International Journal of Sustainable Agricultural Research
2025 Vol. 12, No. 4, pp. 210-218
ISSN(e): 2312-6477
ISSN(p): 2313-0393
DOI: 10.18488/ijsar.v12i4.4558

Adoption of water conservation technologies among smallholder farmers in Osun State, Nigeria

Aminu, Folasade Oluremi[1+]
Morakinyo, Akinwumi Farouq[2]
Suleiman, Abd'Malik[3]

[1,2]*Department of Agricultural Extension and Management, School of Agricultural Technology, Yaba College of Technology, Epe Campus, P. M. B. 2011, Yaba, Lagos State, Nigeria.*
[1]*Email: folaafe02@gmail.com*
[2]*Project Management Department, BPP University, Manchester, UK.*
[2]*Email: Morakinyoakinwumi37@gmail.com*
[3]*Ogun State Agricultural Development Program (OGADEP), Idi-Aba, Abeokuta, Ogun State, Nigeria.*
[3]*Email: mhssule@gmail.com*


(+ Corresponding author)

Article History
Received: 8 October 2025
Revised: 19 November 2025
Accepted: 26 November 2025
Published: 1 December 2025

Keywords
Adoption
Multivariate probit
Smallholder farmers
Sustainable water use
Technologies
Water conservation.

ABSTRACT

Water scarcity and inefficient water management practices pose significant threats to agricultural productivity and rural livelihoods in Nigeria, particularly among smallholder farmers who rely heavily on rain-fed agriculture. Despite increasing awareness of water conservation technologies (WCTs) as viable strategies for sustainable agricultural water use, their adoption among farmers remains relatively low and uneven across regions, highlighting the need to understand factors influencing smallholder farmers' adoption of water conservation technologies in Osun State, Nigeria. The study focused on identifying the WCTs embraced by farmers, understanding their motivations for adoption, and analyzing the factors influencing their adoption decisions. Data was collected via a pre-tested questionnaire administered to 120 smallholder farmers selected through a multistage sampling process. Descriptive statistics and a multivariate probit (MVP) model were employed for data analysis. Findings indicated that the majority (55.8%) of farmers were male, aged 41-50, with primary education (41.7%), and household and farm sizes averaging 6 persons and 4 hectares, respectively. The most adopted WCTs included irrigation/dam (68.3%), grass strips (62.5%), stone bund (50%), soil bund (41.7%), and contour ploughing (32.5%). Reasons for adoption ranged from yield increase to flood control and soil fertility improvement. The MVP model revealed several factors influencing adoption, including farmers' demographics, education, farming experience, land acquisition methods, and access to credit and extension services. The study suggests enhancing educational opportunities, credit access, farmer associations, and extension services as essential policy measures to foster technology adoption in the study area.

Contribution/Originality: This study contributes to the existing literature by providing empirical evidence on the determinants of water conservation technology adoption among smallholder farmers in Osun State, Nigeria. It integrates socioeconomic, institutional, and motivational factors, offering insights that bridge gaps in understanding farmers' adoption behavior and guiding policies for sustainable water resource management.

1. INTRODUCTION

Water scarcity, exacerbated by climate change-induced droughts, poses a significant challenge to agriculture, particularly in rain-fed systems prevalent in developing countries (Apio, Thiam, & Dinar, 2023). The agricultural sector in Nigeria is predominantly rain-fed, with a large portion comprising smallholder farmers who use traditional farming methods for subsistence production, facing low productivity and vulnerability to weather fluctuations (Ojo, Baiyegunhi, Adetoro, & Ogundeji, 2021). Water stress not only threatens food production but also farmers' incomes, especially in rain-fed agricultural systems (Almer, Laurent-Lucchetti, & Oechslin, 2017). Nigerian agriculture grapples with water scarcity, compounded by increasingly frequent and severe climate events such as prolonged droughts (United Nations Framework Convention on Climate Change (UNFCCC), 2020). The scarcity of water resources is considered the most significant threat to achieving the Sustainable Development Goals (SDGs) by 2030 (Agholor & Nkosi, 2020). Addressing this challenge is crucial for safeguarding water resources and ensuring agricultural sustainability amidst climate-induced disruptions (Apio et al., 2023).

