause a more likely adoption of row planting. CSA innovations that reduce seeding rates are more likely to adopt improved varieties, compost, row planting and agroforestry. Thus, a positive perception of farmers toward the implications of CSA innovations on climate change adaptation enhances adoption of improved varieties, crop residue management, crop rotation, compost, row planting, soil and water conservation, intercropping and agroforestry.

Likewise, the perception that CSA innovation increases soil organic matter and carbon may cause a more likely adoption of crop residue management and compost. Also, farmers' perception that CSA innovations reduce the amount of chemical fertilizer leads to a more probable adoption of improved varieties and compost and a farmer's perception that CSA innovations rehabilitate land implies a higher expectation to adopt crop rotation. Thus, a positive perception of farmers toward the implications of CSA innovations on climate change mitigation enhances adoption of crop residue management, crop rotation and compost, while a negative perception of agroforestry increases soil organic carbon and helps farm-level climate mitigation.

4. Discussions of findings

The results in general revealed that farmers in the Upper Blue Nile Highlands are aware that the perception of CSA innovations adoption on food security, climate change adaptation and mitigation. However, farmers' perception of benefits of CSA innovations significantly differ among agroecosystems ($p < 0.001$). First, farmers believe that adoption of climate smart innovations enhances food security through increasing productivity and income (91 and 80%, respectively), which is also supported by other studies in sub-Saharan Africa and Ethiopia. For instance, farmers who adopt maize potato intercropping, intercropped maize with grain legumes increased crop productivity (Baudron *et al.*, 2014; Kidane *et al.*, 2017; Miheretu, 2014; Thierfelder *et al.*, 2012; Valbuena *et al.*, 2012) and (Lal, 2006; Lorenz and Lal, 2014) argued that agroforestry increases yield via increased soil organic carbon. Other studies also support result and reported that crop residue retention and crop rotation and/or intercrop association among other benefits increase yield (Ngwira *et al.*, 2013). Similarly, crop residue management and crop rotation of wheat and teff have also increased crop yield concurring with the perception of farmers (Araya *et al.*, 2011). Although, majority of reviewed scientific studies showed an increase in crop yield due to SWC (Wolka *et al.*, 2018), some literature shows decrease in yield among adopters of SWC (Adimassu *et al.*, 2017).

Second, farmers believe that that adoption of climate smart innovations enhances climate change adaptation or resilience via increasing soil fertility (86%) concurs with the previous studies on crop residue management who reported that crop residue management, crop rotation and compost through appropriate tillage system increases soil fertility

(Bhupinderpal-Singh and Rengel, 2007; FAO, 2013; Giller *et al.*, 2009). Likewise, study in Malawi concurs this result and reported that farmers have a positive perception of the compost that it improves soil productivity (Mustafa-Msukwa *et al.*, 2011). However, this study showed a tradeoff effect of adoption of crop residue management and compost due to the computation of demand for crop residue hinders adoption of crop residue management as well as compost (FAO, 2013; Giller *et al.*, 2009; Jaleta *et al.*, 2013).

Similarly, farmers believe that CSA innovations reduce soil erosion (50%) that agrees with the result of Akalu *et al.* (2013), Kagabo *et al.* (2013) that reported soil erosion, soil fertility and crop yield improves after adopting terraces along the mounatnious area and another literature also reported agroforestry based farming of "khat," coffee and sugarcane has reduced soil erosion (Adane, 2009). Furthermore, the finding corroborates the findings that conservation agriculture, i.e. crop rotation and crop residue management, not only improves soil health but also improved suppression of weed infestation (Ngwira *et al.*, 2014a, 2014b; Palm *et al.*, 2014). Another study (Mashingaidze, 2004) reported that farm land that is mulched and minimum tillage had less weed infestation than un-mulched and conventional tillage in maize–cowpea–sorghum rotation farming system. While maintaining permanent soil cover through crop residues, i.e. conservation agriculture, impedes weed germination and hence reduce weed pressure (Muoni and Mhlanga, 2014). Also, the finding supports (Fentie and Beyene, 2019) who reported that row planting not only reduces seeding rate but also prevents water logging and increases productivity.

