ISSN 2349-7807

International Journal of Recent Research in Commerce Economics and Management (IJRRCEM)
Vol. 8, Issue 3, pp: (74-83), Month: July - September 2021, Available at: www.paperpublications.org

EFFECTS OF ADOPTION OF CSA INTERVENTIONS ON MAIZE PRODUCTIVITY AMONG SMALL SCALE FARMER HOUSEHOLDS IN MOIBEN SUB-COUNTY, KENYA

[1*]Noah Kemboi, [2]Elijah K. Ng'eno, [3]Joseph K. Rotich

[1]Department of Agricultural Biosystems and Economics, University of Kabianga, Kenya
[2]Department of Applied Economics, University of Eldoret, Kenya, P.O Box 1125-30100, Eldoret, Kenya
[3]Department of Agricultural Biosystems and Economics, University of Kabianga
*University of Kabianga, P.O Box 2030-20200, Kericho, Kenya
Corresponding Author: [1*]Noah Kemboi
Email: noahkemboi0@gmail.com

Abstract: **Climate-Smart Agriculture (CSA) is an agricultural activity that seeks to improve production sustainably to enhance food security and agricultural development. The use of climate-smart agricultural interventions is crucial in ensuring increased agricultural productivity, income, food security, and livelihood for the majority of small scale farmers in Kenya. To achieve this, various agricultural and economic interventions are often used to increase agricultural production. However, despite these interventions, maize production in Uasin Gishu County has declined from 4.4 million bags in 2017 to 3.7 million bags in 2018. Maize farmers have been making negative gross margins of about Kshs 2,000 per acre per year. The focus of the study was to assess the effects of adoption of CSA interventions on maize productivity. The study was guided by the diffusion innovation theory. Descriptive and cross-sectional survey designs were employed in this study. The study drew a sample of 109 small scale maize farmers' households from a target population of 10,109 through stratified and simple random sampling techniques. Primary data were collected using a structured interview schedule and analyzed using descriptive and multiple linear regression. Multiple linear regression estimates on the effects of the adoption of CSA interventions revealed that a unit increase in adoption of early maturing maize varieties, increased herbicide use and crop rotation increased maize production by 431.7%, 644.3% and 611.5% respectively while adoption of early dry planting and tree planting reduce maize yield by 407.3% and 242.4% respectively. Therefore, in conclusion, the estimated results of this study rejected the null hypothesis that adoption of CSA interventions have no significant effect on maize productivity among small scale maize farmers' households in Moiben Sub-County, Kenya. Based on our findings, the study recommends that more farmers need to be trained on the use of CSA interventions as this intervention will help to cut the cost of production and help farmers to realize high-profit margins from their maize output.**

Keywords: **Adoption, Climate-smart Agriculture, maize productivity, small scale farmer household.**

---

1. INTRODUCTION

Maize is one of the most important cereal crops in the world. In the agricultural economy, it acts as food for human beings and a major staple food crop in most sub-Saharan African countries. The importance of the maize crop cannot be overemphasized. According to Dowswell (1996), maize has been put to a wide range of uses than any other cereal: as human food, as a feed grain, a fodder crop, and for hundreds of industrial purposes because of its broad global distribution, its low price relative to other cereals, its diverse grain types, and its wide range of biological and industrial properties. In terms of production, the United States is the largest producer, producing 42% of the total maize production in the world (Food and Agriculture Organization, (FAO), 2015). In Africa, the largest maize producer is Nigeria with over 33 million tons, followed by South Africa, Egypt, and Ethiopia (IITA, 2019). In East Africa, in the period 2011-2015, Tanzania, followed by Kenya, were consistently the biggest producers of maize in the region with the former producing 6 million Metric Tonnes (MT) of maize and the latter producing 2.85 million MT in 2015 (Kilimo trust, 2017). In Kenya, Maize is the main staple food crop, accounting for nearly 40% of the cultivated land area, 2.4% of Kenya's GDP, and 12.65% of agricultural GDP (FAO, 2016). More than 75% of the maize production is done by small-scale farmers, although only 20% of what is produced by smallholders is sold in the market (Chemonics, 2010).

Climate change has significantly affected global agriculture in the 21stcentury and the Intergovernmental Panel on Climate Change (IPCC) assessment report indicates that most countries will experience an increase in average temperature, more frequent heat waves, more stressed water resources, desertification, and periods of heavy precipitation (IPCC, 2014).Climate-Smart Agriculture (CSA) is regarded as a method of re-aligning agricultural developments and plans to address the three main objectives of increased food security, response to changes in climate, and reduction in emission of greenhouse gases, especially in the third world countries (Neufeldt, 2013). According to FAO (2013), CSA is an agricultural approach that aims at promoting increased productivity and responds to changes in climate with a view of achieving food security in a country and foster economic development goals.

