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EFFECTS OF FARMERS' PERCEIVED CHARACTERISTICS ON ADOPTION OF CLIMATE-SMART AGRICULTURE TECHNOLOGY IN THE WEST USAMBARA MOUNTAINS TANZANIA

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Abstract

The adverse impacts of climate change are currently vivid in smallholder agriculture particularly cereal crops such as maize in the West Usambara Mountains Tanzania. For the past 10 years, Climate Change Agriculture and Food Security (CCAFS) project disseminated and promoted to smallholder farmers improved maize seed technology so that they can adopt it as adaptation strategy to climate change in agriculture. This study assessed effects of farmers' perceived characteristics on adoption of improved maize seed technology in adapting to climate change in CCAFS project areas in the West Usambara Mountains. A cross-sectional survey was used to collect quantitative data by using structured questionnaire from randomly selected 124 households from Yamba and Boheloi in Gare ward. Data analysis was conducted by using SPSS version 16 to generate descriptive statistics such as frequencies, percent, means and standard deviations, and inferential statistics through binary logistic regression. The findings show that there was moderate level of adoption (57%) of improved maize seed technology in CCAFS project area. There were positive effects of perceived relative advantage ($\beta 1=2.84$; $p=0.01$), trial ability ($\beta 4=3.07$, $p=0.001$) and observability ($\beta 5=2.82$; $p=0.001$) on farmers' adoption of improved maize seed technology in the study area. Farmers' perception towards complexity ($\beta 3= -2.59$; $p=0.001$) had negative effect on adoption of improved maize seed technology. This study recommends that government and agriculture sector stakeholders should work on enhancing agricultural extension and education services so that many farmers can have adequate information and knowledge regarding importance of using improved maize seeds for climate change adaption in the West Usambara Mountains.

Keywords: *Improved technology, Adoption, Climate change, Adaptation*

INTRODUCTION

The global increase in temperature above the average is projected to reach 1.5°C above pre-industrial level by 2030 and will increase further 2°C by 2052 if carbon emissions continue to increase at a higher rate (IPCC, 2008). Climate change is expected to bring more adverse impact on food security in developing countries particularly the Sub-Saharan Africa where agriculture is dominated by smallholder farmers who highly depend on rainfall (Barrios et al., 2008; Ziervogel et al., 2008). Statistically significant differences in temperature and precipitations and other climatic parameters extended for a decade or longer justify occurrence in climate change. It is characterised by slow rise in global mean temperature in a continuous pattern while shifting magnitude of sporadic weather extremes and frequencies (IPCC, 2014). Production of maize and other cereal crops will continue declining due to unpredictable rains, loss of land fertility and climate extremes such as floods and droughts (IPCC, 2014).

In sub-Saharan Africa, cereal crops such as maize, wheat and rice are the main food and commercial crops. Maize, wheat and rice generate approximately 30% of the calories to 4.5 billion people in Tanzania and other many developing countries (Hellin et al., 2012). The global maize production will going to decline by three to ten percent by 2050 if global mean temperature will continue increasing at a higher rate (IPCC, 2014). The adverse impact of climate change in cereal crop production will trigger the demand of food for a rapid growing population in developing countries like Tanzania (IPCC, 2014). Research on cereals such as maize and wheat is essential to assist designing and implementing climate resilient strategies particularly in developing countries relying on agrarian economy (Hellin et al., 2012). In order to address climate change impacts, farmers are required to use improved varieties of cereal crops which have ability to tolerance high temperature, drought and pests and diseases (IPCC, 2014; Shuaibu et al., 2014).

In Tanzania, agriculture is a backbone of the nation's economy as it contributes about 24.1% of GDP, 30% of export earnings and employs about 77.5% of Tanzanians (URT, 2013). However, still, small scale agriculture is mostly depending on rainfall to support crop production (Patt & Winkler, 2007). Maize is the most important staple food crop grown in Tanzania compared to other crops such as paddy, wheat, millet and sorghum. Climate models for Tanzania predict about 33% decline in average maize yields with a wide variation between 10% to 84% across the country by 2030 (URT, 2007). Continuous decline in maize production will adversely affect households with low adaptive capacity to climate change (Arslan et al., 2016).