Finally, farmers believe that adoption of climate smart innovations reduces or removes GHGs from the farm and contributes to the local effort of climate mitigation through increased soil organic matter (64%). Several studies showed that adoption of crop residue management increased soil carbon, and it has been recommended as one mechanism of carbon sequestration (FAO, 2013; Humberto and Lal, 2010; Lal, 2006; Lorenz and Lal, 2014; Ngwira *et al.*, 2012).

5. Conclusions and recommendations

5.1 Conclusion

Farmers' perceptions toward CSA innovations are one of the requirements to increase the adoption of CSA innovations in the smallholder agriculture system. Farmers' perception toward CSA innovations should include: CSA innovations sustainably increase productivity and income; CSA innovations enhance soil fertility; diversify livestock feed and energy source; reduces soil erosion, weed infestation and crop failure; enhances soil organic matter, reduces chemical fertilizer use and rehabilitates land.

Positive perception of farmers toward implication of CSA innovations on food security enhances adoption of improved variety, crop residue management and agroforestry. Similarly, positive perception of farmers toward implication of CSA innovations on climate change adaptation enhances adoption of improved variety, crop residue management, crop rotation, compost, row planting, soil and water conservation, intercropping and agroforestry. Moreover, positive perception of farmers toward implication of CSA innovations on climate change mitigation enhances adoption of crop residue management, crop rotation and compost while lacks the perception that agroforestry increases soil organic carbon and help farm level climate mitigation. Hence, positive perception of farmers on the benefit of CSA innovations for enhancing crop productivity, reducing agricultural vulnerability to climate change and reducing/removing of GHGs emissions from farm has enhanced adoption.

Farmers in the midland with brown soil (AES3) and the hilly and mountainous agroecosystem zone (AES5) are more aware of CSA innovations capacity to enhance food security and strengthen climate adaptation/resilience while farmers in the low land/Abay gorge agroecosystems zone (AES1) are most concerned and aware of CSA innovations capacity to contribute for climate adaptation/resilience. Finally, farmers in the hilly and mountainous agroecosystem zone (AES5) are aware of the climate mitigation capacity of CSA innovations.

Thus, following perception of CSA innovations benefits farmers adopt CSA innovations that include improved variety, row planting, crop residue management, crop rotation, compost, soil and water conservation, intercropping and agroforestry. There is good farmer's perception of improved variety, crop residue management, crop rotation, compost, row planting, soil and water conservation, intercropping and agroforestry to enhance climate change adaptation and increase food security while lack of awareness of agroforestry implication on supporting climate mitigation effort at farm level.

5.2 Recommendation

Strengthening efforts on enhancing farmers' adaptive capacity through awareness of CSA innovations should be put as among the development milestones. However, as the farmers' perception varies across AES, extension services should focus on awareness of CSA innovations capacity to enhance food security and strengthen climate adaptation in the midland with brown soil (AES3) and the hilly and mountainous agroecosystem zone (AES5). Whereas, extension services should focus on awareness of CSA innovations capacity to contribute for climate adaptation/resilience in the low land/Abay gorge agroecosystems zone (AES1). Extension services should focus on farmers' awareness on capacity of CSA innovations to deliver climate adaptation (with mitigation co-benefits) in the hilly and mountainous agroecosystem zone (AES5).

Designing policies that aim to enhance information and communication gap of adoption of CSA innovations have a great potential to benefit from the innovations. Programs aimed to reduce maladaptation of CSA innovations should focus on the bundle of innovations for a particular farmer no a piece meal. Supporting farmers through training on CSA innovations such as agroforestry, compost making and crop residue management is imperative for scaling CSA technologies. There is also the need for governments and non-governmental organizations to invest in awareness creation *of* CSA innovations. Further research is also recommended regarding constructs of perception using exploratory factor analysis.

References

Abegunde, V.O., Sibanda, M. and Obi, A. (2019), "The dynamics of climate change adaptation in Sub-Saharan Africa: a review of climate-smart agriculture among small-scale farmers", *Climate*, Vol. 7 No. 11, p. 132, doi: 10.3390/cli7110132.

Adane, T. (2009), "Impact of perennial cash cropping on food crop production and productivity 1", *Ethiopian Journal of Economics*, Vol. 1, pp. 1-34.