In Uasin Gishu County, about 29% of households are practicing crop rotation to adapt to the changes in climatic patterns (GoK, 2014). CSA practices such as minimum tillage are gaining ground in the county. These practices improve and retain soil moisture content to enable the optimum growth of crops. For example, maize and wheat farmers use chisel plows and planters for minimum tillage to help retain soil moisture content and thus aid crop growth during moisture stress. However, the major issues affecting small-scale maize farmers in Moiben Sub County, Uasin Gishu County include low production, post-harvest losses, and poor access to financial incentives as a result of insufficient collaterals, lack of promotion of good agricultural practices and lack of diversification into other enterprises by the farmers (County Integrated Development Plan, (CIDP), 2018).

Despite the importance of CSA addressing the issue of low productivity, approximately 3,964 (39%) of the maize farmer households have adopted while 6,145 (61%) have not adopted. Households that have adopted the CSA interventions are perceived to have realized high productivity of between 25 to 30 bags and low productivity of 12 bags for the non-adopters. The adoption of wheat, horticulture, and dairy economic activities are considered to have high profits as compared to maize production. Therefore, this has thus made the small scale maize farmer households shift from maize production to wheat, horticulture, and dairy activities, thereby reducing the acreage under maize production which has eventually led to low maize productivity. Therefore, from these shortcomings faced by the maize farmer households, this study attempted to analyze the economic factors and the CSA interventions affecting the level of maize productivity among the small scale maize farmer households in Moiben Sub-County, Uasin Gishu County, Kenya.

2. LITERATURE REVIEW

Adoption of improved technologies is a crucial way for Africa to increase the level of production of small farmers in agriculture, hence leading to improvement in economic growth and improved standard of living for tens of millions of poor families (Doss, De Groote, and Owour, 2003). Poor adoption of improved agricultural innovations that can foster farmers' production level is generally considered to lead to reduced agricultural production. Agroforestry is one of the CSA interventions that involves the cultivation and use of trees in farming systems and is a practical and low-cost means of implementing many forms of integrated land management, especially for small-scale producers (Leakey, 2010). In Western Kenya, the use of Tithonia diversifolia, Senna spectabilis, Sesbania sesban, and Calliandra calothyrus species planted as farm boundaries, woodlots, and fodder banks have proven to be beneficial as a source of soil nutrients and improving maize production (Palm *et al.*, 2001). According to the research findings with Faidherbia albida species in Zambia over a decade showed that mature trees can sustain maize yields of up to 4.1 tonnes per 13 hectares as compared to 1.3 tonnes per hectare beyond the canopy of the tree (Palm *et al.*, 2001). Unlike other trees, Faidherbia albida sheds its nitrogen-rich leaves during the rainy season so it does not compete with the crop for light, nutrients, and water. The leaves then re-grow during the dry season and provide land cover and shade for crops (ICRAF, 2009).

Agroforestry contributes to soil conservation in several ways, Mercer and Pattanayak (2003) reported that intercropped trees successfully mitigate soil erosion by forming natural terraces in sloping land and replenish soil fertility with pruning from the trees. Kiepe, (2005) used a slow-growing tree, Senna siamea, to form contour hedgerows in Machakos, Kenya. The trees reduced soil erosion from 5.8 to 1.4 tonnes per hectare over 3 years and did not reduce the crop yield. Trees can conserve the soil in many ways such as cushioning the impact of raindrops on the soil and reduce the amount of rain-splash erosion. More so, their roots bind or stabilize the soil. Planted along 14 contours, they can interrupt the flow of water running off the surface. They can also act as windbreaks protecting the soil against wind erosion (Infonet-biovision, 2010). Agroforestry has the potential to help mitigate the effects of climate change since trees take up and store carbon at a faster rate than crops. Trees control the water table, sequester carbon, and mitigate floods (Sileshi *et al*., 2007).

