Land tenure Security, Soil Water Conservation Adoption and Farm Household Welfare in South-Western Nigeria.

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Abstract

Soil water conservation technologies are required in Nigeria in response to agricultural water constraints. However, land tenure security may hinder the adoption of these technologies. This study therefore aimed to assess the extent to which land tenure security impact upon welfare outcomes of farming households through the adoption of soil water conservation technologies using a case study from South Western Nigeria. Data was collected through head farmer interviews using structured questionnaires, and responses from 236 farmers were used for the study. The study differentiates between perceived and legal land tenure security and allows for joint use of different soil water conservation technologies. Using a double hurdle model, the study finds that land tenure security in terms of legal documentation induces the incremental adoption intensity while perceived tenure security has limited effects. Adopting soil water conservation technologies increased productivity, gross margin and welfare outcome in terms of per-capita income. Agricultural innovation adoption driven by land security has the potential to improve the livelihood of smallholder farmers.

1. Introduction

For decades, overcoming water constraint in agricultural production has attracted significant attention in economic and environmental studies[1]. This is primarily because water stress is posing significant challenges to continued food production and farmers income, especially in rain-fed agricultural systems[2]. The threat of water availability is higher in South-Western Nigeria where about 60 percent of the farming population resides in the drier guinea savanna with only about 5% of these land areas under irrigation. The existing water challenge would be exacerbated by climate change effects. One way to overcome these challenges is the application of soil water conservation technologies (SWCT) (FAO, 1987). SWCTs enhances efficient use of water and limit soil water loss, thus ensuring long term availability of soil moisture. While these technologies are available and reported to be effective[3], their application and use are relatively limited [4]. For example, Junge, et al., (2009) showed that adoption of soil and water conservation technologies among farmers in Osun state was less than 30% even with incentives.

Several empirical studies have attributed the low level of soil and water conservation technology adoption to farmer's characteristics, economic conditions and social factors[5]. Other studies attribute adoption level to risk behavior of farmers[6]. As SWCT investments takes time

[1] Gobarah et al.,
[2] Almer et al.; Kim, Iizumi, & Nishimori; Namara et al. ,
[3] Adgo, Teshome, and Mati,
[4] Junge, et al.,
[5] Adgo, Teshome, and Mati,"; Bagdi et al.,; Bewket, Mango et al.,; Mekuriaw et al.,
[6] Holden and Otsuka,; Wossen, Berger, and Di Falco

(e.g. one growing season) to yield benefits (FAO, 1987), land tenure security may play an important role in risk perception and hence in conservation adoption. Since SWCT are stock investments that are capital and labor intensive, farmers expected access and control of land under investment at the time of expected return may be relevant in their decision process. The risk of land expropriation before full earnings from investments could thus hinder adoption.

Contrary to other countries in Africa, land rights and tenure systems in Nigeria are particularly significant for land related investments. Nigerian land laws recognize several forms of tenure rights including statutory and customary rights and freehold titles which are associated with varying levels of tenure security (Nwocha, 2016). The Nigerian Land Use Act of 1978 vested all lands under the authority of state governments given rights to allocate lands for developmental purposes. While reallocation of land rights attracts certain forms of compensation for certified plots, freehold systems do not enjoy such benefit. At the same time, majority of smallholder land holdings are held in freehold systems leaving them vulnerable to uncompensated land relocation. Further, large scale land reallocation for industrial, commercial agriculture or public investments is spatially less concentrated in core rural area[7]. These factors could lead to differing perception of tenure security among freeholders and titled land holders and influence decision variables of farmers.

Although a few studies account for land tenure security effect on adoption decision, these studies pay attention to particular conservation methods while treating the available technologies as mutually exclusive[8]. However, in reality, multiple applications of technologies are possible. In addition, these studies focus on the binary choice of adoption behavior[9]. Generally, extending adoption behavior to impact using these binary measures conceals relevant details of adoption behavior. This makes it necessary to account for the extent of application of technologies.

Farmers as adopters of technologies are usually concerned about the expected benefit of using specific technologies. The effects of technology adoption on farmer's outcomes are well documented in empirical literature. For example, [10] found that investment and continued use of soil and water conservation technology is associated with twice the productive capacity of non-technology adopters in Ethiopian highlands. With respect to environmental outcomes, farm terraces for soil moisture control resulted in reduced soil erosion. Similarly, higher incomes and farm output of rice were recorded among farmers field with SWC in Iran[11]. However, these studies focused on a single technology adoption and did not consider the complimenting effects of other technologies. Moreover, they only considered the binary effects of adoption or otherwise and did not focus on multiple adoption decisions. Measuring adoption in such a manner masks the differences in intensity of adoption and could overstate or underestimate the impact of adoption depending on the deviation of technology coverage from zero.

Against this backdrop, this paper uses a novel adoption index to measure adoption. This measure is superior to existing binary measures as it accounts for multiple technology uptake and extent of uptake of each technology. Also, it extends the argument of soil water stress and mitigation technology adoption to a different contextual setting under different land institutions by concentrating on Nigeria; Contrary to many countries in Africa where similar studies have been conducted[12], the Nigerian land use act allows varying levels of land ownership with different

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7 Osabuohien,

8 Asfaw and Neka; Ashoori et al.,; Bagdi et al.

9 Bewket,; Knowler and Bradshaw,; Moges and Taye,

10 Adgo, Teshome, and Mati,

11 Ashoori et al.

12 Deininger and Jin,; Deininger et al.

implications for land tenure security. Even though there is a general agreement that titling ensures the security of land ownership, studies have found that other forms of tenure security may be important for investment decisions[13]. Along this line of argument, this study distinguishes between the levels of security based on legal documentation of ownership and transfer rights from perceived security based on farmers' prior knowledge of land market changes. Furthermore, the study extends the adoption decision beyond a specific technology to capture the extent of multiple technology uptakes. The study contributes significant findings to the growing field of enquiry into land institutions and technological innovativeness.

