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Research Article

Impacts of Soil and Water Management Measures on Crop Production and Farm Income of Rural Households in the Damota Area Districts, Southern Ethiopia

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Improving crop productivity and farm income of rural households and ensuring food security through soil and water conservation (SWC) measures are one of the integral parts of sustainable livelihood approaches. The study aims to assess the impact of soil and water conservation measures on improving the rural livelihoods, which is measured in terms of annual crop production and farm income of rural households in the Damota area districts. The data was collected from 378 households (209 adopters and 169 nonadopters of SWC measures) using survey questionnaires, which were randomly chosen by using multistage sampling techniques. Descriptive and inferential statistics with propensity score matching (PSM) method were used to analyze the collected data. The propensity score matching method was used to assess the impacts of soil and water conservation measures by controlling unobserved heterogeneity and were matched with balanced observable characteristics. The result showed that the mean value of wheat production of adopter households was higher (654 kilograms per hectare) than that of nonadopters (496 kilograms per hectare). Similarly, the mean values of farm income of adopter households were higher (17372.67 Ethiopian Birr per year) than those of nonadopter households (13883.22 Ethiopian Birr per year). The result indicated that both crop production and annual farm income were more pronounced when farmers implemented sustainable soil and water conservation measures on their farming lands. This suggests that all rural households need to focus on the large-scale adoption, integration, and maintenances of damaged structures for better agricultural outcomes.

1. Introduction

Land degradation is a global problem but it is critical in rural areas of developing countries [1, 2], mainly due to overexploitation of natural resources even in more sensitive areas [2]. Ethiopia is among the sub-Saharan belt countries in which the majority of the population lives in the highlands where land is continually cultivated. Land degradation has been a major challenge in the Ethiopian highlands due to its adverse impacts on crop productivity and food security [3–5]. A rapid population growth coupled with cultivation of marginal land, improper land resources management and utilization, overgrazing, and soil nutrient depletion caused by soil erosion are the major causes of the decline of agricultural production through affecting crop production [6], which caused financial constraints [7, 8] by reducing yields for the major crops [9]. Its effects on crop production and livelihood damage have been very high. Researchers agree that land degradation has resulted in a significant impact on the productive capacity of land and the stability of the natural environment [10, 11]. For instance, soil erosion in the form of land degradation triggered declining soil fertility and limited water availability, which resulted in low crop yields on Ethiopian highlands [3–5]. Also, due to soil erosion in the form of land degradation, the recurrent incidents of famine and starvation have partly occurred in Ethiopia [12].

One of the techniques of addressing soil erosion and enhancing crop productivity is through the practice of soil and water conservation (SWC) measures [2], because they are supposed to be effective strategies in improving soil nutrient availability [13], enhance crop production, and alleviate poverty [12, 14, 15]. Cognizant of these facts, the government and donors of Ethiopia have invested in SWC practices in association with crop yield, which is the major target of livelihood security strategies [16]. In this regard, mechanical and biological SWC measures such as bench terracing, soil bunds, stone bunds, farm forestry, and others have been implemented in the main intervention areas [2]. However, their impacts on improving yields and incomes of the beneficiary households remained largely unquantified, the economic viability of SWC practices was inconsistent [5], the results were site-specific, and the achievement varies over space for various reasons [5, 12, 16].

Some of the findings of empirical research on the impacts of SWC measures demonstrated that they may increase soil fertility [17, 18] and improve crop production [4, 19], fodder yield [20], and farmers' income [21]. More precisely, the studies of [22–24] revealed the positive impacts of soil bunds and fanya juus conservation measures, which significantly increased the agricultural yields in different parts of the country. Likewise, the study of [6] stated positive impacts of soil bunds, fanya juus, and stone bunds measures on crop productivity of cultivated lands; however, their effects were more pronounced when they were integrated with biological SWC practices and at a longer establishment. The study of [25] also confirmed that the stone terraces had a significantly positive impact on the average crop yields in the Northern Shoa zone of Ethiopia. On the contrary, the review and synthesis of Adimassu et al. [5] reported that soil bunds and stone bunds were very effective in reducing run-off, soil erosion, and nutrient depletion, but their impact on crop yield was negative mainly due to the reduction of the effective cultivable area by soil/stone bunds.

Moreover, the study result of [26] stated that biological soil and water conservation measures did not contribute a significant role on crop yield and interest of household income, despite the fact that their positive impact on crop yield was highly recognized in other empirical studies. On the other hand, according to the study of [13], the effectiveness of SWC measures on crop production was subjective to agroecology and site-specific. In this regard, the findings of [27–29] confirmed that the implemented soil and stone bunds structures reduced crop yield up to 7% for the first few years in Ethiopian high lands but increased yield up to 10% in the low lands of Tigray region [30].

This indicates that there is no consent on the impacts of SWC measures in improving the living conditions of rural households among the research findings reported so far. Therefore, local agroecology-specific SWC impact assessment on crop production and rural livelihoods is essential for the development and the realization of the program. In Damota area districts of Southern Ethiopia, over the last two to three decades, different SWC measures such as soil bunds, stone bunds, fanya juus, and other physical, biological, and agronomic measures were implemented by farmers through community mass-mobilization for the improvement of rural households. Nevertheless, no evidence on the long-term impact of SWC measures implemented so far has been documented. The shortage of data on the effectiveness of SWC measures could lead to ineffective planning, progress, and realization of the program [18]. Therefore, this study aimed to assess the impact of SWC measures on the improvement of the rural livelihoods, which is measured in terms of crop productivity and income of rural households.

2. Materials and Methods

2.1. Description of the Study Area. Damota area comprising Bolosso Sore, Damot Gale, and Soddo Zuriya districts lies within 6°44′30″ to 7°9′49″ Latitude and 37°34′47″ to 37°98′58″ Longitude in the Wolaita zone of the Southern Nations, Nationalities, and People's Region (Figure 1). It is located 395 km south of Addis Ababa, the capital city of Ethiopia. It covers an area of 97,600 hectares. Damota area districts are dominated by rugged and elevated topography particularly in the central part formed by tectonic and volcanic activity. According to the agroclimate classification system, the area is classified as *Dega* and *Woina Dega* zones with an altitude ranging from 1480 to 2855 meters above sea level.

