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INFLUENCE OF SOCIO-ECONOMIC AND INSTITUTIONAL FACTORS ON THE UPTAKE AND THE EXTENT OF APPLICATION OF CLIMATE-SMART AGRICULTURAL TECHNOLOGIES AND MANAGEMENT PRACTICES AMONG SMALLHOLDER POTATO FARMERS IN KENYA

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ABSTRACT

Smallholder farmers in developing countries are facing the threat of climate change and have resorted into numerous adaptation strategies that have collectively been referred to as Climate Smart Agricultural Technologies and Management Practices (CSA TMPs). Potato (*Solanum tuberosum*) is the second most important food crop in Kenya after maize. This study sought to determine the influence of socio-economic and institutional factors on the uptake and the extent of application of climate-smart agricultural technologies and management practices among smallholder potato farmers. The study was carried out in Taita-Taveta, Nyandarua, Nyeri and Elgeyo Marakwet Counties in Kenya. A sample of 312 smallholder farmers was used. A multi-stage sampling technique was used to get the study sample. Researcher administered questionnaires were used to collect primary data. The research instrument was pre-tested in Nakuru County. In this study, descriptive and inferential statistics were used to analyse the collected data using Stata (version 14). Multivariate Tobit regression model was used in identifying factors that influence the uptake and extent of application of CSA TMPs. This study found that farmers had adopted majority of the CSA TMPs under investigation. Older farmers and those with more household members are more likely to adopt climate smart agronomic practices. Some of additional enabling factors that enhance adoption of climate smart agronomic practices include greater extension contacts, non-farm income and land size. This study recommends that farmers should be trained in order to enhance their adoption of climate smart agricultural practices. Training is key in compensating for lack of adequate skills in farming activities. Training can be realized through extension programmes and information dissemination through social media among other platforms. Owing to cost implication involved in climate smart agronomic practices, farmers should be supported on how to access the needed capital through well-structured loan facilities.

Keywords: ***Uptake; Climate-Smart Agricultural Technologies and Management Practices***

INTRODUCTION

A key challenge facing agricultural sector in Kenya as well as most other developing countries in their bid to achieve sustainability is how to deal with the reality of climate change (Gilbert, 2015). Climate change has led to disbandment of known farming practices due to the new reality that is exacerbated by various shocks. Some of the key climate related shocks include rise in air temperatures over land, air temperatures over oceans, sea levels, humidity, ocean heat content, sea surface temperature and earth's lower atmosphere temperature (IPCC, 2012; Niang *et al*., 2014). Other related shocks include decrease in arctic sea ice and snow as well as melting of glaciers. Rise in air temperatures over land leads to increase in the frequency and severity of droughts and heat waves, destructive wildfires, failed crops and low water supplies. These shocks lead to more floods, more hurricanes, more extreme precipitation events, rise in global temperatures, intensified storms, more extreme flooding occurrence and threat for marine life, greenhouse effect and more energy use, higher sea levels, melting glaciers, and stress to marine ecosystems, stronger and more frequent storms, and higher absorption of sun's energy by earth (IPCC, 2012; Niang *et al*., 2014).

CSA TMPs are as a consequence of smallholder farmers' pursuance of the goal to reduce their vulnerability to the harmful effects of climate change (CCAFS, 2020). The

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[#] Corresponding author: ngunjirikrt@yahoo.com main goal behind emergence of CSA TMPs is to increase productivity, economic viability, and sustainability of agricultural systems in the light of climate change (Kinyangi *et al*., 2015). CSA TMPs include adaptations relating, but not limited to, agronomic practices; prudent choice of seed varieties; integrated soil, water, and nutrient management; integrated pest and disease control and management.

Kenya is one of the Sub-Saharan countries that are highly susceptible to unpredictable climate events. It is projected that the impacts of climate related events will affect the country in the years to come (World Bank, 2019). Numerous extreme events and variability of weather are common in many areas. Some of the most important climate-related events witnessed in Kenya include irregular and unpredictable rainfall, frequent droughts, longer rainy seasons and severe floods. The distribution of these effects varies with the arid and semi-arid areas experiencing greater climate hazards as compared to other areas. This affects the livelihoods of very many households because of the associated social, environmental, and economic risk (FAO, 2019; World Bank, 2019).

The need to strengthen local capacities in reducing their vulnerability to current and future climate variability is highly felt by the government and various development partners. Several intervention approaches at a near, medium and long-term perspective have recently emerged. The most current and notable intervention by the Kenyan government (with joint support of the World Bank) through the Ministry of Agriculture, Livestock and Fisheries (MoALF) and Coooperatives is the Kenya Climate Smart Agriculture Project (KCSAP) which is implemented over a five-year period (2017-2022). KCSAP implementing agency at the national level is the Ministry of Agriculture Livestock Fisheries and Cooperatives. The project is anchored in the State Department of Agriculture. County governments are the executing agencies at the county level.

