**ASSESSMENT OF THE IMPACT OF ADOPTION OF SOIL AND WATER CONSERVATION PRACTICES ON MAIZE YIELD IN THARAKA NITHI COUNTY, KENYA**

**ABSTRACT**

Maize (*Zea mays*) 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. Despite various interventions to practice improved soil and water conservation technologies (SWCs) in maize production, adoption of these technologies is low resulting to poor output due factors like poor agronomic practices, drought, low soil fertility and low use of soil technology practices. This study therefore aimed at determining how the 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 logistic regression model for the estimated propensity scores for adopters and non-adopters. The PSM used three matching algorithms (Nearest Neighbor, Radius and Stratification) to match the adopters and non-adopters. The logistic regression 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 = 0.021<0.05 on intercropping and irrigation, respectively and household size P-value = 0.015<0.05 on intercropping. The positive 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. Results showed that intercropping and irrigation led to notable maize gain in yield as key SWCs. There is therefore the need to practice more intercropping and irrigation for increased productivity and food security. Policy makers and extension agents are to encourage campaigns and increase awareness that outline the economic benefits of SWCs adoption and thereafter positively impact crop yield.

**Key words:** Soil Water Conservation Practices, Adoption, Propensity Score Matching, Yield

1. **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 be reversed by promotion of 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. There is an urgent demand to change our intensive crop production systems, replacing them with soil use and management systems that recover, preserve, or improve soil health and are environmentally sustainable, producing healthy and good-quality food (Suzuki *et a*l., 2024).

Up to 65% of productive farms are degraded, and 55% of Africa's agricultural land is at very high risk of future desertification due to 45% of the Africa’s land already being affected by it (Darkoh and Michael, 2018). The restoration of Africa's dry lands is essential for adaptation and the development of resilient and sustainable agricultural systems since they are extremely susceptible to climate change (Mansourian *et al.,* 2021). Agro-based economies dominate Africa’s countries like Ethiopia, Kenya, Malawi, Mozambique and Nigeria where drought affect these countries that generate the majority of the region's food (Katengeza *et al.,* 2019). Success in the agricultural sector directly affects social welfare, expansion of the economy and food security (Gniza *et al.,* 2023) therefore, its significance is evident in rural areas, whose households mainly rely on farming to make ends meet and mitigating the extreme effects of climate change affecting Africa’s production (Thinda *et al.,* 2020).

Maize (*Zea mays*) is one of the significant crops in Kenya for food security where it is a stable 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. It is therefore, 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 is an important food crop, and staple food for majority of people in Kenya, it accounts for 40% of crop area and 51% of all staples grown (De Groote *et al.,* 2023). Although maize is important, its growth is hindered by both biotic and abiotic stresses which include poor fertility and frequent droughts (Simtowe *et al.,* 2021; Jones-Garcia *et al.,* 2021). Therefore, in increasing maize production and adapting to climate change, SWCs have been developed to curb the change that pose risks to productivity. Soil degradation is a major challenge to food security and sustainable development in sub-Saharan Africa. This is due to crop yield decline that implies most of the techniques developed are rarely adopted by farmers and those adopted are on small areas (Ouédraogo & Ouoba, 2025). The production of maize is still more vulnerable to the increasingly frequent occurrence of climate variability, particularly during growing seasons when droughts and floods occur (Mumo *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 challenge of agriculture to meet the increasing demand for food with this deficit and production gap of maize in Kenya, could be credited to adverse effects of climate change, inadequate agronomic practices and low adoption of conservation technologies among maize farmers. For these reasons, this study focused on the maize sector which contributes to alleviating poverty, increasing household income and improving food security. This study also considered the interplay of climate change, conservation agriculture and soil and water conservation practices to curb the dangers of unproductive and poor crop production. As a result of the low adoption of these SWCs technologies, there was a significant information gap about the impacts of using soil and water conservation (SWCs) techniques on the maize production of smallholder farmers in Tharaka Nithi County.

**2.0 METHODOLOGY**

**2.1 Study Area**

The data used in this study was obtained from Tharaka Nithi County (Figure 1), 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 00⁰ 07’ and 00⁰ 26’ South and between longitudes 37֯⁰ 19’ and 37⁰ 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 being Humic-nitisols and having a clay concentration of 78%.

