Analysis of Adoption and Intensity Adoption of Soil and Water Conservation Practices: The Case of Goromti Watershed West Shewa Zone, Oromia National Regional State, Ethiopia

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Abstract

In Ethiopia, soil erosion is a severe problem and a major cause of the decline of agricultural productivity. Interventions were taken by introducing SWC practices. However, the adoption rates of these practices remain below the expected levels in Ethiopia and particularly in the study area. Therefore, this study aims to identify factors affecting adoption and intensity adoption of physical SWC practices in the study areas. A three-stage sampling technique was employed to select 150 sample HHs. Both quantitative and qualitative data were collected from primary and secondary sources. Descriptive statistics and a Double hurdle model were used to analyze data. The first stage of the Double hurdle model results showed that sex of HHs, education level, frequency of extension contact, perception on soil erosion problems, family size, and training affect the probability of adoption of physical SWC practices positively and significantly while age affects it negatively and significantly. Age, plot size, steep slope, training, and frequency of extension contact affect the intensity adoption of physical SWC practices positively and significantly. The finding depicts that the identified demographic, physical, socio-economic, and institutional factors influence the adoption and intensity adoption of physical SWC practices so, the Agricultural and Natural resource Office and other concerned bodies should consider these influential factors to enhance HHs' adoption of introduced physical SWC practices and to promote agricultural productivity and environmental quality.

1. Introduction

Agriculture is the prominent sector that contributes extremely to economic development in Africa (Mohammed and Teshome, 2015; Agere *et al*., 2020). Over partial of the African population is employed in the sector (AGRA, 2018; MoARD, 2010; Asnake *et al*., 2018). The sector accounts for about 42% of the country's Gross Domestic Product (GDP), 90% of export revenues, and 85% of employment (Tsega *et al*., 2018; CSA, 2018). Despite its significant contribution to livelihoods, the sector faces a persistent challenge due to the depletion of natural resources and soil erosion (Sarah *et al*., 2018; Agere *et al*., 2020). As an agrarian nation, Ethiopia's growing economy is facing similar challenges due to lingering soil erosion and land degradation (Asnake *et al.*, 2018; Fontes, 2020).

This has significantly resulted in devastating agricultural productivity (Teklu *et al*., 2015; Mulat *et al*., 2020) and increase food insecurity and poverty (Akalu *et al*., 2016). Land degradation is one of the socio-economic and environmental challenges in Ethiopia, which is caused by the expansion of agriculture due to ever-growing population, removal of crop residues at harvest, open free grazing of livestock, intensive tillage without SWC practices, and inappropriate land use (Gebeyehu *et al*., 2013; Tamrat *et al*., 2018). This is displayed in the form of gully formation, soil fertility depletion and crop yield reduction, and major economic losses (Mulatie *et al*., 2015; Mulat *et al*., 2020). In order to control the effects of land degradation, the Government of Ethiopia (GoE) has taken various SWC practices since the mid-1970s on individual and communal lands through the productive safety net and Food for Work Programs (FFW), with a purpose of not just to reducing soil loss but also improving crop yields and livelihood of the rural farmers (Zenebe *et al*., 2014; Asnake *et al*., 2018).

In particular, the central government started massive SWC campaigns in the 1980s, targeting the low potential (drought-prone and highly degraded) parts of the highlands. On the other hand, the government discouraged farmers from implementing SWC practices in the high potential area while encouraging the adoption of alternative improved technologies, such as the use of fertilizers and improved seeds, to enhance productivity per unit of cultivated area (Asnake *et al.*, 2018).

As such, SWC has been considered as an important part of the agricultural extension package in the country since 1991 when the Ethiopian People Republic Democratic Front (EPRDF) came to power. It should however be noted that the introduction of these measures and technologies has largely used the top-down approach with little participation of the target farmers. Consequently, these efforts have generally failed mainly due to a lack of support and awareness among farmers (Nigussie *et al.*, 2015; Asnake *et al.*, 2018).

Participatory watershed management was recognized at the national level since the early 2000s under the framework of national development strategy. This framework triggered the launching of different sustainable land management programs throughout the country. Along with the national strategy, integrated SWC is implementing different physical and biological SWC practices (such as bench terraces, soil bund, bund stabilizing biological practices, farm forestry, and so on) in the main intervention areas. Similarly, the government of Ethiopia is running a massive SWC campaign for two months every year in the selected areas since 2011 (Asnake *et al.*, 2018).

The campaign aims at encouraging rural farming households to construct SWC structures and change their attitudes towards land degradation and SWC (Gebreselassie et al., 2015; Zenebe *et al.*, 2018). Nevertheless all these efforts by the central government, regional government, donors, and development partners, land degradation remains a serious problem and the adoption of SWC practices is generally low. The low rate of adoption of improved SWC practices is not only usual to Ethiopia; it is a common phenomenon in Sub-Saharan Africa as a whole (Kebede *et al.*, 2018; Million *et al.*, 2019).

As a result, land degradation has continued to be a critical threat to Ethiopian agriculture and to attaining the country's food security targets (Daniel *et al.*, 2015; Birhan *et al.*, 2017). The situation in the Goromti watershed, the study area, is not different from the rest of the country. This watershed faces food production problems, soil erosion, deforestation, and land degradation mainly due to natural and man-made causes. Since 2012, to cope with these problems and with the engagement of stakeholders and active participation of the dwelling community, different SWC practices such as soil bunds, waterway, cut-off drain, fanya juu, terraces, area closure, and afforestation have been practiced. However, the quality, standard, specification, adoption rate of the activities matter.

Agriculture in Ethiopia is not only an economic activity but also a way of life for which agricultural land is an essential resource upon which the welfare of the society is built. Directly or indirectly, the vast majority depends on this sector. This leads to increased vulnerability of the economy and problems related to land degradation (Bunyad et al., 2017). Land degradation, in the form of soil erosion and nutrient depletion is a main threatening factor for aggravating food insecurity and make worse sustainability of agricultural production in Ethiopia (Sarah *et al.*, 2018; Agere *et al.*, 2020). Poor watershed management, population growth, and inappropriate farming practices have contributed to a lion share of the losses caused. Besides, poverty with a rapid increase in human population combines with land degradation poses a serious threat to the national economy and household food security. Furthermore, soil erosion impedes agricultural productivity through declining soil quality (loss of organic matter and mineral contents) through excessive surface runoff (Nigatu *et al.*, 2017).