The objectives of the study are;

i. To examine the effect of land tenure security on SWCT adoption intensity
ii. To assess the impact of adoption intensity levels on the welfare of farming households.

The rest of this paper is structures as follows: section 2 gives the conceptual framework; section 3 gives the methodology; section 4 presents the results and discussion; and section 5 gives the conclusion, summary of findings and implications for policy.

2. Conceptual framework

Figure 1 presents an intuitive conceptual framework underlying the empirical model for estimating the effects of land tenure security on adoption intensity of soil water conservation technologies and how these impact households' welfares. Several levels of factors interact in complex forms to determine the extent of adoption of[14]. At the proximate level, farmers are assumed to be rational and thus objectively choose decision variables to meet their specific utility or profit maximization objective subject to the constraints surrounding them. Farmers may face constraints related to capital, labor availability, and technological know-how and to a larger extent, the uncertainty of investment security. Specifically, a key determinant of the adoption is the expected value of profit from the adoption decision which depends on the security of the investment. This last constraint may be amplified by the existing land ownership regime at the farm level and existing land markets, development and land laws at the macro level[15]. With increased security through certification or titling on land holding, the risk associated with loss of land and investments on water saving technologies will be reduced. The expected benefits from such investments are more secure and may increase the probability for uptake of technologies. The extent to which the land tenure security will influence the adoption of technologies will also depend on (i) farmers' perception of the security of tenure based on the education level, social network, awareness and risk behavior (ii) the existing institutional factors including land laws and land market potentials as well as infrastructure. However, the extent of need for water conservation given the regional and soil characteristics such as the water holding capacity, porosity and stability of the soils as well as regional micro-climate may also interact with farmer's capabilities to affect adoption decision.

Moreover, the adoption of soil water conservation technologies is expected to improve farm household welfare as it increases the potential productivity of farming. Similarly, soil water conservation technologies could allow farmers crop multiple times in a growing year since it minimizes soil water loss allowing availability of water for all year production. Increasing welfare could also occur through increased profitability of farming which results from increased cropping diversity and intensity.

[13] Brasselle, Gaspart, and Platteau,; Holden and Otsuka,
[14] Mponela et al.,; Teshome, de Graaff, and Kassie,; Knowler and Bradshaw,; Mango et al.,
[15] Brasselle, Gaspart, and Platteau

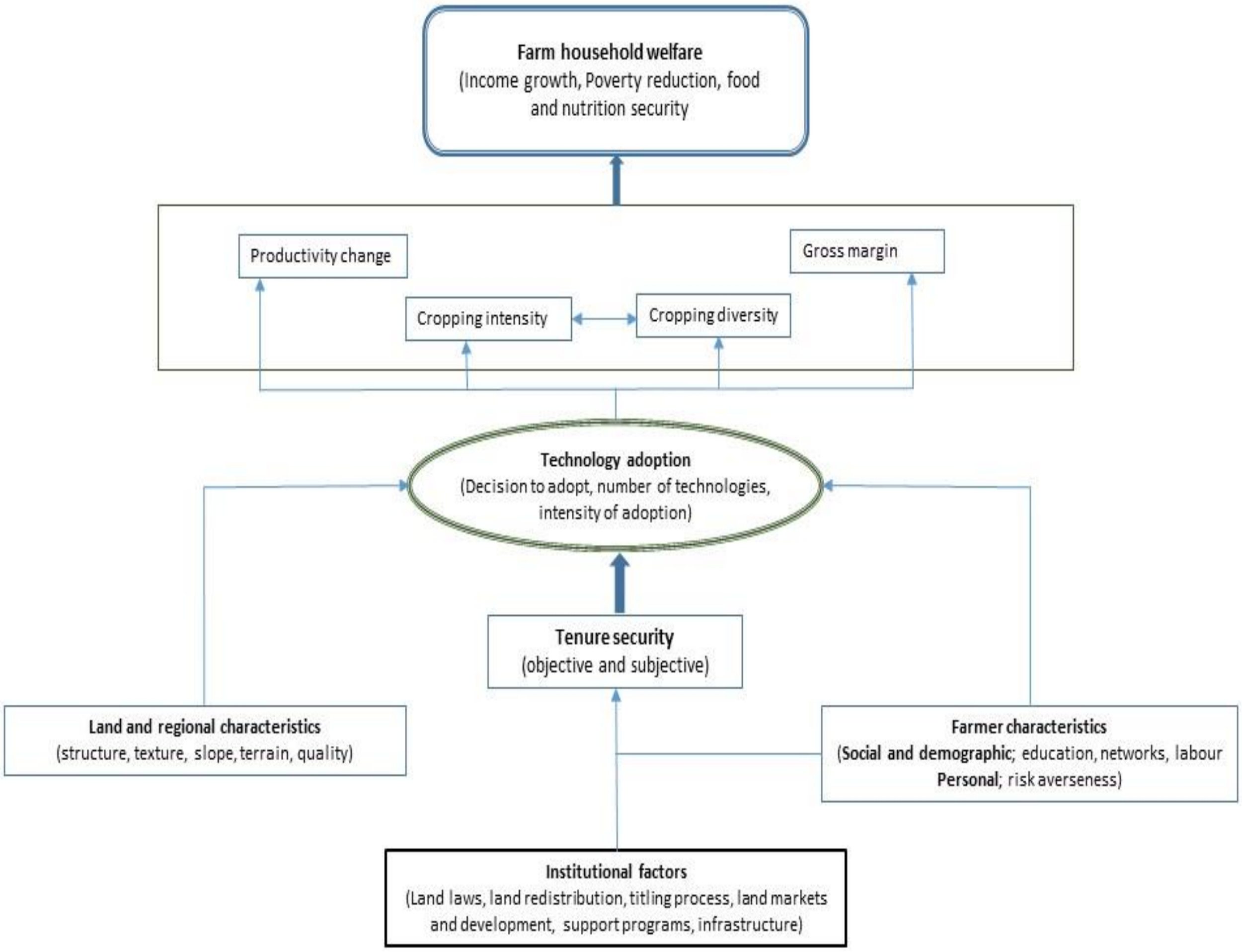

Figure 1: From land tenure security to welfare through soil water conservation technology adoption
Source: Author's compilation from literature review

