Research article

Factors Influencing Adoption of Ecosystem-Based Adaptation Practices: The Case of Small-Scale Maize Farming in Morogoro Region, Tanzania

UPENDO SAITABAU MOLLEL*
Graduate School of International Food and Agricultural Studies,
Tokyo University of Agriculture, Japan
Email: mollelupendo561@gmail.com

KATSUMORI HATANAKA
Department of Agribusiness Management, Tokyo University of Agriculture, Japan

RAMADHONA SAVILLE
Department of Agribusiness Management, Tokyo University of Agriculture, Japan

NINA N. SHIMOGUCHI
Department of Agribusiness Management, Tokyo University of Agriculture, Japan

Received 25 April 2024 Accepted 11 June 2024 (*Corresponding Author)

Abstract Maize is the main staple crop in Tanzania; it is produced in almost all agroecological regions of the country, with production dominated by small-scale rain-fed farming. Maize production in Tanzania is constrained by climate change impacts such as rises in temperature, changes in rainfall patterns, and increases in plant diseases, insects, pests, floods, and droughts. Small-scale maize farmers have low climate change adaptation capacity, as the majority still use unsustainable farming practices such as monoculture, intensive tillage, and burning of crop residues, all of which increase the farmers' vulnerability to climate change impacts. Sustainable farming practices, in particular Ecosystem-based Adaptation (EbA) practices such as the ones considered in this study, are believed to contribute significantly to restoring and conserving agroecosystems, increasing maize productivity and resilience towards climate change. This study aimed to identify the common EbA practices adopted by farmers in Tanzania and to determine the factors influencing adoption of EbA practices in maize farming. The study was conducted in the Kilosa district of the Morogoro region of Tanzania. Both primary and secondary data were used in the study. Primary data was collected through key informant interviews with the agricultural extension officers and a semi-structured questionnaire survey administered to 350 farmers. The T-test and the Tobit regression model were used for data analysis. Based on the T-test results, commonly adopted EbA practices included crop rotation, maize-legume intercropping, and improved seeds. Based on the Tobit regression analysis, farm size, household income, land ownership, access to climate information, labor, knowledge of EbA practices, and membership in the farmer field schools were found to significantly influence the adoption of EbA practices in maize farming. This study highlighted the importance of the government's role in increasing EbA knowledge dissemination to the farmers through improving the training facilities in the farmer field schools and increasing opportunities for the farmers to have access to credit from financial service providers, allowing maize farmers to boost their income and become able to adopt more EbA practices.

Keywords maize farming, climate change, ecosystem-based adaptation practices, Tobit regression model

INTRODUCTION

Maize is an important food crop in Tanzania as it accounts for over 70% of the national starch requirement for human consumption (Mkonda and Xinhua, 2017) and approximately 65% of the smallholder farming households depend on maize for the provision of both food and income (Anderson et al., 2016). Between 65% and 85% of maize produced is consumed by the household producing it while only 20% to 35% is used for commercial purposes (Lana et al., 2017). According to USAID (2010), maize is produced in almost all agroecological regions in the country. It is characterized by small-scale production (Baregu et al., 2015) and is mainly rain-fed as only 3% of the total planted area is irrigated (URT, 2016). In most African countries including Tanzania, maize production is affected by climate change effects as approximately 70% to 80% of maize losses are caused by droughts and floods (Amondo and Simtowe, 2018). Furthermore, with the increasing adverse impacts of climate change, maize yield in Tanzania has been predicted to decline at the local level by 37% in 2050 (Msongaleli et al., 2015). This decrease in the maize yield will affect the household food security and income of the most rural households in the country.

According to the Intergovernmental Panel on Climate Change (IPCC, 2018), Tanzania is among the countries that are most vulnerable to climate change as most of the farmers are suffering from its negative impacts. In addition, the country is ranked among the 13th countries with weak adaptation capacity to climate change (IPCC, 2014). Most of the farmers still employ unsustainable farm practices such as monoculture, intensive tillage, and burning or removal of crop residues after harvest from the farmland, which degrades the health of the agroecosystem (Agula et al., 2018) and exposes the farmers to be more vulnerable to climate change impacts.