**2.2 Research Design**

Cross-sectional survey design was applied in this study to assess soil and water conservation practices (SWCs) and the yield. This design was used since it is an observational study design that measures the outcome and the exposures (Kabubo-Mariara *et al.,* 2007) and can only gather information once to characterize how farmers in the study area perceived climate change and the adaptive techniques, such as the use of SWCs. It was also employed due to its ability to directly compare numerous different factors, for this case socio-economic and institutional variables. Descriptive statistics was also done since it is a scientific method that involves collecting data that enables the description of subjects or a situation. In this study descriptive statistics was useful in attaining information on the underlying determinants that are true and accurate.

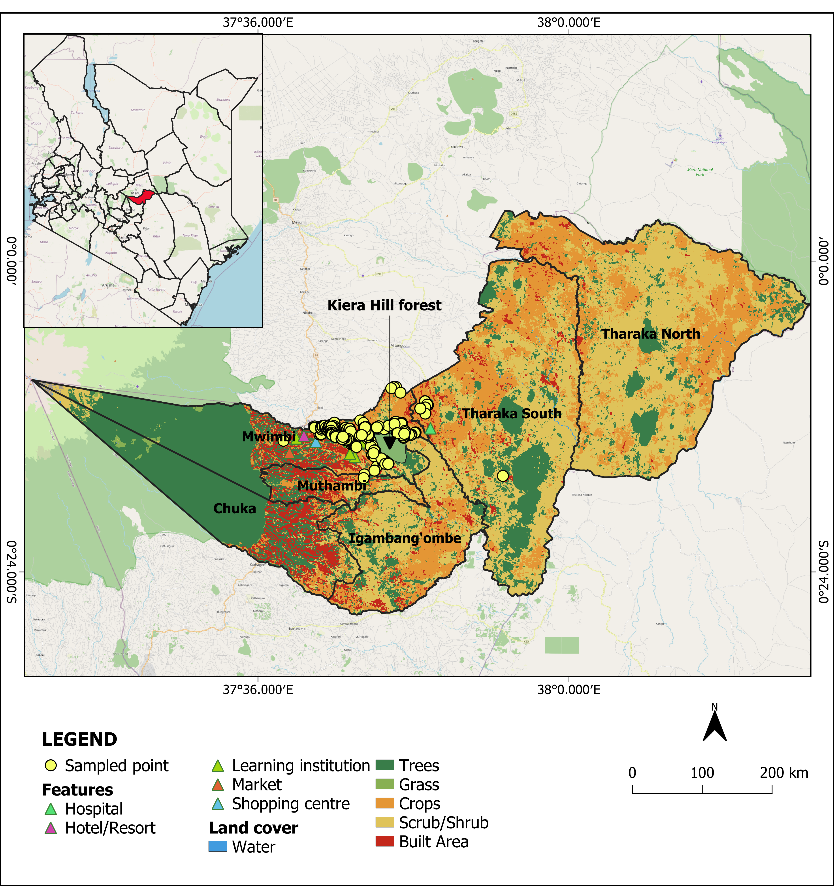


Figure 1: Map of Tharaka Nithi County.

**2.3 Sampling Technique and Sample Size**

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 Mwimbi) 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;

where;

z is the standard normal confidence interval of 95% (z = 1.96)

e is the [marginal of error](https://www.statisticshowto.com/probability-and-statistics/hypothesis-testing/margin-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)

Thus, used was the sample size for finite population which is a correction factor, used to adjust or reduce the standard error to make it more accurate.

where:

N as the target population (5250)

There was minor variance between the expected sample size and the achieved sample size because of the willingness of the respondents to respond to the questionnaire. Therefore, the study sample size was 318 respondents.

**2.4 Data Collection**

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. Thesemi-structured questionnaire obtained the primary information regarding the socio-economic, institutional factors and the effects or impact of adoption of SWCs by the smallholder maize farmers in Tharaka Nithi County.

**2.5 Data Analysis**

The primary data was coded, followed by a consistency check before statistical analysis procedure were done. Data entry was done on Microsoft excel and descriptive statistics was done using SPSS version 28.0 while the analysis was done on Stata software version 17.0. The coded data used statistical tools in descriptive statistics including mean, frequencies, percentages, non-parametric chi-squares and dispersion measures such as variances, standard deviation and ranges. To analyze theimpact of application of soil and water conservation practices on maizeyield, Propensity Score Matching (PSM) was employed. Binary logit regression model under PSM 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.

where;

the likelihood of adopting SWCs

the constant

the independent variables

= estimated regression coefficients for each independent variable

The logistic 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;

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

)

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;

.