3. Methodology

3.1 Description of Data

The data was collected from a survey of 270 farming households in Oyo state, Nigeria using structured questionnaire in a stratified random sampling approach. The first stage saw the purposive selection of Oyo state from the south western region due to the representativeness of varying agro ecological zones within the state. At the second stage, seven local government areas were selected according to the size of the agro-ecological zones they represent. From each of the selected local government area, three sample communities were randomly selected and from which, twelve farming households were randomly selected.

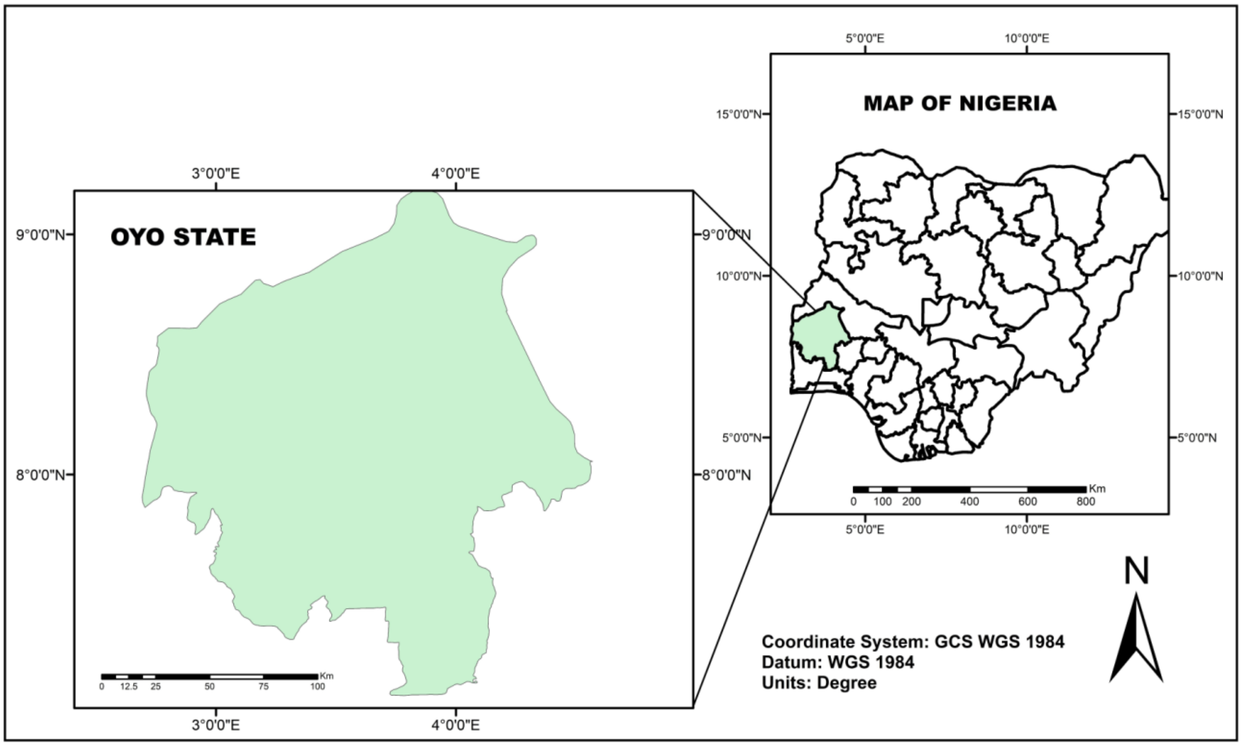

Figure 2: Map of study area, Oyo state in Nigeria

3.2 Socio-economic characteristics of farming households

The important variables used in the study are summarized in table 1. The mean age of the farm household head was 47 years. Above 80% of the household heads were males and married with an average household size of 6. The relatively large farm household size did not reflect in the labor availability of the households as the average household labor size was 2 persons per household. This implies that farming households are relatively dependent on hired labor. Mean schooling years was 8 years implying that most farmers only attained primary education. With regards to social capital and institutional support, about half of the sampled farmers belong to a farmers group and were aware of SWCT. However, only about 43% of the farmers had access to extension services. Over 30% of the farmers reported to have experienced a severe drought event while 45% of the respondents reported having neighbors who utilize one form of SWCT or the other.

Owing to the agrarian nature of the study area, the relative farm size was about 1.5 times the national average (LSMS, 2012). Inherited land ownership without certification dominates the land holding chart. Above 30% of the lands were inherited while about 20% and 22% of the lands were rented either through cash rental, sharecropping or undocumented leasehold respectively. A smaller fraction of the land (15%) held legal titles. However, the general perception of tenure security was high. About 70% of the farmers perceived that their lands were secured from expropriation in the next five farming season.