The adoption of water conservation technologies (WCTs) emerges as a crucial strategy to mitigate water constraints in agriculture, particularly in regions vulnerable to erratic rainfall patterns (Anyokwu & Badmos, 2019). Beyond water conservation, WCT adoption offers various benefits, including enhanced water-use efficiency, improved water quality, reduced cultivation costs, and increased agricultural productivity (Apio et al., 2023; Uygan, Cetin, Alveroglu, & Sofuoglu, 2021). Moreover, WCTs enable farmers to withstand droughts, maintain consistent production cycles, stabilize income streams, and alleviate poverty within farming communities (Abdulai & Huffman, 2014; Food and Agriculture Organization of the United Nations (FAO), 2017). Research by Adgo, Akalu, and Mati (2013) demonstrated that investing in and consistently utilizing soil and water conservation technologies doubled the productive capacity of adopters compared to non-adopters in the Ethiopian highlands. These technologies, such as farm terraces for soil moisture control, have also been shown to reduce soil erosion, as observed in various studies. For instance, in Iran, farms employing water conservation technologies (WCTs) witnessed higher incomes and rice output (Ashoori, Bagheri, Allahyari, & Al-Rimawi, 2016). Therefore, integrating water conservation practices such as soil bunds, stone bunds, contour ridges, terraces, and others into agricultural development initiatives is essential (Mango, Makate, Tamene, Mponela, & Ndengu, 2017).

Despite the potential benefits, the adoption of WCTs faces challenges, including inadequate technical knowledge, limited access to credit, and institutional barriers (Abdulai & Huffman, 2014; Ojo & Baiyegunhi, 2020; Thinda, Ogundeji, Belle, & Ojo, 2020). While available, the adoption of WCTs among farmers remains relatively low, highlighting the need for further research and interventions to promote their uptake and use. This study aims to address this gap by examining the adoption of WCTs among smallholder farmers, elucidating the drivers of adoption, and identifying factors influencing adoption decisions in Osun State.

2. METHODOLOGY

The research was carried out in Osun State, Nigeria, which was established from the southeastern part of Oyo State on 27 August 1991, with its capital being Osogbo. Positioned in southwestern Nigeria, it spans between longitudes 4°30' E and 4°51' E and latitudes 7°30' N and 7°50' N, covering an area of 8,521 square kilometers and a population of 4,435,800 (National Population Commission (NPC), 2022). The state predominantly relies on agriculture, with crops such as maize, yam, cassava, cocoyam, cocoa, kola nut, citrus, and vegetables cultivated, alongside the rearing of livestock including sheep, cattle, pigs, goats, rabbits, and poultry for both consumption and commercial purposes.

Primary data for the study were obtained through the distribution of questionnaires and conducting interviews. The research employed a multistage sampling technique to select participants. Initially, two local government areas (LGAs) were purposively chosen due to their significant agricultural activities. Subsequently, two villages were randomly selected from each LGA, resulting in a total of four villages. Finally, 15 smallholder farmers were randomly chosen from each of the selected villages, amounting to 120 respondents for the study, representing 20% of the respective sample frames.

Data analysis utilized descriptive statistics and a multivariate probit (MVP) model. The MVP model was applied to examine the factors influencing the adoption of water conservation technologies in the study area. This model was selected for its ability to simultaneously assess the impact of various explanatory variables on different WCTs while accounting for potential correlations between unobserved disturbances. By considering these correlations, the model determines whether different WCTs act as complements (positive correlation) or substitutes (negative correlation) (Belderbos, Carree, Diederen, Lokshin, & Veugelers, 2004). The primary WCTs in the study area included soil bund (SB), grass strips (GS), irrigation/dam (I/D), contour ploughing (CP), and stone bund (STB). The general multivariate probit model is specified as.

$$Y * ijk = Xij'\beta k + Uij\,(k = SB, GS, I/D, CP, STB) \quad (1)$$

The model used to estimate the factors influencing farmers' choice of WCTs is specified as.

$$y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_{16} X_{16} + e \quad (2)$$