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:

is the result of a treated individual, which is maize yield for adopters

is the outcome if the individual is the control group, the maize yield for non- adopters

**3.0 RESULTS AND DISCUSSION**

**3.1 Descriptive Statistics of Maize Farmers**

In this study, 345 respondents were issued with the semi-structured questionnaires. Only 318 respondents answered and returned the questionnaires due to willingness of the respondents to answer. The response rate was 92.17% which was high validating the results obtained from the respondents. According to Adeniran (2019), a response rate of 50% was satisfactory, 60% response rate was good, a 70% response rate and beyond was sufficient.

**3.2 Gender, Household Size, Age and Education Level of the Household Head**

The findings obtained from the study observed that 75.47% of the small-scale maize farmers who got involved in adoption of SWCs were males while 24.53% were females. Findings of this study showed that the average number of individuals living in a specific homestead was about 4 people with the least household having one member and a maximum of 10 members in other households (Table 1). During the study, it was observed that the age mean of the decision maker was about 48 (±11.03) years with the years ranging from 26 (lowest) to 98 years (Table 1). In regard to schooling years, the study findings showed that the mean average years of schooling was 7 (±4.33) with some not attending school at all and highest being 21 years (Table 1). From the findings attained, it was confirmed that most respondents (31.76%) attained standard eight or did not complete secondary education while 22.01% attained primary standard 1 to 6 and 7.55% did not attend school at all.

Table 1: Maize Farmers Socio-economic Characteristics

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | Mean | | Std. Dev. | | Min | | Max | | |
| Household Size | 4.248428 | | 1.789713 | | 1 | | 10 | | |
| Age | 48.03145 | | 11.03045 | | 26 | | 98 | | |
| Education | 7.427673 | | 4.330159 | | 0 | | 21 | | |
| Land Area | | 1.33 | | 1.099483 |  | 0 | | 6 |

In regards to gender, most of the household heads were males probably because of the fact that family headship in the study location is primarily a male responsibility and that they are exposed to more of the farm resources compared to their female counterparts. Similar results were reported by Adzawla *et al.* (2019), on gender perspectives of climate change adaptation revealed that majority of those who responded were male and majority of female were involved in production in their own farms. Marie *et al.* (2020), who worked on farmer choices and determinants influencing the uptake of climate change adaptation technologies observed consistent results that homesteads headed by males were more likely than female-headed households to put adaptation strategies into action.

Regarding to household size, the findings showed that the farm could practice more SWCs because there was availability of labor from the household members. Findings obtained from the study agreed with those of Innazent *et al*. (2022) on farm topology of smallholders integrated farming systems in India who analyzed that the average household size was 4 members. Mdoda *et al.* (2022) reported similar findings which revealed the mean household size was 4 persons in the households of irrigated spinach production in South Africa where farmers employed family members in the fields which was essential for increasing production and boosting profitability.

Regarding the educational level, education was a factor in adopting SWCs because literate farmers had the knowledge and know how on what methods to use in their farms. Study findings were in agreement with those of Faleye and Afolami (2020) who analyzed on climate smart agricultural practices among yam-based farmers in Nigeria and reported on the average years of schooling being 7, this meant that most farmers were literate and had the knowledge on the technologies to use on their farms. The findings of this study also agreed to the study findings of Mdoda *et al.* (2022), who studied irrigated agriculture on spinach production in South Africa and revealed that the average schooling years was 7, which equaled to primary schooling indicating that farmers were literate and had the knowledge required.

**3.2 Land Characteristics**

**3.2.1 Land Tenure System, Land Topography, Land Size, Soil Fertility, Soil Erosion**

From the findings, it was indicated that most (86.16%) of the maize farmers owned a farm and had title deeds, while 12.89% rented in, 0.63% rented out and 0.31% borrowed out he study findings showed that the average land size was about 1.3 acres with some not owning any land at all and the maximum holding being 6 acres for maize production (Table 1). Findings obtained from the study indicated that majority (58.18%) of the maize farmers perceived their land to be eroded experiencing soil degradation while 41.82% did not perceive their land of any erosion (Table 2). In regards to the fertility nature of the soil, and it was observed that 23.9% of the respondents had good fertile soils with top soil layer while 71.7% of the respondents had medium fertile soils and 4.4% had low fertile soils where maize did not do better (Table 2). Further, the land topography variable showed that 37.74% of the respondent’s land was flat or gently slopy, 55.66% had medium sloping land while 6.60% of the land was steep (Table 2).