Some of the most common climate smart agricultural technologies and management practices that are promoted throughout the country include crop varieties (resistant to pest/diseases, drought, salinity and flooding), integrated soil management (composting manure/crop residues, more precise matching of nutrients with plant needs, controlled release and deep placement technologies, using legumes for natural nitrogen fixation), integrated water management (improved water harvesting and retention, water-use efficient irrigation systems), integrated nutrient management (soil testing, fertilizer, manure application), integrated pest and disease control management (regular monitoring of crop, application of insecticides when necessary, growing varieties of crops which are resistant to pests, maintaining healthy soil, planting resistant varieties, correct spacing and right timing of planting) and agronomic practices (organic farming, conservation agriculture/resource conservation technologies and cover cropping).

In an effort to end hunger, achieve food security and improve nutrition, and promote sustainable agriculture-Sustainable Development Goal (SDG2), and feed its growing population, the Kenya government launched the 'Big 4 Agenda', a five-year programme that identified potato, besides maize and rice as a key crop for promotion. The objective within the fourth goal of the Big 4 Agenda, food Security and nutrition, is to enhance large scale food production, drive smallholder productivity, and to reduce the cost of food to improve accessibility to all (GoK, 2019). According to World Bank (2019), the need to enhance food production to meet dietary and economic needs of Kenyans through increased potato production has never been felt as much as it is today. Bridging the food security gap as outlined in the Vision 2030 and Millennium development goals (MDGs) in Kenya is highly dependent on ability to enhance smallholder farmers' productivity, economic viability, and sustainability.

Potato (*Solanum tuberosum*), the second most important food crop in Kenya after maize, is a major source of carbohydrates and therefore of high nutritional value. Irish potato matures in 3 to 4 months only with a productivity that is five times higher than maize that takes 3 to 8 months depending on variety. Potato is a major contributor towards Kenya's national goal for food and nutrition security, poverty alleviation, job creation and industrial products (CIP, 2019). According to World Bank (2019), potato can efficiently address food insecurity and alleviate poverty in Kenya. According to Potatopro (2020), about 3 million metric tonnes of Irish potatoes were produced from about 160,000 hectares (ha), generating over 50 Billion Kenya shillings (KES) in year 2019.

It is widely acknowledged that Kenya is supposed to increase its food production capacity (even amidst the challenges posed by climate change). Kenyan population trends is on an alarming increase with average growth rate of 2.5 percent per year, recorded for the past 10 years (2009-2019). Climate smart agricultural technologies and management practices has a potential of correcting the problem of low productivity, poor economic viability, and unsustainable food crop production. Understanding the factors that influence the use and the extent of application of climate-smart agricultural TMPs may help in exploring potential policies, interventions and institutional innovations for improving the welfare of smallholder farming communities.

METHODOLOGY

This study used correlation research design that attempt to determine or estimate the extent to which values of selected variables are related or change in an identifiable pattern with the dependent variable. The study was carried out in Taita-Taveta, Nyandarua, Nyeri and Elgeyo Marakwet Counties of Kenya corresponding with the four of the main Agro Ecological Zones (AEZs) where majority of potato farming is done in Kenya. These AEZs include coastal lowlands (Taita-Taveta), high potential zone (Nyandarua), central highlands (Nyeri) and Western highlands (Elgeyo Marakwet).

The target population of this study were smallholder potato farmers in the selected counties who are about 145,993 (Nyeri), 122,748 (Nyandarua), 87,400 (Elgeyo Marakwet) and 65,514 (Taita Taveta) according to KNBS (2019). However, the accessible population for this study were farming households who grow potatoes in the 2020/2021 cropping year. The sample unit of the study were potato farmers comprising of both users and non-users of selected Climate Smart Agricultural Technologies and Management Practices. The study used a multi-stage sampling technique to obtain a representative sample. The first stage involved purposive selection of four counties owing to potato value chain importance and representativeness of the key AEZs where the crop is popular. In the second stage, four sub-counties were randomly selected (one per county). In the third stage, eight wards were randomly selected (two from each sub-county). The Nassiuma (2000) formula was used to come up with a sample size of 312 for this study representing the users and non-users of selected CSA TMPs.

$$n = \frac{NC^2}{C^2 + (N-1)e^2} \quad \text{.........................1}$$

$$n = \frac{5444.4}{34.9} = 156.0$$

This was adjusted to take care of adopters and non-adopters:

$$n = 156 \times 2$$

$$n = 312$$

Proportionate allocation was used to determine the sample size from each county. To select individuals who participated in the study from each of the wards, systematic random sampling was used, in which respondents were selected at an interval of ten from the sample frame of potato farmers. A researcher administered questionnaire was used to collect primary data.

Descriptive and inferential statistics through econometric modelling were used to analyse data using Stata program (Version 14.1). Multivariate Tobit Regression model was used in determining the factors that influence the uptake and extent of application of climate-smart agricultural TMPs among smallholder potato farmers. Since the data on extent of application of CSA TMPs was censored at a limit, the application of other regression models including Ordinary Least Squares (OLS) could have resulted in biased and inconsistent estimates. Use of Multivariate Tobit model not only allowed for censored observations on CSA TMPs uptake, but also identified the jointness in farmers' decision to apply CSA TMPs in multiple areas (agronomic practices; seed varieties; integrated soil, water and nutrient management; integrated pest and disease control and management). A typical smallholder farmer is presumed to follow sequential decisions; first 'whether to apply CSA TMPs in potato production or not'; and second, conditional on application, 'what is the level or intensity of application'. The procedure also captures latent level of intensity of potential farmers who decide not to apply CSA TMPs on potato growing.