However, in Ethiopia for the past decades, an attempt was made to undertake mitigation measures on soil erosion problems using different approaches for the sustainability of crop production (Fisseha and Tewodros, 2014). As well, the watershed management approach has been applied in the country to reduce environmental degradation and to enhance agricultural productivity which supports sustainable livelihoods security of the households. Recognizing land degradation as a major environmental and socioeconomic problem, the government has made several interventions. As a result, in the Goromti watershed, some parts have been converted with different SWC practices. Nevertheless, the adoption and attainment have fallen far below expectations. The area still loses a tremendous amount of fertile topsoil, and the threat of land degradation is still expanding.

According to Berhanu and Scott (2003), the most important reason for the limited use of SWC practices was HHs' low adoption behavior. Short-term benefits expectations of local communities, technical problems, and insufficient institutional and organizational supports have been blamed for the limited success. Moreover, a result of the reviewed literature indicated demographic, physical, socio-economic, and institutional factors were the underlying causes that affect farmers' knowledge and adoption decisions concerning SWC practices (Mohammed and Teshome, 2015; Million *et al.*, 2019; Muluken et al., 2020).

Addisu *et al.* (2015) identified the determinants of adoption of SWC practices, farmer's perception of cause and consequence of soil erosion, characterized types of SWC techniques adopted in the watershed and most importantly it explored the relationship between socio-economic and physical characteristics of households and adopted SWC practices in the Goromti watershed.

In addition to this, many studies were conducted on the determinants of the adoption of SWC practices in different areas in Ethiopia. But, very few studies accounted for the determinants of intensity adoption of SWC practices. As well, in the study area, there was no empirical study conducted on factors affecting the intensity adoption of SWC practices. Therefore, this study was trying to narrow the research gap in the study area by analyzing factors affecting the adoption and intensity adoption of physical SWC practices in the Goromti watershed of Ambo woreda, Oromia regional state.

2. Methodology

2.1. Description of the Study Area

The study was conducted in Goromti Watershed in Oromia Regional State, Ambo Woreda. It is 15 km far from Woreda capital Ambo town, and 130 km away from Addis Ababa. Geographically, it is located between 8°49'26" to 8°55'22"N lat. and 37°51'57" to 37°54'08"E long. The watershed is surrounded Dese Aklilo kebele in the West, Gatira in the East, and Gosu Kora kebele in the north, Kiba kebele in the North West, and in the South by Southwest Shewa Zone. The watershed is accessed by the gravel road that connects Ambo town with districts and towns of the South West Shewa Zone. The total area of the watershed is about 1664 ha and is composed of mainly Goromti, Boji Bilo, Ya'i Chebo kebeles.

The watershed is characterized by undulating, rugged, and hilly topography. It has an altitude ranging from 2447 to 3185 mean above sea level (M.a.s.l). The topography of the watershed includes 62% of the total area is moderately steep to steep (more than 15% slope), 38% is between gentle and moderate slope (less than 15% slope). Concerning the land use system of the watershed is about 65% is farmland, 3% is forest and Bushland, 3% grassing land, 17% is homestead area, and the remaining 12% is degraded, gully, and covered by other resources. Geologically, the watershed is covered by Alcalitrachyte sand subordinate basalt and three major soil types dominate the watershed.

According to FAO classification (2006), these soils could be approximated with local names as Haplic Luvisols (biyyo boralee), Haplic Alisols (biyyo diimaa), and Calcic Vertisols (biyyo gurracha). In spite of its proximity to the equator, the watershed enjoys a mild temperature condition and is characterized by a 'Dega' (temperate) agro-climatic zone. The climatic type largely consists of Afro-Alpine temperate and warm temperate climates. The lowest and highest annual average temperatures are 13 and 27°C, respectively. The rainfall of the area is bimodal, with unpredictable short rains from March to April and the main season ranging from June to September.

The watershed has an annual rainfall ranging from 1500 to 1700 mm. Indigenous trees mainly Juniperus (Gaattira) Olea abyssinica (Ejersa), Hagenia forests (Heexoo), acacia (laaftoo), podocarpus (Birbirsa) Arundinaria alpine (Shimala), and Erythrina Abyssinia (Korchi), and exotic tree species including Eucalyptus globulus (bargamo adii) and Eucalyptus camaldulesis (Bargamo dimaa) are widely found in the study area. Farming system in the area is typically a mixed crop-livestock system of the high lands of the country, where livestock provide the drought power needed for farming operation and a good part of crop residue are fed to livestock (Addisu *et al*., 2015).

The major crops grown include barley (Hordeum Vulgare), wheat (Triticum Vulgare), oat (Avena *sativum)*, Niger seed (*Guizotia abyssinica*), field pea (*Pisum Vativum*), faba bean (*Vicia faba*), and root crop like potato (*Selenium tuberosum)*. *Enset* (*Ensete Ventricosum*) is the most popular perennial crop grown in all homesteads and serves as a staple food and income source for local people. Livestock keeping is a traditional practice in the area since long before other farming systems experienced it. Soil bund, fanya juu, waterways, cut-off drain, and grass strips are the major SWC practices implemented in the area (AWANRO, 2020).

2.2. Methods of sampling techniques and sample size

In this study, a two-stage sampling technique was employed to select sample respondents. In the first stage, three micro watersheds were selected from seven micro watersheds using random sampling technique. Then, the HHs in the area was stratified into adapters and non-adopters of physical SWC practices. To this effect, a list of HHs was obtained from the Ambo district agricultural and natural resource office (ADANRO, 2020). At the second stage, 150 samples HHs were selected using Cochran's (1977) simple random sampling procedure. Then the sample size thus obtained was assigned to each micro watersheds based on the probability proportional size of the HHs.

$$n = \frac{z^2 qp}{e^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$= \frac{(1.96)^2(0.53)(0.47)}{(0.08)^2} = 150$$

Where:

n = is the sample size for the study

z^2 = is the selected critical value of desired confidence level (1.96)

p = is the estimated proportion of an attribute that is present in the population which is 0.47 in this study

q =1-p that is 0.53

e^2 = is the desired level of precision which is 0.08

Table 1
Sample household heads in selected Micro watersheds

Watershed	Micro watersheds	Total household heads	Sampled household heads		Total sample
			Adopters	Non-adopters	
	Bero	134	21	23	44
Goromti	Yamure	153	23	25	48
	Kabi	178	27	31	58
Total		465	71	79	150
Source: AWANRO, 2020					

2.3. Data types, sources and collection tools

In this study, both primary and secondary data sources were used. To secure primary data, a semi-structured questionnaire was used and administrated by personnel interview. The questionnaire was designed to capture household socio-economic, demographic, physical and institutional factors. Typically, the questionnaire format comprises both qualitative and quantitative questions. Before data collection, the questionnaire was tested. This led to a further revision of the questionnaire to make sure that important factors addressed well. On top of this, enumerators had trained on the study's objectives, the questionnaire's content, and approach to handling the respondents. Furthermore, a focus group discussion secondary were used to supplement information collected from respondents.