Dystric Cambisols, Chromic Vertisols, Chromic Luvisols, Pellic Vertisols, Vitric Andosols, Eutric Nitosols, Orthic Acrisols, and Lithosols soil types dominate the districts of Damota area. The mean monthly minimum and maximum temperatures are 14 and 20°C, respectively [31]. The area receives a long-term average annual rainfall of approximately 1200 mm in a bimodal rainfall pattern. The main rainfall season is from June to September (locally called *Kiremt*) and there is a small rainfall season from February to March (locally called *Belg*). Cropland is the dominant land-use type in the study area followed by shrub-woodlands, grasslands, forestland, bare land, and settlement land. Small-scale subsistence mixed farming is the main livelihood system in the area. The most commonly cultivated crops are barley (*Hordeum vulgare)*, wheat (*Triticum aestivum),* maize (*Zea mays)*, teff (*Eragrostis tef*), bean (*Phaseolus vulgaris*), potato (*Solanum tuberosum*), chickpeas (*Cicer arietinum*), and others. Damota area districts are among the highly populated parts of Ethiopia. For instance, according to 2007 census data, the rural population density of the area varied from 167 persons km^{-2} in the midlands to 746 persons km^{-2} in the highlands [32]. Agriculture in the area could constitute the dominant resource base for the creation of economic opportunities for rural households. It comprises more than 85% of the economic activity in the study area [33].

2.2. Research Design and Approach. The research design has a significant role in facilitating the overall flow of the entire research and provides a blueprint for collecting, measuring, and analyzing data. In this study, cross-sectional survey design was used to assess the impacts of SWC measures in improving households' outcomes measured by annual crop productivity and farm income of the year 2019. Before data were collected, adopter and nonadopter households were identified for the survey. Based on a cross-sectional survey design, the study applied a quantitative-dominant,

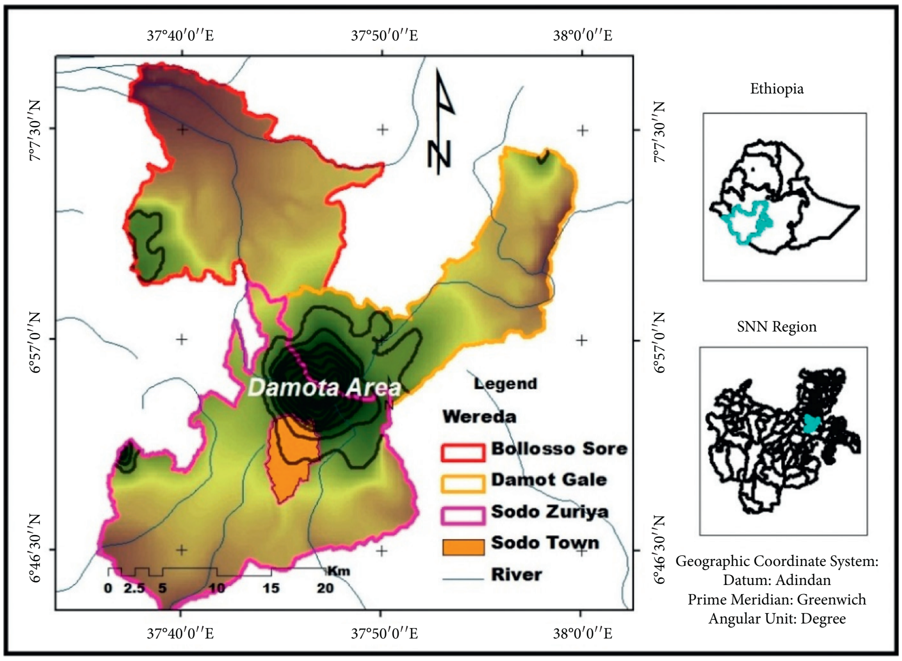

Figure 1: Location map of Damota area districts.

qualitative mixed research approach, which is important for the study at an available time and available resources. Hence, a concurrent type of mixed research method was used in which both quantitative and qualitative data were collected simultaneously and the results were embedded during the analysis.

2.3. Sampling Techniques and Methods of Data Collection. To select sampled districts, kebeles, and households, a multistage sampling procedure was used. This procedure allows selecting small sample units from larger ones while providing equal chances for all the participants to be selected [34, 35]. First, from all soil and water conservation program districts, Damota area districts (Damot Gale, Bolosso Sore, and Sodo Zuria) were selected purposely based on farmers' involvement in the soil and water management practices. In the second stage, from the Damota area districts, three kebeles, namely, Wandara-Gale, Dalbo-wogene, and Gurumo-Koisha, were also purposively selected representing highland and midland agroecological zones. Then farmers were stratified into strata and selected by using a proportional simple random sampling method. To achieve the objective of the study, the data were obtained from both primary and secondary sources. Survey questionnaires containing open- and close-ended questions were collected from November 2018 to March 2019 by trained enumerators who can speak the local language.

To substantiate the findings of the study, focus group discussion, structured interviews, and field observations were conducted. Focus group discussion consisting of three groups, with each group containing nine persons, was conducted to obtain adequate knowledge and experiences on the impacts of conservation measures on wheat production and income. Structured interviews were conducted with twelve key informants, six local leaders, six selected model farmers, and three development agents (DAs) for pertinent information on the conservation measures. Field observation was conducted to see the impacts of SWC on rural livelihoods and the rehabilitation of the land-escape.

2.4. Methods of Data Analysis. The descriptive statistics (frequency, percentage, standard deviation, and mean), inferential statistics (t-test and binomial logistic regression), and econometric method (propensity score matching) were used to analyze the data by using the STATA software package. The propensity score matching (PSM) method estimated the impact of conservation measures on small holder farmers' livelihood measured by annual wheat productivity and farm income of households. The potential outcome analysis of propensity scores was performed based on matched data.

2.4.1. Propensity Score Matching Model Specification. The propensity score matching (PSM) has become a popular approach to estimate causal treatment effects and is being increasingly applied in policy program assessments [36], mainly based on comparable observations, which reduces the selection problem when there are two categories of response. It was chosen among nonexperimental methods as it does not require baseline data and is considered as the second-best alternative next to experimental design in minimizing selection biases [37]. For the estimation of the propensity score, the logit model was used. In this regard, the probability of being in the conservation work is

$$P_i = \frac{e^{z_i}}{1 + e^{z_i}}, \quad (1)$$

where Pi is the probability of adoption.

The odds ratio (Zi) is

$$Zi = \beta 1 + \beta 2 Xi + Ui, \tag{2}$$

where Zi is the probability of adoption, $\beta 1$ = intercept, $\beta 2$ = estimated regression coefficients, Xi = preconservation program intervention characteristics, and Ui = a disturbance term.