Adesina, A. and Jojo, B.-F. (1995), "Farmers' perceptions and adoption of new agricultural technology", *Agricultural Economics*, Vol. 13 No. 1, pp. 1-9, available at: http://impact.cgiar.org/sites/default/files/pdf/230.pdf

Adesina, A. and Moses, Z. (1993), "Technology characteristics, farmers' perceptions and adoption decisions: a Tobit model application in Sierra Leone", *Agricultural Economics*, Vol. 9 No. 4, pp. 297-311, doi: 10.1016/0169-5150(93)90019-9.

Adimassu, Z., Langan, S., Johnston, R., Mekuria, W. and Amede, T. (2017), "Impacts of soil and water conservation practices on crop yield, run-off, soil loss and nutrient loss in Ethiopia: review and synthesis", *Environmental Management*, Vol. 59 No. 1, pp. 87-101, doi: 10.1007/s00267-016-0776-1.

Akalu, T., Rolker, D. and Graaff, J.D. (2013), "Financial viability of soil and water conservation technologies in northwestern Ethiopian highlands", *Applied Geography*, Vol. 37 No. 1, pp. 139-149, doi: 10.1016/j.apgeog.2012.11.007.

Alomia-Hinojosa, V., Speelman, E.N., Arun, T., Wei, H.-E., McDonald, A.J., Tittonell, P. and Groot, C.J. (2018), "Exploring farmer perceptions of agricultural innovations for maize-legume intensification in the mid-hills region of Nepal", *International Journal of Agricultural Sustainability*, Vol. 16 No. 1, pp. 74-93, doi: 10.1080/14735903.2018.1423723.

Araya, T., Cornelis, W.M., Nyssen, J., Govaerts, B., Bauer, H., Gebreegziabher, T., Oicha, T., Raes, D., Sayre, K.D., Haile, M. and Deckers, J. (2011), "Effects of conservation agriculture on runoff, soil loss and crop yield under rainfed conditions in Tigray, Northern Ethiopia", *Soil Use and Management*, Vol. 27 No. 3, pp. 404-414, doi: 10.1111/j.1475-2743.2011.00347.x.

Aryal, J.P., Jat, M.L., Sapkota, T.B., Khatri-Chhetri, A., Kassie, M., Rahut, D.B. and Maharjan, S. (2018), "Adoption of multiple climate-smart agricultural practices in the gangetic plains of Bihar, India", *International Journal of Climate Change Strategies and Management*, Vol. 10 No. 3, pp. 407-427, doi: 10.1108/IJCCSM-02-2017-0025.

Asrat, P. and Simane, B. (2018), "Farmers' perception of climate change and adaptation strategies in the Dabus watershed, North-West Ethiopia", *Ecological Processes*, Vol. 7 No. 1, doi: 10.1186/s13717-018-0118-8.

Babatolu, J.S. and Akinnubi, R.T. (2016), "Smallholder farmers' perception of climate change and variability impact and their adaptation strategies in the upper and lower Niger river basin development authority areas", *Nigeria. J Pet Environ Biotechnol*, Vol. 7, p. 279, doi: 10.4172/2157-7463.1000279.

Baudron, F., Delmotte, S., Corbeels, M., Herrera, J.M. and Tittonell, P. (2014), "Multi-scale trade-off analysis of cereal residue use for livestock feeding vs soil mulching in the mid-Zambezi valley, Zimbabwe", *Agricultural Systems*, Vol. 134, doi: 10.1016/j.agsy.2014.03.002.

Bazzana, D., Foltz, J.D. and Zhang, Y. (2021), "Impact of climate smart agriculture on food security: an agent-based analysis", FEEM Working Paper No. 18.2021, available at: https://ssrn.com/abstract=3857718, doi: 10.2139/ssrn.3857718.

Benjamin, F.Z., Belay, S., Shahid, H., Martha, C.A., Mutlu, O. and Jeremy, D.F. (2012), "Building climate resilience in the blue Nile/abay highlands: a role for earth system sciences", *International Journal of Environmental Research and Public Health*, Vol. 9 No. 12, pp. 435-461, doi: 10.3390/ijerph9020435.