Like other region in Tanzania, the West Usambara Mountains has affected by adverse climate impacts in agriculture and natural resources management (Minderhoud, 2011; Mumbi et al., 2014). AFRICAP (Agricultural and Food Systems' Resilience: Increasing Capacity and Advising Policy) which is a UK's climate-smart agricultural development initiative, and CGIAR (Consultative Group for International Agricultural Research) Research program based in Copenhagen have been implementing CCAFS (Climate Change Agriculture and Food Security) project in collaboration with ARI-Serian (Agricultural Research Institute based in Serian Arusha Tanzania) and Lushoto District Council. The aim of the project was to enhance agricultural resilience to climate change in the West Usambara Mountains Tanzania. The CCAFS project involved other stakeholders including seed companies such as Seed Co. and Pannar, researchers, agricultural extension workers and local government leaders to disseminate and promote climate-smart agriculture technologies such as improved maize seed varieties so as to enhance climate change adaptation and food security in the West Usambara Mountains. The project used extension workers, farmer trainers, demonstration plots and farmer field schools to promote adoption of improved maize seed varieties and other climate-smart agricultural technologies in order to help farmers increase crop yields and rise household income to overcome adverse climate change impacts.

Although there are on-going strategies regarding promotion of improved maize seed technology to farmers, still, there is uncertainty about influence of farmers' perception on adoption of improved maize seed technology for climate change adaptation and livelihood enhancement in CCAFS project areas in the West Usambara Mountains. The empirical studies which have been conducted in the study area have left unexplained the effects of farmers' perceived characteristics on adoption of improved maize seed technology as climate adaptive response

(Mumbi et al., 2014; Radeny et al., 2018; Rukanda, 2014). This study assessed the effects of farmers' perceived characteristics on adoption of improved maize seed technology for climate change adaptation in CCAFS project areas in the West Usambara Mountains. The outputs of this research may assist planning and review policies and strategies related to climate change adaptation in smallholder agriculture in CCAFS project area and West Usambara Mountains Tanzania as a whole.

LITERATURE REVIEW

Diffusion of Innovation Theory

The Diffusion of innovation Theory is most applicable in development sectors including social development, agriculture, health and environment conservation (Rogers, 2003). In this study, technology and innovation have used interchangeably as instrumental design which reduces uncertainty in achieving expected outcome. Improved maize seeds stand for an improved technology produced and supplied by a certified seed company and institution. The technology was disseminated and promoted to smallholder farmers in areas affected by adverse climate change impacts in the West Usambara Mountains particularly the CCAFS project area in Lushoto District Tanzania. According to Rogers, adoption is a decision of full use of technology as an available best course of action and rejection is a decision of not to adopt technology (Rogers, 2003). In order for an innovation to be used, it should be communicated over time among the members of particular society (Rogers, 2003).

The diffusion of innovation is a certainty reduction process which can be influenced by five attributes of the innovation including relative advantage, compatibility, complexity, trial ability and observability (Rogers, 2003). According to this theory, perception of individuals regarding these attributes predicts the rate of adoption of innovation. Hence, this study assessed farmers' perceptions regarding the characteristics of improved maize seed technology as a prediction of farmers' adaptive response to climate change in the West Usambara Mountains particularly in CCAFS project area. By adapting diffusion of innovation theory, this study assumes that there might be higher adoption of improved maize seed technology only if the disseminated technology has demonstrated relative advantage, simplicity, compatibility, trial ability and observability to smallholder farmers in the West Usambara Mountains.

