

SUSTAINABLE SOIL WATER CONSERVATION TECHNOLOGIES AND CHALLENGES AMONG SMALLHOLDER FARMERS IN OSUN STATE, NIGERIA

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Abstract

The study examined the adoption of sustainable soil and water conservation technologies (SWCTs) and challenges among smallholder farmers in Osun State, Nigeria. Specifically, the study described the SWCTs adopted by the smallholder farmers in the study area; analysed the factors influencing the adoption of SWCTs and identified the challenges to SWCTs adoption. Data were collected with the aid of a pre-tested questionnaire from 120 smallholder farmers selected using multistage sampling procedure. Descriptive statistics and Logit regression model were used for data analysis. Results revealed that irrigation (68.3%) grass strips (62.5%) manure/fertilizer application (56.7%) and stone bund (50%) were the major SWCTs adopted by the smallholder farmers in the study area. Sex of farmers, education, household size, farm size, topography, income, livestock ownership, credit access cooperative association membership, frequency of extension contacts, and good road were the factors influencing the adoption of SWCTs. Primary challenges hindering the adoption of Sustainable Soil and Water Conservation Technologies (SWCTs) include the lack of technical guidelines, financial constraints, insufficient technical know-how, poor extension services, and inadequate farm labour. Provision of necessary infrastructural facilities such as good roads, education, credit access, and institutional support should be prioritized by the government and other stakeholders. These measures are crucial for ensuring sustained food production through the adoption of sustainable and environmentally friendly soil and water conservation measures in the study area.

Key words: Adoption, technologies. soil and water, sustainable, smallholder farmers

Introduction

Soil and water resources are indispensable for life and sustenance (Iyilade *et al.*, 2020). However, smallholder farmers grapple with myriads of soil and water-related challenges during production, making them susceptible to land degradation and low productivity (Olawuyi and Mushunje, 2019). Practices such as deforestation, overgrazing, bush burning, continuous cultivation, and excessive use of inorganic fertilizers by smallholder farmers contribute to soil fertility loss (Amusa *et al.*, 2016). The loss of

trees and vegetation cover in agricultural areas, compounded by rugged terrain, soil overexploitation, salinization or acidification, chemical pollution, population pressure, reduced fallow periods, and inadequate conservation measures, have led to alarming rates of soil erosion and exacerbated declines in land productivity (Wassie, 2020; Mebrate *et al.*, 2022). Moreover, the traditional farming methods employed by these smallholder farmers have resulted in dwindling yields and reduced production, perpetuating a cycle of poverty due to low revenues (Olawuyi, 2018). This situation adversely affects the availability and distribution of food crops, particularly arable crops, across the nation and the study area (Olawuyi, 2018). Therefore, safeguarding soil and water resources from degradation is crucial for sustained productivity and food production, provision of regenerative ecosystem services, and preservation of biodiverse landscapes (Iyilade *et al.*, 2020).

Soil and Water Conservation Technologies (SWCTs) refer to technologies that mitigate soil erosion and water runoff, thereby conserving soil (Charles *et al.*, 2019). SWCTs play a vital role in ensuring the sustainable food-producing capacity of the soil by covering the soil surface with crop residues to enhance water percolation and infiltration, reduce topsoil runoff, and improve soil fertility for enhanced agricultural output. Furthermore, a well-planned and efficient combination of SWCTs is essential for mitigating soil degradation and depletion caused by natural occurrence and human activities (Ezeaku, 2012; Amusa *et al.*, 2016). Various studies (Adimassuet *et al.*, 2013; Olawuyi, 2018; Iyilade *et al.*, 2020; Anyokwu and Badmos., 2019; Yifru and Miheretu, 2022; Aminu *et al.*, 2022) have identified SWCTs utilized by smallholder farmers, including terracing, tree planting, agroforestry, cover cropping, contour ploughing, vegetation/grass strips, zero or minimum tillage, organic manure, inorganic fertilizers, bush fallowing, crop rotation, mulching, soil and stone bunds. In addition, farmers personal and social characteristics were identified as significant factors influencing adoption of SWCTs among smallholder farmers.