The dependent variable in this study was the number of CSA TMPs adopted in potato farming.

Let the outcome function for using a particular CSA TMPs be represented by:

$$Y_i^* = \beta_i X_i + u_i \quad \text{..(2)}$$

Where, X_i represents the vector of explanatory variables; β_i represents the vector of parameters to be estimated, and u_i represents the error term.

The different equations specified in this study took the form:

$$Y_i^* = \beta_i X_i + \mu_i Y_i^* = maximum\ (Y_i^*, 0) \qquad (3)$$

Where, Y_i^*= extent of application of the i^{th}farmer who used a specific TMP.

The meaning of the covariates, their definitions, and expected *a priori* signs are presented in Table I.

TABLE I - DESCRIPTION OF VARIABLES USED IN THE MODEL AND THEIR A PRIORI EXPECTATIONS.

Variables	Description of variables	Expected sign
Dependent variable		
APPLIC_Ext	Number of TMPs adopted in potato farming (1 to 5)	
Independent variables		
Age	Age of the household head in years	-/+
Sex	Sex of the household head (1=male 0=female)	+
Education	Years of schooling of household head	+
Household Size	Number of people in households(persons)	+/-
Farm income	Income earned within the farm (in Kshs. per annum)	+/-
Non/off-farm income	Income earned outside the farm (in Kshs. per annum)	+/-
Group membership	Membership to farming-related organizations (1=yes 0=no)	+
Distance to market	Distance from the main market in kilometres	??
Credit access	Household head receiving of credit (1=yes 0=no)	+
Extension contacts	Number of contacts with extension officials in the last 1 yr	+
Technical training	Receipt of potato farming training in last 1 year (1=yes 0=no)	+
Farming Experience	Number of years in potato production (Years)	+/-
Land size	Amount of land owned (acres)	+

Since farm income and off-farm income is correlated, a proxy variable for off-farm income (socio-economic status) was explored following Cantillo-García *et al.* (2019) recommendation on use of household socio-economic status as a proxy variable for income.

RESULTS AND DISCUSSIONS

Description of dependent and independent variables

The description of the dependent and independent variables on the analysis of the socio-economic and institutional factors that influence the uptake and the extent of application of climate-smart agricultural TMPs among smallholder potato farmers is summarized in Table II, Table III and Table IV. The uptake of selected climate smart agricultural practices among the sampled respondents is summarized in Table II. The duration that farmers reported to have implemented the selected CSA TMPs is also provided.

Majority of the CSA TMPs under investigation had been adopted by the respondents. The adoption for the selected CSA TMPs was as follows: conservation agriculture (93.4%); cover cropping (100.0%), potato varieties (high yielding; fast maturing; resistant to drought, salinity, flooding or diseases) (94.8%), soil management practices (95.7%), water management practices (49.2%), nutrient management practices (100%), pest control management practices (100%) and disease control management practices (87.9%).

Most of the CSA TMPs adopters in this study were regular adopters (and not first-time adopters) (Table II). The distribution of regular adopters of the selected CSA TMPs was as follows: conservation agriculture (60.7%), cover cropping (79.3%), potato varieties (52.9%), soil management practices (55.8%), water management practices (80.0%), nutrient management practices (73.8%), pest control management practice (90.8%) and disease control management practices (86.6%).

The results in Table II show that an average farmer in this study had practiced the selected CSA TMPs for the following duration in years: conservation agriculture (1.49 years), cover cropping (4.93 years), potato variety

TABLE II- RESPONDENTS UPTAKE OF SELECTED CSA TMPS

	Adoption			Duration practiced			
CSA TMPs	%	First-time	Regular	Min.	Max.	Mean	S.D.
Conservation agriculture	93.4	112(39.3)	173(60.7)	1	15	1.49	1.955
Cover Cropping	100	63(20.7)	242(79.3)	1	20	4.93	4.021
Potato variety	94.8	136(47.1)	153(52.9)	1	25	3.70	4.788
Soil management	95.7	129(44.2)	163(55.8)	1	30	5.37	7.398
Water management	49.2	30(20.0)	120(80.0)	1	29	9.13	8.333
Nutrient management	100	80(26.2)	225(73.8)	0.5	30	5.71	7.5245
Pest control	100	28(9.2)	277(90.8)	1	30	5.92	7.562
Disease control	87.9	36(13.4)	232(86.6)	0.5	30	6.61	7.9179

(3.7 years), soil management practices (5.37 years), water management practices (9.13 years), nutrient management practice (5.71 years), pest control management practices (5.92 years) and disease control management practices (6.61 years). The specific form of CSA TMPs that were implemented by the respondents are summarized in Table III.

Crop rotations or sequencing/associations of crops was the most adopted conservation agricultural practice among the respondents (Table II). About 97.9% of the farmers practiced crop rotations or sequencing/associations. Those who practiced minimal mechanical soil disturbance (zero-tillage and direct seeding) and mulching (for soil cover and nutrient enhancement) comprised 31.2% and 32.3%, respectively. The most popular cover cropping practices among the sampled farmers included growing of leguminous cover crops (70.2%) and vegetative cover between successive agricultural crops (75.7%).