Table 2: Farmers Perception on Erosion, Fertility and Land Topography of Maize Farmers

|  |  |  |  |
| --- | --- | --- | --- |
|  | Response | Frequency | Percentage |
| Awareness on Erosion | No | 133 | 41.82 |
| Yes | 185 | 58.18 |
| Total | 318 | 100 |
| Soil Fertility | Good | 76 | 23.9 |
| Medium | 228 | 71.7 |
| Low | 14 | 4.4 |
| Total | 318 | 100 |
| Slope/ Topography | Gentle Slope (Flat) | 120 | 37.74 |
| Medium Slope | 177 | 55.66 |
| Steep Slope | 21 | 6.60 |
| Total | 318 | 100.00 |

The study revealed that majority of the maize farmers produced the crop on land owned by the household heads and embraced SWCs as a way of curbing climatic risks. Mogaka *et al.* (2021), obtained similar findings from a study on climate-smart practices in the West parts of Kenya and noted that majority of the maize farmers owned land therefore most of them could practice the SWCs. In regard to soil erosion, the study showed that most maize farmers experienced erosion on the pieces of land which needed measures to prevent erosion. However, Kenee *et al.* (2020) reported inconsistent results which presented only 16.6% of farmers perceived erosion to be severe and only 62.6% considered erosion to be a least cause. The study findings matched with those of Gonde and Kitila (2022) on the study of assessment of farmers awareness towards SWCs in Western Ethiopia and noted a deterioration in soil fertility in most farms was due to continuous tillage, soil erosion and lack of sustainable measures to tackle soil degradation problem.

With regard to soil fertility, the study findings meant that most farmers did not notice nutrient depletion from their farms until it became so critical that crops could not produce well due to the practice of continuous farming that led to nutrients depletion. Findings from the study matched the findings of Mulwa *et al.* (2017) which concluded that crop failure is less likely to occur on fertile soils compared to medium and less fertile ones. Findings of the study also showed that most of the maize farmers were owners of flat and medium sloping land meaning that most of them did not perceive their land to be steep. Findings attained from the study were also in line to the study findings of Gessese *et al.* (2022), whose study examined the adoption and intensity of SWCs in Ethiopia where 38% of the land was gentle and moderately slopy while less than 15% was steep and observed that households who owned gentle or steep slope farm plots used physical procedures to prevent erosion. However, the findings attained from the study were inconsistent to the study findings of Arega *et al.* (2022), who studied on farmer’s psychodynamics in integrated SWCs in Ethiopia and stated that the topography’s role in accelerating soil erosion through soil degradation was minimal.

**3.3 Descriptive Statistics of institutional factors on maize farmers**

**3.3.1 Group Membership**

The study findings showed that 70.75% of the maize farmers were members of a group in the society compared to 29.25% who did not belong to any group (Table 3). This implied that there was a possibility that being part of a group, most farmers got farming information from there. Consistent results were obtained by Kimbi *et al.* (2022), whose study analyzed how credit and saving group membership boosted contract farming among sorghum farmers in Tanzania and reported that farmers readily communicated on agricultural knowledge and also obtained financial resources through these groups in order to purchase production inputs.

Table 3: Group Membership, Extension services and Access to Credit

|  |  |  |
| --- | --- | --- |
| Group  Membership | Frequency | Percentage |
| Group  Member | 225 | 70.75 |
| Non-Group Member | 93 | 29.25 |
| Total | 318 | 100 |

|  |  |  |  |
| --- | --- | --- | --- |
| Access to Extension Services | Response | Frequency | Percentage |
| Willingness to Access | Willing to Access | 242 | 76.1 |
|  | Not Willing to Access | 76 | 23.9 |
|  | Total | 318 | 100 |
| Credit Accessibility | Response | Frequency | Percentage |
| Willing to Access Credit | Not Willing | 191 | 60.06 |
|  | Willing | 127 | 39.94 |
|  | Total | 318 | 100 |