Where; Y = WCTs: Y_1 = Soil bund (1 if adopted, 0 otherwise); Y_2 = Grass strips (1 if adopted, 0 otherwise); Y_3 = Irrigation/dam (1 if adopted, 0 otherwise); Y_4 = Contour ploughing (1 if adopted, 0 otherwise); Y_5 = Stone bund (1 if adopted, 0 otherwise). The explanatory variables were: X_1 = Age of farmers (years), X_2 = Sex (1 if male, 0 otherwise), X_3 = Educational level (at least a primary school education = 1, otherwise = 0), X_4 = Marital status (1 if married, 0 otherwise), X_5 = Household size (number of persons), X_6 = Farming experience (years), X_7 = Farm size (hectares), X_8 = Farmland acquisition (1 if inherited, 0 otherwise), X_9 = Type of labour used (1 if family labour, 0 otherwise), X_{10} = Livestock ownership (1 if owned, 0 otherwise), X_{11} = Topography (1 if plain, 0 otherwise), X_{12} = Membership of cooperative society (dummy), X_{13} = Extension visits (frequency), X_{14} = Income (₦), X_{15} = Good roads (dummy), X_{16} = Access to credit (dummy). e is the random error term, and β_1 to β_{16} are the coefficients to be estimated.

3. RESULTS AND DISCUSSION

3.1. Summary statistics of Selected Socio-Economic Characteristics of the Respondents

Table 1 presents the findings on the socio-economic characteristics of the respondents. The data indicates that the majority (55.9%) of the smallholder farmers were male, reflecting a male dominance in farming activities and a higher likelihood of adopting WCTs compared to females. This aligns with the typical African setting where men, as household heads and decision-makers, have greater access to and control over land and production resources, as noted by Obisesan (2014). Most (27.5%) of respondents fell within the 41 to 50 years age range, with a mean age of 51 years, suggesting an aging farmer population. While older farmers may face challenges in adapting to new technologies, their experience and familiarity with local conditions can facilitate the adoption of WCTs, as supported by the average farming experience of 23 years in the study area. This is consistent with Olawuyi (2018) findings on the importance of experience in adopting soil and water conservation practices. The majority (76.7%) of respondents were married, with an average household size of 6 persons. A smaller household size may negatively influence WCT adoption, as larger households typically offer more labor for technology adoption, as noted by Ndiritu, Kassie, and Shiferaw (2014). Nearly half (49.2%) of farmers cultivated between 1 and 3 hectares of land, with a mean farm size of 4 hectares, indicating smallholder farming practices that may limit both the number and cost of WCT adoption. This corresponds with the findings of Berhanu, Teddy, Dinaw, and Meles (2016) that larger farms are more conducive to WCT adoption due to greater income.

Table 1. Summary of selected socio-economic characteristics of the respondents.

Variable	Frequency	Percentage (%)	Mean
Sex			
Male	67	55.8	
Age (years)			
41-50	33	27.5	51.07±12.410
Educational qualification			
Primary education	50	41.7	
Marital status			
Married	92	76.7	
Household size (no)			
6-10	63	52.5	6.35±2.752
Farming experience			

Variable	Frequency	Percentage (%)	Mean
11-20	39	32.5	23.26 ±12.515
Farm size (ha)			
1-3	59	49.2	4.01±3.213
Land acquisition			
Inheritance	49	40.8	
Income			
≤250,000	56	46.7	334,250.00±22336.591
Cooperative membership			
Yes	71	59.2	
Access to credit			
Yes	53	44.2	
Extension contact			
Yes	50	41.7	
Livestock ownership			
Yes	67	55.8	

Note: n = 120.
Source: Field Survey Data, 2023.

A considerable portion (40.8%) of smallholder farmers inherited their land, with an average income of ₦334,250.00. Ownership of farmland and high income are likely to have a positive influence on the adoption of WCTs. Additionally, a majority (59.2%) were members of cooperative associations, and 44.2% had access to credit facilities, which can facilitate social networking and access to information about new technologies, thereby enhancing WCT adoption. Furthermore, a majority (55.8%) of farmers owned livestock alongside crop farming, providing an additional income stream. Ownership of livestock may enhance farmers' ability to invest in WCTs and improve adoption rates.