The proportion of farmers adopting one conservation technology or the other was generally high. Over 80% of the farmers adopted method SWCT. However, the average adoption intensity was about 50% implying that majority of the farmers utilize technology on limited areas of their farms. The result also shows that there was a favorable bias towards land based and labor-intensive soil water conservation technologies. Finally, an average of two technologies was adopted by each farmer in the study area. The result highlights the need to further explore the implications of joint uptake of technologies by farmers.[16]

Table1: Description of variables used in the study

Variables (units)		Obs.	Mean	Std Dev
Outcome variables				
PCE	Per capita income	236	8.1	10.1
TFP	Total factor productivity	236	2.728	2.058
Gross margin (Naira)	Annual gross profit from farming activity	236	441,383	749,640
Cropping diversity	Number of crops grown on land	234	2.218	0.874
Cropping intensity	Number of times farmer crops on land in a year	235	1.962	0.802
Crop choice	Whether farmer grows quarterly, annual or perennial crops on land	236	1.720	0.631
Demographic characteristics				
Age (Years)	Age of household head	236	47.53	14.62
Gender	Percentage of male headed households	236	0.843	0.023
Marital status (0/1)	Whether household head is married or not	236	0.877	0.329
Household size	Number of individuals in household (adult equivalent)	236	6.483	3.048
Household labor size	Number of household member aged 18-60years	236	2.326	1.989
Education(years)	Number of years of schooling of household head	236	7.898	4.962
Farming experience (years)	Number of years of farming	236	21.27	14.67
Socio-economic characteristics				
Group membership (0/1)	Whether farmer belongs to a social group	236	0.432	0.496
Awareness of WCT (0/1)	Whether farmer is aware of water conservation techniques	236	0.466	0.593
Extension access (0/1)	Access to extension services	236	0.432	0.496
Neighborhood effect (0/1)	If neighboring farmers adopt SWCT	234	0.350	0.487
Drought experience	Farmer has experienced drought at least once	236	0.445	0.498
Land and Tenure security characteristics				
Farm size (hectares)	Total farm size	236	9.834	9.324
Legal land ownership (0/1)	Titled land ownership	236	0.250	0.434
Inherited land (0/1)	Owned land without title	236	0.428	0.496
Rented land (0/1)	Rented land (cash or sharecropping)	236	0.203	0.403
Leased land (0/1)	Leased or borrowed land	236	0.119	0.324
PTS (0/1)	Farmer perceive that land ownership is secure	236	0.797	0.403
Treatment variables				
Cost based SWCT	1=capital intensive SWCT, 2=Labour intensive SWCT 3=Cheap SWCT	236	2.386	0.659
Type based SWCT	1=water based SWCT, 2=land based SWCT 3=crop based SWCT	236	2.153	0.585
Adoption Intensity	Adoption Index normalized by land area	236	0.584	0.301
Adoption decision (0/1)	Farmer adopted at least one SWCT	236	0.898	0.302

Per capita income in thousands

[16] Mponela et al.; Mango et al.,

3.3 Estimation strategy

Following Cragg (1971), this study tests for the decision to adopt and the extent or intensity of adoption of SWCT given land tenure security of farmer and controlling for other farmer observable characteristics. The Craig's model assumes that farmers make two simultaneous adoption decisions at different stages with each stage controlled by similar or different sets of explanatory variables. In order to attain a positive level of adoption, two separate hurdles must be crossed. Different latent variables are estimated at each decision level using the logit and linear models to determine the adoption intensity[17]. For the cross-sectional data collected, the double hurdle is expressed as;

$$A_{i1}^{*} = \partial_i X_{i1} + \alpha_i Y_{i1} + U_i \qquad \text{(Eq. 1)}$$

$$A_{i2} = \delta X_{i2} + \beta_i Z_{i1} + \nu_i \qquad \text{(Eq. 2)}$$

$$A_{i2} = \begin{cases} 1 \; if \; \partial_i X_{i1} + U_i > 0 \\ 0, \; otherwise \end{cases} \qquad \text{(Eq. 3)}$$

Where A_{i1}^{*} is a vector of latent variable consisting of multiple binary decisions to adopt the available SWCT. A_{i2} is the observed measures of adoption intensity, X_{i1} and X_{i2} are vectors of control variables that influence the decision to adopt technologies (such as farmer's characteristics and awareness or extension access) and Y_{i1} and Z_{i1} are indicators of tenure security. Two types of variables were used to denote tenure security; an objective dummy variable which takes the value of 1 if the land holding (either owned, rented or leased) certified and a subjective perception of security that the land holding will be in possession of farmer for at least five growing seasons. ∂, $\alpha, \delta,$ and β are parameters to be estimated while U_i and ν_i are assumed independent and normally distributed error terms capturing the effects of factors not captured within the model.

The second objective of the study assesses the impact of SWCT adoption intensity on welfare indicators of households using, the multinomial treatment effects model developed by Deb and Trivedi (2006a, 2006b). Adoption decisions are usually non-random. In a non-randomized experimental study as this, it is impossible to know the assignment mechanism. There are also possibilities of simultaneity bias if farmers with better welfare are selectively adopting technologies of interest. To circumvent the challenge in a multiple treatment study, the multinomial treatment effect is adopted [18]. To estimate these impacts, it is assumed that the choice of a set of SWCT follows a mixed multinomial logit [19] and thus the probability that farmer i adopts from a pool of technology type m is represented as;

$$pr(A_{im} = 1 | C_i, T_i) = \frac{exp^{\,\emptyset_i C_i + \vartheta_i T_i + e_i}}{\sum_{n=1}^{m} exp^{\,\emptyset_i C_i + \vartheta_i T_i + e_i}} \qquad \text{(Eq. 4)}$$

