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IMPACT OF ADOPTION OF SOIL AND WATER CONSERVATION PRACTICES ON MAIZE YIELD IN THARAKA NITHI COUNTY

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ABSTRACT

Maize is one of the most significant crops for the Kenyan population. Adoption of soil and water conservation practices on maize offers a solution to curb climate change dangers by enhancing increased crop production and improving soil quality. Maize yield is low compared to its potential which is caused by factors like poor agronomic practices, drought, low soil fertility and low use of soil technology practices. This study therefore aimed at determining how adoption of soil and water conservation practices as technologies affected the maize yield in Tharaka Nithi County. Cross-sectional research design was used where multistage sampling procedure was applied to select 318 smallholder maize farmers. Data analysis was done using Propensity Score Matching (PSM) which applied logit regression model that had block numbers which ensured that the estimated propensity scores for adopters and non-adopters were similar. The PSM used three matching algorithms (Nearest Neighbor, Radius and Stratification) to match the adopters and non-adopters. The logit model estimates on socio-economic and institutional factors showed significance on age at 5% on mulching, household size at 5% on intercropping, land size at 5% on irrigation, extension services at 1% on crop rotation and group membership at 10% on irrigation that influenced adoption of SWCs. The positive coefficients indicated that an increase in either of the factors increased the adoption of SWCs, land size P-value = 0.002<0.01, P-value = 0.053<0.1, P-value = 0.021<0.05 on intercropping, crop rotation and irrigation, respectively and household size P-value = 0.015<0.05, P-value = 0.040<0.05, P-value = 0.081<0.1 on intercropping, irrigation and terraces, respectively. The positive Average Treatment Effects (ATT) indicated an average increase in maize yield from intercropping and irrigation as soil and water conservation practices (SWCs) at a range between 290 kgs to 375 kgs and 270 kgs to 725 kgs per hectare, respectively. Therefore, there is need to practice more intercropping and irrigation for increased productivity and food security.

Key words: Soil Water Conservation Practices, Adoption, Impact, Propensity Score Matching, Yield, Average Treatment Effects

INTRODUCTION

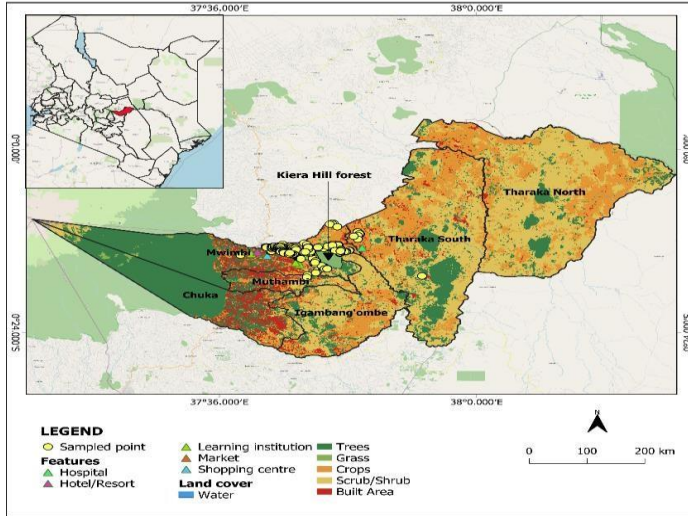
One of the severe problems facing agricultural production is climate change, which is a primary cause of changes in physical and biological systems (Alexandridis *et al.*, 2023). Climate change alters functionality of the ecosystem, population and production reducing yield gaps. The low productivity of crop yields is attributed by factors like droughts, poor agronomic practices, insufficient access to technology and decline in soil fertility (Chekole *et al.*, 2023). Soil fertility decline can therefore be reversed by promotion of various soil fertility enhancing technologies and practices that minimize deterioration of soil fertility and to improve production (Adem *et al.*, 2023). Small holder farmers have used traditional indigenous practices for a long time which have not been beneficial to them for increased crop output (Iyilade *et al.*, 2020) therefore to restore the lost nutrients from poor agronomic practices adoption of different soil and water conservation practices is necessary.

Maize (*Zea mays*) is one of the significant crops in Kenya for food security where it is a staple food for majority of the population (Ocwa *et al.*, 2023). Maize production is influenced by land management techniques and climatic conditions where the tendency of rainfall events and drought patterns influences production (Nogueira *et al.*, 2023). Production of maize is expected to reduce due to effects of climate change such as soil degradation and the adaptability of soil and water maintenance technologies which are necessary in maize production (Bagula *et al.*, 2022). Maize experiences a great deal of sensitivity to drought since its germination depends on rain-fed systems therefore, it is necessary to come up with alternate soil moisture conservation techniques to lessen the consequences of drought stress (Uwizeyimana *et al.*, 2018). Improved agronomic techniques and soil and water conservation techniques would boost maize yields and improve soil quality, leading to a further expansion of agricultural acreage (Kim *et al.*, 2021).