The farmers need to use sustainable farm practices which are considered as Ecosystem-based Adaptation (EbA) practices in this study. EbA refers to the use of ecosystem services and biodiversity as part of an overall adaptation strategy to help people adapt to the adverse impacts of climate change (Nalau et al., 2018). EbA practices ensure sustainable management, conservation, and restoration of natural resources and ecosystems that support and protect agricultural livelihoods such as nutrient cycling provision, soil formation, water infiltration, pollination, pest and disease regulation, and carbon sequestration (Abdelmagied and Mpheshea, 2020; Daigneault et al., 2016). The common example of EbA practices at the farm scale is the use of agroforestry to combat the effects of high temperatures, heavy rains, and other climate change impacts on crops and livestock (Siles et al., 2010) and has the potential to tackle food insecurity and increase the resilience of the farmers towards the impacts of climate change (Catacutan et al., 2017). Despite the importance of maize farming and the benefits of EbA practices in the cultivated ecosystems, less is known about the common EbA practices adopted by small-scale maize farmers and the factors influencing the adoption of EbA practices in maize farming in Tanzania. Based on various literatures, eight EbA practices were selected for this study which were crop rotation, maize-legume intercropping, agroforestry, mulching, improved seeds, organic manure, zero tillage, and planting maize on contour ridges.

Description of the Eight Selected EbA Practices in Maize Farming

Crop rotation is the practice of growing a sequence of crops on the same land cycle after cycle (Dury et al., 2012). Maize-legume intercropping is the cultivation of maize intercropped with legumes such as common beans, soybeans, groundnuts, or cowpeas for a specific period or the entire growing season. Agroforestry practice in maize farming is the integration of trees and maize crops in the same land. Mulching in this study is a practice that consists of leaving a layer of crop residues on the soil surface for soil and water conservation. The use of improved seeds as an EbA practice in this study is the use of improved maize seeds in maize farming because they are high-yielding and tolerant to diseases and drought compared to recycled seeds. The use of organic manure in maize farming either from plant or animal sources helps to improve soil fertility. Zero tillage is a practice in which seeds are placed into untilled soil by opening a narrow slot, trench, or hole of only sufficient width and depth to obtain proper seed placement and coverage (Derpsch et al., 2014). Planting maize on contour ridges involves the construction of small earth structures across the slopes on cultivated land to decrease runoff, increase water infiltration, and capture rainfall close to the crop root system.

OBJECTIVE

The general objective of this study was to analyze the factors influencing the adoption of EbA practices in maize farming. The specific objectives were to identify the common EbA practices adopted by farmers and to determine the factors influencing the adoption of EbA practices in maize farming.

METHODOLOGY

Study Area, Data Collection and Analysis

The study was conducted in the Kilosa district of the Morogoro region in the eastern part of Tanzania. The district is characterized by a semi-humid climate with an average annual rainfall between 800 mm to 1,600 mm and an average annual temperature ranging from 19°C to 30°C. The study area was selected because most of the smallholder farmers are engaged in maize farming and the district experiences climate change impacts (Vatn et al., 2017). According to the population census conducted by the United Republic of Tanzania in 2022, the total population of Kilosa district in 2022 was 617,032 people of which 80% are framers (URT, 2022). With the support of the district agricultural extension officer, purposive sampling was used to select 10 divisions in the Kilosa district with potential for maize farming and with many smallholder maize farmers. The 10 selected divisions were Kidete, Zombo, Madoto, Kimamba B, Msowero, Ulaya, Mhenda, Masanze, Magomeni and Rudewa divisions. From each division, 35 farmers were randomly selected which made a total of 350 farmers. This study employed a cross-sectional research design in data collection. Primary data were collected between January 7th to February 11th in 2023 through key informant interviews with the agricultural extension officers and a semi-structured questionnaire survey administered to 350 farmers who were randomly selected. Data analysis was conducted using the T-test and Tobit regression model.