Bhupinderpal-SinghRengel, Z. (2007), "The role of crop residues in improving soil fertility", Soil Biology, 10, available at: https://link.springer.com/content/pdf/10.1007%2F978-3-540-68027-7_7.pdf

Cochran, W. (1977), "Sampling techniques", available at: https://scholar.google.com.tr/scholar?q=sampling+techniques&btnG=&hl=en&as_sdt=0,5#0

Desalegn, Y. and Filho, L. (2017), "Farmers' perceptions of climate variability and its adverse impacts on crop and livestock production in Ethiopia", *Journal of Arid Environments*, Vol. 140, pp. 20-28, doi: 10.1016/j.jaridenv.2017.01.007.

Ermias, T., Woldeamlak, B., Uhlenbrook, S. and Wenninger, J. (2013), "Understanding recent land use and land cover dynamics in the source region of the upper blue Nile, Ethiopia: spatially explicit statistical modeling of systematic transitions", *Agriculture, Ecosystems and Environment*, Vol. 165, pp. 98-117, doi: 10.1016/j.agee.2012.11.007.

Esayas, B., Simane, B., Teferi, E., Ongoma, V. and Tefera, N. (2019), "Climate variability and farmers' perception in Southern Ethiopia", *Advances in Meteorology*, Vol. 2019, p. 7341465, doi: 10.1155/2019/7341465.

FAO (2013), "Climate-Smart agriculture: source book", FAO, available at: www.cabdirect.org/abstracts/20153237305.html

Fayso, T. (2018), "Understanding adoption in smallholder agriculture: perception and row planting TEFF in Ethiopia", *Agricultural Research and Technology: Open Access Journal*, Vol. 19 No. 1, p. 556078, doi: 10.19080/artoaj.2018.19.556078.

Fentie, A. and Beyene, A.D. (2019), "Climate-smart agricultural practices and welfare of rural smallholders in Ethiopia: Does planting method matter?", *Land Use Policy*, Vol. 85, pp. 387-396, doi: 10.1016/j.landusepol.2019.04.020.

Giller, K.E., Witter, E., Corbeels, M. and Tittonell, P. (2009), "Conservation agriculture and smallholder farming in Africa: the heretics' view", *Field Crops Research*, Vol. 114 No. 1, pp. 23-34, doi: 10.1016/j.fcr.2009.06.017.

Greene, W.H. (2003), *Econometric Analysis*, 5th ed., in Banister, R. *et al.* (Eds), Pearson Education Inc., New York, Vol. 97, No. 457, doi: 10.1198/jasa.2002.s458.

Humberto, B. and Lal, R. (2010), "Principles of soil conservation and management", in *First softcover printing 2010 Principles of Soil Conservation and Management*, ISBN: 978-90-481-8529-0, doi: 10.1007/978-1-4020-8709-7.

Israel Rop, O. and Adepoju Ib, A. (2017), "Response of cassava and maize yield to varying spatial scales of rainfall and temperature scenarios in port Harcourt", *Research Journal of Environmental Sciences*, Vol. 11 No. 4, pp. 137-142, doi: 10.3923/rjes.2017.137.142.

Jaleta, M., Kassie, M. and Shiferaw, B. (2013), "Tradeoffs in crop residue utilization in mixed crop-livestock systems and implications for conservation agriculture", *Agricultural Systems*, Vol. 121, pp. 96-105, doi: 10.1016/j.agsy.2013.05.006.

Juana, J.S., Kahaka, Z., Okurut, F.N., Berhanu, W., Beyene, F., Bonan, G.B., Montle, B.P., Teweldemedhin, M.Y., Komba, C., Muchapondwa, E., Kasulo, V., Kasulo, V., Chikagwa-Malunga, S., Chagunda, M., Roberts, D., Kasulo, V., Abroulaye, S., Issa, S., Abalo, K.E. and Nouhoun, Z. (2013), "Farmers' perceptions and adaptations to climate change in Sub-Sahara Africa: a synthesis of empirical studies and implications for public policy in African agriculture", *Journal of Agricultural Science*, Vol. 5 No. 4, pp. 121-135, doi: 10.5539/jas.v5n4p121.

Kagabo, D.M., Stroosnijder, L., Visser, S.M. and Moore, D. (2013), "Soil erosion, soil fertility and crop yield on slow-forming terraces in the highlands of Buberuka, Rwanda", *Soil and Tillage Research*, Vol. 128, pp. 23-29, doi: 10.1016/j.still.2012.11.002.