Maize yield in developing countries such as Kenya is low compared to other regions in the world (Chekole *et al.*, 2023). The potential yield in Kenya is about 6 to 8 ton per ha while the current yield is 1.0 ton per ha (Kiboi *et al.*, 2019). The production of maize is vulnerable to the increasingly frequent occurrence of climate variability therefore it is necessary to adopt SWCs that curb the risk of climate change resulting to improvement in the production of maize (Mumo *et al.*, 2021). This study focused on the maize sector which contributes to alleviating poverty, increasing household income and improving food security. The challenge of agriculture to meet the increasing demand for food in a sustainable way could be credited to adverse effects of climate change and decline in agricultural farm practices among maize farmers. Therefore, the study considered the interplay of climate change, conservation agriculture and soil and water conservation practices to curb the dangers of unproductive and poor crop production. This has led to a huge gap of knowledge to examine the impact of soil and water conservation application practices on maize yield of smallholder farmers in Tharaka Nithi County, Kenya.

RESEARCH METHODS AND MATERIALS

The data used in this study was obtained from Tharaka Nithi County, Kenya located on the borders of Embu County to the south and south-west, Meru to the north and north-east, Kirinyaga and Nyeri to the west, and Kitui to the east and southeast. The county lies between latitudes 00° 07' and 00° 26' South and between longitudes 37° 19' and 37° 46' East (Mugi-Ngenga *et al.*, 2016) covering around 2609 km². The study area included the upper zones of Maara and Chuka Sub-Counties comprising of two wards in each Sub-County Muthambi, Mwimbi, Magumoni and Igambang'ombe. The area receives sufficient rainfall for agriculture with primary soil type is Humic-nitisols and having a clay concentration of 78%.



Sampling Technique

For the selection of households in the area, a multistage sampling approach was employed. The first stage, Tharaka Nithi County was chosen based on its potential for agriculture and on knowledge about technology being promoted to conserve soil and water. The second stage involved, Maara Sub-County and Chuka Sub-County which was purposively selected due to their informed and varied climate change adaption techniques in the local agroecosystems of Tharaka Nithi County. In the third stage, two wards in each Sub-County; Maara sub-County (Muthambi and Mwingi) and Chuka Sub-County (Magumoni and Igambang’ombe), were randomly selected. Respondent farmers obtained from the sampled wards were generated by the method of simple random sampling.

The Cochran (1975) formula was used to obtain the sample size. The Cochran formula was showed as below;

$$n_o = \frac{Z^2 * P * Q}{e^2} \dots \dots \dots (1)$$

where;

z is the standard normal confidence interval of 95% (z = 1.96) e is the marginal of error at (0.05)

p is the percentage of the population which possesses the characteristics for adoption (0.6)

q is 1 – p (0.4)

The formula projected a sample size of 318 respondents.

For this study, a semi-structured questionnaire and direct field observation were employed as the primary methods for gathering data. Data was collected on socio-economic and institutional variables such as gender, age, education, land size, group membership, extension services and access to credit, with dependent variables such as mulching, intercropping, terraces, grass strips, minimum tillage, irrigation, and crop rotation. The questionnaire was filled, and responses recorded. Descriptive statistics was used to analyze the socio-economic and institutional characteristics of smallholder farmers in Tharaka Nithi County.

Empirical Specification and Estimation Technique

Binary logit regression model was used to determine the propensity scores on the socio-economic and institutional factors that affect the soil and water conservation practices. The model for the adoption of SWCs was specified as.

$$Y_{swc} = f(\beta^0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \dots + \beta_nX_n) \dots \dots \dots (2)$$

where;

Y_{swc} = the likelihood of adopting SWCs

β° = the constant

X_1, X_2, X_3 = are the independent variables

$\beta_1, \beta_2, \beta_3$ = estimated regression coefficients for each independent variable