RESULTS AND DISCUSSION

Ecosystem-based Adaptation Practices Adopted in Maize Farming

Table 1 shows that the common EbA practices adopted in maize farming were crop rotation (115 adapters), maize-legume intercropping (205 adapters), and improved seeds (127 adapters). Maize-legume intercropping had the largest number of adopters which shows that most small-scale maize farmers prefer this practice because it reduces the risk of total crop failure as when one crop fails, farmers can still benefit from another crop on the farm.

Table 1 T-test result of EbA practices adopted on maize farming (n=350 farmers)

No.	EbA practices adopted	Adopters (farmers)	Non-adopters (farmers)	Yield of adopters (kg/ha)	Yield of non-adopters (kg/ha)	*p*-value
1	Crop rotation	115	235	3,490	1,132	0.000
2	Maize-legume intercropping	205	145	2,754	709	0.000
3	Agroforestry	39	311	4,600	1,569	0.000
4	Mulching	70	280	3,673	1,465	0.000
5	Planting maize on contour ridges	9	341	3,011	1,878	0.050
6	Improved seeds	127	223	3,546	973	0.000
7	Zero-tillage	17	333	3,853	1,808	0.002
8	Organic manure	22	328	3,786	1,781	0.000

The result is in line with the study of Rusinamhhodzia et al. (2012) who found that smallholder farmers of Central Mozambique prefer intercropping because it reduces the risk of total crop failure and improves productivity. Table 1 also shows that all the EbA practices have a significant impact on maize yield as adopters of EbA practices have higher maize yield compared to non-adopters. The result is consistent with the study of Abdelmagied and Mpheshea (2020) that EbA practices improve agricultural productivity.

Factors Influencing Adoption of EbA Practices in Maize Farming

The Tobit model, which is also called the censored regression model is designed to estimate linear relationships between variables when there is either left- or right-censoring in the dependent variable (Tobin, 1958). Tobit model uses both the data at the threshold and those above the threshold to estimate the model. The tobit model measures not only the adoption decision but also the intensity of the use of technology once adopted (Tobin, 1958).

In this study, the Tobit regression model was used to analyze the factors influencing the adoption of EbA practices in maize farming. In the Tobit model, the dependent variable Y is ecosystem-based adaptation practices adopted by the farmers on maize farming measured using the adaptive index which was obtained by taking the number of EbA practices adopted by the maize farmers divided by the total number of EbA practices available to the farmers as given in Eq. 1.

$$Y = \beta_0 + \sum_{i=1}^{10} \beta_i X_i + e \qquad (1)$$

Where β_0 is the intercept of *Y*, β_i , i = 1, 2, ...,10 is a regression coefficient with respect to the independent variable X_i and e is the error term. The independent variables used in the model are shown in Table 2.

Table 2 Description of the independent variables used in the Tobit model

Variables	Description
Age	Age of household head (years)
Gender	Dummy (1= male, 0 = female)
Household size	Number of household head size
Farm size	Total maize farm size of the farmer in hectares
Household income	Total annual household income of the farmer from both on-farm and off-farm activities in Tanzanian shillings
Land ownership	Dummy (1 = the farmer own the maize farm, 0 = the farmer rent the maize farm)
Access to climate information	Dummy (1 = the farmer has access to climate information, 0 = the farmer does not have access to climate information)
Access to labour force	Dummy (1 = the farmer has access to family labour or can afford the costs of hired labour, 0 = the farmer does not have access to family labour and can not afford the costs of hired labour)
Knowledge of EbA practices	Dummy (1= the farmer has knowledge of how to use EbA practices and the importance of EbA practices in the farm, 0 = the farmer does not have knowledge on how to use EbA practices and the significance of EbA practices in the farm)
Membership in farmer field school	Dummy (1= the farmer is a member in the farmer field school, 0= the farmer is not a member in the farmer field school)

The discussion of the Tobit regression results in Table 3 is as follows, the model was selected because it had the smallest Akaike Information Criterion, and the value of the log-likelihood was higher which corresponds to a better fit of the data in comparison to other models.