The probability that a household belongs to nonadoption of SWC activities is

$$1 - P_i = \frac{1}{1 + e^{z_i}}. \tag{3}$$

Subsequently, the common support region and matching estimator will be selected to ensure a combination of characteristics observed in the treatment and control group [37]. The balancing rules of the estimations are determined by considering the reduction of standard bias between matched and unmatched groups and equality of means between t-tests and chi-square for joint significances. Furthermore, the average treatment effect on the treated (ATT) on the potential outcome variables should be applied to assess the impact of conservation measures. In this regard, the effect of household's participation in the conservation work on a given outcome (Y) is indicated as

$$Ti = Yi(Di = 1) - Yi(Di = 0), \tag{4}$$

where Ti is the treatment effect (effect due to participation), Yi is the outcome on Household, and Di is whether household i has got the treatment or not. Besides, the potential outcomes $(Yi(Di = 1))$ are observed for each individual i. The unobserved outcome $(Yi(Di = 0))$ is called counterfactual outcome. Hence, estimating the individual treatment effect (Ti) is not possible and therefore it has to shift to estimate the average treatment effects of the population compared to the individual one. Average treatment effect on the treated (ATT) is the difference between expected outcome values with and without treatment for those who actually participated in the treatment and is statistically indicated as

$$\text{TATT} = E(T \mid D = 1) = E[Y(1) \mid D = 1] - E[Y(0) \mid D = 1]. \tag{5}$$

In this method, the counterfactual mean for those being treated, $E[Y(0)\text{ID} = 1]$, is not observed, and there is a need for substitution by ATT. Therefore, the outcomes of individuals from treatment and comparison groups would differ even in the absence of treatment leading to a self-selection bias. However, by rearranging and subtracting $E[Y(0)\text{ID} = 0]$ from both sides of the above equation, ATT can be stated as

$$\begin{aligned} E[Y(1)\text{ID} = 1] - E[Y(0)\text{ID} = 0] = \text{TATT} + E[Y(0)\text{ID} = 1] \\ - E[Y(0)\text{ID} = 0]. \end{aligned} \tag{6}$$

More precisely, for nonexperimental studies to resolve the selection bias, Conditional Independence Assumption (CIA) is needed.

It is specified as

$$Y0\ Y1 \perp D | X, \tag{7}$$

where X is a set of observable characteristics, $Y0$ denotes nonparticipants, $Y1$ denotes participants with a set of observable covariates (X) which are not affected by treatment, and $\perp$ indicates independence; potential outcomes (wheat production and annual farm income of households) are independent of treatment assignment (independent of how the households were selected in the program). Therefore, the CIA implies that the selection is exclusively based on observable characteristics (X) and variables that influence treatment assignment and potential outcomes are simultaneously observed [38, 39].

Thus, after adjusting the observable differences, the mean of potential outcome is specified as

$$E(Yo \mid D = 1, X) = E(Yo \mid D = 0, X). \tag{8}$$

According to [39], setting a common support region ensures that any combination of characteristics observed in the treatment group can also be observed in the control group. In such case, the PSM estimator of ATT can be specified as

$$\begin{aligned} \text{TATT} &= E[EY1 - Y0) | D = 0, P(X)] \\ &= E[Y1 | D = 0, P(X)] - E(Y(0) | D = 0, P(X)]. \end{aligned} \tag{9}$$

$P(X)$ denotes propensity scores calculated on the set of covariates X.

3. Results and Discussion

3.1. Households' Characteristics. This part describes the general relationship between adopter and nonadopter households on SWC measures before matching was conducted. As the survey witnessed, from the total sample respondents, 55.3% adopt soil and water conservation activities, while 44.7% of households do not adopt soil and water conservation measures. In this regard, statistically significant differences were observed between adopters and nonadopters in terms of demographic, socioeconomic, and institutional characteristics (Table 1). Out of 378 sample households, the majority (79.1%) were males; this indicates that the proportion of male-headed households are higher than that of female-headed ones. The average age of the farmers was 47.5 years with a minimum of 30 years and a maximum of 65 years. Nevertheless, adopter households were relatively older (54.41 years) than their counterparts (47.24 years). Besides, the result showed that the majority of adopters of soil conservation measures were attendants of formal schooling up to 6th graders (5.69), whereas the majority of the nonadopters were attendants up to 3rd (3.26) class of schooling. The likelihood of adoption of SWC measure is more for larger family sizes than for their counterparts. In this case, the average family size of nonadopters was slightly smaller (6 persons) than that of the adopters (8 persons). Furthermore, the steeper slopes are

Table 1: Descriptive result of adopting households and their counterparts.

No.	Variable	Households	Frequencies	Mean	SD	SE
1	Sex	Adopters	209	0.78	0.41	0.28
		Nonadopters	169	0.79	0.40	0.34
2	Age	Adopters	209	54.41	6.65	0.46
		Nonadopters	169	47.24	9.73	0.74
3	Education	Adopters	209	5.69	2.91	0.20
		Nonadopters	169	3.26	3.68	0.28
4	Family size	Adopters	209	8.00	2.39	0.16
		Nonadopters	169	6.00	3.53	0.27
5	Land slope	Adopters	209	0.39	0.49	0.03
		Nonadopters	169	0.79	0.42	0.03
6	Live stocks	Adopters	209	8.80	3.99	0.27
		Nonadopters	169	4.37	3.14	0.24
7	Extension	Adopters	209	0.80	0.39	0.027
		Nonadopters	169	0.39	0.48	0.03
8	Farm distance	Adopters	209	2.12	0.92	0.06
		Nonadopters	169	2.39	1.26	0.09

more susceptible to erosion than gentle ones, which is relatively important for prioritization and conservation. In this regard, most of the steeper part of farming land belonged to the adopters, which were more susceptible to soil erosion than the gentle one (Table 1). Concerning the contact of extension services, the majority of nonadopters reported that they have less contact with development experts, which might result in a negative value for the implementation process.

3.2. Farmers' Implementation of Soil and Water Conservation Measures. Soil erosion has been contributing a significant amount of soil loss each year in the districts. To solve the problem, over the last two to three decades, SWC conservation measures mostly implemented by farmers in the districts included soil bunds, stone bunds, and fanya juus (Figure 2), while soil and water conservation measures slightly adopted by small holder farmers included biological and agronomic measures (Table 2). In this regard, a larger group (24.40%) of households adopted soil bunds, about 22.96% of farmers adopted stone bunds, and some (20.57%) of the farmers adopted fanya juus structures (Table 2). They were identified by grouping rural households who have adopted similar SWC conservation measures among the choices of different SWC measures.

This indicates that farmers in the study area were largely adopting structural SWC measures rather than biological and agronomic SWC measures. In the same manner, in our field observation, we verified that the habit of integration of structural soil and water conservation biological and agronomic measures was limited and a few farmers integrated them on their garden to get edible fruits from the trees. The issue needs rigorous efforts by the local government and other development partners to promote the large-scale integration of biological and structural soil and water conservation measures for better results [18].

3.3. Impacts of Soil and Water Conservation Measures. The observed impacts of soil and water conservation measures in the districts of the area are described in Table 3. Accordingly, the majority (37.30%) and 32.27% of respondents indicated that SWC resulted in a reduction of soil erosion and increment of soil moisture, respectively. About 16.15% and 14.28% of respondents indicated that SWC measures resulted in stabilization of gullies and restoration of degraded lands, respectively. Field observation results also revealed observable indicators, which have important contributions towards livelihoods improvement, such as overflow of springs in the plots of adopter households, which are important for irrigation purposes, restoration of dried areas, and levelling of slopping places. This was consistent with the study of [17], which indicated the intervention of soil and water conservation, as it was intended to prevent land degradation, maximize agricultural productivity, improve ground and surface water for domestic and irrigation uses, and promote food security of the rural community.