2.4. Method of data analysis

2.4.1. Descriptive and inferential statistics analysis

In this study, descriptive statistics were used to describe the socio-economic, demographic, physical and institutional relevant characteristics of sample HHs using mean, standard deviation, percentages, minimum, and maximum. Correspondingly, inferential statistics were also employed to compare the proportion and mean of the difference between physical SWC practices adopter and non-adopter HHs in terms of the dummy and continuous variables using the Chi-square (X^2) test and t-test. The result was presented using the table, pie chart and graph.

2.4.2. Econometric Analysis

The Double hurdle model is used to identify factors affecting the adoption and intensity of adoption of physical SWC practices. Most recent literature (Hassen, 2013; Eyerusalem, 2017; Alemayehu *et al*., 2019; Amsalu and Alebachew, 2020) implemented a double hurdle model to identify factors that affect the adoption and intensity of the adoption of agricultural technologies. The double hurdle model allows the decision to adopt and intensity of adoption of physical SWC to be treated separately. Therefore, a separate process can be used to model the probability of adoption and level of adoption (Carroll et al., 2005).

Generally, the Tobit model has the problem of assumption. It assumes the same set of variables determine both the probability of adoption and the intensity of adoption. Due to this assumption, the same variables, in the same way, introduce consistency bias in the model. According to Andrew (1989) one of the important differences between these two models concerns the sources of zeros. Plus the Heckman model is limited because it assumes that, the non-adopters never adopt under any circumstances. In contrast, in the double hurdle model, non-adopters are considered as a corner solution in a utility maximizing model. Hence, a double hurdle model was employed in this study to minimize those problems.

According to Cragg's model, a HH faces two hurdles while deciding on SWC practices. The first is to decide whether or not to adopt physical SWC practices. The second hurdle is related to the intensity of adoption, or the proportion of area covered by physical SWC practices. The most important underlying assumption of the model is that these two decisions are made in two different stages. The first stage of Cragg's model is a probit model to identify the determinants of adoption, and the second stage is a truncated regression model for identifying the determinants of the intensity of adoption (Cragg, 1971). Let d_i^* is the latent variable describing a HH's decision to adopt, y_i^* is the latent variable describing its decision on the intensity of adoption, and d_i and v_i are their observed counterparts, respectively.

Based on the specification by Cragg (1971) and Peter (2005), the two hurdles for a household can be written as:

$$d_i^* = \alpha z_i + u_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

$$\mathrm{v}_\mathrm{i}^* = \beta \mathrm{x}_\mathrm{i} + \epsilon_\mathrm{i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where,

$$d_i = \begin{cases} 1, if d_i^* > 0 \\ 0, if d_i^* \leq 0 \end{cases} and \mathrm{v}_i = \begin{cases} \mathrm{v}_i^*, if \mathrm{v}_i^* > 0 and d_i^* > 0 \\ 0, if otherwise \end{cases}$$

Where z_i is the vector of variables explaining whether a HH adopts physical SWC practices, x_i is a vector of variables explaining the level of adoption, and u_i and ε_i are the error terms. The dependent variable in the first stage is the HH's adoption decision. This variable is binary in nature, taking numeric values 1 for adopters, and 0 for non-adopters.

In the second stage, the dependent variable is the proportion of area covered by physical SWC practices. In the Double hurdle model, both hurdles have equations associated with them, incorporating the effects of HH characteristics and circumstances. Such explanatory variables may appear in both equations and either of them (Teklewold *et al.,* 2006). According to Carroll *et al.* (2005), equations 2 and 3 are assumed to be independent, and therefore the error terms are randomly and independently distributed, $v_i \sim N(0, 1)$ and $\varepsilon_i \sim N(0, \sigma^{\varepsilon^2})$.

The log-likelihood function for the Double hurdle model is:

$$\log L = \sum \ln\left[1 - \Phi(\alpha Z_i \left(\frac{\beta X_i}{\sigma}\right)\right] + \sum \ln\left[\Phi(\alpha Z_i)\frac{1}{\sigma}\phi\left(\frac{Y_i - \beta X_i}{\sigma}\right)\right] \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where Φ and ϕ are the standard normal cumulative distribution function and density function, respectively. The log-likelihood function is estimated using the maximum likelihood estimation (MLE) technique. The double hurdle model is reduced to the Tobit model when the probit mechanism ($d_i^* > 0$) is absent in Equation 2. This can also be seen in

the log-likelihood function presented in Equation 3 when Φ ($Z_i\alpha$) = 1. The Tobit model arises if $\alpha = \beta/\sigma$ and $\mathbf{x} = \mathbf{z}$ (Martinez-Espineira, 2006).
The absence of the probit mechanism implies that the decision about adoption and level of adoption is made simultaneously. We also develop a Tobit model and do a standard likelihood ratios test between the Tobit and double hurdle model to know how these decisions are made. Following Gujarati (2003), the Tobit model for our specific case can be written as:

$$y_i = \begin{cases} y_i \mathit{iflandallocatedforphysicalSWCpractices} \\ 0\mathit{otherwise} \end{cases} \text{.................... ....}(5)$$

Where $\beta_0 \ldots \beta_x$ are the unknown parameters to be estimated and $x_{1i} \ldots x_{ki}$ are the same set of explanatory variables used in the second stage of the Cragg model. Using MLE, the Tobit model is estimated. According to Maddala (1992), the likelihood function for the Tobit model can be written as:

$$L = \prod_{V_i>0} \frac{1}{\sigma} f\left(\frac{yi - \beta x_i}{\sigma}\right) \prod_{V_i<0} F\left(-\frac{\beta X_I}{\sigma}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

By maximizing the function concerning βandσ, we get the MLE estimates of these parameters. As the Tobit model is nested in the Cragg model, it is possible to compare these two models through a standard likelihood ratio test when the determinants in both hurdles are the same (Buraimo *et al.*, 2010). The test statistics can be computed as in Greene (2000):

$$\Gamma = -2\left[\ln L_T - \left(\ln L_P + \ln L_{TR}\right)\right]\tilde{X}_{k^2} \text{.................... ....} (7)$$

Where, Γ = likelihood ratio statistic; *ln*= natural logarithm, L_T,L_P and $L_{TR}$are log-likelihoods of the Tobit, Probit, and Truncated regression models, respectively, X^2 = chi-square statistic

and k is the number of independent variables in the equations. Rejection of the null hypothesis ($\Gamma > X^2{}_k$) argues for the superiority of the double hurdle model over the Tobit model and establishes that the decisions about adoption and intensity adoption are made in two different stages.