$X_1 = Age$

$X_2 = Gender$

$X_3 = Education$

$X_4 = Occupation$

$X_5 = Extension Services$

$X_6 = Access to credit$

The logit regression model estimated propensity scores that were used to determine the average treatment effect which measured the impact on maize yield on Propensity Score Matching model. The PSM was used to reduce the selection biasness. The PSM model equation used in this study was as below;

$$P(X_i) = prob (T_i = 1|X_i) \dots\dots\dots (0 < p(X_i) < 1) \quad (3)$$

X_i is a vector of adoption of technology control variables, the outcomes are independent of adoption of technology $p(X_i)$. To calculate the propensity scores based on the ATT effect, the first condition is the balancing hypothesis determined as below;

$$T|X|P(x) \dots\dots\dots (4)$$

Observations with the same propensity scores, the distribution of pre-treatment characteristics must be similar in the treated and control groups, therefore the second condition is the Conditional Independence Assumption (CIA) given the propensity score as;

$$Y_1, Y_0 | T|X \rightarrow Y_1, Y_0, | T P(X) \dots\dots\dots (5)$$

The average treatment effect on the treated (ATT) measured the performance difference between the treatment and control groups. After computing the propensity score, the ATT τ effect was estimated as:

$$\tau = E(Y_{1i} - Y_{0i} | D_i = 1) \dots\dots\dots (6)$$

$$\tau = E\{E(Y_{1i} - Y_{0i} | D_i = 1, P(X))\} \dots\dots\dots (7)$$

$$\tau = E\{E(Y_{1i} - Y_{0i} | D_i = 1, P(X)) - E\{Y_{0i} | D_i = 0, P(X_i)\} | D_i = 1\} \dots\dots\dots (8)$$

Y_{1i} is the result of a treated individual, which is maize yield for adopters
 Y_{0i} is the outcome if the individual is the control group, the maize yield for non- adopters

RESULTS AND FINDINGS

Table 1: Logit Regression, Estimation of Propensity Scores Results

Variable	Intercropping Co-efficient	Terraces Co-efficient	Mulching Co-efficient	Grass Strips Co-efficient	Minimum Tillage Co-efficient	Stone Bunds Co-efficient	Rotation Co-efficient	Irrigation Co-efficient
Land size	0.499*	0.160	-0.032	0.328**	-0.169	-0.294	0.4295**	0.2757*
Household size	0.195**	0.121**	-0.094	0.072	-0.098	0.133	0.1459	0.1499*
Gender	0.664**	0.130	0.599**	0.142	-0.159	0.091	-0.0698	-0.0953
Age	-0.010	-0.004	0.024**	-0.018	-0.003	-0.013	0.0269**	0.0198*
Education	0.006	-0.017	-0.034	0.0005	-0.300*	-0.083***	0.0003	0.0555*
Extension	-1.227*	0.129	1.123*	-0.981*	0.672	0.031	1.3745*	0.0129
Membership	1.660*	-0.923*	0.723**	0.609**	-0.442	-0.968***	0.7057	1.162*
Credit Access	-0.824*	-0.026	0.242	0.118	0.854	0.725***	0.0964	0.3337

*, **, and *** represents significance level at 1%, 5% and 10%,

respectively. Prob>chi2 = 0.0000

Number of observations = 318

The logit regression model used, estimated propensity scores for matching the adopters and non-adopters of SWCs. From the study results, farm size had a positive co-efficient statistically significant at 1%, 5% and 10% on intercropping, irrigation and crop rotation, respectively (Table 1). The study findings agreed to those of Wordofa *et al.* (2020) indicating that an increase land area increased the adoption of intercropping, irrigation and crop rotation. Additionally, land size as a variable also had a negative co-efficient and was significant on grass strips at 5%. This indicated that as land size increased, the less grass strips as SWCs were practiced by the smallholder maize farmers. This was because land is a scarce resource and practicing grass strips involved taking land that could be used for production. The household size from the study findings, had a positive co-efficient on intercropping and irrigation at 5%. This showed that the more the number of people living in a household, the more irrigation and intercropping was practiced. The findings matched those of Mazumder *et al.* (2023) who reported that the greater the number of people the more practice of conservation techniques were done. the study also found household size variable to have a negative co-efficient on terraces at 10% significance level. Age as a variable had a negative co-efficient on crop rotation and irrigation at 10% significance level (Table 1), this showed that as age increased by one, adoption of crop rotation and irrigation decreased.