Enhancing agricultural production through sustainable SWCTs aligns with the United Nation's Sustainable Development Goals 2, 12 and 15. Which emphasizes zero hunger, responsible consumption and

production, and sustainable land use respectively. However, smallholder farmers often constraints such as unstable agricultural policies, limited knowledge of conservation practices, and inadequate research to support the adoption of specific conservation technologies. It is against this backdrop that this study was designed to examine the types of SWCTs adopted by smallholder farmers, assess the factors influencing their adoption, and identify challenges hindering the adoption of SWCTs in the study area.

Methodology

The research was conducted in Osun State, Nigeria. Osogbo is the capital. The state is located on coordinates 7°30’N 4°30’E. It has an area of 9,251km² (24sqm) and an estimated population of 4,435,800 as of 2022. The major occupation of the people in the area is farming. Crops cultivated include maize, yam, cassava, cocoyam, cocoa, kolanut, citrus and vegetables. Livestock like sheep, cattle, pig, goat, rabbit and poultry are additionally raised for sales and consumption.

The study utilized primary data collected through the administration of questionnaires and interviews schedules. A multistage sampling technique was employed, involving purposive selection of two

local government areas (LGAs) known for agrarian activities, followed by random selection of two villages from each LGA, resulting in a total of four villages. Finally, 15 smallholder farmers were randomly chosen from each village, making a total of 120 respondents for data collection and analysis.

Analytical techniques

The study employed descriptive statistics including frequency count, percentage, mean and standard deviation to analyse the major SWCTs adopted by the smallholder farmers as well as the challenges to the adoption of these technologies in the study area. Additionally, Logit regression model was utilized to determine the factors influencing the adoption of SWCTs in the study area. The model is explicitly specified as:

$$Y = \beta_0 + \beta_1V_1 + \beta_2V_2 + \dots + \beta_{16}V_{16} + e_i \dots (1)$$

Where, Y is dependent variable (Responses of the adoption of SWCTs either 1 if Yes or 0 otherwise), β_0 = constant; $\beta_1 \dots \beta_{13}$ = coefficients of the explanatory variables. Following Nkegbe and Shanker, (2014); Apio *et al.*, (2023), the independent variables (X1-X16) are grouped as presented in Table 1 below.

Table 1: Measurement of Independent Variables

Variable	Measurement
Personal and Household Characteristics	
Sex	Sex of the smallholder farmer (1if male and 0 otherwise)
Age	Age of farmer (years)
Education	Literacy of the smallholder farmer (1 if at least primary school and 0 otherwise)
Marital status	Marital status of farmer (1 if married, 0 otherwise)
Household size	Number of people in the household
Farming experience	Number of years of farming
Labour type	Type of labour used (1 if family labour, 0 otherwise)
Farm/plot characteristics	
Land acquisition	Means of farmland acquisition, 1 if inherited, 0 otherwise
Farm size	Total area of land under SWC (hectares)
Topography	The slope of the plot as perceived by a farmer (1 if steep and 0 otherwise)
Economic Characteristics	
Income	Amount realised from farming activities (Naira)
Livestock ownership	Whether the farmer owns livestock (1 if yes, 0 otherwise)
Credit access	Whether the farmer had access to credit (1 if yes, 0 otherwise)
Institutional Characteristics	
Cooperative	Membership of cooperative association(1 if yes, 0 otherwise)
Extension contacts	Frequency of contacts with extension officers Number of times)
Road	Condition of roads from farm to the market (1 if good, 0 otherwise)

Results and Discussion

Soil and Water Conservation Technologies (SWCTs) Adopted in the Study Area

Table 2 presents the adoption rates of SWCTs among the smallholder farmers in the study area. The majority (69.2%) of the sampled farmers adopted at least one SWCT. Among the SWCTs, irrigation/dam was the most widely adopted, with 68.3% of the

farmers using it. Farmers cited benefits such as enhanced water-use efficiency by reduced water loss, increased fertilizer-use efficiency, decreased labour costs, and better disease and pest control. Similar result was reported by Apio *et al.*, (2023). Grass strips planted along a contour which can reduce soil erosion and runoff was adopted by 62.5% of the farmers. This is in line with the findings of Yousuf and Singh,

(2019) that the strip technology is effective in reducing soil erosion, reducing runoff velocity, and increasing soil moisture leading to higher crop production.

This was followed by the adoption of manure/fertilizer application by 56.7% of the smallholder farmers. This reinforces the importance of this practice on the yield of crops. This result supports the findings of Agboola and Balogun (2020) who emphasized the role of inorganic fertilizer as soil conservation technique in Kogi State to its ability to sustain crop yield and retain soil fertility.