3. Results And Discussion

3.1 Descriptive Statistics Results

3.1.1. The adoption of physical SWC practices

From the total sample, respondents around 71(47.33%) of HHs adopt physical SWC practices Whereas 79(52.67%) of respondents didn't adopt physical SWC practices. As shown in Figure 2, adopter HHs in the study area applied different physical SWC practices on their farm plot to minimize soil loss, increase soil fertility and improve the productivity of degraded lands. These practices include soil bund, fanya juu, cut-off drain, and waterways. However, it is not usual to see stone bunds or stone-faced bunds due to the scarcity of stone, which is attributable to the geological feature of the study area. The result shows that 29.11% of sample respondents applied soil bund to decrease soil erosion problems. Those indicated that soil bund is the most widely used physical SWC practice in the study area than the others.

Next to the soil bund, sample respondents applied a cut-off drain though it prevents loss of seeds, fertilizers, manure, and soil due to water flowing onto the plot from uphill. The result of this study revealed that 26.58% of respondents adopted cut-off drain. Likewise, 25.32% of sample respondents in the study area adopted fanya juu to decreases the speed of runoff more than a soil bund. On the other way, 18.99% of sample respondents constructed waterways in their farm plots to safely transport runoff water from a field via natural field drainage ways.

3.1.2. Sustainability of physical SWC practices

For ensuring, the sustainability and beneficial impacts of the implemented physical SWC practices on productivity, SWC practices have to be regularly maintained. Therefore, the effort of the HHs to maintain implemented physical SWC practices indicates their acceptance of the practices. For this purpose, respondent HHs answer to some questions concerning the maintenance of implemented physical SWC practices.

As presented in Table 3, 40 percent of respondents maintain physical SWC practices regularly, while 7.33 percent of HHs did not. However, 52.67 percent of respondents did not have introduced physical SWC practices in their plot.

Following this, respondents were asked to list the main reasons that discourage them from maintaining SWC practices. About 3.33% of the respondents reported that lack of skill and knowledge is one factor to use the conservation practices continuously (Table 5). 2.22% and 6.67% of the respondents reported a lack of support and shortage of labor to maintain conservation practices, respectively. In addition to the above reason, from the focus group discoutions the reasons for not maintaining SWC practices were minimum understanding of the severity of erosion and low knowledge of HHs on conservation practices.

Table 3
Maintenance of physical SWC practices in the study area

Did you maintain SWC Practices?	Frequency (Freq.)	Percent (%)
Yes	60	40
No	11	7.33
I don't have physical SWC practices	79	52.67
Lack of skill and Knowledge	3	3.33
Lack of support	2	2.22
Shortage of household labor	6	6.67
Source: Survey result, 2021		

3.1.3. The advantages of physical SWC practices in the study area

As Figure 3 shows, the advantage respondents obtained from adopting physical SWC practices. The HHs rank first reduced soil erosion (38.46%), improved crop yield (30.77%), controls flood (16.92%), and increased water availability (13.85%), respectively. During the group discussion and informant interview held with HHs, the effectiveness of SWC practices emphasized as they observed better growth and development of crops with conservation technologies where fertile sediment were trapped.

3.1.4. The intensity of adoption of physical SWC practices

As Table 4 shows, the mean proportion of area covered by physical SWC practices of adopter respondent HHs were around 57.23% with the standard deviation of 11.66% in the study areas. As well as, the maximum and minimum proportion of area covered by physical SWC practices were 77.77% and 28.57%.

Table 4
The intensity of adoption of physical SWC practices

	Mean	Std. Dev	Min	Max
The proportion of area covered by physical SWC practices (%)	57.23	11.659	28.57	77.77
Source: Own surveyed data 2021				

3.1.5. Descriptive statistics for dummy variables

As indicated in Table 5, from the total 150 sample respondents, about 123(82%) of sample respondents were male HHs whereas 27(18%) were female HHs. Among the total sample respondents, 62(87.32%) male HHs and 9(12.68%) female HHs adopt physical SWC practices. Whereas 61(77.22%) male HHs and 18(22.78%) female HHs were non-adopters of physical SWC practices. The X^2- test result of sex distribution between the adopters and non-adopters of physical SWC practices was insignificant.

As explained in Table 5 the participation of HHs in off-farm activities harms the probability adoption of physical SWC practices (Million *et al.*, 2019). The chi-square test was employed to test association between off-farm activity participation and adoption of physical SWC practices. The result indicates that from the total 49(39.33%) off-farm activities participant HHs, 18(36.73%) were physical SWC practice adopters while 31(63.27%) were non-adopters. The X^2-test result shows that, there is a statistically significant difference between adopters and non-adopters in terms of off-farm activity participation.

HHs awareness of soil erosion problems on their plot, causes, and consequences of the soil erosion problems will increase, the probability use of SWC practices. As various studies indicated, the perception about soil erosion problem by HHs is one of the determinant factors for HHs to make decisions on SWC investment. The perception of sample respondents on soil erosion has paramount importance to adopt physical SWC practices. The survey result indicated that about 42 percent of the respondents perceived soil erosion as a problem on their plots. Additionally, the respondents were asked to rank the degree of soil erosion problems on their plots. As surveyed result shows, 24, 34.67, and 41.33 percent of respondents ranked, the degree of soil erosion problems low, medium, and high, respectively.

Among the total 63(42%) respondents who perceived soil erosion as a problem, 30(73.02%) were physical SWC adopters, while 33(26.98%) were non-adopters. That indicates most respondents who perceived soil erosion as a problem adopt physical SWC practices in their farm plot to minimize soil loss and enhance soil fertility compared to its counterpart. On the other hand, among the respondents who lack the perception of soil erosion problems, 42 (28.74%) were physical SWC practice adopters, while 46(71.26%) were non-adopters. The X^2- test result shows that, there is a statistically significant difference between adopters and non-adopters in terms of perception of soil erosion problems. That indicates awareness creation about the soil erosion problems is very important to increase the adoption of physical SWC practices.

The slope of the plots expands problems of soil erosion. Therefore, there is a relationship between slope and the adoption of physical SWC practices. The degree of soil erosion influences the variation plot gradient. As a result in Table 5 indicated 17.33, 32.67, and 50 percent of the respondents' farm plots were flat, gentle, and steep slope, respectively. The cross-tabulation result indicates that 2.67, 34.67, and 62.67 percent of flat, gentles, and steeps slope plot owner HHs were physical SWC Practice adopters.

While 32, 30.67, and 37.33 percent of flat, gentle, and steep slope farm plot owner HHs did not adopt physical SWC practices. These indicate that respondent HHs who own gentle or steep slope farm plots adopted physical SWC practices because these types of plots are prone to soil erosion problems. The X^2-

test result shows that, there is a statistically significant difference between adopters and non-adopters of physical SWC practices in terms of the slope of the farm plot. From this result, we can conclude that gentles or steeps slope plots have a positive relationship with the adoption of physical SWC practices.