Importance of Improved maize seed technology as an adaptation strategy to climate change

Technological advancement of maize seed production has developed climate tolerant maize varieties by using climate-adapted germplasm. This is done by generation of germplasm which is climate resilient through combination of conventional, molecular and transgenic breeding mechanisms. The application of proven pest and disease and drought resistant breeding mechanisms has contributed in increasing maize production in drought experienced regions (Bänziger et al., 2006). For instance, hybrids of maize produced by the International Wheat and Maize Improvement Center (CIMMYT) have proven to be very tolerant to climate stress by producing more 20% compared to other commercially available hybrids (Bänziger et al., 2006). However, more development of germplasm of maize is required to increase further the yield gains as a way of reducing potentially negative effects of climate change in maize production.

On-going innovation on molecular breeding and phenotyping provides important technological mechanisms of germplasm development for climate resilience in agriculture (Cabrera-Bosquet et al., 2012). In maize seed technology, donors with higher drought tolerance have been identified and being incorporated into the breeding process. Moreover, alleles which are novel and resistant to drought, heat and water logging, and stress combinations have also identified as the latest technology in genome sequencing. Hence, these developments of germplasm for maize seeds which are climate resilient should speed up to assure food security and enhanced climate change adaptation (Cabrera-Bosquet et al., 2012; Arslan et al., 2016). In particular, development of improved maize seed technology is very essential to smallholder farmers depending on agrarian economy in the West Usambara Mountains and elsewhere in Tanzania.

Historically, before liberalization of trade in 1980s, improved maize seeds were produced, distributed and sold by a state owned seed company known as Tanzania Seed Company (Tanseed) which had the monopoly over seed industry (Lymo et al., 2014). Since the evolution in trade liberalization, multinational seed companies and non-governmental organizations are actively involving in the production, distribution and selling of maize seeds. These private maize seed producers are such as Pannar Company from South Africa, Kenya Seed Company, Seed Co. from Zimbabwe and IFAD. Now, Tanseed, government agricultural research institutions, companies and non-governmental organizations are producing hybrid maize seeds which comply with specific agro-ecological zones in Tanzania in the context of climate change. Some examples of hybrid maize seeds which are produced, distributed and sold to farmers in Tanzania include PAN 6544 and PAN 695 produced by Pannar Seed Company, H513 by Kenya Seed and CG 414 by CIBA-GEIGY (Lymo et al., 2014). This study assessed the effects of perceived characteristics of improved maize seed technology on farmers' adoption of the technology as climate adaptive response in CCAFS project area in the West Usambara Mountains in Tanzania.

MATERIALS AND METHODS

The study was conducted in Gare ward of Lushoto District in the West Usambara Mountains Tanzania where CCFAS project for enhancing climate resilience in farming systems has implemented from 2010 to 2019. A cross-sectional quantitative survey was used to collect data through semi-structure questionnaire. Based on agro-ecological zones, purposive sampling was used to select Yamba village from humid cold zone and Boheloi villages from humid warm zone. Simple random sampling was used to select Mshaghasho hamlet from 11 hamlets of Boheloi village and Yamba hamlet from 8 hamlets of Yamba village. The total number of farming households from the two surveyed hamlets was 179. The calculation of sample size of households was done by using Slovin's formula as follows:

$$n = \frac{N}{1 + Ne^2} = \frac{179}{1 + 179(0.05)^2} = 124$$

Where; n = minimum sample size; N = survey population; e = standard error at 95% confidence level. From the calculated sample size of 124 households, stratified random sampling was used to choose farming households constituted the study sample from each hamlet (Table 1). During survey, each household was represented by an adult member as respondent, and hence, Boheloi village was represented by 61 respondents from Mshaghasho hamlet and Yamba village was represented by 63 respondents from Yamba hamlet in a sample size of 124 as shown in Table 1. Structured questionnaire constructed from close open and close ended questions was used an instrument of data collection. Data analysis was done through SPSS version 16 by using binary logistic regression to examine the effects of perceived relative advantage, compatibility, complexity, trial ability and observability on farmers' adoption of improved maize seed technology.