Conservation agriculture (CA) is another CSA intervention that consists of 3 ideologies, namely; reduced tillage; permanent organic soil structure, and also varied crop rotation (Nichols, Vrhulst, Cox and Govaerts, 2015). The adoption of conservation agriculture has the potential of playing a critical role in increasing agricultural productivity (Agricultural Research Council, 2014). The other specific benefits of implementing CA include an increase in yields, reduced labour requirements, and improvement in soil fertility, efficiency in soil moisture retention, and reduction in soil erosion (Giller, Witter, Corbeels, and Tittonell, 2009). Overall, the adoption of conservation agriculture seeks to achieve efficient and proper utilization of agricultural resources in comparison with routine practices, through the integrated management of available soil, water, and other biological resources (Knowler and Bradshaw 2007). Empirical analysis executed by Branca, McCarthy, Lipper, and Jolejole (2011), on 217 individual kinds of research on CA globally, confirmed that improved agronomic practices including agroforestry, crop rotation, and crop variety improvement can lead to improved cereal productivity by an average of 116 %. Equally, reduced tilling and crop residue led to an increase of 106%, while the adoption of agroforestry increased by 69%. In dry agricultural regions, it was found out that tillage management and adoption of agricultural innovations were useful (Branca, 2011). Most importantly, for this research by Branca (2011), was the finding that conservation agriculture adoption in SSA brought greater productivity than the adoption of conservation agriculture in the Asian countries because of poor agricultural practices witnessed in the former region.

Minimum or zero tillage as one of the CSA interventions shows that intensive tillage may damage soil biological properties, crop growth, and yield through soil degradation and may also increase the environmental degradation potential in the long term (Alhameid *et al*., 2017; Kumar *et al*., 2017). On the other hand, the no-tillage system offers the possibility of soil, water, and climate protection and future environmental quality and economic benefits under temperate conditions (Wittwer *et al*., 2017). Intensive research on crop yields with no-tillage has been conducted in most European countries (Soane *et al*., 2012). Extensive reviews of the effects of no-tillage on soil environments from a long-term study in Germany have been performed by Tebrügge and Döring (1999). They concluded that environmentally sound production can be achieved by no-tillage and reduced tillage systems, which both might reduce negative impacts on soil. Tebrügge (2003) presented a comparison between plow tillage and no-tillage, based on the results of a large number of research projects with an extensive list of quantitative and qualitative indicators related to environmental problems. He concluded that no-tillage provides comparable yields and improves and maintains numerous other soil functions and cross-linkages in the ecosystem. Babaji, (2007) revealed that an on-farm trial conducted in Ghana on maize, soybean, sorghum and groundnut under reduced and conventional tillage, the result show 3.64t/ha and 2.58t/ha for maize under reduced and conventional tillage, 2.36t/ha and 1.97t/ha for soybean, 3.30t/ha and 3.42t/ha for sorghum, 4.66t/ha and 4.61t/ha for groundnut and 3.50t/ha and 2.95t/ha for wheat respectively.

Experts view the influence of no-tillage on yield very pessimistically, which is not congruent with the experience of most no-tillage farmers (Tebrügge and Böhrnsen, 2003). Vyn and Raimbult (1993) also found that in no-tillage maize yields remained significantly lower than yields from plow tillage on silt loam soil in a 15-year-long tillage study with continuous maize in Ontario. The degree of yield reduction varies strongly under European conditions (Van den Putte *et al*., 2010). Dick *et al*., (1991) reported that no-tillage maize initially yielded less than plow tillage but showed similar yields during the later years on the poorly drained fine-textured soil of a 25-year long-term tillage experiment in Ohio. Continuous no-tillage maize yields should at least equal conventional plow tillage yields on light, coarse-textured, and well-drained soils (Duiker *et al*., 2006).

The performance of no-tillage in temperate regions may enhance maize silage yield through the integration of additional conservation practices such as cover cropping and crop rotation (Nunes *et al*., 2018). Under temperate conditions, long-term continuous no-tillage maize increases soil health benefits over plowed tillage and leads to modest improvements in yield for loamy fine sand and silt loam, but not for a clay loam (Nunes *et al*., 2018). Changes in cropping systems, soil tillage, and irrigation often create changes in soil quality and strongly influence soil properties (Kilic *et al*., 2012) and thus crop yield (Fan *et al*., 2012; Ali *et al*., 2018). According to Grassini *et al*., (2011), soil tillage and crop rotation are identified as the most important factors affecting maize yield besides sowing and plant population density. Few studies have been conducted on the effects of crop rotation and soil tillage systems under irrigated conditions on maize grain yield, and very few have been conducted on maize silage yield (Boomsma *et al*., 2010). Therefore, there is a lack of empirical knowledge from long-term trials about the relative importance and temporal development of tillage, herbicides use, and crop rotation effects on maize yield in the current study area.