The results in Table II show that all the farmers who had adopted potato variety CSA TMPs were growing high yielding (100.0%) and fast maturing (100.0%) potato varieties. About 62.3% of the farmers who practiced varieties CSA TMPs potato that were resistant to draught while those who grew varieties that were resistance to salinity and flooding comprised 52.2% and 43.3%, respectively. The most popular soil management practices among the respondent farmers were fertilizer and manure application. About 95.7% and 94.8% of the farmers used fertilizer and manure in their potato farming, respectively. It was just 9.5% of the farmers who tested their soils. The most implemented water management practice among the farmers was on-farm water harvesting as practiced by 40.0% of the total farmers. Other water management practices were implemented by very few farmers as follows: Solar pumping system (4.3%), drip irrigation (4.6%) and others (2.6%). Some of the farmers implemented nutrient management practices in their potato farming enterprises as summarized in Table III. Most farmers had applied fertilizer to their potatoes as a nutrient management practice as represented by 42.0% of the total responses. About 21.6% and 8.2% of the farmers used manure and soil testing for nutrient management in their potato farming, respectively.

The most implemented pest control management practices among the sampled farmers included regular monitoring of crop (65.9%) and application of insecticides when necessary (59.7%). Other farmers also grew varieties of crops that were resistant to pests (37.4%). About 15.4% of the farmers implemented other pest control management practices.

Majority of the farmers who had adopted disease control management practices had embraced disease resistant varieties and correct spacing (not too close together so that to limit the sunshine and air that reaches the leaves, and allows diseases to thrive) as represented by 38.0% and 28.9% of the total responses, respectively. Some of the other disease control management practices implemented by the farmers included planting at the right time (18.4%) and maintaining healthy soil to support friendly insects and helps prevent plant diseases (8.9%).

TABLE III - SPECIFIC FORM OF CSA TMPs THAT WERE IMPLEMENTED BY THE RESPONDENTS

CSA TMPs	Description	Freq.	Percent
Conservation agricultural	Minimal mechanical soil disturbance (zero-tillage, direct seeding)	89	31.2
	Mulching (for soil cover and nutrient enhancement)	92	32.3
	Crop rotations/sequencing/associations (for nitrogen-fixation)	279	97.9
Cover cropping	Growing leguminous cover crops	214	70.2
	Growing vegetative cover between successive crops	231	75.7
Potato variety	Resistance to drought	180	62.3
	Resistance to salinity	151	52.2
	Resistance to flooding	125	43.3
	High yielding	289	100
	Fast maturing	289	100
	Disease resistant	167	57.8
Soil management	Soil Testing	79	9.5
	Fertilizer application	292	95.7
	Manure application	289	94.8
Water management	Solar pumping system	13	4.3
	Drip irrigation	14	4.6
	On Farm Water Harvesting	122	40.0
	Other water management practice	8	2.6
Nutrient management	Soil Testing for nutrient management	86	28.2
	Fertilizer application for nutrient management	305	100
	Manure application for nutrient management	305	100
	Others nutrient management practices	62	20.3
Pest control	Regular monitoring of crop	201	65.9
	Application of insecticides when necessary	182	59.7
	Growing varieties of crops which are resistant to pests	114	37.4
	Other pest control management	47	15.4
Disease control	Maintaining healthy soil - friendly insects to prevent diseases	27	8.9
	Planting resistant varieties	116	38.0
	Spacing plants correctly with an aim of disease control	88	28.9
	Planting at the right times	56	18.4
	Other disease control management practices	19	6.2

The description of the independent variables (socio-economic and institutional factors) that could influence the uptake and the extent of application of climate-smart agricultural TMPs among smallholder potato farmers is summarized in Table IV.

TABLE IV - SOCIO-ECONOMIC AND INSTITUTIONAL FACTORS THAT INFLUENCE THE UPTAKE AND THE EXTENT OF APPLICATION OF CLIMATE-SMART AGRICULTURAL TMPS AMONG SMALLHOLDER POTATO FARMERS (n=305)

Variable	Min.	Max.	Mean	Std. Dev.
Age of the household head in years	25	68	40.85	9.05
Sex of the household head (1=male; 0=female)	0	1	.623	.49
Years of schooling of household head	0	16	11.66	3.06
Number of people in households(persons)	1	7	4.42	1.66
Farm income earned (in KES. per annum)	12,000	300,000	115,681.97	6,572.24
Non/off-farm income (in KES. per annum)	1,000	800,000	73,601.01	12,551.08
Group membership (1=yes 0=no)	0	1	.282	.451
Distance from the main market (in Km)	.2	20.0	5.177	0.25
Receipt of credit in the last 1 year (1=yes 0=no)	0	1	.049	.217
Number of extension contacts in the last 1 year	0	5	.55	.056
Receipt of training - last 1 year (1=yes, 0=no)	0	1	.315	.465
Years of experience in potato production (years)	1	30	7.44	1.60
Total land holding (acres)	.25	5.00	1.27	.82

The results in Table IV show that an average potato farmer was aged 40.85 years. The youngest farmer was aged 25 years while the oldest was 68 years. Majority of the farmers were male as represented by 62.3% of the total responses. The female farmers in this study comprised only 37.7%. The mean years of schooling of the sampled farmers was 11.66 years.