Farm size was statistically significant ($p<0.1$) with a positive coefficient showing that the increase in farm size increases the likelihood of the farmer to adopt EbA practices in maize farming. Large farm size provides enough space for the farmer to adopt a wide range of EbA practices in the farm like the use of different kinds of crop diversification such as intercropping, and crop rotation compared to farmers with small farm sizes. This is similarly in line with a study by Belay et al. (2017) who found that large farm size provides farmers with an opportunity to practice crop diversification which helps to reduce risks associated with unpredictable weather changes.

Household income had a significant (p<0.001) positive effect on the adoption of EbA practices in maize farming. In this study, the household income was the combination of the income generated by the farmer from both on-farm and off-farm activities. The increase in the household income of the farmer increases the probability of the farmer to adopt more EbA practices in the farm. Small-scale farmers need to have sufficient income to afford the cost of using several EbA practices in the cultivated field. For example, using improved maize seeds, organic manure, cost of controlling weeds in a zero-tilled farm, and labor cost in some of the labour-intensive EbA practices such as planting maize on contour ridges. This result is in line with the previous findings that the increase in income enhances the likelihood of the farmer to invest in more productive farm inputs such as improved seeds and practicing crop diversification in the farm (Kom et al., 2020).

Land ownership had a positive coefficient and statistically significant (p<0.001) influence on the adoption of EbA practices in maize farming indicating that the increase in the access of the farmers to land ownership increases the probability of the farmers being concerned with the conservation and protection of the farmlands for short- and long-term benefits. Hence, the farmers will adopt more EbA practices such as water and soil conservation measures (mulching, organic manure, agroforestry, contour farming, crop rotation, intercropping, zero tillage) compared to the rented farmlands because the farmers do not have full access to the land. The result is consistent with the study of Tran et al. (2019) whose findings showed that land ownership had a positive influence on the adoption of climate-smart agriculture technologies.

Access to climate information influences the adoption of EbA practices in maize farming as it was statistically significant (p<0.001) with a positive coefficient showing that farmers who have access to information regarding climate events such as temperature and rain intensity are more likely to adopt EbA practices to combat the effects of climate variability in farming. For instance, if the farmers know that there will be low rainfall, they will anticipate planting maize on the contour ridges as an in-situ water harvesting technique to increase surface run-off storage near the cropped area. The finding is in line with the study of Rahman et al. (2021) who found that climate information is a crucial factor determining climate change adaptation.

Access to the labour force was statistically significant (p<0.05) with a positive coefficient which indicates that the increase in the access of the farmer to farm labor also increases the probability of the farmer adopting more EbA practices in maize farming. Access to labor implies the ability of the farmer to afford labor costs especially hired labour or the availability of a family labour force to the farmer. Some of the EbA practices are labor intensive such as the application of organic manure in the farm, mulching, planting maize on the contour ridges, and maize-legume intercropping require the farmer to have access to farm labour either family labour, hired labour, or communal labour to help with farm work. This result is consistent with the previous study of Ng´ombe et al. (2017) whose findings showed that the availability of labour was positively correlated with the adoption of conservation agriculture practices in Zambia.

Knowledge of EbA practices significantly (p<0.001) influences the adoption of EbA practices in maize farming. The positive coefficient shows that the more the farmers get knowledge on how to use EbA practices in the farm and the importance of EbA practices in the cultivated ecosystem, the higher the likelihood of adopting EbA practices in maize farming. For instance, if the farmers know the usefulness of EbA practices like mulching, they will not burn or remove crop residues from the field instead they will use it for mulching purposes to increase organic matter and soil moisture content. This finding is similarly in line with the previous study conducted in Ghana by Agula et al. (2018) who found that farmers who know the biological function of ecosystem-based farm management practices have higher probabilities of adoption compared to farmers without adequate knowledge on the usefulness of ecosystem-based farm management practices.