Where A_{im} is the type of technology adopted in the set A_{im} = 1……*m* as in the subgroups (defined in the next session). C_i is a vector of exogenous factors with a set $C_i(X_{i1}, X_{i2}, Y_{i1})$ with the parameter to be estimated given as $\emptyset_i$. The T_i variables are factors that influence both the outcome and latent choice variable while ϑ_i is the parameter estimate. A positive parameter ϑ for T would indicate a positive relationship between outcome and decision variables while a negative value would imply otherwise. The expected outcome is obtained through the equation;

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[17] Mango et al., "Gebremariam and Tesfaye, "
[18] Kirui

$$w_i^* = \xi_i X_{i1} + \alpha_i \sum_{N=1}^{n} A_{im} + \vartheta_i T_i + \varepsilon_i \quad \text{(Eq. 5)}$$

Where w_i^* is the unobserved latent outcome variable. The choice variables for the respective technologies are represented by relative dummy variables taking values 1 to n whose parameter estimate are α. Given the joint impact of unobserved factors for A_{im} and w_i^*, the outcome of a coninuos analysis would be given as;

$$pr(W_i = w_i, A_{im} = 1 \,|C_i, T_i) = (\xi_i X_{i1} + \alpha_i \sum_{N=1}^{n} A_{im} + \vartheta_i T_i)\, Xg\, (\emptyset_i C_i + \vartheta_i T_i) \quad \text{(Eq. 6)}$$

The parameters are defined as in equation 4 and 5. Variables were included in the model depending on the outcome variable of interest motivated by theory and literature. Two models are specified in this study. The first uses estimates of continuous adoption intensity measure as core dependent variable. In the second, adoption intensity is classified into none, low and high; cost-based classification and efficiency classes (decision mechanism explained in the next section).

3.4 Conservation adoption index

Assuming a farmer applies technology only to a third of his land area, grouping such farmer with those who adopt across the entire farm overestimates the effect of such decision. To observe these relative differences, we estimate a SWC technology adoption index. The indicators used in computing the indices are presented in table 1. In creating the conservation index, the technology use intensity A_{ij} for each technology was obtained using the ratio formula;

$$A_{ij} = \frac{Quantity\ of\ technology\ or\ land\ area\ under\ mth\ technology\ of\ ith\ farmer}{Total\ cropped\ area\ of\ farmer\ i} \quad \text{(Eq. 7)}$$

The adoption index was created following the statistical background by Jain *et al*., (2009). For a finite number of *i* farmers, (1, 2……*n*) and a set of water conservation technology indicators j (1, 2……*m*), there exist a matrix A_{ij}; where the matrix A_{ij} is value of the *j*th indicator of farmer *i*. Given that each indicator is expressed in different units of measurement, we standardize them using;

$$\mathcal{T}_{ij} = \frac{A_{ij} - \bar{A}_j}{\mu_j} \quad \text{(Eq. 8)}$$

Where $\mathcal{T}_{ij}$ is the standardized from of A_{ij}, $\bar{A}_j$ is the mean and μ_j while is the standard deviation of the *jth* indicator. The pattern of adoption of a farmer $\mathcal{K}_\text{i}$ is obtained as the deviation for each farmer's adoption intensity from the best value $\mathcal{T}_{bj}$;

$$\mathcal{K}_\text{i} = \left\{ \sum_{j=1}^{m} \frac{(\mathcal{T}_{ij} - \mathcal{T}_{bj})^2}{\mu_j} \right\}^{1/2} \quad \text{(Eq. 9)}$$

The composite index of adoption was obtained using equation by;

$$\mathcal{K}i_i = \frac{\mathcal{K}_\text{i}}{K}\ for\ K = \bar{\mathcal{K}} + \alpha\mu \quad \text{(Eq. 10)}$$

Where $\bar{\mathcal{K}}$ the mean of is $\mathcal{K}_\text{i}$, α is an integer to correct the presence of extreme values in the data and μ is the coefficient of variation. The value of status index is expected to be non-negative lying between zero and 1. The adoption intensity increases in ascending order. Using this value, adoption groups were defined by;

$$1 = \mathcal{K}i_i = 0; 2 = 0 < \mathcal{K}i_i < \bar{\mathcal{K}} \pm \mu_k; 3 = \mathcal{K}i_i > \bar{\mathcal{K}} \pm \mu_k \quad \text{(Eq. 11)}$$

Where 1, 2 and 3 denotes non-adoption, low adoption intensity and high adoption intensity respectively.

The SWCT were also classified into two sets of closely related technologies using the Wards clustering linkage analysis. Two sets of three groups each were generated from the process;

1. Cost based grouping: (i) capital intensive (ii) labor intensive (iii) cheap methods
2. Efficiency based grouping (i) water based (ii) land based (iii)crop based

3.5. Types of soil water conservation technology adopted

Table 2 summarizes the types of technologies and extent of adoption. Out of the sixteen SWCT identified from literature, fifteen had at least one adopter. While some of the technologies were adopted by more than a third of the respondents, others were adopted by only a few. For example, less the 1% of the farmers adopted strip cropping and drought resistant varieties. Table 2 summarizes the correlation between the different soil water conservation technologies. Some adoption decisions are significantly correlated with 95% confidence level. The table shows that adopting agroforestry methods discourages the use of fallowing by 16% but encourages cultivation of drought resistant varieties and implementation of strip cropping at 18% and 28% respectively. The adoption of cover cropping is associated with agroforestry practice (25%) and use of drought resistant varieties (15%). Similarly, controlled tillage is co-adopted with cover-cropping in one year at 27.7% and increases the fallowing practice by 14.6%. The result suggests that most farmers utilize more than one technology at the time.