Kahsay, H.T., Guta, D.D., Belay, S. and Gidey, T.G. (2019), "Farmers' perceptions of climate change trends and adaptation strategies in semiarid highlands of Eastern Tigray, Northern Ethiopia", *Advances in Meteorology*, Vol. 2019, pp. 1-13, doi: 10.1155/2019/3849210.

Kassie, M., Teklewold, H., Jaleta, M., Marenya, P. and Erenstein, O. (2015), "Understanding the adoption of a portfolio of sustainable intensification practices in Eastern and Southern Africa", *Land Use Policy*, Vol. 42 No. 5, pp. 400-411, doi: 10.1016/j.landusepol.2014.08.016.

Kidane, B.Z., Hailu, M.H. and Haile, H.T. (2017), "Maize and potato intercropping: a technology to increase productivity and profitability in Tigray", *Open Agriculture*, Vol. 2 No. 1, pp. 411-416, doi: 10.1515/opag-2017-0044.

Kumar, M., Pravesh, R. and Kumar, D. (2015), "Comparison of weighting assessment techniques and its integration with GIS-based multi criteria decision making", *Proceedings of the National Academy of Sciences, India Section A: Physical Sciences*, Vol. 85 No. 1, pp. 197-209, doi: 10.1007/s40010-014-0186-9.

Lal, R. (2006), "Enhancing crop yields in the developing countries through restoration of the soil organic carbon Pool in agricultural lands", *Land Degradation and Development*, Vol. 17 No. 2, pp. 197-209, doi: 10.1002/ldr.696.

Lorenz, K. and Lal, R. (2014), "Soil organic carbon sequestration in agroforestry systems. A review", *Agronomy for Sustainable Development*, Vol. 34 No. 2, pp. 443-454, doi: 10.1007/s13593-014-0212-y.

Luangduangsitthideth, O., Limnirankul, B. and Kramol, P. (2018), "Farmers' knowledge and perceptions of sustainable soil conservation practices in Paklay district, Sayabouly province, Lao PDR", *Kasetsart Journal of Social Sciences*, pp. 1-7, doi: 10.1016/j.kjss.2018.07.006.

Mashingaidze, A. (2004), "Improving weed management and crop productivity in maize systems in Zimbabwe", available at: https://library.wur.nl/WebQuery/wurpubs/fulltext/22637.

Meijer, S.S., Catacutan, D., Ajayi, O.C., Sileshi, G.W. and Nieuwenhuis, M. (2015), "The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in Sub-Saharan Africa", *International Journal of Agricultural Sustainability*, Vol. 13 No. 1, pp. 40-54, doi: 10.1080/14735903.2014.912493.

Miheretu, B.A. (2014), "Farmers' perception and adoption of soil and water conservation measures: the case of Gidan Wereda, North Wello, Ethiopia", *Journal of Economics and Sustainable Development*, Vol. 5 No. 24, pp. 1-10, doi: 10.1007/s10557-010-6232-1.

Muoni, T. and Mhlanga, B. (2014), "Weed management in Zimbabwean smallholder conservation agriculture farming sector", *Asian Journal of Agriculture and Rural Development*, Vol. 4 No. 3, pp. 269-278, available at: http://search.proquest.com/openview/68cef05c97e44a1379788b956308e788/1?pq-origsite=gscholar&cbl=1786339

Mustafa-Msukwa, A., Mutimba, J., Masangano, C. and Edriss, A. (2011), "Assessment of the adoption of compost manure", *South African Journal of Agricultural Extension*, Vol. 39 No. 1, pp. 17-25.

Ngwira, A., Sleutel, S. and de Neve, S. (2012), "Soil carbon dynamics as influenced by tillage and crop residue management in loamy sand and sandy loam soils under smallholder farmers' conditions in Malawi", *Nutrient Cycling in Agroecosystems*, Vol. 92 No. 3, pp. 315-328, doi: 10.1007/s10705-012-9492-2.

Ngwira, A., Thierfelder, C. and Lambert, D.M. (2013), "Conservation agriculture systems for Malawian smallholder farmers: Long-term effects on crop productivity, profitability and soil quality", *Renewable Agriculture and Food Systems*, Vol. 28 No. 4, pp. 350-363, doi: 10.1017/S1742170512000257.