Stone bund/ Stone lines running along the contour was the SWCT for 50% of the sampled farmers. The use of stone bund technology serves multiple purposes, including slowing down run off, increasing water infiltration, reducing soil erosion, and rehabilitating eroded or abandoned land by trapping silt. This supports the submission of Achuchaogu *et al.*, (2022) that stone lines installed on farm can mitigate the force of winds and further decrease runoff velocity, thus effectively contributing to soil erosion control and land rehabilitation efforts.

The adoption of intercropping by nearly half of the farmers highlights its significance in agricultural practices. This technique showcases the adaptability and versatility of agricultural methods in addressing soil and water conservation challenges while optimizing crop production. intercropping, whether row, strip, or relay, offers various benefits such as improved soil coverage, reduction of raindrop impact and protection against soil erosion as noted by Vanwalleghe, (2016).

The adoption of crop rotation by 47.5% of the farmers underscores its importance as a sustainable SWCT. According to Sahoo *et al.*, (2017), implementing suitable crop rotation with canopy cover crop can sustain soil fertility, suppress weed growth, decrease pests and disease infestation, increase input use efficiency, and enhance overall system productivity while reducing the soil erosion. Soil bund was adopted

by 41.7% of the respondents. Soil bunds, constructed along contours with water collection channels, serve to control runoff and erosion by reducing the slope length of fields, thereby decreasing the velocity of runoff. This practice not only prevent soil erosion but also helps retain soil moisture, ultimately enhancing land productivity by providing a more favourable environment for crop growth. Mulching was adopted by 40.8% of the respondents. As described by Kumar *et al.*, (2017), mulch, whether organic or inorganic serves multiple purposes such as protecting soil from erosion, reducing evaporation, increasing infiltration, regulating soil temperature and improving soil structure. Additionally, mulching prevents the formation of hard crust after rainfall, and organic mulches as highlighted by Prats *et al.*, (2016), enhance soil fertility and biodiversity, further contributing to soil health and moisture conservation efforts.

Furthermore, the adoption of contour farming by 32.5% of the farmers demonstrate its recognised benefits in soil conservation and crop productivity enhancement. By conducting ploughing and furrowing along contours rather than up and down slopes, contour farming conserves soil moisture by increasing infiltration rate and time of concentration, it effectively reduces soil erosion and conserves soil fertility and moisture in both low and high rainfall areas thereby improving overall crop productivity. However, the effectiveness of this practice depends on factors such as rainfall intensity, soil type, and topography as noted by (Achachuoguet *al.*, 2022). Additionally, cover cropping adopted by 30% of the farmers in the study area, plays a vital role in improving soil structure, increasing nitrogen level, and suppressing weed. Cover crops like *Puerariamucuna* and *Mucunanot* not only reduce the need for manual weeding by suppressing weeds such as spear grass (*Imperata cylindrica*), but also provide livestock feed and increased crop yield. Moreover, the sale of cover crop seeds can generate additional income for adopters.

Table 2: SWCTs Adopted by the Smallholder Farmers in the Study Area

Adoption of SWCTs	Frequency	Percentage
No	37	30.8
Yes	83	69.2
*SWCTs Adopted		
Soil bund	50	41.7
Gras strips	75	62.5
Irrigation	85	68.3
Contour ploughing	39	32.5
Stone bund	60	50
Crop rotation	57	47.5
Cover cropping	36	30.0
Inter cropping	58	48.3
Mulching	49	40.8
Manure/fertilizer application	68	56.7

*Multiple Response

Factors Influencing the Adoption of Sustainable SWCTs

Table 3 presents the outcomes derived from the logit regression analysis concerning the factors influencing the adoption of sustainable Soil and Water Conservation Technologies (SWCTs) within the study area. The chi-square value of 22.384, significant at a 1% alpha level, indicates that the model adequately fits the data. Furthermore, the pseudo R^2 value of 0.723 suggests that approximately 72.3% of the variation in SWCT adoption were explained by the predictor variables included in the model. The signs of the coefficients indicate the direction of change in the probability of SWCT adoption in response to alterations in the explanatory variables. A positive sign signifies an increase in the likelihood of adoption, whereas a negative sign denotes the opposite.