In addition, age also had a positive co-efficient on mulching at 5% significance level. This showed that older people practiced more mulching compared to younger people. The results are in line with those of Islam *et al.* (2021) who reported that age had positive significance on techniques used to curb the dangers of climate change. From the study findings, education was found to have a negative association on minimum tillage at 1%, stone bunds and irrigation at 10% (Table 1). This indicated that the more a farmer was educated, the less practice on minimum tillage, stone bunds and irrigation. This was probably because most educated farmers did not focus on farm work, they did more of off-farm activities making adoption of SWCs limited. The results disagreed with those of Checco *et al.* (2023) whose report showed that education had a positive association on improved rice varieties. The study findings also showed that extension and training had a positive association on mulching and crop rotation at 1% significance level. This showed that farmers with knowledge from extension officers practiced more of mulching and crop rotation as SWCs. Additionally, extension and training had a negative relation with intercropping and grass strips at 1% significance

level. This showed that farmers with knowledge on extension services practiced intercropping and grass strips less compared to those with no knowledge. Kogo *et al.* (2022) had inconsistent results who concluded a positive association on extension and training on maize farmers in western Kenya.

Group membership had a positive relationship on intercropping at 1%, mulching and grass strips at 5% while irrigation at 10% significance level (Table 1). This showed that a farmer belonging to a group practiced intercropping, mulching, grass strips and irrigation more compared to those who did not belong to any group. The study results agreed to those of Njenga *et al.* (2021) who reported a positive co-efficient on group membership because farmers learnt about technologies through membership. Group membership also had a negative association on terraces and stone bunds at 1% and 10%, respectively. This showed that those who did belong to a group practiced less of terraces and stone bunds. The study results are consistent to those of Oduniyi *et al.* (2022) who found membership to have a negative association on adopting land management practices. Access to credit had a negative co-efficient on intercropping at 1% significance level (Table 1). This showed that those who accessed credit practiced less of intercropping than those who did not. Findings of this study matched the results of Anang *et al.* (2022) whose analysis concluded that majority of soybean farmers lacked access to finances, which prevented them from adopting SWCs to increase the level of productivity. Additionally, access to credit had a positive association with stone bunds at 10% significance level. This indicated that those farmers who accessed credit adopted stone bunds more compared to those who never accessed credit. This was probably because stone bunds required finances for installation hence expensive to lay them as soil and water conservation practices.

Table 2: Average Treatment Effect on the Treated (ATET) Group on Maize Yield

SWCs	Matching Algorithm	Treated	Control	ATT	Std. Err.	T-statistic
Intercropping	Nearest Neighbor	214	62	375.706	260.743	1.441
	Radius	214	103	291.741	168.643	1.73**
	Stratification	213	104	365.558	199.942	1.828**
Terraces	Nearest Neighbor	176	86	-246.028	227.401	-1.082
	Radius	176	142	-72.72	191.506	-0.38
	Stratification	176	142	-74.774	178.804	-0.418
Mulching	Nearest Neighbor	91	60	382.934	240.604	1.592
	Radius	91	216	253.715	231.548	1.096
	Stratification	91	216	313.008	229.425	1.364
Grass strips	Nearest Neighbor	109	71	227.725	316.842	0.719
	Radius	109	209	219.206	202.906	1.08
	Stratification	109	209	217.157	142.233	1.527
Minimum tillage	Nearest Neighbor	12	10	-248.75	359.715	-0.692
	Radius	12	206	-	114.314	-2.35*
	Stratification	12	206	-	274.106	-2.548*
Stone bunds	Nearest Neighbor	37	29	-51.946	109.391	-0.475
	Radius	37	249	-	92.429	-2.87*
	Stratification	37	249	-	87.237	-3.294*

Rotation	Nearest Neighbor	271	40	-94.491	327.216	-0.289
	Radius	271	45	-57.64	254.482	-0.227
	Stratification	271	45	-24.37	342.11	-0.071
Irrigation	Nearest Neighbor	133	73	271.511	247.562	1.097
	Radius	133	185	727.734	199.679	3.645*
	Stratification	133	185	562.435	223.395	2.518*

*, ** and *** represents significance level at 1%, 5% and 10%, respectively.