Table 1: Stratified sampling of farming households in selected CCAFS project villages of Gare ward

NAME OF VILLAGE	NAME OF HAMLET	SURVEY POPULATION	SAMPLE SIZE
Boheloi village (located in humid warm zone)	Mshaghasho	88	61
Yamba village (located in humid cold zone)	Yamba	91	63
TOTAL		**179**	**124**

The logistic regression model for data analysis is shown below.

$$\frac{p}{1-p} = \frac{odds}{1-odds} = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \varepsilon i$$

Whereby; p = odds= probability for a farmer to adopt improved maize seed technology, β0= constant term, β1 to β5 = coefficients of X1 to X5, X1=relative advantage, X2=compatibility, X3=complexity, X4=trial ability, X5=observability and εi = error term.

RESULTS AND DISCUSSION

Demographic characteristics of respondents

The study surveyed demographic characteristics of respondents including sex, age, household size, marital status and maize farming experience. The study found that 65% of participants comprised of males while 35% were females (Table 2). Marital status of respondents revealed that most of participants were married (73.4%) while others were single and widows.

Table 2: Demographic characteristics of survey respondents

VARIABLE	NUMBER OF RESPONDENTS	PERCENT
SEX		
Male	80	65%
Female	43	35%
MARITAL STATUS		
Married	91	73.4%
Single	18	14.5%
Widow	15	12.1%

Based on education level, majority of respondents had primary education (75%) (Table 3). Other respondents never attended school (17.8%) and a few had post primary education (7.2%).

Table 3: Household size and education level of respondents

VARIABLE	NUMBER OF RESPONDENTS	PERCENT
EDUCATION		
Never attend school	22	17.8%
Primary education	93	75%
Other	9	7.2%
HOUSEHOLD SIZE		
1-5	56	45.2%
6-10	61	49.2%
Above 10	7	5.6%
MARITAL STATUS		
Married	91	73.4%
Single	18	14.5%
Other	15	12.1%

Results shown in Figure 1 revealed that participants belong in different age groups whereby the majority ranged from 30 to 50 years. The survey revealed that most farmers comprised of both young people and adults who involve in maize production. Moreover, 45.2% of respondents belong to households with 1 to 5 members while others were from households comprising of

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more than 5 members. The maximum household size was 14 years while the average age was 6.2 years having standard deviation 2.7. Hence, this age distribution justifies that there is high density in household size in the study area.