Membership in the farmer field school is an important variable influencing the adoption of EbA practices in maize farming. The coefficient of the farmer field school is positive and statistically significant (p<0.05) indicating that the increase in the participation of the farmers in the farmer field school to gain knowledge from the training on how to use EbA practices in the farm, increases higher chances for the adoption of EbA practices in maize farming. Farmer field schools in the study area train the farmers on several EbA practices such as effective ways of practicing zero-tillage, planting maize on contour ridges, maize-legume intercropping, and agroforestry. This finding is consistent with the study of Bhutto et al. (2018) who found that participation of the farmers in the farmer field school programs positively influenced the adoption of sustainable agricultural practices.

Table 3 Tobit regression result of the factors influencing adoption of EbA practices (n=350)

Coefficients	Estimate	Std. Error	z value	pr(>|z|)
(Intercept)	-1.812e-01	3.262e-02	-5.557	0.000 ***
Age	3.132e-04	4.935e-04	0.635	0.526
Gender	-3.663e-04	1.471e-02	-0.025	0.980
Household size	-4.916e-03	3.304e-03	-1.488	0.137
Farm size	9.877e-03	5.880e-03	1.680	0.093.
Household income	1.736e-07	2.749e-08	6.316	0.000 ***
Land ownership	1.199e-01	1.461e-02	8.207	0.000***
Access to climate information	1.863e-01	2.052e-02	9.081	0.000 ***
Access to the labor force	3.389e-02	1.395e-02	2.429	0.015*
Knowledge of EbA practices	1.270e-01	1.928e-02	6.585	0.000 ***
Membership in farmer school	5.452e-02	2.301e-02	2.369	0.018 *
Log (scale)	-2.456e+00	7.175e-02	-34.232	0.000***

*Note: ***p< 0.001, **p< 0.01, *p< 0.05 and . p< 0.1, Source: Field survey in Tanzania, 2023*

CONCLUSION

The common EbA practices adopted by the maize farmers in the Kilosa district in Tanzania were found to be crop rotation, maize-legume intercropping and the use of improved seeds. The adoption of EbA practices were found to have significant impact on maize yield, as the adopters of EbA practices had higher maize yield compared to non-adopters of EbA practices. Factors influencing the adoption of EbA practices in maize farming were identified as farm size, household income, land ownership, access to climate information, access to labour force, knowledge of the EbA practices, and membership of the farmers in the farmer field school. This study highlighted the importance of the government's role in increasing EbA knowledge dissemination to smallholder farmers through improving the training facilities in farmer field schools. It is also important for the government to increase opportunities for smallholder maize farmers to have access to credit from financial service providers to boost their income and become able to adopt more EbA practices in maize farming.

REFERENCES

Abdelmagied, M. and Mpheshea, M. 2020. Ecosystem-based adaptation in the agriculture sector, A nature-based solution (NbS) for building the resilience of the food and agriculture sector to climate change. Rome, FAO.

Agula, C., Akudugu, M.A., Mabe, F.N. and Dittoh, S. 2018. Promoting ecosystem-friendly irrigation farm management practices for sustainable livelihoods in Africa, The Ghanaian experience. Agricultural and Food Economics, 6, 13, Retrieved from DOI https://doi.org/10.1186/s40100-018-0109-1

Amondo, E. and Simtowe, F. 2018. Technology innovations, Productivity and production risk effects of adopting drought tolerant maize varieties in rural Zambia. Vancouver: International Association of Agricultural Economics (IAAE).

Anderson, J., Marita, C. and Musiime, D. 2016. National survey and segmentation of smallholder households in Tanzania, Understanding their demand for financial, agricultural, and digital solutions. CGAP: Washington, DC, USA.

Baregu, S., Festo, M., Mwaijande, F. and Lein, B. 2015. Assessment of policy coherence for development for food security in Tanzania. Tanzania Food Security Profile.