Table 2: Soil water conservation technologies in arable crop production

Conservation group	Conservation technology	Percent adopted
Irrigated farming	(a) Drip Irrigation	6.78
	(b) Sprinklers	13.13
	(c) Controlled drainage	5.10
	(d) Rainwater capturing	5.93
	(e) Use of poor-quality water	13.98
Soil enhancement	(a) field levelling	5.08
	(b) furrow diking	-
	(c) conservative tillage	15.25
	(d) composting	15.68
Crop and cultural practices	(a) Mulching	6.78
	(b) Cover cropping	26.69
	(c) Agroforestry	5.10
	(d) Intercropping	48.73
	(e) Drought resistant crops	0.85
	(f) Strip cropping	0.42
	(g) Fallowing	24.15

Table 3: Cross correlations between different soil water conservation technologies

	D_dum	S_dum	CD_dum	RWC_dum	WWU_dum	FL_dum	CT_dum	CMPT_dum	M_dum	CC_dum	AGF_dum	ITC_dum	DRV_dum	STRP_dum	FAL_dum
D_dum	1														
S_dum	0.294***	1													
CD_dum	-0.0624	0.253***	1												
RWC_dum	-0.0677	0.0617	0.0235	1											
WWU_dum	0.0857	-0.0121	-0.0377	0.106	1										
FL_dum	-0.0624	-0.0329	0.0342	0.105	-0.0377	1									
CT_dum	0.0262	-0.0603	-0.0982	0.0930	0.0328	-0.0446	1								
CMPT_dum	0.162*	-0.0297	0.00629	0.0397	0.0278	0.0593	0.0764	1							
M_dum	1	0.294***	-0.0624	-0.0677	0.0857	-0.0624	0.0262	0.162*	1						
CC_dum	0.104	0.0489	-0.0961	0.0107	0.00527	0.122	0.277***	0.161*	0.104	1					
AGF_dum	0.0143	0.0813	0.0342	-0.0581	-0.0377	0.298***	-0.0446	0.0593	0.0143	0.253***	1				
ITC_dum	0.00686	-0.00266	-0.110	0.0423	-0.0997	-0.0327	-0.0128	0.0693	0.00686	0.102	-0.0327	1			
DRV_dum	-0.0249	0.101	0.189**	-0.0232	-0.0373	0.189**	-0.0392	0.0873	-0.0249	0.153*	0.189**	0.0948	1		
STRP_dum	-0.0176	-0.0254	-0.0151	-0.0164	0.162*	-0.0151	-0.0277	0.151*	-0.0176	0.108	0.282***	0.0669	-0.00603	1	
FAL_dum	-0.126	-0.178**	-0.0474	0.118	0.0137	-0.0879	0.136*	-0.0454	-0.126	0.0626	-0.169**	-0.0349	-0.0675	-0.0476	1

***, ** and * significant at 1%, 5% and 10%

Where D= Drip Irrigation, S= Sprinklers, CD = Controlled drainage, RWC = Rainwater capturing, WWU = Use of poor quality water, FL = Field leveling, FAL = Furrow diking, CT = Conservative tillage, CMPT = composting , M = Mulching, CC = Cover cropping, AGF = Agroforestry, ITC = Intercropping, DRV = Drought resistant crops, STRP = Strip cropping

4. Results and discussion

4.1 Land tenure security and adoption patterns of soil water conservation technologies

Table 4 shows the diversity of adoption decisions, extent and proportion of farmers within each category by their tenure security status. Adoption of SWCT was predominant among titled land owners. For instance, 93% of the titled land holders adopt a technology compared to 87% of those with rented lands. Similarly, those who perceived that their lands are relatively secured also had a high adoption level (90%). Comparing the adoption intensity by a cut-of using standardized mean value, low level adoption was dominant in rented lands while high adoption intensity was visible in titled lands. As expected, more than 65% of the farmers with perception of secured tenure had high adoption intensity compared to only 35% with low intensity. In terms of cost implication of technology type, the proportion of farmers adopting capital intensive and costly technologies more than doubled those with untitled and rented lands. This implies that the likelihood of adopting efficient and costly technologies may increase with tenure security of land. The result is however different when considering perceived tenure security (PTS). The proportion of the farmers with PTS adopting the capital intensive, labor intensive and cheap traditional methods were 16%, 37% to 44%, respectively. It shows that while farmers report tenure security, it does not reflect in their risk-taking behavior.

Table 4: Adoption patterns by land tenure security

	Level/type of adoption	Titled owned land	Untitled owned land	Rented land	PTS =1	Total
Adopt_SWCT	Dummy =1	93.10	89.66	87.55	90.00	89.83
Adoption Intensity	Low	38.78	43.06	54.33	35.00	53.39
	High	61.22	56.94	45.67	62.30	23.73
Cost implied adoption	Capital intensive	33.33	12.82	17.65	16.49	19.07
	Labour intensive	38.89	38.46	33.25	37.28	32.63
	Cheap	27.78	48.72	49.01	44.38	38.14
Type of SWCT	Water efficiency method	50.00	24.14	28.1	31.38	32.63
	Land management	32.76	48.28	41.67	42.55	41.53
	Crop related method	10.34	17.24	17.67	15.96	15.68
Total		24.58	36.86	38.55	67.80	

4.2 Effect of land tenure security on adoption intensity of SWCT

Table 5 summarizes the results of determinants of soil water conservation technologies with special reference to land tenure security. For this study SWCT adoption were hypothesized to be driven by three sets of factors; socioeconomic and demographic, institutional and land tenure security factors. All outcome variables are reported in natural logs and the marginal effects results are reported for the limited dependent variable models.