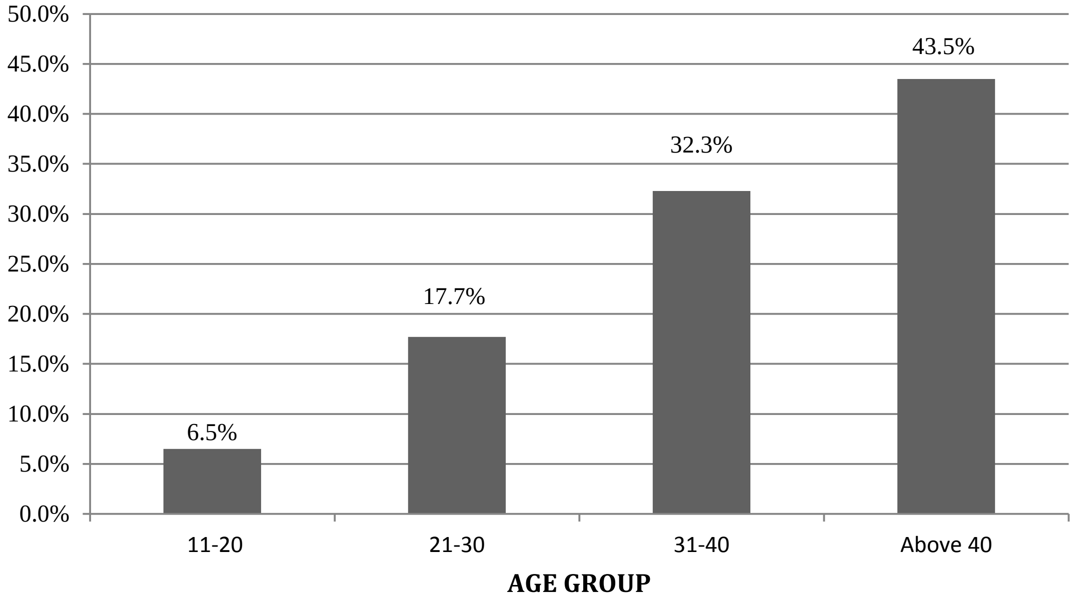

Figure 1: Age distribution of respondents (n=124)

Farmers adoption of improved maize seed technology for adaptation to climate change in the West Usambara Mountains

The Climate Change Agriculture and Food Security (CCAFS) project in the West Usambara Mountains disseminated and promoted improved maize seeds and other practices as climate-smart agriculture technologies so that they can be adopted by smallholder farmers. This study assessed farmers' uptake of improved maize seed technology for climate change adaptation in CCAFS project areas named as Climate Smart Villages (CSVs).

The results shown in Figure 2 revealed that there was 57% level of adoption of improved maize seed technology in Yamba and Boheloi villages which are among the climate Smart Villages of CCAFS project. Other farmers (47%) have not yet decided to use improved maize seeds in the project area although CCAFS project has existed for 10 years in their villages. The results demonstrate that there was moderate uptake of improved maize seed technology for climate change adaptation among smallholder farmers in CCAFS project area in the West Usambara Mountains.

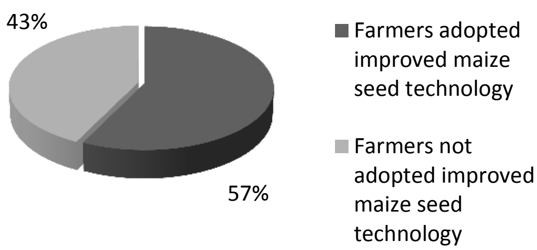

Figure 2: Incidence of adoption of improved maize seed technology among farmers in CCAFS project area (n=124)

Farmers' perceived characteristics of improved maize seed technology disseminated by CCAFS project for climate change adaptation in the West Usambara Mountains

The perception of farmers on improved maize seed technology with regard to adaptation to climate change in agriculture was assessed in order to reveal knowledge pertaining to the usefulness of this technology to smallholder farmers in CCAFS project area. Farmers' perception assessment was based on disseminated improved maize technology's profitability, compatibility, complexity, trial ability and observability in the process of decision making regarding adoption of the technology (Table 3).

Table 4: Perception of farmers on characteristics of improved maize technology for climate change adaptation in CCAFS project area (n=124)

CHARACTERISTICS OF IMPROVED MAIZE SEED TECHNOLOGY	FARMERS RESPONSE
More benefits are gained when a farmer grow improved maize seeds in responding to climate change impacts (i.e. profitability).	74.2%
The operations and management practices of a maize farm planted with improved seeds are similar to that applied on the farm planted with unimproved maize seeds (i.e. Compatibility).	57.3%
Maize farming using improved maize seeds has more complex management practices than that using locally unimproved maize seed varieties (i.e. Complexity)	38.7%)
In responding to adverse climate change impacts, I have tried farming using improved maize seeds before making decisions on investing in improved maize seed technology (i.e trial ability).	50%
I have more attracted with yields produced by my fellow farmers using improved maize seeds before I made a decision of adoption of such a technology (i.e. observability).	58.9%

In regard to profitability of improved maize seed technology, the study revealed that 74.2% of farmers participated in the survey agreed with the statement said that more benefits are gained when a farmer grow maize by using improved maize seeds in responding to climate change impacts (i.e. profitability). The findings demonstrated that if farmer use improved maize seeds, produce more yields than when use locally unimproved maize seeds. Other results revealed that 57.3% of respondents perceived compatibility in farming practices and management between a farm grown using improved maize seeds and farm grown with unimproved maize seeds. Therefore, farm applications and management between improved maize seed technology and traditional unimproved maize seeds to some farmers are well-matched in application in the CCAFS project area.