An average farmer in this study had households size of 5 members. An average farmer in this study earned on-farm income of approximately KES. 115,681.97 per annum (the lowest and the highest on-farm income was KES. 12,000.00 and KES. 300,000.00, respectively. The mean non/off-farm income from the sampled farmer in this study was KES. 73,601.01 per annum (the lowest and the highest non/off- farm income was KES. 1,000.00 and KES. 800,000.00, respectively. The percentage of farmers with at least one member of their household belonging to an organization was 28.2% for the overall sample.

The average distance of the sampled farmers to the nearest market centre was 5.18 kilometres (with a standard deviation of 0.25 kilometres). The minimum and the maximum distance to the nearest market centre was 0.2 kilometres and 20 kilometres, respectively. Most of the farmers did not access credit for agricultural purposes (95.1%) as only 4.9% of the farmers had access to credit.

The average number of times that farmers accessed extension services that was relevant to potato farming within the last 12 months was 0.55 times with a standard deviation of .056. Actually, most farmers in this study did not access extension services. Majority of the farmers had not received any training on potato farming in the last 12 months (68.5%). The few farmers (31.5%) who had received training that was related to potato farming indicated to have covered topics on crop husbandry, integrated soil and nutrient management, access to agricultural information, pests and diseases control and improved crop varieties. The mean years of experience in potato farming among the respondent farmers was 7.44 years with a standard deviation of 1.60 years. The average acreage under potato farming among the study respondents was 1.27 acres with a standard deviation of 0.82 acres. The least and the maximum acreage were 0.25 and 5.0 acres, respectively.

Multivariate Tobit Regression modelling

Multivariate Tobit Regression model was used in analysing the factors that influence the uptake and extent of application of climate-smart agricultural TMPs among smallholder potato farmers.

Diagnostic tests for Multivariate Tobit Regression analysis

Multivariate Tobit Regression modelling took the form of multiple regression since the independent variables were more than one. In any multiple regression, all independent variables are entered at once in the regression model/equation and every independent variable is assessed for its unique predictability of the dependent variable.

Before the estimation of the determinants of uptake and extent of application of climate-smart agricultural TMPs among smallholder potato farmers was carried out, some validity tests/checks of the data were undertaken to ensure that the model results were plausible. These included multicollinearity test, heteroscedasticity test, serial correlation test and test for omitted variables bias.

Multivariate Tobit Regression analysis for the influence of selected factors on the uptake and the extent of application of CSA TMPs

The results of running Multi-Variate Tobit (MVT) regression for the uptake and extent of application of climate-smart agricultural TMPs on the set of the independent variables selected for this study is displayed in Table V.

The calculated Wald Chi-square (72.578) is statistically significant (P= 0.0125) indicating that the independent variables used in this model jointly provide plausible explanation for the differences in uptake and extent of application of climate-smart agricultural TMPs among smallholder potato farmers.

The coefficients of age of the household head were positive and statistically significant in agronomic practices and integrated pest and disease management regressions but not statistically significant for crop varieties and integrated soil, water and nutrient management. This imply that older farmers are more likely to practice agronomic practices and integrated pest and disease management CSA TMPs but there is no statistically significant difference in the extent of application of crop varieties and integrated soil, water and nutrient management between old and young farmers. Older farmers may be more experienced with regard to production technologies and may have accumulated more physical and social capital to afford implementation of various CSA TMPs.

Older farmers are likely to have been exposed to climate smart agricultural technologies, accrued more assets, and established wide social networks, and hence are more likely to adopt technologies. These findings, concurs with the assumption that older people with time, accumulate wealth, experience and resources, and are more likely to adopt the climate smart practices (Deressa *et al.*, 2011). The results are however inconsistent with argument that young people tend to be more educated, open minded and more likely to understand the advantages associated

TABLE V - MULTIVARIATE TOBIT REGRESSION ANALYSIS

Variables	Agronomic practices	Crop varieties	Integrated SWN	Integrated PDC
Age	0.058(0.01)***	0.001(0.012)	0.002(0.008)	0.037(0.013)***
Sex	0.01(0.161)	0.146(0.2)	0.166(0.127)	0.732(0.195)***
Education (years)	0.011(0.023)	0.016(0.028)	0.042(0.019)**	0.072(0.028)**
Household size	-0.088(0.046)*	0.058(0.057)	-0.099(0.036) ***	-0.039(0.056)
Socio-economic status (Farm income)	0.001(0.017)	0.001(0.000)***	0.001(0.052)	0.001(0.000)***
Non-farm income	0.001(0.000)**	0.001(0.000)***	0.001(0.000)	0.001(0.000)***
Group membership	0.147(0.027)***	1.198(0.289)***	1.118(0.183)***	0.492(0.283)*
Input market distance	-0.205(0.234)	-0.135(0.033)***	0.024(0.021)	0.053(0.033)
Access to credit	0.067(0.379)	-0.047(0.47)	1.444(0.47)***	-0.17(0.301)
Number of extension contacts	0.413(0.181)**	0.536(0.127)***	0.255(0.08)***	0.168(0.063)***
Farming experience (years)	0.024(0.015)	0.112(0.015)***	0.141(0.012)***	0.014(0.01)
Land size	0.369(0.051)***	0.161(0.124)	0.121(0.041)***	0.061(0.063)
_cons	4.561(0.577)***	2.984(0.711)***	4.838(0.459)***	4.768(0.726)***