The first stage hurdle model in column 1 shows a statistically significant effect of land tenure security on the adoption intensity of a collection of soil water conservation technologies. A shift from other land tenure type to titled lands increased the adoption probability of SWCT by

19%. In terms of adoption intensity (column 2), secure land tenure increased the level of adoption of technologies by 34% point. A probable reason for the reported result is that titled lands are usually compensated in the case of expropriation; hence, risk neutral and adverse farmers may be willing to invest on such lands. The result in columns 3 and 4 shows similar outcomes to those of Deininger and Jin (2006)[20]. Increasing tenure security was found to increase the probability of having both high and low levels of adoption intensity. The results are further more robust for high adoption intensity compared to the low-level intensity with confidence of 90% and 95% respectively. Enhancing security of tenure may not only affect the adoption of technologies but may further ensure that technology use is not marginal. Exploring the differences in objective and subjective definitions of tenure security, the results show that perceived tenure security had no effects on either the adoption decision or intensity of adoption. As expected, the differences in the level of effects may be attributed to the level of uncertainty included in subjective perception of tenure security.

In addition to the land tenure security variables, other variables affecting the adoption intensity were; farming experience, neighborhood effects, drought experience. On average, an average annual increase in farming experience increases the probability of low adoption intensity by 17% but reduces the probability of high intensity adoption by 21%. With increasing experience, farmers may have better assessment of the threshold of positive technology adoption impact. Increasing experience may reveal the differences between the outcomes of various adoption intensification. Contrary to the findings in some previous studies[21], farm size had a negative effect on the probability of low intensity of adoption with. Holding all other factors constant, a standard deviation in land area cultivated by farming household decreased the adoption intensity by 34% but increased the general intensity of adoption as well as high intensity of adoption. A possible reason could be that increasing the extent of coverage of each technology over the expanding land area may be influenced by economics of scale. The potential to increase adoption increased with experience of drought. The result shows that drought experience in any one year increases both the number of adopted technologies and the coverage or extent of overall adoption by 2% to 29% respectively. Knowledge of drought impact may increase the importance of water conservation for risk adverse farmers. As expected from the conceptual model, having neighbors utilizing any one of the soil water conservation techniques increase the adoption levels across all models. Between 8% and 29% increase in adoption probability is reported for having a neighbor who adopts a method for soil water saving. Regular access to water plays a critical role in determining the decision for water saving. The study shows that access to irrigation reduced the probability of adopting a water saving technology by 11% and 2.3% for general adoption decision and low intensity of adoption respectively. This may be because; irrigation facilities may serve as year-round assurance of water supply reducing the risk of water stress on farmers' production activities.

4.3 Impact and mechanisms of adoption of SWCT on welfare

Table 6 presents the results of the multinomial treatment effects of the soil water conservation technologies adoption on welfare and other mediating factors. The OLS regression results are rough estimation of the direction of effect of adoption intensity on the outcome variables. The second stage results levels of adoption intensity on welfare (per capital income) are reported in panel 1. The mediating effects (total factor productivity changes, gross margin, cropping intensity and cropping diversity) are also reported in columns 3 to 6. While there are

[20] Deininger and Jin.

[21] Moges and Taye,; Mango et al.,; Mponela et al.

other controls variables modeled, only the treatment effect of adoption variables is reported in the study. And finally, the economically and statistically significant results are explained in this section.

After controlling for socio-economic, demographic and institutional variables, the results show a general positive effect of adoption variables on the farmers' outcomes. The OLS result shows that a standard deviation increase in adoption intensity increases per capita expenditure by 7.4%. Only increasing total factor productivity explains the effect of adoption on welfare. As the result show, total factor productivity marginally increases at 90% confidence interval by 7.2% for every percentage point increase in adoption intensity. This is in line with other studies that suggest that adoption decisions would not only be taken under certain socio-economic condition of the farmer but also has significant positive impact on farmers wellbeing [22]

[22] Adgo, Teshome, and Mati,; Deininger and Jin.

Table 5: Effects of land tenure security on adoption, number of technologies adopted and intensity of adoption

Variables	Model 1	Model2	Model 3	Model 4
	Determinants of adoption	Intensity of Adoption	Low level adoption intensity	High adoption intensity
Age	0.0262***	-0.0296	-0.067	0 .2281
	(0.0032)	(0 .0687)	(0.1863)	(0.1903)
Female	-0.0384	-0.0575	-0.00502	-0.0682
	(0.0284)	(0 .0574)	(0.1303)	(0 .1317)
HH labor	0.000035	0.0141	0.0339	- 0.0548
	(0.0141)	(0.0285)	(0.0745)	(0.0762)
Education	0.0167	0.0226	0.00166	0.0174
	(0.0129)	(0.0260)	(0.0531)	(0.0534)
Farming experience	-0.0141	-0.0187	0.1754***	-0.2139***
	(0.0121)	(0.0235)	(0.0692)	(0.0571)
Off-farm work	-0.059	-0.1105***	-0.04476	-0.108
	(0.0235)	(0 .0507)	(0.0872)	(0.0869)
Awareness	0.0120	0.0161	0.0701	0.0581
	(0.0187)	(0 .0381)	(0.0719)	(0.0756)
Extension access	-0.0311	-0.0474	-0.0633	-0.0880
	(0.0241)	(0.0484)	(0.1091)	(0 .1068)
Neighborhood	0.0359***	-0.0638	0.0306***	0.2169**
	(0.0994)	(0.0448)	(0.0923)	(0.0946)
Drought exp	0.0880***	0.1605***	0.02309***	0.2937**
	(0.0242)	(0.0502)	(0.0108)	(0.1082)
Irrigation access	-0.1185**	0.0287	-0.0230***	0.1891**
	(0.0207)	(0 .0421)	(0.0949)	(0.0958)
Farm size	0.0913	0.1408***	-0.0342***	0 .4588***
	(0.0155)	(0.0340)	(0.0897)	(0.1831)
Flat land	-0.007384		-0.149*	- 0.1440*
	(0.00698)		(0.0823)	(0.0835)
Porous soil	0 .0147*		-0.00142	0.0382
	(0.00765)		(0.093)	(0 .0948)
Owned land	-0.0320	-0.0790	0.0593	-0.0286
	(0 .0218)	(0.0439)	(0.0931)	(0.0941)
Secure tenure	0 .1976***	0.3417***	0.1684*	0.0495**
	(0.0259)	(0.0640)	(0.089)	(0.0105)
Perceived secure tenure	0.4088	-0.0797	0.2888***	-0.2503**
	(0.3471)	(0.0580)	((0.0988)	(0.1018)
Dum_NAEZ	-0.03180		0 .3960***	-0.2891**
	(0.4188)		(0 .121)	(0.127)
Dum_CAEZ*	0.4066**		0.2378**	-0.0030
	(0.04213)		(0.1120)	(0.1452)
N	236	236	236	236
Pseudo R2/R2				
Wald chi2	246.3		246.3	246.3
	(0.000)		(0.000)	(0.000)