In assessing technology use complexity, a few survey participants (38.7%) perceived that application of improved maize seed technology is more complex than unimproved maize seeds in farm management. However, majority of farmers perceived that since they have started using improved maize seed technology, there is no complex application of this technology to most of farmers. This justified that many farmers have ability to apply this improved maize seed technology disseminated and promoted by CCAFS project in the study area for about 10 years.

Moreover, adoption decision of disseminated and promoted climate-smart agriculture technologies may depend on farmers' perceived trial ability and observability. The results from this study revealed that 50% of respondents perceived that trial ability was contributed to their decisions of using or rejecting improved maize seed technology. In the first time, farmers tried using improved maize seeds after being disseminated and promoted before making decisions of adoption in order to avoid risks of losses following full investment on such technology. More findings indicated that 58.9% of respondents perceived observability as an essential factor to consider before farmers' adoption of improved maize seed technology. Often, farmers have been visiting farms of early adopters in order to learn farm practices of improved maize crops before making decisions of adoption.

The effects of perceived characteristics of improved maize seed technology on farmers' adoption of improved maize seed technology for climate change adaptation

The effects of perceived characteristics of improved maize seed technology on farmers' adoption for climate change adaptation were examined through binary logistic regression analysis. In the logistic regression, Omnibus Test of Model Coefficients was used to identify the model fitness after explanatory variable being included in the logistic regression model. In Table 5, results of Omnibus test revealed that inclusion of block of variables contributed significantly to model fitness (χ^2 =111.314; p<0.001).

Table 5: Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	111.314	5	0.001
	Block	111.314	5	0.001
	Model	111.314	5	0.001

Different from coefficient of determination (R^2) used in linear regression, logistic regression model uses two pseudo R^2 (i.e. Cox & Snell R^2 and Nagelkerke R^2) to determine variation of dependent variable explained by explanatory variables included in block 1. From the table of model summary below, variation in adoption of improved maize seed technology was explained between 59.2% and 79.6% by the variables added in block 1.

Table 6 : Model summary

Step	-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
1	57.964	0.592	0.796

The logistic regression analysis of the effects of farmers' perceived characteristics of improved maize seed technology revealed that perceived relative advantage, complexity, trial ability and observability have significant effect on farmers' adaption of improved maize seed technology in CCAFS project area in the West Usambara Mountains. There was no significant effect perceived complexity on farmers' adoption of improved maize seed technology in the study area. The logistic regression outputs are shown in Table 6.

Table 6: Logistic regression analysis of farmers' perceived characteristics of improved maize technology in CCAFS project area

PERCEIVED CHARACTERISTICS	B	S.E.	WALD	P VALUE	EXP(B)	95% C.I. FOR EXP(B)	
						LOWER	UPPER
Constant	-3.89	1.068	13.24	0.001	0.02		
Relative advantage	2.84**	0.903	9.89	0.002	17.10	2.91	100.38

Compatibility	0.28	0.705	0.15	0.695	1.32	0.33	5.25
Complexity	-2.59***	0.760	11.59	0.001	0.07	0.02	0.33
Trialability	3.07***	0.814	14.25	0.001	21.59	4.38	106.45
Observability	2.82***	0.793	12.69	0.001	16.85	3.56	79.69

**p<0.01, ***p<0.001

The regression analysis revealed that perceived relative advantage had positive significant effect on farmers' adoption of improved maize seed technology in CCAFS project area (β1=2.84; p=0.01). The odds of farmer who perceived that improved maize seed technology has relative advantage to adopt that technology were higher by times 17.10 than other farmers. The strength of relationship between perceived relative advantage of improved maize seed varieties and farmers adoption of that technology measured by Wald statistics was 9.89. The lower confidence interval (LCI) and upper confidence interval (UCI) of the likelihoods of adoption of improved maize seed technology expressed by perceived relative advantage at 95% confidence level were 2.91 and 100.38.