In our field observation, we also observed that the conserved with SWC part of the districts generated significant outcomes in surface and subsurface water resources, which could result in better agricultural production and thereby improve the livelihood of the rural households. The reemergence of dried springs and increasing river flows during dry periods are some of the observed impacts in most of the treated parts of the districts, although the level of changes varies between the three districts of Damota area. In this regard, a relatively larger proportion of farmers' participation in irrigation work was observed in Damot Gale than in Bolosso Sore and Sodo Zuria districts. This was due to a continuous rise in the groundwater table, which is probably attributed to irrigation works in Damot Gale district (Figure 3).

According to the data obtained from Wolaita zone agricultural office, due to implemented SWC practices, irrigable land potential in the area is estimated at 26,450 hectares; out of these, 17,453 hectares are irrigated. In this way, the majority of irrigation user households produced different kinds of crops two times per year. In the same way, on-site field observation result revealed that most irrigation user households have to produce crops by using improved varieties of seeds, mainly maize and vegetables like onion, tomato, and cabbage. According to their explanation, the reason for their preference for vegetable production is because it is more commercial and can generate an amount of better income from a small plot of land.

As some of the irrigation user farmers explained, due to SWC based-irrigation work, they have improved their living standard and food security status as well as income level. During the field work, we also confirmed that implemented soil and water management activities promoted the practice of apiculture, which has resulted in employment creation for the youths and women. Apiculture promotes the production of bee forage, which is mainly common economic activity for adopter households compared to their counterparts. In this regard, the majority of adopter youths and women own, on average, more than one beehive, which benefited them in terms of economic profit (Figure 4). Besides, through SWC

Figure 2: Some of the implemented physical SWC measures of Damota area districts.

Table 2: Major SWC measures implemented in the study area.

Types of SWC measures	Frequency	Percentage
Soil bunds	51	24.40
Stone bunds	48	22.96
Fanya juus	43	20.57
Combinations	37	17.70
Biological measure	19	9.09
Agronomic measures	11	5.28

Source: own survey, 2019.

Table 3: Indicators of the impacts of SWC.

Indicators	Frequency	Percentage
Reduced soil erosion	141	37.30
Increased soil moisture	122	32.27
Stabilized gullies	61	16.15
Restoration of degraded areas	54	14.28

Source: own survey, 2019.

work programs, women and some low-income farmers got training on bee production, fattening of sheep, goat, oxen, and others, which generated additional income for them.

3.3.1. Impact of Soil and Water Conservation on Crop Production. Crop production is the major livelihood activity for the majority of the sample households in the districts of the area. The major crops grown in the districts in order of importance include wheat, maize barley, teff, bean, and others, and their mean values showed variation between adopter and nonadopter households (Table 4). The variation could be due to the effects of SWC activities. As shown in Table 4, the highest mean values of crop production were derived from wheat and barley, followed by teff, maize, and beans, though there are other types of crops grown in the districts of the area. Results of the households survey show that, on average, the wheat productions of the adopter and nonadopter households were 663 and 573 kilograms per hectare, respectively (Table 4), which were calculated by the differences of total products produced and total variable costs. Similarly, the average bean productions of the adopter and nonadopter households were 528 and 314 kilograms per hectare, respectively (Table 4). The findings of this study are consistent with those of the studies of [23, 40] which confirmed an improvement in crop yield of adopter households as compared to nonadopters in the West Hararghe and Tigray region of Ethiopia, respectively.

3.4. Descriptive Results of Potential Outcome Variables. Outcome variables were measured by the total amount of net outputs obtained from adopter households and nonadopters of SWC measures during the 2019 production season. More precisely, wheat is the major staple crop, which is predominantly produced by smallholder farmers in Damota area districts. Also, the highest percentage share of livelihood strategies was derived from farm income, which is calculated as the difference between total cash income obtained from crops, livestock, and off-farm activities and the total cost incurred by the households. The descriptive result showed that these output variables revealed significant variation between adopter and nonadopter households (Table 5). However, the variation of potential outcomes does not show whether the difference is exclusive because of adopting SWC measures or not. Hence, additional analyses became compulsory, and the PSM method was used to solve the problem.

3.5. Propensity Score Result of Outcome Variables

3.5.1. Econometric Model Output. Before proceeding to the estimation of the propensity score, the tests for outlying observations, multicollinearity, and the goodness of fit of variables were checked based on the data and the explanatory variables. Fortunately, in our data, no outlying observations (from participants and nonparticipants) were observed with extreme influence (residual value >2.5). Subsequently, the result of multicollinearity was checked by using the values of the variance inflation factor (VIF) and showed that there was no problem of multicollinearity. Besides, our postestimation result showed that the model

Figure 3: Water availability and irrigation work in Damot area districts.

Figure 4: Bee production and women's participation in Damota area districts.

Table 4: Descriptive statistics for crop production in the study area.

Crop production (kg/ha)	Households		P values
	Adopters Mean	Nonadopters Mean	
Wheat (kg/ha)	666	573	0.01**
Barely (kg/ha)	641	427	0.01**
Teff (kg/ha)	618	398	0.04*
Maize (kg/ha)	544	345	0.03*
Bean (kg/ha)	528	314	0.02*

The symbols * and ** indicate significance at 5% and 10% probability levels, respectively.

Table 5: Descriptive results of potential outcome variables.

Outcomes	Total sample ($N = 378$) Mean	Adopters ($N = 209$) Mean	Nonadopters ($N = 169$) Mean	t-value ($P < 0.05$)
Wheat pr. (kg/ha)	618	663	573	−8.47**
Farm income (Birr/yr)	170132.04	17148.3254	13384.6154	−7.18**

Source: survey result of 2019. **Significant at 10% probability level.

performed a good output, implying that the goodness-of-fit test using Hosmer–Lemeshow test resulted in statistical insignificance, suggesting that the model explained the relationship between variables nicely. A binary logit model was used to estimate propensity scores using a composite of preintervention characteristics of the sampled households [41], and matching was performed using propensity scores of each observation. The dependent variable of the model was a dummy indicating whether a given household has adopted SWC measures, taking a value of 1 or 0 otherwise. According to matching theory [38], the propensity scores generated through the logit model would include predictor variables and the outcome of interest [42]. Therefore, before matching, the result of logit estimation showed that the probability of households taking part in SWC work has been significantly determined by six variables out of eight predictors (Table 6). Age of household heads, level of education, family size, contact with extension agents, farming experience, and the number of livestock holding in tropical livestock units were found to be statistically significant as well as positive predictors of soil and water conservation measures at 10 and 1% probability levels (Table 6). This implies that those farmers who have relatively older age, with better education, larger family size, land-holding, and are living relatively near their farming lands with better access to the extension agents have a high chance of being involved in soil and water conservation programs. On the other hand, sex and farm distances of households were negative and insignificant predictors (Table 6), stating that females and households who are traveling a long distance from their home to farm land were less likely to be involved in SWC activities.