Ngwira, A., Aune, J.B. and Thierfelder, C. (2014a), "On-farm evaluation of the effects of the principles and components of conservation agriculture on maize yield and weed biomass in Malawi", *Experimental Agriculture*, Vol. 50 No. 4, pp. 591-610, doi: 10.1017/S001447971400009X.

Ngwira, A., Johnsen, F.H., Aune, J.B., Mekuria, M. and Thierfelder, C. (2014b), "Adoption and extent of conservation agriculture practices among smallholder farmers in Malawi", *Journal of Soil and Water Conservation*, Vol. 69 No. 2, pp. 107-119, doi: 10.2489/jswc.69.2.107.

Nyang'au, J.O., Mohamed, J.H., Mango, N., Makate, C. and Wangeci, A.N. (2021), "Smallholder farmers' perception of climate change and adoption of climate smart agriculture practices in Masaba south sub-county, Kisii, Kenya", *Heliyon*, Vol. 7 No. 4, p. e06789, doi: 10.1016/j.heliyon.2021.e06789.

Palm, C., Blanco-Canqui, H. and DeClerck, F. (2014), "Conservation agriculture and ecosystem services: an overview", *Agriculture, Ecosystems and Environment*, Vol. 187, pp. 87-105, available at: www.sciencedirect.com/science/article/pii/S0167880913003502

Prager, K. and Posthumus, H. (2010), "Socio-economic factors influencing farmers' adoption of soil conservation practices in Europe", in Napier, L. (Ed.), *Human dimensions of Soil and Water Conservation: A Global Perspective*, Nova Science Publishers, Inc., New York, pp. 203-223.

Precious, M., Long, T.B., Blok, V. and Omta, O. (2018), "How the characteristics of innovations impact their adoption;: an exploration of climate-smart agricultural innovations in South Africa", *Journal of Cleaner Production Journal*, Vol. 172, pp. 3825-3840.

Rogers, E.M. (2003), *Diffusion of Innovation*, 5th ed., Macmillan Publishing Co., New York, ISBN: 0-02-926650-5.

Saguye, T.S. (2017), "Assessment of farmers' perception of climate change and variability and its implication for implementation of climate-smart agricultural practices: the case of Geze Gofa district, Southern Ethiopia", *Journal of Geography and Natural Disasters*, Vol. 7 No. 1, pp. 18-32, doi: 10.4172/2167-0587.1000191.

Simane, B. (2013), "The sustainability of community-based adaptation in the choke mountain watersheds, blue Nile highlands", *Ethiopia. Sustainability*, Vol. 5, pp. 1-37, doi: 10.3390/su50x000x.

Simane, B., Benjamin, Z. and Mutlu, O. (2013), "Agroecosystem analysis of the choke mountain watersheds, Ethiopia", *Sustainability*, Vol. 5 No. 2, pp. 592-616, doi: 10.3390/su5020592.

Simeneh, D. (2015), "Perception of farmers toward physical soil and water conservation structures in Wyebla watershed", *Northwest Ethiopia. Academic Journal of Plant Sciences*, Vol. 7 No. 3, pp. 34-40, doi: 10.5829/idosi.ajps.2015.7.3.12822.

Teklewold, H., Gebrehiwot, T. and Bezabih, M. (2019), "Climate smart agricultural practices and gender differentiated nutrition outcome: an empirical evidence from Ethiopia", *World Development*, Vol. 122, pp. 38-53, doi: 10.1016/j.worlddev.2019.05.010.

Teklewold, H., Mekonnen, A. and Kohlin, G. (2019), "Climate change adaptation: a study of multiple climate-smart practices in the Nile basin of Ethiopia", *Climate and Development*, Vol. 11 No. 2, pp. 180-192, doi: 10.1080/17565529.2018.1442801.

Teklewold, H., Mekonnen, A., Kohlin, G. and Di Falco, S. (2017), "Does adoption of multiple climate-smart practices improve farmers' climate resilience? Empirical evidence from the Nile basin of Ethiopia", *Climate Change Economics*, Vol. 8 No. 1, p. 1750001, doi: 10.1142/S2010007817500014.