With regard to the effect of perceived compatibility, the study revealed that farmers' perception on compatibility had no significant effect on adoption of improved maize seed technology in CCAFS project area (β2= 0.28; p=0.695). Therefore, there are no chances for perceived compatibility to affect adoption of improved maize seed technology in the study area.

Moreover, the survey found that perceived complexity had negative significant effect on farmers adoption of improved maize seed technology in CCAFS project area (β3= -2.59; p=0.001). The likelihoods of a farmer who perceived that disseminated maize seed technology is complex to apply is times 0.07 less chance to adopt the technology than other farmers. The Wald statistics revealed strength of relationship of 11.59 existing between complexity and likelihoods of adoption of improved maize seed technology. The lower and upper confidence interval of relationship between perceived complexity and adoption of improved maize seed technology was 0.02 and 0.33. The findings justified that the more the farm application complexity of disseminated technology such as improved maize seeds perceived by farmer, the lower the likelihoods of adoption of such technology.

Technology trial ability had positive significant effect on farmers adoption of improved maize seed technology in the study area (β4=3.07; p=0.001). There were higher chances by times 21.59 for farmer who tried the improved maize seed technology can adopt it than other farmers. The strength of relationship between trial ability and adoption of improved maize seed technology measured by Wald statistics was 14.25. The lower and upper interval of the relationship between trial ability and adoption of this technology was 4.38 and 106.45.

Some farmers can make decision to adopt disseminated technology after observing performance of such technology from other farmers. In the study area, it was revealed that perceived observability had positive significant effect on farmers' adoption of improved maize seed technology (β5=2.82; p=0.001). A farmer who ever observed farm application of improved maize seed technology had higher likelihoods by times 16.85 of adopting observed technology than other farmers. The strength of relationship revealed by Wald statistics between observability and adoption of improved maize seed technology was 12.69. The lower confidence interval was 3.56 and upper confidence interval was 79.69 at 95% confidence level.

CONCLUSION

Climate change has contributed to adverse impacts on cropping system by reducing yields of cereals particularly maize in the West Usambara Mountains in Tanzania. During the period of past ten years, Climate Change Agriculture and Food Security (CCAFS) project was initiated in West Usambara Mountains whereby it disseminated and promoted improved maize seed technology as among the adaptive strategies to climate change in smallholder agriculture. The adoption of improved maize seed technology in CCAFS project areas depends on perceived characteristics of technology including technology's relative advantage, complexity, trial ability and observability. Since the inception of CCAFS project in 2010 to the present, there is moderate adoption of improved maize seed technology in the project area. Farmers' perception towards relative advantage, trial ability and observability had positive effects on adoption of improved maize seed technology. However, perception of farmers towards technology complexity had negative effect on adoption of improved maize seed technology in CCAFS project area. Perception on technology compatibility had no effect on adoption improved maize seed varieties. The study recommends that government and agricultural sector stakeholders can continue promoting the use of improved maize seed technology through enhancement of extension services and education so that many farmers can be attracted by this technology. Therefore, adoption and investment in maize farming using improved seeds which are early maturing, tolerant to drought, resistant to pest and diseases, and produce more yields can be more resilient to climate change than locally available unimproved maize seed varieties in the West Usambara Mountains.

REFERENCES

[1] Arslan, A., Belotti, F. and Liper, L. (2016). *Smallholder Productivity under Climatic variability: Adoption and Impact of Widely Promoted Agricultural Practices in Tanzania*. ESA Works Paper No. 16-03, Rome, FAO.