Table 6: Distribution of sampled household heads.

Variables	Coeff.	St. err	z	$P>\|z\|$
Constant	−5.87	1.131	−5.19	0.000
Sex	−0.65	0.433	−1.50	0.134
Age	0.060	0.021	2.76	0.006
Education	0.134	0.048	2.76	0.006
Family size	0.187	0.059	3.15	0.002
TLU	0.330	0.050	6.55	0.000
Land slopes	−2.39	0.368	−6.51	0.000
Extension agents	1.787	0.364	4.90	0.000
Farm distances	−0.302	0.170	−3.78	0.076

Source: own survey, 2019. Number of observations: 378; LR Chi^2 (08): 270.29; pseudo-R^2: 0.5200; and Prob > Chi^2: 0.000.

3.5.2. Distribution of Propensity Scores. The main purpose of imposing a common support region is to ensure or check any combination characteristics observed in the treatment and comparison group. In this study, before a common support region is imposed, the majority of adopter households are found on the right side of the distribution, but nonadopter households are found in the center and on the left side of the distribution (Figure 5). Thus, in the matching principle, deleting all the observations out of the common region, whose propensity scores are smaller than the minimum and larger than the maximum, is considered as the right decision [39].

The assumption is that potential outcome variables are independent of treatment status and would not be influenced by unobserved confounders (unmeasured variables that influence potential outcome variables). In this study, the estimated propensity scores ranged between 0.123386 and 0.999095 (mean 0.812) for the adopters and between 0.000898 and 0.977294 (mean 0.23244299) for nonadopters (Table 7). Basically, propensity scores less than the minimum and greater than the maximum would not be considered in the matching process [39]. This needs the use of a common support region or the joint area under the distribution of propensity scores lies between two groups. Therefore, our common support region according to [39] would lie between 0.000898 and 0.999095. Households outside this range were not included under the matching process due to their contribution to bias in the estimation effects [39]. Fortunately, all of the nonadopters of our study were within matching ranges of PS, but 48 households from the adopters were removed in estimating the ATE.

In propensity score matching, the only estimation of the propensity score is not sufficient to estimate the ATT. Because propensity score is a continuous variable and the probability of observing two units with the same propensity does not protect selection and outcome bias, to minimize the problem of unobservable characteristics, postmatching techniques have been undertaken. This is because matching attempts to reduce the bias due to confounding variables that could be found in an estimate of the treatment effect obtained from simply comparing outcomes among the groups. Consequently, matching estimators (algorithms) were searched in matching the treatment and control households in the common support region. In this regard, after indicating common support region, distribution of our estimated propensity scores lies between 0.123 and 0.976 (mean = 0.758) for the adopters and between 0.127 and 0.977 (mean = 0.456) for the nonadopters (Table 8). Accordingly, postmatching needs to be conducted based on this distribution of households.

3.5.3. Choice of Matching Algorithm. Matching on propensity scores is supplemented through the use of a matching algorithm (Table 8) that sorts the observations in the treatment group by their estimated propensity score and matches each unit sequentially to a unit in the control group that has the closest propensity score [43]. In this regard, various matching algorithms that have been proposed in the literature must provide consistent estimates of the ATT under the CIA and the overlap condition [39]. The overlap assumption requires that, for all possible values of X, there are both treated and untreated units [44]. Conditional Independence Assumption states that, given a set of observable covariates X that are not affected by treatment, potential outcomes Y are independent of treatment assignment T [44]. Hence, excluding units outside the area of common support can improve balance on covariates and can avoid extrapolation to units in one group which were so dissimilar on their covariates that no comparable units in the other group were found [39].

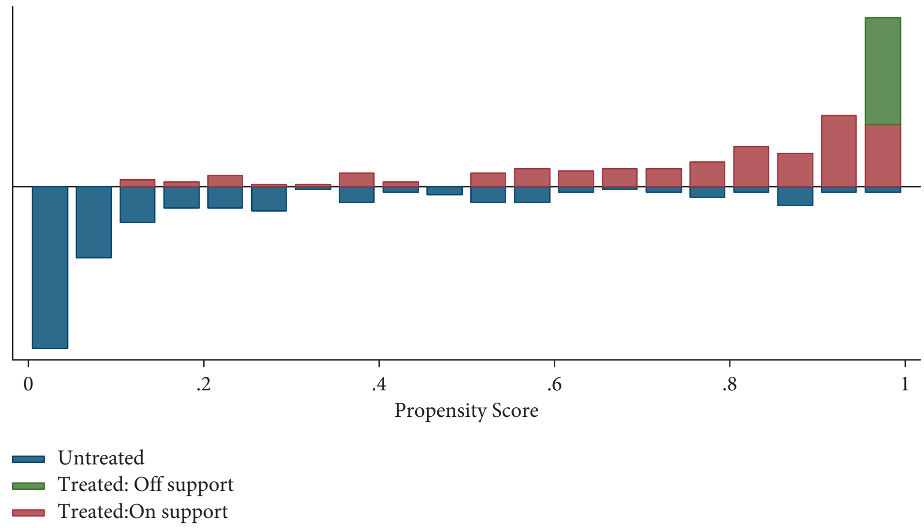

Figure 5: Distribution of propensity scores before the common region is imposed.

Table 7: Propensity score distribution before selecting the common support region.

Respondents	Observation	Mean	SD	Min.	Max.
Total HHS	378	0.55291005	0.380011813	0.000898	0.999095
Adopters	209	0.81204371	0.218822681	0.123386	0.999095
Nonadopters	169	0.23244299	0.279155693	0.000898	0.977294

Table 8: PS distribution after selecting the common support region.

Respondents	Observation	Mean	SD	Min.	Max.
Total HHS	330	0.65933103	0.27732	0.123386	0.977294
Adopters	161	0.75892140	0.22332	0.123386	0.976396
Nonadopters	169	0.45636835	0.26673	0.127513	0.977294

Source: survey of 2019.

Based on this reality, the matching techniques were performed by using different matching algorithms (adopter household is matched to nonadopters based on the result who has the most similar estimated propensity score) through different matching algorithms [43, 45]. In nearest-neighbor matching, an individual from the comparison group is chosen as a match for a treated individual in terms of the closet propensity score while in caliper matching an individual from the comparison group is chosen as a matching partner for a treated individual that lies within a given caliper or propensity score range [39]. In this study, the average treatment effect (ATE) was estimated using the nearest-neighbor matching approach as it imputes the missing potential outcomes for the untreated group using average outcomes for individuals with similar observed characteristics, based on covariates X [44]. Besides, according to [42], the choice of matching estimator was supported through the application of balancing test, pseudo-R^2, and matched sample size. Therefore, as recommended, the matching estimator estimates all explanatory variables with low R^2 value and the relatively large sample size was selected. In this regard, Kernel matching with band width (0.5) was found to be the best matching algorithm for the data we have on 330 matched observations (Table 9). This is consistent with the study of [46], which aimed to construct the counterfactual outcome by using Kernel matching.