A literature review on the use of crop rotation as one of the CSA interventions shows that rotating different crops can break pest cycles and add extra nutrients to the soil (Al-Rumikhani, 2002). Crop rotations build soil fertility, preserve the environment, control weeds, diseases, and insects, and add to crop and market diversity (Baldwin, 2006). The effectiveness of crop rotation has been studied in an arid area, Saudi Arabia, where rotations of cereals and alfalfa crops managed with centre pivot systems showed an improvement in soil hydrological properties and subsequent yield improvement (Al-Rumikhani, 2002). Another long-term study in Syria conducted by Jones and Singh (2000) showed an increase in crop yield of a barley-legume rotation compared to continuous barley. A study done in Egypt showed the ability of crop rotation in decreasing the nematode population in the soil (Ahlam *et al*., 2015). Therefore, based on the studies conducted across different parts of the world, it has been demonstrated that rotating crops every other year has various economic and environmental benefits.

The study adopted the diffusion of innovation and the theory of the firm. The theory of diffusion of innovations has four components namely innovation, communication, time, and social systems. According to Rogers, (2003), innovation is an idea that is perceived as new by an individual or unit of adoption. The theory provides a framework to investigate the adoption and diffusion of innovations in a social system. Diffusion theory examines the process by which innovations are adopted over time (Gregor and Jones, 1999). Rogers (2003) defined diffusion as “the process by which an innovation idea is communicated to the members of a community through certain channels over some time”. He noted that uncertainty is an important obstacle to the adoption of an innovation and that to reduce the risk and uncertainty of adopting the innovation, individuals should be aware of its benefits and shortcomings to know the consequences of that idea.

According to Rogers (2003), the innovation-decision process involves data collection and data analysis tasks in which an individual is encouraged to minimize risk concerning both benefits and risk of using a particular innovation. This process entails 5 stages that include the acquisition of knowledge, persuasion skills, decision making, action, and evaluation. In the first step, individuals learn about the existence of a particular innovation and seek information about it. The individual then needs to be persuaded by highlighting the benefits of the innovation before he/she decides to adopt the innovation. He/she then put the innovation into practice and seeks support on the innovation. The diffusion of innovation of technology is used in this study to show how ‘Common Interest Group’ as an extension approach affects the process of technology transfers and adoption. This is because adoption is a procedure of an interrelated series of cultural, personal, institutional, and social factors that include the five stages of awareness, information, knowledge, evaluation, trial, and adoption. As well as the traits of technology, such as simplicity, visibility of results, usefulness towards meeting an existing need, and low capital investment.

3. RESEARCH METHODOLOGY

Descriptive research and cross-sectional survey designs were employed in the study to determine the effect of adoption of CSA interventions. These designs were preferred because they are exploratory, allow for comparisons and analysis of the research findings, and also enabled the researcher to collect, summarize, present, evaluate and interpret the data in a simpler and more understandable form (Kothari, 2008). The target population was 10,109 small scale farmers in Moiben Sub County. Nassiuma (2000) sample size formula was used to calculate the desired sample size and a sample of 109 small-scale farmer households was used for data analysis. A stratified random sampling procedure was used to obtain the sample of small scale maize farmers in the whole Sub-County. Simple random sampling was finally used to select individual farmers for interview. Interview schedules were used to collect data from small-scale farmer household in the study area.

Descriptive statistics was presented using frequencies and percentages. A Multiple linear regression model was used to analyze the effects of adoption of CSA interventions on the level of maize productivity among small scale maize farmer and the significance of relationship between the variables in respect to the dependent variable. The results was analyzed and then presented in tables.

To determine the effects of the adoption of climate-smart agricultural interventions on the level of maize productivity among small scale maize farmer households in Uasin Gishu County, Kenya, a Multiple Linear Regression (MLR) analysis model was used in a way that it is consistent with the production theory and as adopted from Brown (2009) as shown in equation 3.1.

$$Y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5 + b_6 x_6 + b_7 x_7 + e \text{ ………………….………………(3.1)}$$

Where, Y = Maize productivity (output),

X_1 = Early-maturing maize varieties

X_2= Early dry planting

X_3 = Minimum or zero tillage

X_4= Use of herbicides

X_5= Use of crop rotation.

X_6= Tree planting (Agroforestry)

X_7 = Use of chisel tilling

b_0 to b_6 are the regression coefficients and e is the error term that is normally distributed with a mean of zero and constant variance of sigma squared, e~$N(0, \sigma^2)$.

4. RESEARCH FINDINGS AND DISCUSSIONS

The hypothesis of the study was that the adoption of CSA interventions has no significant effect on maize productivity among small scale maize farmer households in Moiben Sub-County, Kenya. Table 1 presents results of the effect of adoption of CSA interventions on maize productivity.