[2] Barrios, S., Ouattara, B. and Strobl, E. (2008). The Impact of Climatic Change on Agricultural Production: Is It Different for Africa? *Food Policy*, 33(4):287 – 298.

[3] Bänziger, M., Setimela, P.S., Hodson, D. and Vivek, B. (2006). Breeding for Improved Abiotic Stress Tolerance in Africa in Maize Adapted to Southern Africa. *Agriculture Water Management*, 80:212-214.

[4] Cabrera-Bosquet L, Crossa J, von Zitaewitz J, Serret MD, Araus J.L. (2012). High-throughput Phenotyping and Genomic Selection: The Frontiers of Crop Breeding Converge. *Journal of International Plant Biology,* 54:312-320.

[5] Hellin, J., Shiferaw, B., Cairns, J. E., Reynolds, M., Ortiz-Monasterio, I., Banziger, M., Sonder, K. and La Rovere, R. (2012). *Journal of Development and Agricultural Economics*, 4(12):311-321.

[6] IPCC (2014). Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom, NY, USA, pp. 1-32.

[7] IPCC (2018). Summary for Policymakers. In: *Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global*

response to the threat of climate change, sustainable development, and efforts to eradicate poverty. V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.). World Meteorological Organization, Geneva, Switzerland, pp.1-32.

[8] Lymo, S., Mduruma, Z., and De Groote, H. (2014). The Use of Improved Maize Varieties in Tanzania. *African Journal of Agricultural Research,* 9(7):643 – 657.

[9] Minderhoud, P.S.J. (2011). Historical Soil Erosion in the West Usambara Mountains, Tanzania: A Study Based on Hillslope Deposits. MSc. Thesis in Physical Geography and Earth Sciences, Utrecht University.

[10] Mumbi, C.T., Marchant, R. and Lane, P. (2014). Vegetation Response to Climate Change and Human Impacts in the Usambara Mountains. *ISRN forestry,* Vol. 2014, pp.1-12.

[11] Ortiz, R., Taba, S., Tovar, V.H.C, Mezzalama, M., Xu, Y., Yan, J. and Crouch, J.H. (2009). Conserving and Enhancing Maize Genetic Resources as Global Public Goods: A Perspective from CIMMYT. *Crop Science,* 50:13-28.

[12] Patt, A. G. and Winkler, J. (2007). *Applying Climate Information in Africa: An Assessment of Current Knowledge.* Technical Report Prepared for the U.S. National Oceanic and Atmospheric Administration.

[13] Rogers, E.M. (2003). *Diffusion of Innovations (5th ed.).* New York: Free Press. pp. 1-10.

[14] Radeny, M., Ogada, M.J., Recha, J., Kimeli, P., Rao, E.J.O. and Solomon, D. (2018). *Uptake and Impact of Climate-Smart Agriculture Technologies and Innovations in East Africa.* CCAFS Working Paper No. 251. Wageningen, Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), pp. 1- 63.

[15] Rukanda, J. (2014). *Climate Change: Farmers' Perception and their Adaptation Strategies. A Case of Lushoto District, Tanzania.* Sebastian Kolowa Memorial University & YES-Tanzania National Chapter.

[16] Shuaibu, H., Akpoko, J.G. and Umar, S. (2014). Farm Households' Coping Strategies to Climate Change: A Review. *British Journal of Applied Science & Technology*, 4(20):2864-2877.

[17] United Republic of Tanzania (URT) (2007). *National Adaptation Programme of Action.* Technical Report, Vice President's Office, Division of Environment, Dar es Salaam, Tanzania.

[18] URT (2013). *Tanzania's National Agriculture Policy*. Ministry of Agriculture, Food Security and Cooperatives, Dar es Salaam.

[19] Ziervogel, G., Cartwright, A., Tas, A., Adejuwon, J., Zermoglio, F., Shale, M. and Snith, B. (2008*). Climate Change and Adaptation in African Agriculture.* Technical Report, Rockefeller Foundation, Stockholm Environment Institute.