Note: Wald chi2 (48) = 72.578; P = 0.0125 with innovations and therefore more likely to adopt the technologies (Murage *et al*., 2013). The results of this study were also contrary to other studies (Howley *et al*., 2012; Okuthe *et al*., 2013) that had shown negative correlation between age and adoption of technologies, where old people were considered to be conservative, less flexible and highly sceptical. These finding was attributed to lack of interest in farming on the part of youths, partly due to lack of access to land and lack of knowledge of climate smart agricultural practices as compared to the old. However, old age is also associated with loss of energy, risk aversion, and short-term investment planning (Kassie *et al*., 2013; Asfaw *et al*., 2014). Youths are more likely to adopt new technologies because of their ability to access more information using the internet.

Contrary, Ali and Erenstein (2017) noted that old age had a negative relationship with adoption of climate change adaptation strategies, explaining that agriculture is a labour intensive venture which requires healthy, risk-bearing and energetic farmers. Again, older farmers may not be aware of recent innovations.

These results also agree with Findji and Howland (2019) who found that the proportion of farmers adopting selected CSA practices was higher for the older larger-scale than middle aged farmers. Similarly, Mogaka *et al*. (2021) found that age had a positive and significant effect on the adoption of climate-smart soil practices. According to Mogaka *et al*. (2021), for every one more year increase in farmers' age, the probability of implementing climate smart agronomic practices increased by 48% - in fact as farmers grew older, their preference for climate smart agricultural practices that could rehabilitate and protect their soils increased.

The results also agree with Tanti *et al*. (2022) who found age having a positive relationship with adoption of crop rotation (however, beyond a certain age, the likelihood of adoption decreased). According to Tanti *et al*. (2022) age was insignificant for the adoption draught resistant seeds CSA technology, just like in this study.

The coefficient of sex of the household head was positive and statistically significant in integrated pest and disease control management regression but not statistically significant for agronomic practices, crop varieties and integrated soil, water and nutrient management regression. This implies that male headed households are more likely to practice integrated pest and disease control management CSA TMP than their female counterparts. The gender differences in the adoption of climate smart agricultural practices could be attributed to variance in socioeconomic status and exclusion patterns against women. There is also skewed and limited access to extension services and information, particularly on the part of women. These results agree with Mogaka *et al.* (2021) who found that gender of the household head was significantly correlated to the choice of climate smart agricultural practices among farmers with male household head having a higher probability of choosing intercropping (by 15%) and liming (by 11%) compared to their female counterparts. These results are also supported by Okuthe *et al*. (2013) who found out that men were more likely to adopt agricultural technologies than women because of skewed dissemination of information in favour of men.

The coefficients of years of education of the household head were positive and statistically significant in integrated soil, water and nutrient management and integrated pest and disease management regressions but not statistically significant for agronomic practices and crop varieties regressions. This implies that integrated soil, water and nutrient management and integrated pest and disease management CSA TMPs were practiced more by farmers with more years of education than those with less years of education. More educated farmers are more likely to engage in off-farm activities, and reduce their participation in CSA TMPs that are more involving and labour intensive (such as climate smart agronomic practices). Similarly, more educated farmers are more likely to invest in CSA TMPs with higher returns on labour, and will only invest in technologies if they offer better returns. On the other hand, educated farmers have a better ability to understand the benefits of CSA, and this may foster adoption (Kurgat *et al*., 2020). Additionally, education increases one's ability to understand and evaluate the information about new technologies. It also influences the attitude and acceptability of information in such way that educated people tend to be open minded, rational and able to assess and compare the advantages and disadvantages of technologies and innovations. The results of this study agree with Wamalwa (2017), who found that education level has significant influence on adoption of technologies/innovations related to climate change adaptations such as growing of high yielding varieties (Weir & Knight, 2000). These results were also consistent with findings of various studies (Jones *et* *al*., 2010; Frank & Penrose, 2012) that clearly affirmed education as having significant influence on adoption of climate smart agricultural practices. These results also agree with Mogaka *et al*. (2021) who found that education level positively influenced of the choice of climate smart soil practices among farmers. In their findings, a one-year change in the level of education by a farmer increases the probability of choosing organic fertilizer use and soil liming. These results however disagree with Tanti *et al*. (2022) who found that education was negatively associated with agronomic CSA TMPs (crop rotation). Similarly, Birir (2020) noted that education was positively correlated with the adoption of crop varieties CSA TMPs – more educated individuals were more able to adopt crop varieties CSA TMPs (high yielding crop varieties) with ease. According to this study, crop varieties CSA TMPs was not significantly influenced by level of education.