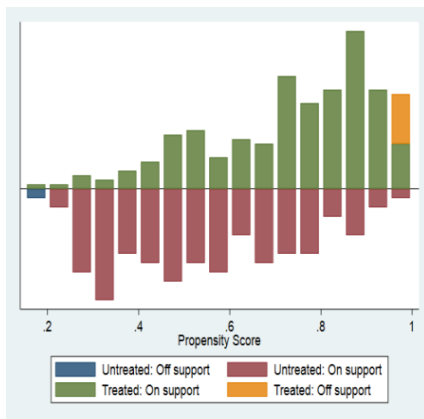
The study therefore investigated the impact on maize yield where three matching algorithms (Nearest Neighbor, Radius and Stratification) determined the Average Treatment Effect (ATT) using the Propensity Score Matching Model (PSM). The Average Treatment Effect (ATT) showed the difference in yield between the adopters and non-adopters of SWCs. The study findings showed that the ATT on intercropping and irrigation was an approximate increase range of 290 kgs to 375 kgs per hectare and 270 kgs to 725 kgs per hectare (Table 2), respectively for those who adopted compared to those who did not. The findings from the study agreed with the report of Takam-Fongang *et al.* (2019) who confirmed that the average treatments were positive and significant on adoption on improved maize varieties in Cameroon. Additionally, the ATT on minimum tillage and stone bunds was negative with a decrease in maize yield of about 248 kgs to 690 kgs per hectare and 50 kgs to 287 kgs per hectare (Table 2), respectively for those who adopted either minimum tillage or stone bunds. Results obtained from this study disagree to the study outcome of Ahmed *et al.* (2017) whose report indicated that the adoption of technology was positive and improved maize productivity leading to significant gains in consumption for the adopters than the non-adopters in Ethiopia. Further the results obtained from this study indicated that the adoption of terraces and crop rotation had a negative ATT and decreased production but was insignificant (Table 2). Additionally, the study findings also showed that the adoption of mulching and grass strips had a positive ATT and increased production but was not significant (Table 2).

The Common Support Graph

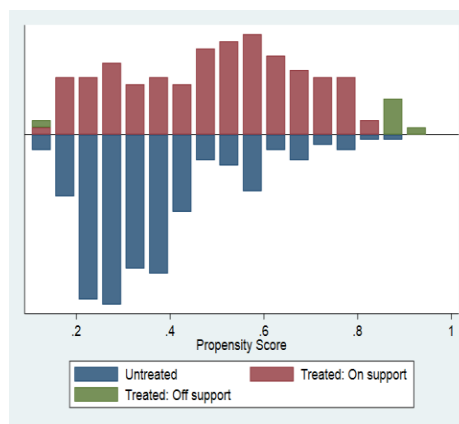
The common support graph indicates the regions of matching enough shares to members of the treatment and control groups. The area of shared support is where the estimated propensity ratings for participants and non-participants have similar densities. It is accessed by examining a graph of the propensity scores across treatment and comparison groups. It is therefore distributed as;

Treated on support: Shows adopters having a suitable comparison group

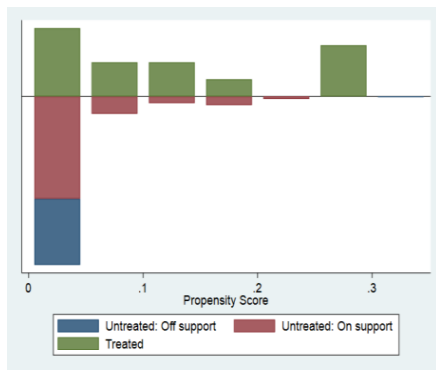
Treated off support: Shows adopters having no suitable comparison group
 Untreated on support: Shows non-adopters having a suitable comparison group
 Untreated off support: Shows non-adopters having no suitable comparison group



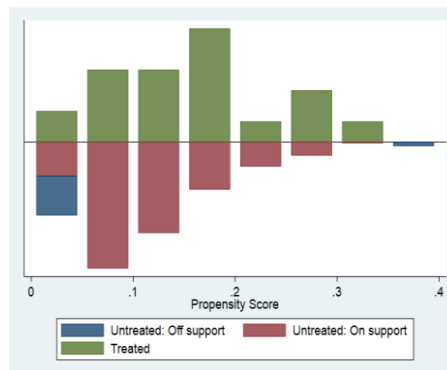
Common support graph on intercropping



Common support graph on irrigation



Common support graph on minimum tillage



Common support graph on stone bunds

CONCLUSION

The study was conducted to determine the impact of adoption of SWCs on maize yield. The results from the PSM model signified that the adoption of SWCs was sufficient to attain an impact in the maize yield. There was positive impact in maize yield for adopters of intercropping and irrigation as SWCs. Therefore, there is need for adoption of SWCs that curb erosion, drought and improve the maize production. In relation to maize productivity, small scale farmers who adopt the SWCs are far much better than the non-adopters this consequently brings the attainment of food security under climate change.

RECOMMENDATIONS

The study recommended that to increase maize yields, stake holders and policy makers should encourage campaigns and awareness that outline the economic benefits of SWCs to increase their adoption. Provision of information through extension services is important to enable farmers to have the ability to apply the practices and share the information

with other farmers. Maize small-scale farmers are urged to practice and explore soil and water conservation methods like irrigation and intercropping to avoid usage of practices that may decrease production.

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