***, ** and * significant at 1%, 5% and 10%. Robust standard errors

Results further show that per capita income increases with differences in levels of adoption intensity of SWCT. While low level of adoption relative to no adoption show no statistical impact on welfare, high level adoption increases per capital income relative to non-adopters. High adoption intensity increased per capital income by 74%. The result is similar to those of Teshome et al, (2014)[23] who finds that poverty reduces with adoption of agricultural technologies. Increasing gross margins, and total factor productivity explains the impact of high adoption level impact on per capital expenditure. Total factor productivity and gross margins increase by 46% and 40% respectively for high level of adoption intensity.

Further exploration of the effects of expected cost implications of adoption decisions on the outcome variables show a significant increase in per capital income for cheap technologies. Earlier studies have shown that the technology cost may be important for the effect on the outcome[24]. Thus, when the cost of technologies outweighs the income effect, negative welfare effect may be observed. On the alternative, capital intensive and labor-intensive choices of soil water conservation technologies had negative but insignificant effects on the outcome variables.

Land management and crop-based soil water conservation technologies also had positive effects on per capita income. While land management models increased PCI by 38.6%, crop related models increased the outcome by 29.6%. Although water related methods have a positive effect, the results are not statistically significant. One possible explanation is that water efficiency methods are relatively more expensive and may affect the marginal income or output effects negatively which could impact the welfare effect. In general, gross margin increases show the media of effect for land management practices, while crop related methods are associated with increasing cropping diversity and hence better welfares.

Table 6: Impact of SWCT adoption on welfare and proposed mechanism of effect

Variables	Adoption type and level	PCE	TFP	Gross Margin	Cropping intensity(#)	Crop diversity (#)
Adoption intensity (OLS)		0.6088**	0.5496*	0.4003	0.3174	0.6193**
		(0.2187)	(0.3174)	(0.3879)	(0.2523)	(0.2974)
Adoption intensity	Low	0 .4449**	0.1892	0.0936	0.8203***	0.5175**
		(0.1673)	(0.1269)	(0.1190)	(0.1286)	(0.1731)
	High	0.3151*	0.478**	0.7069***	0.6710***	0.7746***
		(0.1953)	(0.1857)	(0.1589)	(0.1711)	(0.2246)
Cost implied adoption	Capital intensive	-0.0219	0.109	0.208	0.314**	0.249**
		(1.618)	(0.302)	(0.167)	(0.154)	(0.113)
	Labor intensive	-0.1519	-0.201	0.0309	-0.682**	0.388**
		(0.1579)	(0.376)	(0.170)	(0.263)	(0.176)
	Cheap	0.4804***	-0.323	0.0709	-0.760***	0.151
		(0.1644)	(0.389)	(0.169)	(0.246)	(0.166)
Type of SWCT	Water efficiency method	0.034	0.293*	0.532***	0.278*	-0.252***
		(0.1632)	(0.1778)	(0.164)	(0.163)	(0.0805)
	Land management	0.386**	0.1817	0.0707	-0.353	0.0311
		(0.1486)	(0.1458)	(0.209)	(0.275)	(0.152)

[23] Teshome, de Graaff, and Kassie,

[24] Liverpool-Tasie et al.

	Crop related method	0.2963*	0.1735	-0.0773	-0.103	1.236**
		(1.680)	(0.1598)	(0.0699)	(0.330)	(0.519)
N		236	236	236	236	236
Robust Std errors		YES	YES	YES	YES	YES

***, ** and * significant at 1%, 5% and 10%; Robust standard errors

5. Conclusion

Land tenure security may have important implications for adoption of agricultural technologies and in particular for Soil water conservation technologies uptakes and welfare of farming households. This study assessed the effects of land tenure security on adoption of technologies and the impacts of different levels of adoption on welfare of farming households in South-Western Nigeria. The study utilized survey data drawn from 236 farming households from across the represented agro-ecological zones of the state. The study adopted the double hurdle combined with multinomial logit models to assess the question.

From a conceptual model, land tenure security increases the discounted expected value from land and lowers the risk of loss of investments on the land. The study corroborates the conceptual predictions that different tenure security affects the uptake of technologies. Secured tenure was associated with high level of SWCT adoption both in number and by intensity. Although perceived tenure security had lower effects on adoption level, the results points to favorable effects of tenure security on adoption.

Defining different levels of adoption intensity, type and costs of technologies, the study finds that technology adoption has multiple advantages for households' outcomes ranging from improving welfare to increasing farm productivity, gross profit from farm production to increasing cropping intensity and diversity. First, having tenure security on land directly or indirectly by legal documentation increases the propensity to implement soil water conserving practices as compared to assumption of security which are subjective from farmers' experiences. Therefore, policies that aim at improving farmers' welfare through technology recommendation should consider the role of land tenure security as mediators between technology availability, adoption and impacts.

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