**3.3.2 Extension Services, Training and Information Channels**

The findings showed that 76.10% of the maize farmers needed extension services, training and information while 23.90% did not need any extension services (Table 3). The study findings implied that extension contact was low because of limited extension officers who give information and trainings to small-scale farmers. Bashir *et al.* (2018) examined a study on the smallholder farmer implementation of cowpea technologies in Nigeria and reported consistent results that extension agencies expectations to play in the diffusion and acceptance of technology was undermined by farmers’ lack of contact with extension agents. Results from the study also agreed to the findings of Oyetunde-Usman *et al.* (2021), who surveyed the factors of adoption on multiple workable agricultural practices in Nigeria, and reported that access to extension services was below its peak making farm households perceive a high adoption risk for sustainable agricultural practices.

**3.3.3 Maize Farmers Access to Credit**

The study findings demonstrated that 39.94% of maize farmers required credit while 60.06% did not need any credit (Table 3). Based on the study findings, it is possible that it was difficult for small scale farmers to apply for credit since collateral was needed by the financial agents The findings obtained from the study agreed with those of Kimathi *et al.* (2021), on the adoption of resilient potato varieties and its determinants on smallholder farmers in Meru County, Kenya who reported that access to financial assistance was typically accompanied with usage of SWCs for climate change adaptation. Findings from the study were inconsistent with those of Nsele *et al.* (2022), who examined the variables impacting urban farmers long-term adoption of new practices in the Democratic Republic of the Congo and reported that only 22.8% of the respondents accessed credit.

**3.4 Adoption of the Selected SWC Technologies**

Intercropping, crop rotation and terraces were the most adopted technologies in Tharaka Nithi County (Table 4). The high rate of adoption was attributed to the practice of intercropping due to small pieces of land and farmers needed to utilize land with more crops, terraces were practiced because the topography of land was so steep to prevent runoff and soil erosion. Crop rotation was adopted probably because most farmers perceived it to be monotonous to plant one crop throughout. These study findings were similar to those of Wafula and Kelvin (2022), on application technologies on nutrient uptake and their effects on maize and beans production in Machakos County, Kenya and reporting that there was higher grain yield of 1.64 t/ha from bean-maize intercropping system and lowest yield of 0.44 t/ha from sole beans. Further, Turyahabwe *et al.* (2022), studied on factors affecting the uptake of SWCs by small holder farmers in Eastern Uganda and reported similar findings that over half of the farmers in the area used crop rotation, which decreased soil erosion and increased crop yield.

However, the study findings were in contrast with those of Mcharo and Waswa (2022), who studied effect of gender differentiated adoption of SWCs by farmers in Kenyan agricultural highland catchment and reported that crop rotation was hardly used which was attributed to the tiny farm sizes, which made it economically unfeasible to rotate the main crop. Destaw and Fenta (2021) on climate change adaptation among rural farmers in Northern Ethiopia reported similar findings that producer’s top goal to lessen the influence of soil erosion and surface runoff on produce output was highland area terracing. The report also indicated that climate change adaptation technologies were location specific, implying that they were adopted depending on the topography of the area. Findings obtained from this study also agreed to the work analyzed by Mairura *et al.* (2022), on the study of farm factors affecting soil fertility in Tharaka Nithi County, Kenya who reported that terraces were frequently used in maize. This was possibly because maize is a significant food and income crop that was planted in numerous conservation agriculture techniques.

Table 4: Levels of Adoption of the selected SWC technologies

Technologies Yes Frequency No Frequency

Intercropping 214 (67.3) 104 (32.7)

Irrigation 133 (41.82) 185 (58.18)

Mulching 91 (28.62) 227 (71.38)

Stone bunds 37 (11.64) 281 (88.36)

Minimum tillage 12 (3.77) 306 (96.23)

Crop Rotation 271 (85.22) 47 (14.78)

Terraces 176 (55.35) 142 (44.65)

Grass Strips 109 (34.28) 209 (65.72)

Irrigation and grass strips were averagely adopted by the small holder farmers (Table 4) which was attributed to farmers not being aware of how to manage grass strips and the kind of grasses to plant. Irrigation was not well adopted probably due to water scarcity and expensive structures to lay. Sezen *et al.* (2022) had similar findings in Turkey and reported that depending on the rate of recurrence, regimes and volumes of irrigation, application water was reduced. Alotaibi *et al.* (2021) examined the adoption of sustainable water management practices in Saudi Arabia and reported similar findings that use of waste water and industrial treatment in irrigation was low which was probably caused by insufficient information on farmers about safe use of waste water. The study findings were inconsistent with those of Birhan and Tekalign (2022) who studied sustainable agriculture using technology to conserve soil and water in Central Ethiopia and reported that grass strips were one of the methods used to prevent surface runoff as a vegetative measure and was adopted highly and that the farmers used grass strips to control grazing of the animals in their farms.