The analysis highlights several significant personal characteristics influencing SWCT adoption among smallholder farmers, notably sex, education level, and household size. The estimate for respondents' sex was found to be significant and positively associated with SWCT adoption at a 5% alpha level. This implies that male farmers are more inclined to adopt SWCTs compared to their female counterparts, possibly due to the labour-intensive nature of designing and maintaining SWCT structures, as observed by Asfaw and Mulugeta (2017). Similarly, education level exhibited a positive and significant relationship with SWCT adoption at a 5% level of significance. This suggests that farmers with higher levels of education are more likely to adopt SWCTs, aligning with findings from Zhang *et al.*, (2019), who noted that literate farmers are typically more receptive to modern technologies than their illiterate counterparts. Moreover, household size demonstrated a positive and significant effect on SWCT adoption at a 5% level. This indicates that larger household sizes are associated with a higher probability of SWCT adoption, likely due to the labour-intensive nature of SWCT implementation, as suggested by Abdul-hanan *et al.*, (2014).

Under the farm/plot characteristics, farm size ($p < 0.01$) and topography ($p < 0.05$) of the land were the factors influencing adoption of SWCTs. The positive and significant relationship between farm size ($p < 0.01$) and SWCTs adoption implies that farmers with larger landholdings are more likely to adopt these practices compared with those with smaller farms. Similarly, the positive and significant relationship with topography implies that adoption of SWCTs increases with steeper land slopes. This is in agreement with

previous research by Nkegbe and Shankar (2014) which found that farmers who perceive their plots to be steeply sloped are more inclined to adopt soil and water conservation practices.

Income ($p < 0.05$), ownership of livestock ($p < 0.05$), and access to credit ($p < 0.05$) emerged as significant factors influencing the adoption of SWCTs within the economic context. The positive significance of these variables indicates that higher income levels, livestock ownership, and access to credit facilities correlate with an increased likelihood of SWCT adoption. This underscores the pivotal role of income and credit access as vital sources of capital facilitating the adoption of SWCTs in the study area. These findings corroborate previous research by Abdul-hanan *et al.*, (2014), emphasizing that farmers with improved access to credit are more likely to embrace technological advancements compared to those facing capital constraints. Similarly, the positive correlation between livestock ownership and SWCT adoption aligns with the observations of Iyilade *et al.*, (2020), suggesting that households with livestock, often indicative of greater wealth and resources, are more inclined to adopt SWCTs compared to their less affluent counterparts.

Institutional characteristics such as cooperative membership, frequency of extension contacts, and infrastructure quality, notably good roads, were also identified as significant influencers of SWCT adoption in the study area. Cooperative membership exhibited a positive and significant association at a 5% alpha level, indicating that farmers affiliated with cooperative associations are more likely to adopt SWCTs compared to non-members. This finding supports the notion put forth by Ojo *et al.*, (2021) that organizational membership fosters valuable connections between farmers and various stakeholders, leading to increased adoption of innovative practices. Similarly, the positive relationship between the frequency of extension contacts and SWCT adoption suggests that more frequent visits by extension agents enhance the likelihood of technology adoption. This finding resonates with the observations of Ayamga and Dzanku (2015), who noted that farmers receiving regular visits from extension officers are more receptive to modern agricultural practices. Furthermore, the positive significance of good road infrastructure implies that improved road networks, facilitating efficient transportation from farm to market, enhance market participation and consequently promote the adoption of SWCTs in the study area.

Table 3: Factors Influencing the Adoption of Sustainable SWCTs

Variable	Coefficient	S.E.	Wald	Sig.
Personal Characteristics				
Sex	0.488**	1.220	5.710	0.017
Age	0.080	0.033	0.160	0.689
Education	0.253**	0.216	2.379	0.024
Marital status	-0.129	0.303	0.182	0.670
Household size	0.037**	0.111	1.914	0.036
Farming experience	-0.020	0.049	0.171	0.679
Labour type	2.124	0.808	0.117	0.652
Farm/plot characteristics				
Land acquisition	-0.205	0.371	0.307	0.580
Farm size	0.914***	0.625	6.913	0.009
Topography	0.300**	0.482	0.389	0.029
Economic Characteristics				
Income	0.084**	0.246	3.117	0.017
Livestock ownership	0.051**	0.909	1.003	0.033
Credit access	0.084**	0.246	2.117	0.022
Institutional Characteristics				
Cooperative Membership	0.051**	0.909	0.403	0.012
Frequency of extension contacts	0.068**	0.315	2.137	0.044
Road	0.115**	0.010	4.147	0.042
Constant	5.160	2.156	5.724	0.007