Thierfelder, C., Cheesman, S. and Rusinamhodzi, L. (2012), "A comparative analysis of conservation agriculture systems: Benefits and challenges of rotations and intercropping in Zimbabwe", *Field Crops Research*, Vol. 137, pp. 237-250, doi: 10.1016/j.fcr.2012.08.017.

Tran Van, S., Boyd, W., Slavich, P. and Van, T.M. (2015), "Perception of climate change and farmers' adaptation: a case study of poor and non-poor farmers in northern central coast of Vietnam", *Journal of Basic and Applied Sciences*, Vol. 11, pp. 323-342, doi: 10.6000/1927-5129.2015.11.48.

Tran, N.L.D., Rañola, R.F., Ole Sander, B., Reiner, W., Nguyen, D.T. and Nong, N.K.N. (2019), "Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam", *International Journal of Climate Change Strategies and Management*, Vol. 12 No. 2, pp. 238-256, doi: 10.1108/IJCCSM-01-2019-0003.

Valbuena, D., Erenstein, O., Homann-Kee Tui, S., Abdoulaye, T., Claessens, L., Duncan, A.J., Gérard, B., Rufino, M.C., Teufel, N., van Rooyen, A. and van Wijk, M.T. (2012), "Conservation {agriculture} in mixed crop–livestock systems: {scoping} crop residue trade-offs in {Sub}-{Saharan} {Africa} and {South} {Asia}", *Field Crops Research*, Vol. 132, pp. 175-184, doi: 10.1016/j.fcr.2012.02.022.

Wolka, K., Mulder, J. and Biazin, B. (2018), "Effects of soil and water conservation techniques on crop yield, runoff and soil loss in sub-Saharan Africa: a review", *Agricultural Water Management*, Vol. 207 No. January, pp. 67-79, doi: 10.1016/j.agwat.2018.05.016.

Wooldridge, J. (2013), "Introductory econometrics: a modern approach", 5th ed., *Introductory Econometrics*, Cengage Learning, Mason, OH, South-Western, doi: 10.1007/9783319659169.

Workneh, N. and Parikh, A. (1999), "The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru Woreda (district) of Ethiopia", *Agricultural Economics*, Vol. 21 No. 2, pp. 205-216, doi: 10.1016/s0169-5150(99)00020-1.

Further reading

Barnett, J. and O'Neill, S. (2010), "Maladaptation", *Global Environmental Change*, Vol. 20 No. 2, pp. 211-213, doi: 10.1016/j.gloenvcha.2009.11.004.

Chaudhuri, A. and Dutta, T. (2018), "Determining the size of a sample to take from a finite population", *Statistics and Applications*, Vol. 16 No. 1, pp. 37-44.

Clayton, S., Devine-Wright, P., Stern, P.C., Whitmarsh, L., Carrico, A., Steg, L., Swim, J. and Bonnes, M. (2015), "Psychological research and global climate change", *Nature Climate Change*, Vol. 5 No. 7, pp. 640-646, doi: 10.1038/nclimate2622.

Corner, A., Markowitz, E. and Pidgeon, N. (2014), "Public engagement with climate change: the role of human values", *WIREs Climate Change*, Vol. 5 No. 3, pp. 411-422, doi: 10.1002/wcc.269.

Klöckner, C.A. (2013), "A comprehensive model of the psychology of environmental behaviour-a meta-analysis", *Global Environmental Change*, Vol. 23 No. 5, pp. 1028-1038, doi: 10.1016/j.gloenvcha.2013.05.014.

Melka, Y., Habtemariam, K., Ketema, M., Abebaw, D. and Schmiedel, U. (2015), "The effect of drought risk perception on local people coping decisions in the central rift valley of Ethiopia", *Journal of Development and Agricultural Economics*, Vol. 7 No. 9, pp. 292-302, doi: 10.5897/JDAE2015.0674.

Price, J.C., Walker, I.A. and Boschetti, F. (2014), "Measuring cultural values and beliefs about environment to identify their role in climate change responses", *Journal of Environmental Psychology*, Vol. 37, pp. 8-20, doi: 10.1016/j.jenvp.2013.10.001.

Soliman, M. and Wilson, A.E. (2017), "Seeing change and being change in the world: the relationship between lay theories about the world and environmental intentions", *Journal of Environmental Psychology*, Vol. 50, pp. 104-111, doi: 10.1016/j.jenvp.2017.01.008.

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