HHs those who are members in different local organizations are assumed to have more access to information and better interpret and use the available information related to new technologies. As presented in Table 5, from the total 121(80.67%) member HHs, 61(50.41%) were adopters, whereas 60(49.59%) are non-adopters. The X^2-test result shows that, there is insignificant difference between adopters and non-adopters in terms of membership in different local organizations.

Training is essential to fill knowledge and information gaps. Both governmental and non-governmental organizations have provided training for DAs and HHs concerning natural resource conservation through field visits, workshops, and experience sharing. The involvement of HHs in conservation-related pieces of training has importance for the adoption of physical SWC practices. As a result in Table 5 showed 121(80.67%) of the respondent HHs got training on SWC practices; whereas, 29(19.33%) of respondents did not get training on SWC practices. Out of the trained respondent HHs, 68(56.20%) were adopters, while 53(43.80%) were non-adopters. The X^2-test result shows that, there is a statistically significant difference between adopters and non-adopters in terms of training on SWC practices.

Table 5
Descriptive statistics results of dummy and categorical variables

Variables	Categories	Adoption of Physical SWCPs				χ2-value
		Adopter (n = 71)		Non-adopter (n = 79)		
		Freq.	%	Freq.	%	
Sex of HH	Male	62	50.41	61	49.59	2.59
	Female	9	33.33	18	66.67	
Off-farm activities	Yes	18	36.73	31	63.27	3.28*
	No	53	52.48	48	47.52	
Perception of Soil Erosion problem	Yes	30	73.02	33	26.98	28.74***
	No	41	28.74	46	71.26	
Slope	Flat	2	7.69	24	92.31	23.61***
	Gentle	26	53.06	23	46.94	
	Steep	47	62.67	28	37.33	
Membership in local organizations	Yes	61	50.00	60	50.00	2.38
	No	10	34.48	19	65.52	
Training on SWC practices	Yes	68	56.20	53	43.80	19.73***
	No	3	10.34	26	89.66	
Note: *** and * showed 1% and 10% significance level						

Source: Own surveyed data of 2021

3.1.6. Descriptive statistics for continuous variables

As indicated in Table 6, the average age of HHs in the study area was 46.31 with a standard deviation of 9.96 of which, physical SWC practices adopters were 43.28 years, and non-adopters were 49.01 years. The result of t-test shows that there is statistically significant difference between adopters and non-adopters at a 1% significance level in terms of age of the HHs.

Education can influence the adoption of newly introduced technologies and innovations. Hence, educated HHs expected to be in better position to get and use information that contributes to adopting physical SWC practices. As presented in Table 6, the average educational level in schooling years of adopter HHs were 7.80 years with a standard deviation of 1.73 whereas non-adopter, HHs was 4.84 years with a standard deviation of 2.01. The t-test result indicated that, there was a statistically significant mean difference between adopters and non-adopters at a 1% in terms of the education level of the HHs in the study area. That means adopters have a higher level of education compared to non-adopters.

To standardize the analysis number of livestock was converted to tropical livestock unit (TLU) as the conversion factors given in Appendix Table 1. The result in Table 6 shows the average livestock ownership of adopter HHs was 4.02, while 5.03 for the non-adopter HHs with standard deviations of 1.49 and 2.02, respectively. The t-test result indicated that the mean livestock holding difference between adopters and non-adopters was statistically significant at a 1% significance level. This show that there is a statistical mean difference between adopters and non-adopters in terms of livestock holding.

To compute family sizes, the standard conversion factor given in Appendix Table 2 used. The result of Table 6 showed that, the average family size of adopter HHs was 3.04 and non-adopter HHs was 2.06 with standard deviations of 0.75 and 0.83, respectively. The t-test result indicates that, there is a statistically family size mean difference between adopter and non-adopter HHs at a 1% significance level. That means there is a statistical mean difference between adopters and non-adopters in terms of family size. As presented in Table 6, the average plot size of adopter HHs was 3.60 ha with a standard deviation of 1.38 ha, while the average land allocation of non-adopters was 1.97 ha with a standard deviation of 1.15 ha. The t-test result indicated a statistical mean plot size difference between adopters and non-adopters of HHs at a 1% significance level. This show that larger plot sizes might lead to intensely adopt physical SWC practices.

The result in Table 6 showed that the average distance from homestead to the farm plot for adopter HHs was 18.27 walking minutes with a standard deviation of 9.03, while 20.55 walking minutes with a standard deviation of 12.34 for non-adopting HHs. Extension contact refers to the number of contacts respondent HHs made with DAs per month. Based on survey data as shown in Table 6, the average extension contacts of adopter HHs respondent made with DAs was 5.80 days, and non-adopters were 2.88 days with a standard deviation of 1.74 and 1.91, respectively. The t-test result indicated that statistical mean of extension contact difference between adopters and non-adopters of HHs at a 1% significance level.

Table 6
Descriptive statistics of continuous variables

Variables	Adoption of Physical SWC Practices				
	Adopter (n = 71)		Non-adopter (n =79)		t-test
	Mean	Std. Dev	Mean	Std. Dev	
Age of HH	43.60	9.64	49.01	9.59	3.45***
Education level of HH	7.80	1.73	4.84	2.01	-9.13***
Family Size	3.04	0.75	2.06	0.83	-7.39***
Total livestock (TLU)	4.02	1.49	5.03	2.02	2.85***
Plot Size (ha)	3.60	1.38	1.97	1.15	-7.20***
Distance (Min)	18.27	9.03	20.55	12.40	1.24
Number of extension contact	5.80	1.74	2.88	1.91	-9.18***
Note: *** showed 1% significance level					

Source: Own surveyed data of 2021

3.2. Result of econometric models

Double hurdle model was used to estimate the determinants of adoption and intensity adoption of physical SWC practices. Accordingly, explanatory variables were checked for problems of multicollinearity, and heteroscedasticity. Following Gujarati, 1995 the problem of multicollinearity for continuous explanatory variables was investigated using a technique of variance inflation factor (VIF). The values of VIF were less than ten. As a result, there is no serious problem of multicollinearity.

To observe the degree of association between dummy explanatory variables contingency coefficient was computed. Contingency coefficient is a chi-square-based measure of association, where a value of 0.75 or above indicates a stronger relationship between explanatory variables (Healy, 1984). It was checked, and it is less than 0.75. To avoid heteroscedasticity robust standard error is estimated. Log-likelihood test of Double hurdle versus Tobit model: $\Gamma = 233.198 > \chi 2\ (14) = 29.141$, the test statistics of Double hurdle versus Tobit model indicate the rejection of Tobit model. Therefore, Double hurdle is an appropriate model than Tobit model for this study. It shows that HHs on the adoption decision and intensity of adoption of physical SWC practices made in two separate stages.