-2 Log likelihood 137.072, Chi-squared 22.384, Nagelkerke R Square 0.723

***, ** Statistically significant at 1%,5% degree of freedom

Major Challenges to the Adoption of SWCTs

The primary challenges faced by smallholder farmers were identified through the utilization of a 3-point Likert Scale, gauging the severity of these challenges from very serious to not serious. Utilizing a benchmark (mean) of 2, the results pertaining to the major challenges encountered by the farmers, as presented in Table 4, reveal that inadequate technical guidelines emerged with a mean score of 2.61, ranking as the foremost challenge. Farmers emphasized the necessity for comprehensive information, training, appropriate guidelines, regulatory frameworks, and incentives to bolster the adoption of SWCTs within the study area. This aligns with the insights from Agholor and Nkosi (2020), advocating for the development of user-friendly technologies and guidelines tailored to both male and female farmers to address similar challenges in Enyibe Ermelo, Mpumalanga Province, South Africa. Financial constraints, with a mean value of 2.60, was identified as the second-ranking challenge. Farmers underscored the need for financial resources to initiate investments in SWCTs. However, the majority of farmers face financial limitations, hindering their adoption efforts

despite being cognizant of the benefits associated with SWCTs. This finding confirms the observations of Amusa *et al.*, (2016), highlighting the lack or insufficient financial capacity of farmers as a significant obstacle in Ekiti State, Nigeria.

Lack of technical know-how, with a mean value of 2.59, emerged as the third major challenge. Despite farmers' awareness of the benefits of SWCTs, a significant proportion of smallholder farmers lacked the requisite knowledge and skills to effectively implement these technologies in the study area. Inadequate technical support, particularly in terms of poor extension services, ranked fourth. This underscores the importance of effective extension services in disseminating accurate information and providing on-plot demonstrations of modern agricultural technologies, as highlighted by Abdulhanan *et al.*, (2017). Lastly, inadequate farm labour was identified as the fifth major challenge confronting farmers. Given the labour-intensive nature of designing and maintaining SWCT structures, sufficient labour is indispensable.

Table 4: Major Challenges to the Adoption of SWCTs

Constraints	Mean	Std. Dev.	Rank
Financial constraint	2.60	0.795	2 nd
Lack of technical know-how	2.59	0.690	3 rd
Poor extension services	2.47	0.634	4 th
Inadequate farm labour	2.37	0.734	5 th
Inadequate technical guidelines	2.61	0.584	1 st

Conclusion and Recommendations

The study concludes that smallholder farmers in the study area exhibit an above-average awareness of the importance of adopting Soil and Water Conservation Technologies (SWCTs), reflected in their notable adoption rates. Significant factors influencing SWCT adoption include sex, education level, household size, farm size, topography, income, livestock ownership, cooperative association membership, frequency of extension visits, and road infrastructure quality. Nevertheless, the primary challenges hindering SWCT adoption encompass the lack of technical guidelines, financial constraints, insufficient technical know-how, inadequate extension services, and a shortage of farm labour. In light of these findings, recommendations are proposed to address these barriers and foster greater SWCT adoption.

Firstly, measures to enhance farmer education, such as organizing adult education programs, should be implemented by local government authorities, as education was identified as a key factor facilitating SWCT adoption. Additionally, access to credit facilities in the form of soft loans and subsidies should be facilitated to enable farmers to procure necessary inputs for soil and water management, and productivity enhancement. Furthermore, efforts should be directed towards strengthening and mobilizing extension agents to maintain regular contact with farmers, facilitating the dissemination of information, training, and demonstrations on optimal SWCT utilization. Alternatively, the promotion of knowledge-sharing among farmers, particularly by encouraging highly skilled individuals to train their peers, can help mitigate the challenges posed by inadequate or poor extension services. Lastly, prioritizing the provision of essential infrastructural facilities such as good roads, alongside institutional support from the government, is crucial for ensuring sustained food production through the implementation of sustainable and environmentally friendly SWCTs.

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