3.5.4. Balance Test for the Propensity Score and Covariates. After matching is completed, sequences of model adequacy checks should be performed to check whether balance on the covariates has truly been achieved through the matching procedure or not by using the selected matching algorithm [39]. This can be done by comparing several statistics of the adopter and nonadopter households before and after matching by using standardized bias between matched and unmatched samples, mean quality using t-test, pseudo-R^2, and chi-square test for joint significances (Table 10). In our case, the mean bias before matching was 71%, but after matching the mean bias was in the range of 12% (Table 10). Before matching, the value of pseudo-R^2 was high (0.522), but, after matching, the value displayed lower pseudo-R^2 (0.080). Before matching, the majority of variables showed significant differences, whereas, after matching, the majority

Table 9: Performance of different algorithms.

Marching estimator	Performance criteria			
	Balancing test*	Pseudo-R^2	Mean bias	Matched sample size
Nearest neighbor				
Nearest neighbor (1)	5	0.032	12.9	330
Nearest neighbor (2)	3	0.065	20.9	330
Nearest neighbor (3)	5	0.057	19.7	330
Nearest neighbor (4)	4	0.046	14.4	330
Nearest neighbor (5)	4	0.051	16.2	330
Caliper				
Caliper 0.1	5	0.032	12.9	330
Caliper 0.25	5	0.032	12.9	330
Caliper 0.5	5	0.032	12.9	330
Kernel				
Kernel (bw0.01)	6	0.038	13.5	293
Kernel (bw0.1)	5	0.047	16.6	330
Kernel (bw0.25)	4	0.064	16.1	330
Kernel (bw0.5)	6	0.03	12.8	330

Source: own survey results (2019). *The number of insignificant explanatory variables between the matched groups.

Table 10: Distribution of matching quality results.

Group	Mean bias		Pseudo-R^2		Balancing test	
	Before matching	After matching	Before matching	After matching	Before matching	After matching
Adopter/nonadopter	71.9	12.8	0.522	0.080	2	6

Source: survey data (2019).

of variables resulted in insignificant values (Table 10), which implies that the groups have a similar distribution in covariates (Table 10).

Overall, the matching procedure can balance the characteristics in matched observations and the groups have a similar distribution in the covariates after matching has been performed. After checking all the steps of propensity score matching, the study applied the result for the evaluation of the effect of SWC measures among groups of farmers having the same observed characteristics.

3.5.5. Sensitivity Analysis. Sensitivity analysis was performed to check for unobservable biases (Table 11). In this regard, the critical level (first row = 1) depicts the impacts of SWC measures on rural households (Table 11). The first column of the table shows outcome variables that bear statistical differences between adopter and nonadopter households. The rest of the values corresponding to each row of the significant outcome variables are p-critical values at a different critical value of e^{γ}. The results show that inference for the effect of soil and water conservation measures does not change, though the adopter and nonadopter households were allowed to differ in their odds of being treated ($e^{\gamma} = 3$) in terms of unobserved covariates. Therefore, it is concluded that our impact estimates (ATT) are insensitive to unobserved selection bias, being pure effects of the soil and water conservation practices (Table 11).

3.5.6. Estimation of Treatment Effects on the Matched Sample. In the propensity score matching, ATT estimation is the last stage and it suggests confirmation of important covariates that have been included. As a result, no hidden confounders could threaten the analysis of treatment effects [37]. In this regard, the balance is approved on the propensity scores and covariate groups compared to the potential outcomes (Table 12). Furthermore, the *t*-value obtained after matching revealed no statistically significant difference between adopter and nonadopter households. This indicates that our matching processes can balance the characteristics in both adopter and nonadopter comparison groups, which allowed us to compare the mean values between the groups (Table 12).

The result showed that higher mean values of outcome variables were observed under adopter households than under their counterparts. In particular, the mean value of wheat productivity of adopter households was higher (654 kilograms per hectare) than the mean value of the nonadopters (496 kilograms per hectare) (Table 12). The possible reason could be related to the effect of SWC practices on increasing moisture availability of the soil through increased infiltration and protecting of removal of essential nutrients and reduction of run-off in the plots of adopter households. In line with this finding, the study of [23] found an improvement in crop yield of adopter households as compared to nonadopters in the Harerghe region of Ethiopia. Furthermore, the key informant interview indicated that some adopter households integrated physical soil and water

Table 11: Result of sensitivity analysis.

Outcome variables	$e^{\gamma}=1$	$e^{\gamma}=1.1$	$e^{\gamma}=1.2$	$e^{\gamma}=1.3$	$e^{\gamma}=1.4$	$e^{\gamma}=1.5$
Wheat productivity	$7.8e-07$	0.000012	0.000112	0.00066	0.002779	0.008948
Total farm income	0.116788	0.036804	0.009685	0.002203	0.000445	0.000082

Source: survey results (2019)); e^{γ} (Gamma) = log odds of differential due to unobserved factor.

Table 12: Average treatment effect on the treated (ATET) groups.

Outcome variables	Sample	Adopters	Nonadopters	Difference	SE	*t*-value
Wheat production (kg/ha)	Unmatched	663.2	473.96	18.92	.2359	8.02
	ATET	654.6	496.1	15.86	.3135	5.06
Farm income (Birr/yr)	Unmatched	17148.325	13384.615	3763.709	616.2437	6.11
	ATET	17372.671	13883.225	3489.4456	783.426	4.45

Source: survey results of 2019.

conservation measures with agronomic and biological measures which significantly increased their crop production. The result was consistent with the study of [10] which reported that integration of physical SWC measures with agronomic activities resulted in a successive increase in grain yield of wheat to adopter households compared to nonadopter households. Nevertheless, the majority of farmers of the area perceived the hedges of agronomic SWC measures as occupying larger areas of farming land; and the widespread integration was limited. Likewise, the previous review of Adimassu et al. [5] indicated combining of physical soil and water conservation measures with the agronomic SWC practices, which has not been given due attention at different levels in the country as a whole, and suggested the need for monitoring strategies to integrate agronomic practices with physical SWC practices.

In the same way, the mean values of farm income of adopter households were higher (17372.67 Ethiopian Birr per year) than the mean values of nonadopter households (13883.22 Ethiopian Birr per year) (Table 12). This might be because SWC practices reduced run-off and loss of nutrients and improved access to crop production due to improvements in soil properties, which are closely linked with economic and social development (better output usually leads to better incomes). The finding was in agreement with the study of [23], which confirmed the effectiveness of SWC measures on some of the crop productivity and income of rural livelihoods. The studies of [12, 20, 22] stated the impact of SWC measures on increased water availability, reduced run-off and increased infiltration, which also leads to the increased economy and better income of rural households. On the contrary, the study of [46] revealed that SWC intervention did not result in a significant difference between adopting and nonadopting households in terms of crop yield and household income.