3.2.1. Determinants of the adoption of physical SWC practices (First hurdle)

Sex of the household head: This variable influenced the probability adoption of physical SWC practices positively and significantly at a 5% significance level. The model result confirmed that the probability of being male HH increases, the adoption of physical SWC practices. Female HHs spent their time in domestic activities and responsibilities. Thus, they have no sufficient time to get extension services about SWC practices. In addition, male HHs have a higher chance to involve in SWC practices since constructing and maintaining physical SWC practices demand much labor. Consistent with this result, the studies by Solomon (2016), Daniel and Mulugeta (2017), Zewditu (2019) obtained that male HHs have a higher chance to involve in SWC practices since constructing and maintaining SWC practices demand much labor. This finding is opposing with previous studies by (Fikadu and Engdawork, 2019; Olawuiy and Mushunye, 2019).

Age of the household head: This variable affected the probability adoption of physical SWC practices negatively and significantly at a 1% significance level. The probit regression result confirmed that, as the age of HHs increases, the acceptance level of HHs about the introduced physical SWC practices decreased. This implies that younger HHs expended more effort on physical SWC practices relative to older ones. Therefore, younger HHs have the willingness to adopt the introduced physical SWC practices compared to older HHs. This result was similar to the studies by Aneley *et al.* (2007), Daniel and Mulugeta (2017), and Mountain and Park (2018). They reported that HHs with younger age have a higher ability to adopt SWC practices. However, this finding is contrary to the results by Fikru (2009), Nelson *et al.* (2017), Olawuiy and Mushunye (2019), and Mehariw (2020) that verified, age of HHs positively influence the adoption of SWC practices.

The education level of household head: This variable influenced the probability adoption of physical SWC practices positively and significantly at a 1% significant level. The model result confirmed that, as HHs get a better education level, their attitude towards the probability adoption of physical SWC practice increased. These implied that HHs with relatively better education levels are more likely to adopt physical SWC practices, and they can anticipate the consequences of soil erosion problems than others. This result is in line with the studies of (Fikru, 2009; Melkie, 2016; Daniel and Mulugeta, 2017; Belete, 2017; Muluken et al., 2020; kalkidan, 2021), which stated that a better education level of HHs has a positive relationship with the adoption of SWC practices. This finding is inconsistent with the previous study of Asnake *et al*. (2018).

Household heads perception about soil erosion problems: The model result in Table 7 showed this variable affected the probability adoption of physical SWC practices positively and significantly at a 5% significance level. The Double hurdle model result indicated that as HHs perceived their plots are prone to soil erosion problems, they like more to adopt physical SWC practices than those who did not perceive soil erosion problems. Therefore, better awareness of HHs about soil erosion problems contributes to the sustainable use of the introduced SWC practices. This result is in line with the studies by (Zewditu, 2019; Million *et al*., 2019), which argued that the perception of HHs on soil erosion problems increases the probability adoption of SWC practices.

Number of extension contacts: This variable positively and significantly influenced the adoption of physical SWC practices at a 5% level of significance. The model result revealed that an increase in the frequency of extension contact increases the probability adoption of physical SWC practices. This implies that HHs who have close contact with extension agents can develop awareness and understanding of the soil erosion problem and become encouraged to adopt physical SWC practices. This finding is similar to studies by Aneley *et al*. (2007), Zewditu (2019), and Muluken et al. (2020) that state extension services have a positive effect on SWC practice.

Training on SWC practices: This variable affected the probability adoption of physical SWC practices positively and significantly at a 10% significance level. The probit model result showed that HHs participation in training related to SWC practice increases the adoption of physical SWC practices. These implied that HHs who take training acquire adequate and recent information and technical support about the implementation and relevance of SWC practices. Therefore, they improve their awareness of the participation of physical SWC practices and facilitate the uses of conservation measures. This result is in line with the findings of Addisu *et al*. (2015), Belete (2017), Birtukan *et al*. (2020), and Temitope et al. (2021). They reported that access to training has a positive relationship with the adoption of SWC practices. However, this result contradicts a finding of (Fikru, 2009) which stated that training on SWC practice negatively affects the probability adoption of soil or stone bund and tree plantations.

Family size: As regression results in Table 7 indicated, this variable influenced the probability adoption of physical SWC practices positively and significantly at a 5% significance level. The Probit model result confirmed that HHs with larger family sizes are more like to adopt physical SWC practices compared to the others. It implies that larger families have a better labor force to construct labor-intensive SWC practices, which are more labor demanding than biological measures. This study agreed with the findings of Adissu *et al*. (2015), Belete (2017), Asnake *et al*. (2018), Agere *et al*. (2020), Mehariw (2020), Gizachew and Birhanu (2021), and Temitope et al. (2021). They confirmed that a large family size could provide the required labor for constructing and maintaining conservation practices.

3.2.2. Determinants of the intensity adoption of physical SWC practices (Second Hurdle)

The second hurdle of the Double hurdle model measured the intensity adoption of physical SWC practices among adopting HHs. The intensity adoption of physical SWC practice is significantly affected by four explanatory variables. As shown in Table 9, the result of the second hurdle indicates that variables such as; plot size, steep slope, training, and number of extension contact are the significant factors that affect the intensity adoption of physical SWC practices.

Plot size: As result in Table 9 indicated, this variable affected the intensity adoption of physical SWC practices positive and significantly at a 5% significance level, which implies that an increase in plot size leads to an increase in the intensity adoption of physical SWC practices. The computed result indicated that a unit increase in plot size increases the intensity adoption of physical SWC practices by 1.17 percent. The HHs that allocated large plot size has more opportunities to control soil erosion by covering their land by physical SWC practices than those who own less plot size. This finding is congruent with previous studies conducted by (Aneley *et al.*, 2007; Olawuyi and Mushanji, 2019; Eyerusalem, 2017; Amsalu and Alebachew, 2020).

Slope of the plot: The probability of steep slope plot affected the intensity adoption of physical SWC practices positively and significantly at a 1% significance level. The model result indicated that HHs having steep slope plots increases their intensity adoption of physical SWC practices by 18.93 percent respectively. This implies that, as the HHs plot inclines, the implementation of SWC practices is very intense to respond to the urgent soil erosion problems. Hence, steeper slopes increase the intensity of adopting physical SWC practices. The result is in line with the studies by (Berhanu and Scott, 2003; Aneley *et al.*, 2007; Mengistu, 2012; Eyerusalem, 2017) argued that slope of the plot is one of the factors that significantly influence the intensity adoption of conservation practices.