The coefficients of farm income were positive and statistically significant in crop varieties and integrated pest and disease management regressions but not statistically significant for agronomic practices and integrated soil, water and nutrient management regressions. This implies that crop varieties and integrated pest and disease management CSA TMPs were practiced more by farmers with more incomes from their farming activities than those with less income. This may be because as farmers get more revenue from their farms, they always think of increasing production, and an increase in farmland results in greater number of CSAPs that a farmer can adopt. The findings of this study are consistent with Waaswa *et al.* (2021) who in their bid to understand the socioeconomic determinants of adoption of climate-smart agricultural practices among smallholder potato farmers in Gilgil Sub-County, Kenya found that the non-adoption of climate smart seed varieties (potato seedlings and mini-tubers) by farmers with low farm income can be explained by the high cost of acquiring and establishing these climate smart agricultural practices. The findings were also in consonant with Wamalwa (2017), who found that the more the income a farmer earned (from both farm and off-farm work), the more was their ability to respond to environmental variations through adoption of innovations and technologies including climate smart practices. According to Jones *et al*. (2010), farm income enables farmers to buy inputs, innovate in the face risks, and support long term sustainable adaptation. They further argued that adoption of innovations or technologies involved substantial capital requirement that depended on income level. These results also concurred with Watsula (2000), who found out that farm income had positive impact on adoption of disease control measures among farmers.

The coefficients of non-farm income were positive and statistically significant in agronomic practices, crop varieties and integrated pest and disease management regressions but not statistically significant for integrated soil, water and nutrient management regressions. This implies that agronomic practices, crop varieties and integrated pest and disease management CSA TMPs were practiced more by farmers with more incomes from non-farm activities than those with less. The high adoption of CSA TMPs by the farmers with non-farm income could be due to the high-cost implication in their implementation. More educated farmers are more likely to engage in off-farm activities. According to Awotide *et al*. (2016), income-constrained farmers are not able to adopt various farm technologies including CSA TMPs. The higher adoption of numerous CSAPs by farmers with off-farm income can be attributed to their ability to meet the associated costs (Zakaria *et al*., 2020). Mujeyi *et al*. (2020) asserted that farmers with high off-farm income were inclined to embrace CSAPs and other climate change adaptation strategies than their counterparts. Another study by Gedikoglu & Parcel (2013) on impact of off-farm income on adoption of agricultural technologies in United States of America similarly, revealed a positive relationship.

The coefficients of group membership were positive and statistically significant in agronomic practices, crop varieties, integrated soil, water and nutrient management and integrated pest and disease management regressions. This implies that group membership increases farmers practice of the selected CSA TMPs. In their investigation on the role of institutional factors in climate-smart technology adoption in agriculture (evidence from an Eastern Indian state), Tanti *et al*. (2022) found that the estimated coefficients of the social capital variables, such as membership in the self-help group, were statistically significant and increased the probability of adoption of climate smart agricultural practices (crop rotation adoption increased by 10% while crop diversification increased by 17% as a result of group membership). This study also agrees with Birir (2020) who found that group membership positively affected the adoption of CSA practices.

The coefficient of farmers' distance to the nearest input market was negative and statistically significant in crop varieties regression but not statistically significant for agronomic practices, integrated soil, water and nutrient management and integrated pest and disease management regressions. This implies that greater distance to the input market centres hinders farmers practice of crop varieties CSA TMP (ability to acquire seed varieties that are resistant to pest/diseases, drought, salinity and flooding). These results agree with Tanti *et al*. (2022) who found that longer distance to the market discourages the adoption of most CSA practices with households that were near an input market having an advantage in adoption of key climate smart agricultural practices.

The coefficient of farmers' access to credit was positive and statistically significant in integrated soil, water and nutrient management regression but not statistically significant for agronomic practices, crop varieties and integrated pest and disease management regressions. This implies that access to credit enhances farmers' practice of integrated soil, water and nutrient management CSA TMP. The influence of credit on adoption of CSA TMPs is due to heavy capital outlay required in the implementation process. The lack of influence of access to credit on adoption of agronomic practices, crop varieties and integrated pest and disease management may be attributed to low access and uptake of credit among majority of farmers in the study area. The finding of Tanti *et al*. (2022), disagree with the results of this study by showing that access to formal credit did not influence the adoption of CSA practices because financial institutions provide credit based on the size of the landholdings and therefore failed to influence CSA adoption at smallholder farming level. This study agrees with Bryan *et al*. (2009) who found that one of the main barriers to adaptation against climate change and practice of climate smart agriculture, as cited by farmers in South Africa and Ethiopia was lack of access to credit. In their analysis of options and constraints of adaptation to climate change, Bryan *et al*. (2009) found that practice of CSA TMPs would be enhanced if farmers could access credit. According to Oduniyi *et al*. (2022), access to credit enhances the resource base of farmers, hence improving their ability to invest in technologies on the farm, which may be costly beyond their capability.