Table 1: Estimates of Climate-Smart Agricultural Interventions on Maize Productivity

Source	**Sum of Squares**	**Df**	**Mean Square**	**Number of observation**	**=**	**103**
Regression	4980.402	7	711.486	F(7,96)	=	25.597
				Prob >F	=	0.001^b
Residual	2668.436	96	27.597	R Square	=	0.651
				Adjusted R Square	=	0.626
Total	7648.838	103				

Variables	**Unstandardized Coefficients**		**Standardized Coefficients**	**T**	**Sig. p>|z|**
	B	**Std. Error**	**Beta**		
(Constant)	16.870	1.683		10.021	0.000*
Early maturing maize varieties	4.317	1.368	0.252	3.155	0.002*
Early dry planting	-4.073	1.298	0.237	3.138	0.002*
Minimum tillage	-1.535	1.327	-0.086	-1.157	0.250
Use of herbicides	6.443	1.556	0.375	4.140	0.000*
Crop rotation	6.115	1.447	0.356	4.227	0.000*
Tree planting	-2.424	1.090	-0.140	-2.224	0.029**
Chisel tilling	-4.229	1.459	-0.226	-2.898	0.055

Legend
Number of observation = 103
LR Chi^2 (7) = 238.66
Pseudo R^2 = 0.8068
Prob >Chi^2 = 0.000
* = significant at 1% level and
**=significant at 5%

Source: Author's Computation from Survey Data, 2021

Table 1 of results shows the coefficient of determination (adjusted R-squared) that was computed to determine the degree to which the independent variable (predictor variable) explained the variation of the dependent variable in the Multiple Linear Regression (MLR). Results revealed that R-Squared (R^2) and Adjusted *R*-Squared values are 0.651 and 0.626 respectively. This implies that 62.6% of the variability in the output of maize productivity in the study area is accounted for by the specified independent variables. The remaining 37.4% is due to other factors beyond the scope of this study. The table further shows the results of the *F*-ratio test for regression model the goodness of fit for the data. From the results, the output shows that the independent variables significantly predict the dependent variable, F (7, 96) = 22.597, p< 0.001. From the results, p<0.001 is less than 0.05 and therefore, indicates better reliance on the model parameter as they were efficient and unbiased.

Results in Table 1 revealed that three variables early dry planting and tree planting have negative coefficients hence the negative effect on maize production while early maturing maize varieties, use of herbicides and crop rotation have positive coefficients hence positive effect on maize production

From Table 1 of results, the adoption of early maturing maize varieties as a CSA intervention was found to be statistically significant at a 1 percent level with a positive coefficient of 4.317. The result on the adoption of early maturing maize varieties implies that a unit increase in its adoption leads to a 431.4% increase in the yield of maize and this result conforms to the expected sign of the study. The study is convergent to the study done by Bezu, Kassie, Shiferaw, and Ricker-Gilbert, (2014) on the adoption and impact of improved maize varieties on maize yield in Cameroon. The study found out a significant and positive effect of 36% on maize yield. Ogundari and Bolarinwa, (2018) also did a study using meta-regression analysis to investigate variations in the estimates of the impacts of adopting agricultural innovations and technologies on production, economic, and social outcomes across developing countries, and showed good results of studies focusing on the impact of high-yielding varieties over those focusing on agricultural technologies such as agricultural conservation. The study reported a positive impact of the adoption of high-yielding varieties such as improved maize varieties on maize yields. Therefore, this study is convergent to that of Bezu, Kassie, Shiferaw, and Ricker-Gilbert, (2014) and Ogundari and Bolarinwa (2018).

The study further revealed that the adoption of early dry planting as a CSA intervention was statistically significant at 1% probability level. However, the adoption of early dry planting as a CSA intervention had a negative coefficient of -4.517 hence a negative effect on maize productivity. This implies that if a farmer adoptions early dry planting as a CSA intervention, maize yield would decline by 451.7%. This result conforms to the expected sign of the study. Despite the known advantage of a faster start when early dry planting is adopted, planting into dry soil also poses the risk. Germination is initiated by a precipitation event that is not the start of a rainy season. In this situation, the crop can start to germinate but then die during subsequent drying of the soil and seedling. This result is convergent to that of Cooper et al., (2008) and Benin *et al.*, (2016), who found a negative impact of early dry planting. They opined that there is a risk that if the seed stays for a long period in the soil without sufficient moisture to trigger germination, high temperatures can cause loss of vigour, or it can be damaged or eaten by insects or other animals which in the long run will lead to a drop in the level of production. In addition to planting dry seeds, Lutts *et al.*, (2016) opined that seeds can be 'primed' with water, an enhancement method that might improve seed performance under stress conditions such as drought or when freshly harvested or aged seeds are used which might fail to germinate demonstrated how simple soaking seeds in water before sowing can increase the speed of germination and emergence, leading to better crop stands, and allow seedlings to grow much more vigorously. Therefore this study is convergent to that of Cooper *et al.*, (2008) and Benin *et al.*, (2016).