Training on SWC practices: This variable is positively and significantly affects the intensity adoption of physical SWC practices at a 1% significance level. The model result indicates that HHs who participates in training are more likely to apply a significant amount of land to physical SWC practices than those HHs who did not participate. Compared to HHs who did not participate in training, the intensity adoption of physical SWC practices increased, by 5.4 percent for HHs who participates in training. This result is similar with studies of (Tesfaye, 2017; Fikadu and Engdawork, 2019) which argued that training influences the intensity adoption of agricultural technology positively.

Number of extension contact: This variable influenced the intensity adoption of physical SWC practices positively and significantly at a 1% significance level. The truncated model result confirmed that as the number of extension contact increases, the intensity adoption of physical SWC practices increased by 3.4 percent. This implies that frequent contact with development agents has the better technical skill to manipulate the introduced physical SWC practices. The HHs who have more contact with extension workers would acquire more information related to the benefit of SWC, the techniques of implementation, and maintenance. Also, it increases the probability of developing up-to-date information on the new agricultural technologies. This finding is in line with the research result reported by Aneley *et al.* (2007), Eyerusalem (2017), Fikadu and Engdawork (2019), and Amsalu and Alebachew (2020).

Table 7
Cragg’s Double hurdle model results

Variables	First hurdle (Adoption)		Second hurdle (Intensity)	
	Coef.	Std. Err.	Coef.	Std. Err.
Sex of the HH	0.76**	0.353	0.87	1.501
Age of the HH	-0.07***	0.022	0.02	0.049
Education level of HH	0.31***	0.088	0.38	0.536
Family size	0.51**	0.21	-0.198	0.817
Distance from home to the farm plot	0.01	0.015	-0.06	0.052
Plot size	-0.08	0.193	1.17**	0.512
Steep slope	0.24	0.422	18.9***	2.824
Perception of soil erosion	0.79**	0.329	1.60	1.103
Training on SWC practices	1.00*	0.523	5.37***	1.869
Number of extension contact	0.25**	0.105	3.424***	0.635
Off-farm activity participation	-0.23	0.338	-0.13	0.879
Membership to local organization	-0.43	0.33		
Livestock owenership	-1.00	0.091		
Constant	-2.686	1.429	10.14	5.12
Number of obs. =150 Wald $Chi^2(14)$ = 80.62 P > Chi^2 = 0.0000 Log likelihood = -37.011 Pseudo R^2= 0.6433			Limit: lower = 0 Upper = +inf Number of obs = 71 Wald Chi^2 (12) = 873.05 Log likelihood = -204.059 Prob > chi2 =0.0000	
Note: *, **and*** significant level at 10%, 5%, and 1% respectively				

Source: Own estimation result of 2021

4. Conclusions

The study identifies the determinants of the adoption and intensity adoption of physical SWC practices in Goromti watershed Ambo Woreda of Oromia region, Ethiopia with the specific objectives of identifying factors affecting adoption and intensity adoption of physical SWC practices in the study area. The analysis was made using descriptive statistics like chi-square and t-tests to compare the variables with HHs adoption decision on physical SWC practices and econometric analysis by Double hurdle model to analyze the factors that affect the probability of adoption and intensity adoption of physical SWC practice. The first stage of Double hurdle model analysis indicated that sex, age, education level, frequency of extension contact, perception of soil erosion problem, family size, and training significantly determine the adoption of physical SWC practices in the study area. The second stage of Double hurdle model indicates that plot size, gentle slope, steep slope, training, and frequency of extension contact significantly determine the intensity adoption of physical SWC practices. In general, the study concluded that the adoption and intensity adoption of physical SWC practices were driven by a host of demographic, physical, socio-economic, and institutional factors. Hence, it is believed that these findings will be an important achievement for future research and policy formulation in Ethiopia as it provides first-hand information about factors affecting the adoption and intensity adoption of physical SWC practices in the study area.

List Of Abbreviations

AGRA	Alliance Green Revolution in Africa
AWANRO	Ambo Woreda Agricultural and Natural Resource Office
CSA	Central Statistical Agency
EPRDF	Ethiopian People Republic Democratic Front
FAO	Food and Agricultural Organization of the United Nations
FFW	Food-for-Work Program
GDP	Gross Domestic Product
GIS	Geographical Information System
GoE	Government of Ethiopia
MM	Millimetre
M.a.s.l	Mean Above Sea level
MLE	Maximum Likelihood Estimation
MoA	Ministry of Agriculture
SLM	Stainable Land Management
SPSS	Statistical Package for Social Sciences
SRCCL	Statistical Report on Climate Change and Land
SWC	Soil and Water Conservation Practices
TLU	Tropical Livestock Unit
UNCCD	United Nations Convention to Combat Desertification
WFP	World Food Program
WOCAT	World Overview of Conservation Approaches and Technologies

Declarations

Competing interests: There is no competing interest to this manuscript

Authors' contribution: co-authors for this manuscript contributed advisory service for the thesis during thesis work

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Authors' Declaration

I declare that this thesis is my own work. I have followed all ethical and technical principles of scholars in the preparation, data collection, data analysis and compilation of the Thesis. Any scholarly matter that is included in the Thesis has been recognition through citation.

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the Degree of Master of Science (M.Sc.), In Watershed Management and Soil and Water Conservation Bahir dar University, Bahir Dar.