Mulching, minimum tillage and stone bunds adoption was very low in Tharaka Nithi County (Table 4). This was probably because farmers never had enough crop residues to cover the ground so as to retain the soil moisture, farmers not having knowledge on minimum tillage and farmers finding it hard and tiresome to place the stones on the farm edges respectively. Li *et al.* (2021) had similar findings which reported that mulching was practiced less depending on local conditions, cost and type of material. Findings of Olowa *et al.* (2019) who studied the factors affecting adoption of SWCs among fluted pumpkin producers in Nigeria agreed with the study findings that minimum tillage was not predominant in the area because of shortage and fragmentation of land. Goba *et al.* (2022) whose work evaluated farmer’s awareness on soil erosion and management SWCs measures in southwest part of Ethiopia reported inconsistent results that stone bunds were adopted at only 48% and they assisted in reducing erosion by water on the farms, and that the use of these physical measures to conserve soil and water, increased soil fertility and subsequently improved agricultural productivity. Overall, encouraging the adoption of SWCs measures offers a sustainable approach to mitigating climate-related hazards and promoting resilience (Ouédraogo & Ouoba, 2025). Soil and water conservation measures (SWCs) have been given a top agenda and consideration, which is the main effect of reducing soil erosion and improving soil fertility (Debisa *et al*., 2025).

The logistic regression model used, estimated propensity scores for matching the adopters and nonadopters 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 5). 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% (Table 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% (Table 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 (Table 5). Age as a variable had a negative co-efficient on crop rotation and irrigation at 10% significance level (Table 5), 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 (Table 5). This showed that older people practiced more mulching compared to younger people. The results were 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 since the old were the most experienced. From the study findings, education was found to have a negative association on minimum tillage at 1%, stone bunds and irrigation at 10% (Table 5). 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 of the study disagreed with those of Checco *et al.* (2023) whose report showed that education had a positive association on improved rice varieties observing that the more the number of years spent in school, the higher the farmer's ability to gather data.

Table 5: Binary Logit Regression, Estimation of Propensity Scores Results

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Intercropping | Terraces | Mulching | Grass Strips | Minimum Tillage | Stone Bunds | Rotation | Irrigation |
| Variable |  | Co-efficient | Co-efficient | Co-efficient | Co-efficient | Co-efficient | Co-efficient | Co-efficient | Co-efficient |
| Land size |  | 0.499\* | 0.160 | -0.032 | -0.328\*\* | -0.169 | -0.294 | 0.430\*\*\* | 0.276\*\* |
| Household size |  | 0.195\*\* | -0.121\*\*\* | -0.094 | 0.072 | -0.098 | 0.133 | 0.146 | 0.150\*\* |
| Gender |  | -0.664\*\* | 0.130 | -0.599\*\*\* | 0.142 | -0.159 | 0.091 | -0.070 | -0.095 |
| Age |  | -0.010 | -0.004 | 0.024\*\* | -0.018 | -0.003 | -0.013 | -0.027\*\*\* | -0.020\*\*\* |
| Education |  | 0.006 | -0.017 | -0.034 | 0.001 | -0.300\* | -0.083\*\*\* | 0.000 | -0.056\*\*\* |
| Extension |  | -1.227\* | 0.130 | 1.123\* | -0.981\* | 0.672 | 0.031 | 1.375\* | 0.013 |
| Membership |  | 1.659\* | -0.923\* | 0.723\*\* | 0.609\*\* | -0.442 | -0.968\*\*\* | 0.706 | 1.162\* |
| Credit Access |  | -0.824\* | -0.026e | 0.242 | 0.118 | 0.854 | 0.725\*\*\* | 0.096 | 0.334 |

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

Prob>chi2 = 0.0000

Number of observations = 318

**3.5 Econometric Analysis on Adoption of Soil and Water Conservation Practices on Maize Yield Using Propensity Score Matching**

The study findings also showed that extension and training had a positive association on mulching and crop rotation at 1% significance level (Table 5). 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 5). 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 (Table 5). This showed that those who did belong to a group practiced less of terraces and stone bunds. The study results were 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 5). 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 (Table 5). 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.