Herbicide use was another CSA intervention that was found to be statistically significant at a 1 percent level with a positive coefficient of 6.443 on maize production. A unit increase in the use of herbicides in maize production increases maize productivity by 644.3% per acre. The current result is in convergence with those of Nadeem *et al*., (2006), grain yield of the maize crop was increased with the use of herbicides as the herbicide application quickly suppresses the germination of the weeds and ultimately provides a competition-free environment for the crop plant to get all the available resources alone. These results were in line with the findings of Hassan *et al*., (2010), who reported that herbicides are the most efficient and effective in controlling weeds in maize and also increase the grain yield, crop growth, and canopy development. Chikoye *et al*., (2010) and Khan, (2008) also observed remarkable variations in grain yield of maize under the application of herbicides with no herbicides.

Results further revealed that the adoption of crop rotation as a CSA intervention was statistically significant at 1% level with a coefficient of 6.115 on maize production. This shows that an increase in the adoption of crop rotation as a CSA intervention leads to a 611.5% increase in the yield of maize, which conforms to the expected sign of the study. Rotating different crops can break pest cycles and add extra nutrients to the soil. It also builds soil fertility, control weeds, diseases, and insects, and thus lead to an increase in maize productivity. The current result is convergent with those of Al-Rumikhani, (2002) who did a study on the effectiveness of crop rotation in Saudi Arabia where rotations of cereals and alfalfa crops managed with centre pivot systems showed an improvement in soil hydrological properties and subsequent yield improvement. Another long-term study in Syria conducted by Jones and Singh (2000) showed an increase in crop yield of a barley-legume rotation compared to continuous barley. A study done in Egypt showed the ability of crop rotation in decreasing the nematode population in the soil (Ahlam *et al*., 2015). Therefore, based on the result of this study, and those conducted across different parts of the world, it has been demonstrated that rotating crops every other year has various economic and environmental benefits.

Finally, adoption of tree planting as a CSA intervention was also found to be statistically significant at a 5% level with a negative coefficient of 2.424 on maize production. This implies that a unit increase in the adoption of tree planting per acre as a CSA intervention reduces maize production by 242.4%. This means that when trees are grown in a narrow alley, it is likely that they will grow bigger, their crowns will shade most of the plants below it reducing its yield. However, tree planting around the borders of the land has proven to be beneficial as a source of soil nutrients as well as acting as windbreakers and thus improving maize production. The current study is divergent to that of Palm et al., (2001) who did a study on Faidherbia albida species of trees in Zambia over a decade and found out that mature trees can sustain maize yields of up to 4.1 tonnes per 13 hectares as compared to 1.3 tonnes per hectare beyond the canopy of the tree. The study is also divergent to that of Akinnifesi *et al.,* (2006) who did a study in a long-term trial in Makoka-Malawi found out that when gliricidia is intercropped with maize, maize yield increased in the range of 100 to 500%, averaging 315% over a ten-year period. Increase in yield is more apparent from the third year after tree establishment and onwards (Akinnifesi *et al.,* 2006).

5. SUMMARY, CONCLUSION AND RECOMMENDATION

The results on the estimates of the effects of the adoption of climate-smart agricultural interventions on the level of maize productivity using the Multiple Linear Regression (MLR) analysis model revealed that the adopted CSA interventions that include early maturing maize varieties, early dry planting, herbicide use, crop rotation, and tree planting were statistically significant at 1% level. The study further revealed that the adoption of early dry planting as a CSA intervention was statistically significant at 1% probability level. However, the adoption of early dry planting as a CSA intervention had a negative coefficient of -4.517 hence a negative effect on maize productivity. This implies that if a farmer adopts early dry planting as a CSA intervention, maize yield would decline by 451.7%. Herbicide use was another CSA intervention that was found to be statistically significant at a 1 percent level with a positive coefficient of 6.443 on maize production. Crop rotation as a CSA intervention was statistically significant at a 1% level with a coefficient of 6.115 on maize production. This shows that an increase in the adoption of crop rotation as a CSA intervention leads to a 611.5% increase in the yield of maize, which conforms to the expected sign of the study. Tree planting had a positive significant effect with a coefficient of -2.42 units. Therefore, in conclusion, the estimated results of this study rejected the second null hypothesis that the adoption of CSA interventions has no significant effect on maize productivity among small scale maize farmer households in Moiben Sub-County. Therefore, the study recommends the following strategies for strengthening maize production amongst the smallholder farmers, that relevant stakeholders, county and national governments should come up with innovative CSA solutions that will help boost maize production among small scale maize farmer households and more farmers need to be trained on the use of CSA interventions as this intervention will help to cut the cost of production and help farmers to realize high-profit margins from their maize output.