3.2. Types of Water Conservation Technologies Adopted by the Smallholder Farmers

The findings presented in Table 2 reveal that a majority (66.7%) of the surveyed farmers embraced at least one of the WCTs in the study area. Among these, irrigation/dam was the most widely adopted WCT, with 68.3% of farmers utilizing it.

Farmers highlighted that the use of irrigation/dam enhances water-use efficiency by minimizing water loss from excess deep percolation, evaporation, and runoff. Additionally, Michael (2008) as cited in Apio et al. (2023), suggested that irrigation offers various benefits including enhanced fertilizer-use efficiency, decreased labor costs, improved disease and pest control, and suitability for undulating sloped lands. This underscores the multifaceted advantage of employing irrigation techniques in agriculture.

Grass strips, planted along contours to mitigate soil erosion and runoff, were adopted by 62.5% of farmers. Stone bunds/stone lines, which serve as semi-permeable barriers along contours to slow runoff speed, increase water spread over fields, enhance infiltration, and reduce soil erosion, were utilized by 50% of respondents. These structures not only help in conserving soil but also contribute to rehabilitating degraded land by trapping silt, especially in dry, stony areas.

Soil bunds, embankments constructed along contours with a water collection channel or basin at their upper side, were adopted by 41.7% of farmers.

This technique controls runoff and erosion from cultivated fields by reducing the slope length, thereby decreasing the velocity of runoff. Soil bunds are also effective in controlling soil loss, retaining moisture, and ultimately improving land productivity.

Furthermore, contour farming, involving field activities such as plowing and furrowing carried out along contours rather than up and down slopes, was adopted by 32.5% of farmers. This method conserves water by reducing surface runoff and promoting water infiltration into the crop area.

Table 2. Adoption and type of water conservation technologies adopted.

Adoption	Frequency	Percentage
Yes	80	66.7
***Type of WCTs**		
Soil bund	50	41.7
Grass strips	75	62.5
Irrigation/Dam	82	68.3
Contour ploughing	39	32.5
Stone bund	60	50.0

Note: *Multiple responses.
Source: Field Survey Data, 2023.

3.3. Reasons for Adopting Water Conservation Technologies

Farmers, as technology adopters, are typically motivated by the expected benefits of specific technologies (Anyokwu & Badmos, 2019). The results on reasons for adopting WCTs, as presented in Table 3, indicate that the majority (88.3%) of respondents embraced WCTs due to their significant impact on crop yield. Additionally, 82.5% adopted WCTs to control flooding on their farmland, while 79.2% cited the reduction of soil loss as a primary reason for adoption. Other reasons included the improvement of soil fertility (71.7%), while 59.2% of farmers adopted WCTs to provide fuelwood for cooking and forage for feeding livestock. These findings are consistent with the observations of Yifru and Miheretu (2022).

Table 3. Reasons for adopting water conservation technologies.

*Reasons for Adoption	Frequency	Percentage
Increase yield	106	88.3
Control flood	99	82.5
Improve soil fertility	86	71.7
Reduce soil loss	95	79.2
Provide fuelwood and forage	71	59.2

Note: *Multiple responses.
Source: Field Survey Data, 2023.

3.4. Factors Influencing the Adoption of Water Conservation Technologies

The multivariate probit model was jointly estimated for five water conservation technologies (WCTs): soil bund, grass strips, irrigation/dam, contour plowing, and stone bund. The empirical results of the analysis are summarized in Table 4. The p-value of the Wald test statistic for the overall significance of the model is 0.000, indicating a high overall significance of the multivariate probit regression. Furthermore, the likelihood ratio test of rho (ρ) is highly significant (p-value=0.0005), suggesting that a multivariate probit specification fits the data well.

The results presented in Table 4 reveal that the coefficient of age was significant and negatively influenced the adoption of soil bund ($p<0.10$) and grass strips ($p<0.05$). This implies that the likelihood of farmers adopting soil bunds and grass strips as WCTs decreases as they grow older. This finding is consistent with the observations of Apio et al. (2023), who noted that farmers tend to become more risk-averse as they age, leading to decreased interest in long-term investments in farming and subsequently lower adoption rates. Conversely, the adoption of irrigation/dam as a WCT was found to increase with the age of farmers at the 1% alpha level. This supports the findings of Aminu, Balogun, Ojo, AbdulAzeez, and Aderibigbe (2022) who observed that the probability of adopting manure/fertilizer application as a soil conservation technology increases with the age of farmers in Osun State.