The coefficients of number of extension contacts were positive and statistically significant in agronomic practices, crop varieties, integrated soil, water and nutrient management and integrated pest and disease management regressions. This implies that greater frequency of extension contacts enhances farmers practice of the selected CSA TMPs. These results agree with Tanti *et al*. (2022) who found that access to government extension services positively and significantly determined the adoption of CSA practices. With greater access to extension services, farmers likelihood of adopting crop diversification, crop rotation, and drought-resistant seeds increased by 11%, 14%, and 28%, respectively (Tanti *et al*., 2022). Additionally, agricultural training and demonstrations from the extension department positively enhanced the adoption of crop diversification and micro-irrigation adoption by 14% and 12%, respectively (Tanti *et al*., 2022). These study findings are also in line with other studies that observed a positive impact of extension service on CSA adoption (Aryal *et al*., 2021; Abid *et al.*, 2015; Bryan *et al*., 2009; Khan *et al.*, 2020).

The coefficients of farming experience were positive and statistically significant in crop varieties and integrated soil, water and nutrient management regressions but not statistically significant for agronomic practices and integrated pest and disease management regressions. This implies that greater farming experience enhances the extent of practice of crop varieties and integrated soil, water and nutrient management CSA TMPs. Farming experience is linked to more information in terms of farming technologies (Rogers, 2003). These results disagree with Mogaka *et al.* (2021) who found that farming experience had a negative and significant influence on the choice of climate smart soil practices among farmers -in their results, a unit increase in the years of farming experience decreases the probability of choosing agroforestry and organic manure (equally by 18%). The results also disagree with Tanti *et al.* (2022) who found that years of farming experience was negatively associated with agronomic practices CSA TMP (crop rotation) and the use of crop varieties CSA TMPs (drought-resistant seeds), mainly because older farmers were conservative and wanted to continue with traditional practices. According to Tanti *et al.* (2022), farmers who were new to farming were more likely to use drought-resistant seeds and practice crop rotation than their experienced counterparts. These results are also not consistent with Wamalwa (2017), who found that more experienced farmers (partly due to age) lacked ability to adopt new technologies and management practices in crop farming. These findings were also inconsistent with those of Okuthe *et al*. (2013) who found no relationship between farming experience and adoption of integrated natural resource management technologies in Ndhiwa Sub County, Kenya.

The coefficients of land size were positive and statistically significant in agronomic practices and integrated soil, water and nutrient management regressions but not statistically significant for crop varieties and integrated pest and disease management regressions. This implies that greater land size enhances the extent of practice of agronomic practices and integrated soil, water and nutrient management CSA TMPs due to advantages of economies of scale and likelihood of implementing commercial farming. The finding of Mogaka *et al*. (2021), corroborates with the results of this study showing that farmers with large farm sizes were more likely to adopt integrated soil, water and nutrient management CSA TMPs. According to Mogaka (2021), farmers with large farm sizes were more likely to choose inorganic fertilizer than those with smaller farm sizes. For every additional acre of farm size, the probability of farmers choosing inorganic fertilizer as their choice of climate smart soil practice increased by 23%. These results also agree with Tanti *et al.* (2022) who found that land size positively influenced the adoption of crop varieties CSA TMPs (drought-resistant seeds) as farmers with large land size were more dependent on agriculture and at the same time had the capacity to invest in the practices. These findings were also in agreement with Parwada *et al*. (2010), who indicated that large scale farmers were always on the forefront in adoption of new technologies such as climate smart agronomic practices and integrated soil, water and nutrient management. However, in some cases farm size had been shown to be negatively associated with adoption of innovations. This is often due to shift to intensive practices that efficiently utilize the scarce land resources and increase productivity, where the option of increasing production by expansion of land does not exist (Deressa *et al.*, 2009).

CONCLUSION AND RECOMMENDATIONS

Most farmers have adopted majority of the CSA TMPs under investigation. The uptake and extent of application of climate-smart agricultural TMPs (agronomic practices; crop varieties; integrated soil, water and nutrient management; integrated pest and disease control) in Kenya is influenced by several factors. Older farmers and those with more household members are more likely to adopt climate smart agronomic practices. Some of additional enabling factors that enhance adoption of climate smart agronomic practices include greater extension contacts, non-farm income and land size. Households with more farm and non-farm income as well as those with members belonging to groups are more likely to adopt crop varieties CSA TMPs. More experienced potato farmers with greater access to input market as well as those with access to extension services also increase their chances of greater application of crop varieties CSA TMPs. Most of the farmer who practice integrated soil, water and nutrient management CSA TMPs are those with more years of education, large household sizes, belonging to groups and having access to credit and extension services. Having more years of farming experience and more land also enhances the practice of integrated soil, water and nutrient management. Some of the enabling factors for uptake and application of integrated pest and disease control in potato farming include more years of education, access to extension services, income (farm and non-farm) and group membership. Male farmers and those who are older are also advantaged in the uptake and application of integrated pest and disease control.

Farmers should be trained in order to enhance their adoption of climate smart agricultural practices. Training is key in compensating for lack of adequate skills in farming activities. Training can be realized through extension programmes and information dissemination through social media among other platforms. Owing to cost implication involved in climate smart agronomic practices, farmers should be supported on how to access the needed capital through well-structured loan facilities. There is need of linking farmers to reliable market for them to realize optimal incomes from their farming activities. Farmers groups should be supported and strengthened. Labour saving technologies should be promoted alongside climate smart agricultural TMPs because of their complementarity relationships. Gender empowerment initiatives are required in order to support women who are mostly disadvantaged in their involvement in climate smart agriculture due to array of factors (social, economic and cultural).

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