Belay, A., Recha, J.W., Woldeamanuel, T. and Morton, J.F. 2017. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. Agriculture and Food Security, 6, 24, Retrieved from DOI https://doi.org/10.1186/s40066-017-0100-1

Bhutto, N.N., Rahman, A., Nahiyoon, A.A., Ahmed Khan, R. and Zaman, B. 2018. Role of farmers' training on cotton production through farmer field school (FFS) approach in Sanghar, Sindh, Pakistan. International Journal of Farming and Allied Sciences, 7, 18-22.

Catacutan, D., Van Noordwijk, M., Nguyen, T., Öborn, I. and Mercado, A. 2017. Agroforestry, contribution to food security and climate change adaptation and mitigation in Southeast Asia. White Paper. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Daigneault, A., Brown, P. and Gawith, D. 2016. Dredging versus hedging, Comparing hard infrastructure to ecosystem-based adaptation to flooding. Ecological Economics, 122, 25-35.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate change 2014, Impacts, adaptation, and vulnerability. In Field, Barros, C.B., Estrada, V.R., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L. (Eds), Part A: Global and Sectoral Aspects. Contribution of Working Group II to MEQ the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, and New York, NY.

Intergovernmental Panel on Climate Change (IPCC). 2018. Summary for policymakers. In Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., et al. (Eds.), 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. World Meteorological Organization.

Kom, Z., Nethengwe, N.S., Mpandeli, N.S. and Chikoore, H. 2020. Determinants of small-scale farmers' choice and adaptive strategies in response to climatic shocks in Vhembe District, South Africa. GeoJournal, 87 (2), 677-700.

Lana, M.A., Vasconcelos, A.C.F., Gornott, C., Schaffert, A., Bonatti, M., Volk, J., Graef, F., Kersebaum, K.C. and Sieber, S. 2017. Is dry soil planting an adaptation strategy for maize cultivation in semi-arid Tanzania? Food Security (2018) 10, 897-910, Retrieved from DOI https://doi.org/10.1007/s12571-017-0742-7

Msongaleli, B.M., Rwehumbiza, F., Tumbo, S.D. and Kihupi, N. 2015. Impacts of climate variability and change on rainfed sorghum and maize: implications for food security policy in Tanzania. J Agric Sci., 7, 124-142, Retrieved from https://doi.org/10.5539/jas.v7n5p124

Nalau, J., Becken, S. and Mackey, B. 2018. Ecosystem-based adaptation, A review of the constraints. Environmental Science and Policy, 89, 357-364.

Ng'ombe, J.N., Kalinda, T.H. and Tembo, G. 2017. Does the adoption of conservation farming practices result in increased crop revenue, Evidence from Zambia. Agrekon, 56 (2), 205-221, Retrieved from DOI https: //doi.org/ 10.1080/03031853.2017.1312467

Rahman, M., Toiba, H. and Huang, W.C. 2021. The impact of climate change adaptation strategies on income and food security, Empirical evidence from small-scale fishers in Indonesia. Sustainability 2021, 13 (14), 7905.

Tobin, J. 1958. Estimation of relationships for limited dependent variables. Econometrica, 26 (1), 24-36, Retrieved from DOI https://doi.org/10.2307/190

Tran, N.L.D., Rañola, R.F., Sander, B.O., Reiner, W., Nguyen, D. T. and Nong, N.K.N. 2019. Determinants of adoption of climate-smart agriculture practises in rice production in Vietnam. International Journal of Climate Change Strategies and Management, 3, Retrieved from DOI https:// doi.org/10.1108/IJCCSM-01-2019-0003

United Republic of Tanzania. 2016. World food program (WFP) strategic review 2016. Framework for Food and Nutrition Security in Tanzania, United Republic of Tanzania.

United States Agency for International Development (USAID). 2010. Staple foods value chain analysis. Country Report Tanzania, USAID, Compete Program Document.