ACKNOWLEDGEMENT

I thank God for the gift of life during this work. Special thanks to my supervisors Dr. Elijah K. Ng'eno and Dr. Joseph K. Rotich for their unreserved advice and guidance in this work. I also thank all people who have assisted me in one way or another during my research.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

[1] Ahlam, R. V., Mohammed, K., and Mami, Y. (2015). Impact of heat treatment on polyphenol oxidase and peroxidase action in Algerian stored dates. *International Journal of Agricultural Sciences*, *5*(3), 120-124.

[2] Akinnifesi, F., Ajayi, O. C., Mullila-Mitti, J., DeWolf, J. J., Matakala, P. W., and Kwesiga, F. R. (2006). Adoption, profitability, impacts and scaling-up of agroforestry technologies in southern African countries. *ICRAF, Lilongwe*.

[3] Alhameid, A., Ibrahim, M., Kumar, S., Sexton, P., and Schumacher, T.E. (2017). Soil organic carbon changes impacted by crop rotational diversity under no-till farming in South Dakota, USA. *Soil Sci. Soc. Am. J. 81, 868–877*.

[4] Ali, A., Usman, M., and Adaikwu, A.O. (2018). Effect of tillage methods on soil properties, growth, and yield of maize (Zea mays L.) in Makurdi, Nigeria. *Int. J. Sci. Health c. Res. 3.*

[5] Al-Rumikhani, Y. A. (2002). Effect of crop sequence, soil sample location and depth on soil water holding capacity under center pivot irrigation. *Agricultural water management*, *55*(2), 93-104.

[6] Babaji, B.A. (2007). Effects of conservation tillage on agricultural development. A Paper Presented at the Mid Term Review (MTR), Samaru Zone, Kaduna State. Pg12.

[7] Benin, S. (Ed.). (2016). *Agricultural productivity in Africa: Trends, patterns, and determinants*. Intl Food Policy Res Inst.

[8] Boomsma, C.R., Santini, J.B., West, T.D., Brewer, J.C., McIntyre, L.M., and Vyn, T.J., (2010). Maize grain yield responses to plant height variability resulting from crop rotation and tillage system in a long-term experiment. *Soil Tillage Res*. 106, 227–240.

[9] Branca, G., McCarthy, N., Lipper, L., and Jolejole, M. (2011). '*Climate-Smart Agriculture*: A synthesis of empirical evidence of food security and mitigation benefits of from improved cropland management', Food and Agriculture Organization of the United Nations (FAO), Rome.

[10] Brown, S.H. (2009). Multiple linear regression analysis: a matrix approach with MATLAB. *Alabama Journal of Mathematics*, *34*, 1-3.

[11] Chemonics. (2010). *Staple Foods Value Chain Analysis: Country Report Kenya*. Washington, DC. Chemonics International.

[12] Dick, W.A., McCoy, E.L., Edwards, W.M., and Lal, R., (1991). Continuous application of no-tillage to Ohio soils. *Agron. J.* 83, 65–73.

[13] Doss, C.R. (2003). Understanding farm level technology adoption: lessons learned from CIMMYT's micro surveys in Eastern Africa.

[14] Duiker, S., Haldeman, J.F., and Johnson, D.H., (2006). Tillage and Maize Hybrid Interactions.

[15] Fan, R., Zhang, X.P., Liang, A., Shi, X., Chen, X., Bao, K., Yang, X., and Jia, S., (2012). Tillage and Rotation Effects on Crop Yield and Profitability on a Black Soil in Northeast China.

[16] Food and Agricultural Organization (2015). *The State of Food Insecurity in the World:* Strengthening the Enabling Environment for Food Security and Nutrition, Rome: FAO, Available at http://www.fao.org/3/a-i4030e.pdf

[17] Food and Agricultural Organization **(**2016). Climate Change and Food Security: risk and responses, Rome.

[18] Food and Agriculture Organization, (2013). *The Millennium Development Goals:* The Road Ahead. Available online: www.fao.org/mdg/ (Accessed on 22 July 2020).

[19] Giller, K.E., Witter, E., Corbeels, M., and Tittonell, P. (2009). Conservation agriculture and smallholder farming in Africa: *The heretics' view*. *Field Crops*, 114, 23–34.

[20] Government of Kenya (2014). *Mid Term Review Report*, *Agricultural Sector Development Support Program*. Nairobi: Ministry of agriculture livestock and fisheries. Nairobi, Kenya: Citat.