The study finally 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, respectively for those who adopted compared to those who did not (Table 6). The results showed that intercropping and irrigation led to notable maize gain in yield as key SWCs practices. 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 increasing maize yield.

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, respectively for those who adopted either minimum tillage or stone bunds (Table 6). The study noted decrease of maize production through minimum tillage probably because maize farmers lacked knowledge on minimum tillage for being used to convectional tillage for long time. Additionally, shortage and fragmentation of land also led to majority of farmers not practicing minimum tillage. These study findings agreed with those of Huang *et al.* (2022) who noted that minimum tillage lowered annual soil and nutrients compared to conventional tillage. This was possible due to potential competition for nutrients from weeds and degrading soil structure. Results obtained from the study disagreed 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.

Stone bunds also decreased maize production probably because farmers found it difficult and tiring to place edges on farm edges, especially on large farms. 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 6). 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 6).

Table 6: 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 | -268.685 | 114.314 | -2.35\* |
|  | Stratification | 12 | 206 | -698.398 | 274.106 | -2.548\* |
| Stone bunds | Nearest Neighbor | 37 | 29 | -51.946 | 109.391 | -0.475 |
|  | Radius | 37 | 249 | -265.233 | 92.429 | -2.87\* |
|  | Stratification | 37 | 249 | -287.335 | 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.

**3.6 Sensitivity Analysis**

Sensitivity analysis revealed that the PSM calculations' dependability needed to be tested. It made it easier for the research to comprehend how sensitive the propensity score deviation-based estimations are. Sensitivity analysis (Figure 2) evaluated the matched clusters' quality. As a result, this research evaluated how the unobserved variables affect the ATE and ATT values. The study therefore came to the conclusion that the degree of relevance was both adequate and significant.

Common support graph on intercropping



Common support graph on irrigation



Common support graph on minimum tillage



Common support graph on stone bunds



Figure 2: Sensitivity analysis

**4.CONCLUSION**

Findings of this study concluded that the effect of land size, gender, household size, slope, education, soil erosion perception, group membership and extension services were significant with positive or negative association with the number of soil and water conservation methods practiced in order to curb erosion and increase maize production. Land size, household size, farmers’ perception, topography of the land, extension services, group membership and access to credit were significant and had a positive influence on the adoption of SWCs. Gender and education were significant and had a negative influence on the adoption of soil and water conservation practices (SWCs). The overall adoption rate of soil and water conservation practices (SWCs) was sufficient and significant. SWCs adopted depended on the topography of the land and also it was contributed by factors like land size, age, gender, education, group membership among other socio-economic and institutional factors. The adopters had an increased rate of improving yields in comparison to non-adopters who did not observe most of SWCs. This clearly indicated that for effective adoption of SWCs and increase in maize production, several factors needed to be taken into account to advocate more adoption. The results from the PSM model signified that the adoption of SWCs was sufficient to attain an impact in the maize yield. The study findings showed that intercropping and irrigation led to notable maize gain in yield as key SWCs. There was positive impact in maize yield for adopters of intercropping and irrigation as SWCs which increased returns on maize productivity. Minimum tillage and stone bunds as SWCs adopted were significant but decreased maize production. Therefore, there is the need for adoption of SWCs that curb erosion, drought and improve the maize production. In relation to maize productivity, small scale farmers who adopted the SWCs were far much better than the non-adopters this consequently brings the attainment of food security under climate change and income.

**5. 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. This will enable farmers get awareness and information on adoption of SWCs and their benefits. Maize small-scale farmers are also urged to practice and explore soil and water conservation methods like irrigation and intercropping to avoid usage of practices that may decrease production. Government and stakeholders are also to focus and organize more training for the smallholder maize farmers and especially the younger farmers since the aging farmers are less likely to use the practices. Therefore, there is need for further research to look into more technologies in different crops to examine the impact of adoption.

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**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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