Despite the significant contribution of soil and water conservation measures to the improvement of crop production and farm income under adopter households, soil erosion is still the greatest problem; the impacts of implemented SWC measures resulted in insignificant results on some of the soil fertility indicators [31], and the adoption rate is not widespread among all households. The key informant interview also indicated that the implementation of soil and water conservation measure in the area is still influenced by the socioenvironmental settings of farm communities. Our field observations confirmed that little attention was given to the maintenance of demolished structures, and the implementation of soil and water conservation measures in the area has been targeted through annual government-led community mobilization rather than focusing on the quality of the structures [31]. This finding was in agreement with the study of [18, 47], which stated the ineffectiveness of conservation structures, which was due to poorly constructed bund design, layout problem, and less participation of farm communities in conservation work.

4. Conclusions and Implications

This study examined the impacts of SWC practices on crop production and farm income of rural households in Damota area districts, Southern Ethiopia. The implemented soil and water conservation measures have resulted in higher crop production and farm income for most adopter households compared to their counterparts. The mean value of wheat production of adopter households (654 kilograms per hectare) was higher than the mean value of nonadopter households (496 kilograms per hectare). The possible reason could be related to the effect of SWC practices on increasing moisture availability of the soil through increased infiltration and protecting of removal of essential nutrients and reduction of run-off in the plots. Similarly, the mean values of farm income of adopter households (17372.67 Ethiopian Birr per year) were higher than the mean values of nonadopter households (13883.22 Ethiopian Birr per year). This might be due to the fact that SWC practices reduced run-off and loss of nutrients and improved access to crop production due to the improvements in soil properties, which also resulted in higher farm income for adopter households. Generally, the implementation of SWC practices is effective in improving crop production, farm income, and rural livelihoods. Nevertheless, maintenance of demolished structures, widespread adoption, and integration of physical conservation with biological and agronomic measures have received little attention. This suggests that all rural households need to focus on the large-scale adoption, integration, and maintenance of damaged structures for better agricultural outcomes.

Data Availability

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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References

[1] L. M. Kiage, "Perspectives on the assumed causes of land degradation in the rangelands of Sub-Saharan Africa," *Progress in Physical Geography: Earth and Environment*, vol. 37, no. 5, pp. 664–684, 2013.

[2] M. Sileshi, R. Kadigi, K. Mutabazi, and S. Sieber, "Determinants for adoption of physical soil and water conservation measures by smallholder farmers in Ethiopia," *International Soil and Water Conservation Research*, vol. 7, no. 4, pp. 354–361, 2019.

[3] F. Laekemariam, K. Kibret, T. Mamo, E. Karltun, and H. Gebrekidan, "Physiographic characteristics of agricultural lands and farmers' soil fertility management practices in Wolaita zone, Southern Ethiopia," *Environmental Systems Research*, vol. 5, no. 1, p. 24, 2016.

[4] T. Erkossa, T. O. Williams, and F. Fanuel, "Integrated soil, water and agronomic management effects on crop productivity and selected soil properties in Western Ethiopia," *International Soil and Water Conservation Research*, vol. 6, pp. 305–316, 2018.

[5] Z. Adimassu, S. Langan, R. Johnston, W. Mekuria, and T. Amede, "Impacts of soil and water conservation practices on crop yield, run-off, soil loss and nutrient loss in Ethiopia: review and synthesis," *Environmental Management*, vol. 59, no. 59, pp. 87–101, 2017.

[6] T. Tanto and F. Laekemariam, "Impacts of soil and water conservation practices on soil property and wheat productivity in Southern Ethiopia," *Environmental System Research*, vol. 8, no. 13, 2019.

[7] P. Wainaina, S. Tongruksawattana, and M. Qaim, "Tradeoffs and complementarities in the adoption of improved seeds, fertilizer, and natural resource management technologies in Kenya," *Agricultural Economics*, vol. 47, no. 3, pp. 351–362, 2016.

[8] A. Belachew, W. Mekuria, and K. Nachimuthu, "Factors influencing adoption of soil and water conservation practices in the Northwest Ethiopian highlands," *International Soil and Water Conservation Research*, vol. 8, no. 1, pp. 80–89, 2020.

[9] S. Asfaw, N. Mccarty, L. Lipper, and A. Arslan, "Adaptation to climate change and food security in Africa," in *Proceedings of the 4th International Conference of the African Association of Agricultural Economics*, Hammamet, Tunisia, September 2013.

[10] T. Gashaw, A. Bantider, and H. G. Silassie, "Land degradation in Ethiopia: causes, impacts and rehabilitation techniques," *Journal of Environment and Earth Science*, vol. 4, no. 9, pp. 98–105, 2014.

[11] T. Kyawt, S. Rajendra, and D. Avishek, "Assessment of land degradation and its impact on crop production in the dry zone of Myanmar," *The International Journal of Sustainable Development and World Ecology*, vol. 22, no. 6, pp. 533–544, 2015.

[12] E. Adgo, A. Teshome, and B. Mati, "Impacts of long-term soil and water conservation on agricultural productivity: the case of Anjeni better land use planning in river basins: case study of Upper Blue Nile River," *Science Total Environment*, vol. 574, pp. 95–108, 2013.

[13] N. Haregeweyn, A. Tsunekawa, J. Nyssen et al., "Soil erosion and conservation in Ethiopia," *Progress in Physical Geography: Earth and Environment*, vol. 39, no. 6, pp. 750–774, 2015.

[14] M. Kassie, P. Zikhali, K. Manjur, and S. Edwards, "Adoption of sustainable agriculture practices. evidence from a semi-arid region of Ethiopia," *Natural Resources Forum*, vol. 33, no. 3, pp. 189–198, 2009.

[15] T. Amare, A. D. Zegeye, B. Yitaferu, T. S. Steenhuis, H. Hurni, and G. Zeleke, "Combined effect of soil bund with biological soil and water conservation measures in the northwestern Ethiopian highlands," *Ecohydrology and Hydrobiology*, vol. 14, no. 3, pp. 192–199, 2014.

[16] G. Gebregzibeher, D. Abera, G. Gebresamuel, M. Giordano, and S. Langan, *An Assessment of Integrated Watershed Management in Ethiopia*, International Water Management Institute (IWMI Working Paper 170), Colombo, Sri Lanka, 2016.

[17] S. Hishe, J. Lyimo, and W. Bewket, "Soil and water conservation effects on soil properties in the Middle Silluh Valley, Northern Ethiopia," *International Soil and Water Conservation Research*, vol. 5, no. 3, pp. 231–240, 2017.