The sex of the farmers was found to positively influence the adoption of irrigation/dam ($p<0.10$) and stone bund ($p<0.01$). This indicates that male farmers are more likely to adopt irrigation, dams, and stone bunds compared to female farmers.

Table 4. Factors influencing water conservation technologies in the study area.

Factor	Soil bund	Grass strips	Irrigation/dam	Contour ploughing	Stone bund
Age	-0.35*(-1.74)	-0.70**(-2.55)	0.05***(2.59)	0.44(1.53)	0.59(1.06)
Sex	0.27(0.98)	0.01(0.35)	0.40* (1.92)	-0.02(-1.05)	0.04***(2.61)
Educational level	-0.70*(-1.67)	0.70(1.59)	0.51**(2.34)	0.10(0.25)	-0.23(-0.52)
Marital status	-0.76** (-2.09)	-0.20(-0.56)	0.46(1.40)	0.38(0.97)	0.08**(2.19)
Household size	-0.02 (-0.40)	-0.00(-0.08)	0.03(0.52)	0.08(1.51)	0.02**(2.01)
Farming experience	0.12(1.59)	-0.01(-0.50)	0.01**(2.24)	0.04**(2.13)	0.08***(3.33)
Farm size	0.03(0.96)	-0.15(-0.56)	-0.04(-1 24)	-0.06(-1.38)	0.04(1.50)
Land acquisition	-0.34 (-1.09)	0.32(1.06)	0.46(1.49)	-1.03*** (-3.01)	0.16(0.47)
Labour type	-0.76(-1.39)	0.13(0.24)	0.42(0.71)	-0.41(-0.69)	-1.45*(-1.81)
Livestock ownership	0.19(0.62)	-0.01**(-2.04)	0.01**(2.14)	0.46* (1.74)	0.72**(2.08)
Topography	-0.01(-0.02)	0.65(1.10)	-0.38(-1.34)	-0.67(-1.55)	0.04(0.13)
Cooperative membership	-0.39(-1.23)	0.02**(2.07)	0.16**(2.31)	0.24**(2.25)	0.53*(1.92)
Extension services	-0.38**(-2.28)	0.12(1.39)	0.01**(2.03)	0.10**(0.31)	-0.13(-0.38)
Income	0.00(0.18)	-0.00**(-2.32)	0.00**(2.20)	0.00(0.89)	-0.00(-0.72)
Good roads	0.22(0.68)	-0.23(-1.32)	-0.12(-0.36)	0.11(0.32)	-0.57(-1.49)
Credit facilities	0.18(0.52)	0.10(0.30)	0.00***(2.60)	-0.01(-0.02)	1.38***(3.53)
Constant	1. 70(1.00)	0.37(0.33)	0.11(0.10)	-0.78(-0.66)	0.54(0.45)

Note: N= 120; Log pseudo likelihood= -299.49806; chi2(10)=31.6784; Prob > chi2= 0.0005. **, ** and * indicate significance at 1%, 5%, and 10% levels, respectively. Figures in parentheses are z-values.

This finding aligns with Asfaw and Neka (2017) who noted that male farmers are more involved in SWC practices due to the labor-intensive nature of designing and maintaining SWC structures. Additionally, Iyilade, Alalade, Longe, Alokan, and Akinola-Soji (2020) reported that male farmers, as primary decision-makers, have greater control over resources critical for technology adoption; hence, the higher adoption rates.

The educational level of the farmers significantly influenced the adoption of soil bund (p<0.10) and irrigation/dam (p<0.05). While the adoption of soil bunds decreased with higher education levels, the adoption of irrigation/dams increased. This is consistent with Zhang, Fu, Wang, and Zhang (2019), suggesting that literate farmers are more likely to adopt modern technologies. Marital status negatively influenced soil bund adoption (p<0.05), indicating that unmarried farmers are more likely to adopt soil bund. Conversely, stone bund adoption increased with marital status and household size (p<0.05 and p<0.10) respectively, suggesting that married farmers with larger households are more inclined to adopt stone bunds, possibly due to increased labor availability. Adoption of stone bunds also decreases when the labor type is family labor at a 10% alpha levels. This could be attributed to the fact that stone bunds are more labor-intensive and are mostly convenient for farmers with large household sizes.