[21] Grassini, P., Thorburn, J., Burr, C., and Cassman, K.G., (2011). High-yield irrigated maize in the Western U.S. Corn Belt: I. On-farm yield, yield potential, and impact of agronomic practices. *Field Crops Res.* 120, 142–150.

[22] Gregor, S., & Jones, K. (1999). Beef producers online: Diffusion theory applied. *Information Technology & People*.

[23] Intergovernmental Panel On Climate Change. (2014). Ipcc. *Climate change*.

[24] Kiepe, P. (2005). No runoff, no soil loss: Soil and Water Conservation in Hedgerow Barrier Systems. Ph.D. Thesis. Wageningen Agricultural University, Netherlands, 156 pp.

[25] Kilic, K., Kilic, S., and Kocyigit, R. (2012). Assessment of spatial variability of soil properties in areas under different land use. *Bulg. J. Agric. Sci*. 18, 722–732.

[26] Kothari, C.R. (2008). *Research methodology*: Methods and techniques, (pp. 1-56). New Delhi: New Age International (P) Limited, Publishers (ISBN 10: 81-224-1522-9).

[27] Kumar, A., Dorodnikov, M., Splettstößer, T., Kuzyakov, Y., and Pausch, J. (2017). Effects of maize roots on aggregate stability and enzyme activities in soil. Geoderma 306, 50–57.

[28] Leakey, R.B., (2010). Should we be Growing More Trees on Farms to Enhance Sustainability? The special report, *International Society of Tropical Foresters News*, 1-12.

[29] Lutts, S., Benincasa, P., Wojtyla, L., Kubala, S., Pace, R., Lechowska, K., and Garnczarska, M. (2016). Seed priming: new comprehensive approaches for an old empirical technique. *New challenges in seed biology-basic and translational research driving seed technology*, 1-46.

[30] Mercer, D. (2003). 'Adoption of agroforestry innovations in the tropics: A review', *Agroforestry Systems*, 61-62(1-3): 311–328.

[31] Nassiuma, D.K. (2000). *Survey sampling*: Theory and methods. Njoro, Kenya: Egerton University Press.

[32] Neufeldt, H. (2013). Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. *Agriculture and Food Security* 1 (1): 1-13. Available at: http://link. springer.com/article/10.1186%2F2048-7010-1-15

[33] Nunes, M.R., van E.M., Schindelbeck, R., Ristow, A.J., and Ryan, M., (2018). No-till and cropping system diversification improves soil health and crop yield. Geoderma 328, 30–43.

[34] Ogundari, K., and Bolarinwa, O.D. (2018). Impact of agricultural innovation adoption: A meta-analysis. *Australian Journal of Agricultural and Resource Economics*, 62(2), 217–236. https://doi.org/10.1111/1467-8489.12247.

[35] Rogers, E.M. (2003). *Diffusion of innovations* (*5th ed.).* New York: *2(2): 107-111*.

[36] Sileshi, G., Akinnifesi, F.K., Ajayi, O.C., Chakeredza, S., Kaonga, M., and Matakala, P.W. (2007). Contributions of agroforestry to ecosystem services in the Miombo eco-region of Eastern and Southern Africa. *African Journal of Environmental Science and Technology*. **1**(4): 68-80.

[37] Soane, B.D., Ball, B.C., Arvidsson, J., Basch, G., Moreno, F., and Roger-Estrade, J. (2012). No-till in northern, western and south-western Europe: a review of problems and opportunities for crop production and the environment. *Soil Tillage Res.* 118, 66–87.

[38] Tebrügge, F. (2003). No-tillage visions- protection of soil, water, and climate and influence on management and farm income. In: García-Torres, L., Benites, J., Martínez-Vilela, A., Holgado-Cabrera, A. (Eds.), *Conservation Agriculture*: Environment, Farmers Experiences, Innovations, Socio-Economy, Policy. Springer, Netherlands, Dordrecht, pp. 327–340.

[39] Tebrügge, F., and Düring, R.A. (1999). Reducing tillage intensity — a review of results from a long-term study in Germany. *Soil Tillage Res*. 53, 15–28.

[40] Van den Putte, A., Govers, G., Diels, J., Gillijns, K., and Demuzere, M. (2010). Assessing the effect of soil tillage on crop growth: a meta-regression analysis on European crop yields under conservation agriculture. *Eur. J. Agron.* 33, 231–241.

[41] Wittwer, R.A., Dorn, B., Jossi, W., and van der Heijden, M.G.A. (2017). Cover crops support the ecological intensification of arable cropping systems. *Sci. Rep*. 7, 41911.