[18] M. Belayneh, T. Yirgu, and D. Tsegaye, "Effects of soil and water conservation practices on soil physicochemical properties in Gumara watershed, Upper Blue Nile Basin, Ethiopia," *Ecological Processes*, vol. 8, no. 1, p. 36, 2019.

[19] S. D. Walie and G. Fisseha, "Perception of farmers toward physical soil and water conservation structures in Wyebla Watershed, Northwest Ethiopia," *World Journal of Agricultural Sciences*, vol. 12, no. 1, pp. 57–63, 2016.

[20] W. Kebede, "Evaluating watershed management activities of campaign work in southern nations nationalities and peoples' regional state of Ethiopia," *Environmental System Research*, vol. 4, no. 6, 2015.

[21] T. Amede, *Restoring Soil Fertility in the Highlands of east Africa through Participatory Research*, International Center for Research in Agroforestry, Nairobi, Kenya, 2003.

[22] A. Ayalew, "Construction of soil conservation structures for improvement of crops and soil productivity in the Southern Ethiopia," *Journal of Environmental Sciences*, vol. 1, pp. 21–29, 2011.

[23] Y. Kassa, F. Beyene, J. Haji, and B. Legesse, "Impact of integrated soil and water conservation program on crop

production and income in West Harerghe Zone, Ethiopia," *International Journal of Environmental Monitoring and Analysis*, vol. 1, no. 4, pp. 111–120, 2013.

[24] D. Nigatu, F. Kalkidan, and M. Tewodros, *Soil and Water Conservation Practices on Crop Productivity and its Economic Implications in Ethiopia*, University of Twente, Enschede, Netherlands, 2017.

[25] M. Alemayehu, F. Yohannes, and P. Dubale, "Effect of indigenous stone bunding (Kab) on crop yield at Mesobit-Gedeba, North Shoa, Ethiopia," *Land Degradation & Development*, vol. 17, no. 1, pp. 45–54, 2006.

[26] Y. Abebe and A. Bekele, "The impact of soil and water conservation program on the income and productivity of farm households in Adama District, Ethiopia," *Science, Technology and Arts Research Journal*, vol. 3, no. 3, pp. 198–203, 2014.

[27] E. Kato, C. Ringler, M. Yesuf, and E. Bryan, "Soil and water conservation technologies: a buffer against production risk in the face of climate change? insights from the Nile basin in Ethiopia," *Agricultural Economics*, vol. 42, no. 5, pp. 593–604, 2011.

[28] M. Kassie, S. Holden, G. Kohlin, and R. Bluffstone, *Economics of Soil Conservation Adoption in High Rainfall Areas of the Ethiopian Highlands*, Resources for the Future, Washington, DC, USA, 2008.

[29] Z. Adimassu, K. Mekonnen, C. Yirga, and A. Kessler, "Effect of soil bunds on runoff, soil and nutrient losses, and crop yield in the central highlands of Ethiopia," *Land Degradation & Development*, vol. 25, no. 6, pp. 554–564, 2014.

[30] K. Vancampenhout, J. Nyssen, D. Gebremichael et al., "Stone bunds for soil conservation in the Northern Ethiopian highlands: impacts on soil fertility and crop yield," *Soil and Tillage Research*, vol. 90, no. 1-2, pp. 1–15, 2006.

[31] M. Masha, T. Yirgu, and M. Debele, "Effectiveness of community-based soil and water conservation in improving soil property in Damota Area, Southern Ethiopia," *Applied and Environmental Soil Science*, vol. 2021, Article ID 5510587, 11 pages, 2021.

[32] Central Statistical Authority (CSA), *Population and Housing Census of Ethiopia*, Central Statistical Authority (CSA), Addis Ababa, Ethiopia, 2007.

[33] M. Teshome, "The role of geo information technology for predicting and mapping urban change detection: Wolaita Sodo town case study, Ethiopia," *International Journal of Current Research and Academic Review*, vol. 7, no. 10, 2019.

[34] Central Statistical Authority (CSA), *Agricultural Sample Survey. Report on Area and Production of Crops, Private Peasant Holdings, Main Season*, Central Statistical Authority (CSA), Addis Ababa, Ethiopia, 2015.

[35] M. Tesfaye and L. Seifu, "Climate change perception and choice of adaptation strategies: an empirical evidence from smallholder farmers in east Ethiopia," *International Journal of Climate Change Strategies and Management*, vol. 8, no. 2, pp. 253–270, 2015.

[36] C. Heinrich, M. Alessandro, and G. A. Vázquez, "Primer for applying propensity score matching: impact-evaluation guidelines," IDB, New York, NY, USA, Technical Notes, No. IDB-TN-161, 2010.

[37] S. O. Becker and A. Ichino, "Estimation of average treatment effects based on propensity scores," *STATA Journal: Promoting communications on statistics and Stata*, vol. 2, no. 4, pp. 358–377, 2002.

[38] A. Bryson, R. Dorsett, and S. Purdon, *The Use of Propensity Score Matching in the Evaluation of Labour Market Policies*, Department for Work and Pensions, London, UK, 2002.

[39] M. Caliendo and S. Kopeinig, *IZA DP No. 1588: Some Practical Guidance for the Implementation of Propensity Score Matching*, University of Cologne, Cologne, Germany, 2005.

[40] M. Hadush, "The role of community based watershed management for rural livelihood in Adwa, Central Tigray zone," *International Journal of Weather, Climate Change and Conservation Research*, vol. 2, no. 1, pp. 22–46, 2015.

[41] P. R. Rosenbaum and D. B. Rubin, "The central role of the propensity score in observational studies for causal effects," *Biometrika*, vol. 70, no. 1, pp. 41–55, 1983.

[42] J. Jalan and M. Ravallion, "Estimating the benefit incidence of an antipoverty program by propensity-score matching," *Journal of Business & Economic Statistics*, vol. 21, no. 1, pp. 19–30, 2003.

[43] F. J. Thoemmes and E. S. Kim, "A systematic review of propensity score methods in the social sciences," *Multivariate Behavioral Research*, vol. 46, no. 1, pp. 90–118, 2011.

[44] N. Mango, S. Siziba, and C. Makate, "The impact of adoption of conservation agriculture on smallholder farmers' food security in semi-arid zones of southern Africa," *Agriculture & Food Security*, vol. 6, no. 1, 2017.

[45] K. Ming and P. R. Rosenbaum, "Substantial gains in bias reduction from matching with a variable number of controls," *Biometrics*, vol. 56, no. 1, pp. 118–124, 2000.

[46] A. Yitayal, "Impact of soil and water conservation policy on the livelihood of farm households in Adama District, East Shewa Zone, Oromia National Regional State, Ethiopia," M. Sc thesis, Haramaya University, Dire Dawa, Ethiopia, 2012.

[47] A. Bekele and E. Kissi, "Assessment of community based watershed management practices: emphasis on technical fitness of physical structures and its effect on soil properties in Lemo district, Southern Ethiopia," *Environmental System Research*, vol. 720 pages, 2018.