Farmers' experience positively influenced the adoption of irrigation/dam, contour ploughing, and stone bund (p<0.05 and p<0.01) respectively. This implies that experienced farmers are more eager to gather information and adopt new technologies. Subsequently, they tend to be well-informed about innovations in agricultural practices much more than less experienced farmers. This aligns with the findings of Nkegbe (2018), which suggest that farming experience tends to broaden farmers' perspectives towards the adoption of conservation practices for increased productivity. The adoption of contour ploughing was found to decrease based on land acquisition method at a 1% significance level. This indicates that farmers who inherited their farmlands were less likely to adopt contour ploughing than those who did not.

Livestock ownership negatively influenced grass strip adoption (p<0.05) but positively influenced irrigation/dam, contour ploughing, and stone bund adoption (p<0.05, p<0.10, and p<0.05, respectively). This suggests that larger livestock herds decrease grass strip adoption due to the need for grass as feed during the dry season but increase adoption of other WCTs, possibly indicating higher wealth and power. This is consistent with the findings Nkegbe and Shankar (2014), who attributed this to the fact that grass is required for feeding animals, especially during the long dry season. This also aligns with the findings of Iyilade et al. (2020), indicating that households with wealth and power are more likely to adopt technologies than their poorer counterparts.

Cooperative association membership significantly influenced the adoption of grass strips, irrigation/dam, contour ploughing, and stone bund ($p<0.05$ and $p<0.10$), suggesting that members are more likely to adopt these WCTs, benefiting from information exchange and networking. This is consistent with the findings of Yifru and Miheretu (2022) that membership in a local organization assists a person in obtaining information on improved farming practices. Extension contacts, while reducing the probability of adopting soil bunds ($p<0.05$), consistent with the finding of Abdul-Hanan, Ayamga, and Donkoh (2014) increase the probability of adopting irrigation/dam ($p<0.05$) and contour ploughing ($p<0.05$). This implies that obtaining regular visits and technical advice from extension officers, which serve as vital channels for transferring knowledge, technologies, and best practices in farming, positively influences the adoption of irrigation/dams and contour ploughing as WCTs. This is in consonance with the findings of Agholor and Nkosi (2020) that Agricultural extension services play a crucial role in disseminating information, facilitating networking among farmers and promoting adoption of innovation. Ayamga and Dzanku (2015) observed that farmers who receive infrequent visits from extension officers may be less likely to adopt WCTs due to limited exposure to relevant knowledge and assistance.

Furthermore, income had an inverse relationship with grass strip adoption but a positive relationship with irrigation/dam adoption ($p<0.05$). Higher income levels enable farmers to afford the upfront costs associated with implementing WCTs. This aligns with the findings of Aminu, Rosulu, Balogun, and Babawale (2018), which indicate that farmers with higher income employed structural and mechanical erosion control practices (SMECP) more frequently than low-income farmers. Similarly, access to credit facilities increased the adoption of irrigation/dams and stone bunds, highlighting the role of credit in facilitating technology adoption among smallholder farmers.

4. CONCLUSION

The study identified several water conservation technologies (WCTs) adopted by smallholder farmers, including irrigation/dams, grass strips, stone bunds, soil bunds, and contour ploughing. Key factors influencing the adoption of water conservation technologies among smallholder farmers were also determined. Therefore, effective policy measures to promote WCT adoption should focus on improving farmers' education, access to information, and practical programs such as workshops, on-farm demonstrations, and training through extension services. Strengthening farmer cooperative associations and increasing access to credit facilities are also recommended. Additionally, promoting farmer-to-farmer knowledge sharing and encouraging knowledgeable farmers to train others can address the challenge of inadequate extension services in the study area.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The study involved minimal risk and followed ethical guidelines for social science fieldwork. Formal approval from an Institutional Review Board was not required under the policies of Yaba College of Technology, School of Agricultural Technology, Lagos State, Nigeria. Informed verbal consent was obtained from all participants, and all data were anonymized to protect participant confidentiality.
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

Abdul-Hanan, A., Ayamga, M., & Donkoh, S. A. (2014). Smallholder adoption of soil and water conservation techniques in Ghana. *African Journal of Agricultural Research, 9*(5), 539-546. https://doi.org/10.5897/AJAR2013.7952

Abdulai, A., & Huffman, W. (2014). The adoption and impact of soil and water conservation technology: An endogenous switching regression application. *Land Economics*, *90*(1), 26-43. https://doi.org/10.3368/le.90.1.26

Adgo, E., Akalu, T., & Mati, B. (2013). Impacts of long-term soil and water conservation on agricultural productivity: The case of Anjenie watershed, Ethiopia. *Agricultural Water Management*, *117*, 55–61. https://doi.org/10.1016/J.AGWAT.2012.10.026

Agholor, A. I., & Nkosi, M. (2020). Sustainable water conservation practices and challenges among smallholder farmers in Enyibe Ermelo Mpumalanga Province, South Africa. *Journal of Agricultural Extension*, *24*(2), 112-123. https://doi.org/10.4314/jae.v24i2.12

Almer, C., Laurent-Lucchetti, J., & Oechslin, M. (2017). Water scarcity and rioting: Disaggregated evidence from Sub-Saharan Africa. *Journal of Environmental Economics and Management*, *86*, 193-209. https://doi.org/10.1016/j.jeem.2017.06.002

Aminu, F. O., Balogun, E. O. S., Ojo, O. O., AbdulAzeez, S. A., & Aderibigbe, O. F. (2022). *Adoption of soil conservation practices among smallholder farmers in Ilesa East Local Government Area, Osun State, Nigeria*. Paper presented at the Proceedings of UNIOSUN Sustainable Agriculture Conference, held at College of Agriculture, Osun State University, 16th – 17th November, 2022.

Aminu, F. O., Rosulu, H. O., Balogun, E. O. S., & Babawale, O. H. (2018). Analysis of adoption of sustainable land management practices for yam production in Osun State, Nigeria. *Journal of Agricultural Science and Practice*, *3*(6), 154-160. https://doi.org/10.31248/JASP2018.115

Anyokwu, E. E., & Badmos, O. S. (2019). *Land tenure security, soil water conservation adoption and farm household welfare in Southwestern Nigeria*. Bonn, Germany: Centre for Development Research (ZEF), University of Bonn.

Apio, A. T., Thiam, D. R., & Dinar, A. (2023). Farming under drought: An analysis of the factors influencing farmers' multiple adoption of water conservation practices to mitigate farm-level water scarcity. *Journal of Agricultural and Applied Economics*, *55*(3), 432-470. https://doi.org/10.1017/aae.2023.23

Asfaw, D., & Neka, M. (2017). Factors affecting adoption of soil and water conservation practices: The case of Wereillu Woreda (District), South Wollo Zone, Amhara Region, Ethiopia. *International Soil and Water Conservation Research*, *5*(4), 273-279. https://doi.org/10.1016/j.iswcr.2017.10.002

Ashoori, D., Bagheri, A., Allahyari, M. S., & Al-Rimawi, A. S. (2016). An examination of soil and water conservation practices in the paddy fields of Guilan province, Iran. *Anais da Academia Brasileira de Ciências*, *88*(2), 959-971. https://doi.org/10.1590/0001-3765201620140613

Ayamga, M., & Dzanku, F. (2015). *The land rights and farm investment Ghana: The missing link in the operationalisation of tenure security*. Paper presented at the International Conference of the African Association of Agricultural Economists, Hammamet, Tunisia.

Belderbos, R., Carree, M., Diederen, B., Lokshin, B., & Veugelers, R. (2004). Heterogeneity in R&D cooperation strategies. *International Journal of Industrial Organization*, *22*(8-9), 1237-1263. https://doi.org/10.1016/j.ijindorg.2004.08.001

Berhanu, A., Teddy, G., Dinaw, D., & Meles, B. (2016). Soil and water conservation practices: Economic and environmental effects in Ethiopia. *Global Journal of Agricultural Economics and Econometrics*, *4*, 169-177.

Food and Agriculture Organization of the United Nations (FAO). (2017). *Water for Sustainable Food and Agriculture*. Retrieved from A Report Produced for the G20 Presidency of Germany, Rome:

Iyilade, A. O., Alalade, O. A., Longe, M. P., Alokan, A. O., & Akinola-Soji, B. (2020). Factors influencing adoption of sustainable soil and water conservation practices among smallholder farmers in Kwara State, Nigeria. *Journal of Agricultural Extension*, *24*(4), 113-121. https://doi.org/10.4314/jae.v24i4.12

Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2017). Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. *International Soil and Water Conservation Research*, *5*(2), 122-129. https://doi.org/10.1016/j.iswcr.2017.04.003

Michael, A. M. (2008). *Irrigation theory and practice* (2nd ed.). Delhi, India: Vikas Publishing House Pvt. Ltd.

National Population Commission (NPC). (2022). *Population statistics and demographic indicators of Nigeria*. Abuja, Nigeria: National Population Commission.

Ndiritu, S. W., Kassie, M., & Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. *Food Policy, 49*, 117-127. https://doi.org/10.1016/j.foodpol.2014.06.010

Nkegbe, P. K. (2018). Soil and water conservation practices and smallholder farmer multi-activity technical efficiency in Northern Ghana. *Ghana Journal of Development Studies, 15*(1), 55-91. https://doi.org/10.4314/gjds.v15i1.4

Nkegbe, P. K., & Shankar, B. (2014). Adoption intensity of soil and water conservation practices by smallholders: Evidence from Northern Ghana. *Bio-based and Applied Economics Journal, 3*(2), 159-174. https://doi.org/10.22004/ag.econ.182908

Obisesan, A. (2014). *Gender differences in technology adoption and welfare impact among Nigerian farming households*. MPRA Paper No. 58920.

Ojo, T. O., & Baiyegunhi, L. J. S. (2020). Determinants of climate change adaptation strategies and its impact on the net farm income of rice farmers in South-West Nigeria. *Land Use Policy, 95*, 103946. https://doi.org/10.1016/j.landusepol.2019.04.007

Ojo, T. O., Baiyegunhi, L. J. S., Adetoro, A. A., & Ogundeji, A. A. (2021). Adoption of soil and water conservation technology and its effect on the productivity of smallholder rice farmers in Southwest Nigeria. *Heliyon, 7*(3), e06433. https://doi.org/10.1016/j.heliyon.2021.e06433

Olawuyi, S. O. (2018). Farmers' preference for soil and water conservation practices in Nigeria: Analytic hierarchic process approach. *Journal of Economics and Behavioral Studies, 10*(4), 68-80. https://doi.org/10.22610/jebs.v10i4(J).2408

Thinda, K. T., Ogundeji, A. A., Belle, J. A., & Ojo, T. O. (2020). Understanding the adoption of climate change adaptation strategies among smallholder farmers: Evidence from land reform beneficiaries in South Africa. *Land Use Policy, 99*, 104858. https://doi.org/10.1016/j.landusepol.2020.104858

United Nations Framework Convention on Climate Change (UNFCCC). (2020). *Climate change is an increasing threat to Africa*. Retrieved from https://unfccc.int/news/climate-change-is-an-increasing-threat-to-africa

Uygan, D., Cetin, O., Alveroglu, V., & Sofuoglu, A. (2021). Improvement of water saving and economic productivity based on quotation with sugar content of sugar beet using linear move sprinkler irrigation. *Agricultural Water Management, 255*, 106989. https://doi.org/10.1016/j.agwat.2021.106989

Yifru, G. S., & Miheretu, B. A. (2022). Farmers' adoption of soil and water conservation practices: The case of lege-lafto watershed, Dessie Zuria District, South Wollo, Ethiopia. *PloS One, 17*(4), e0265071. https://doi.org/10.1371/journal.pone.0265071

Zhang, B., Fu, Z., Wang, J., & Zhang, L. (2019). Farmers' adoption of water-saving irrigation technology alleviates water scarcity in metropolis suburbs: A case study of Beijing, China. *Agricultural Water Management, 212*, 349-357. https://doi.org/10.1016/j.agwat.2018.09.021