Tables

Tables 2 and 8-9 are not available with this version

Appendix

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Figures

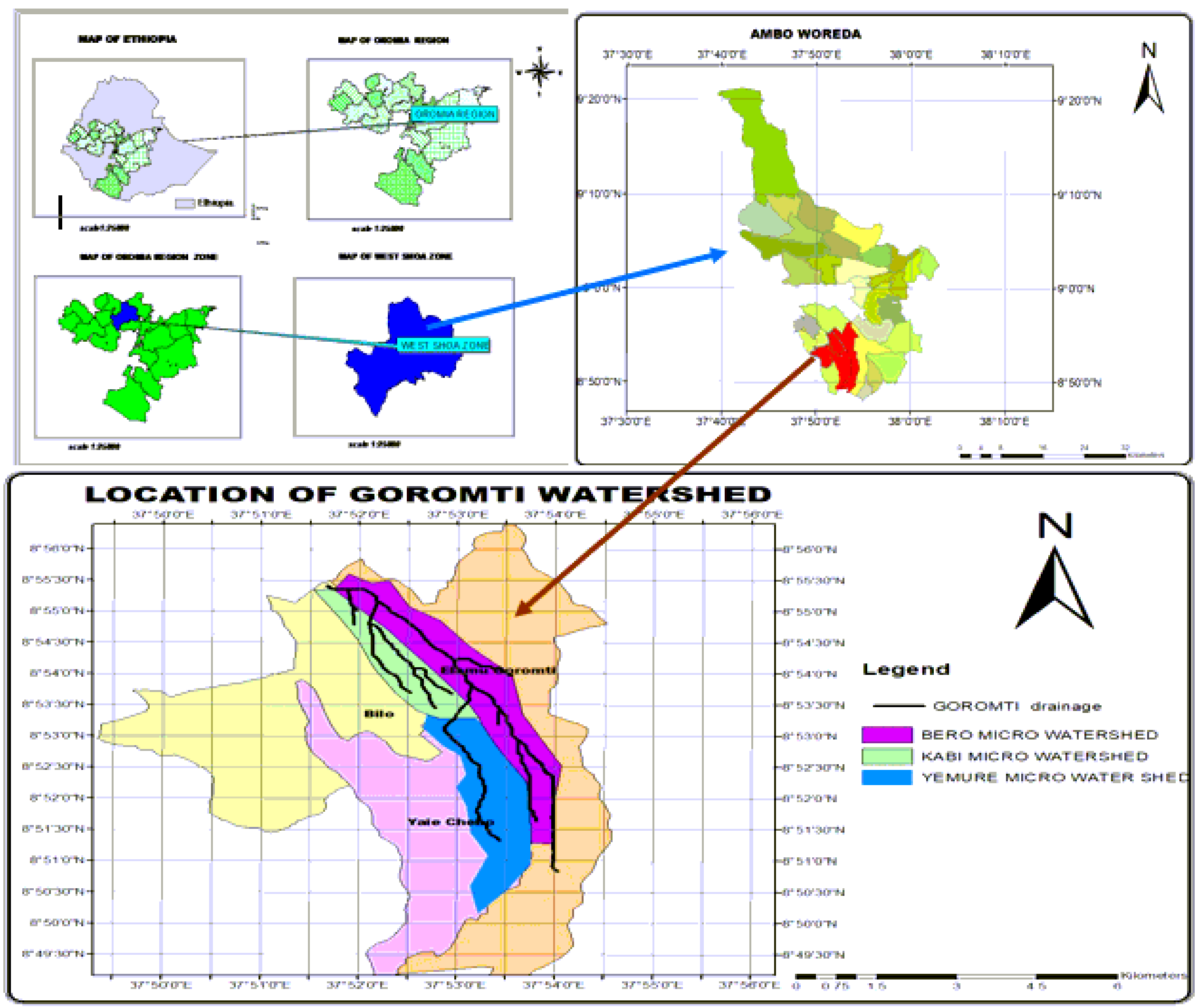

Figure 1

Map of the study area

Source: Sketch from GIS, 2021

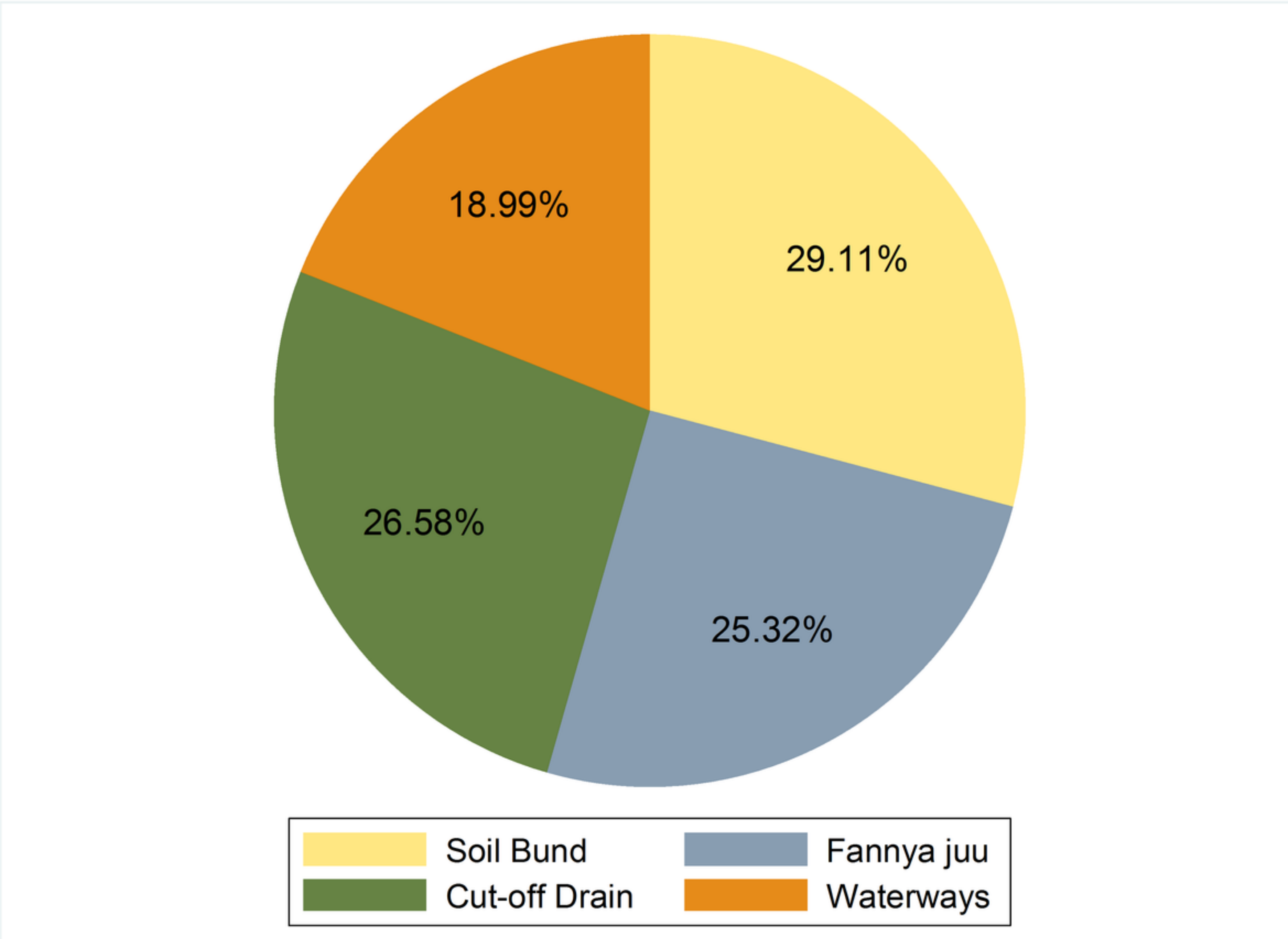

Figure 2

Types of physical SWC practices adopted in the study area

Source: Own surveyed data of 2021

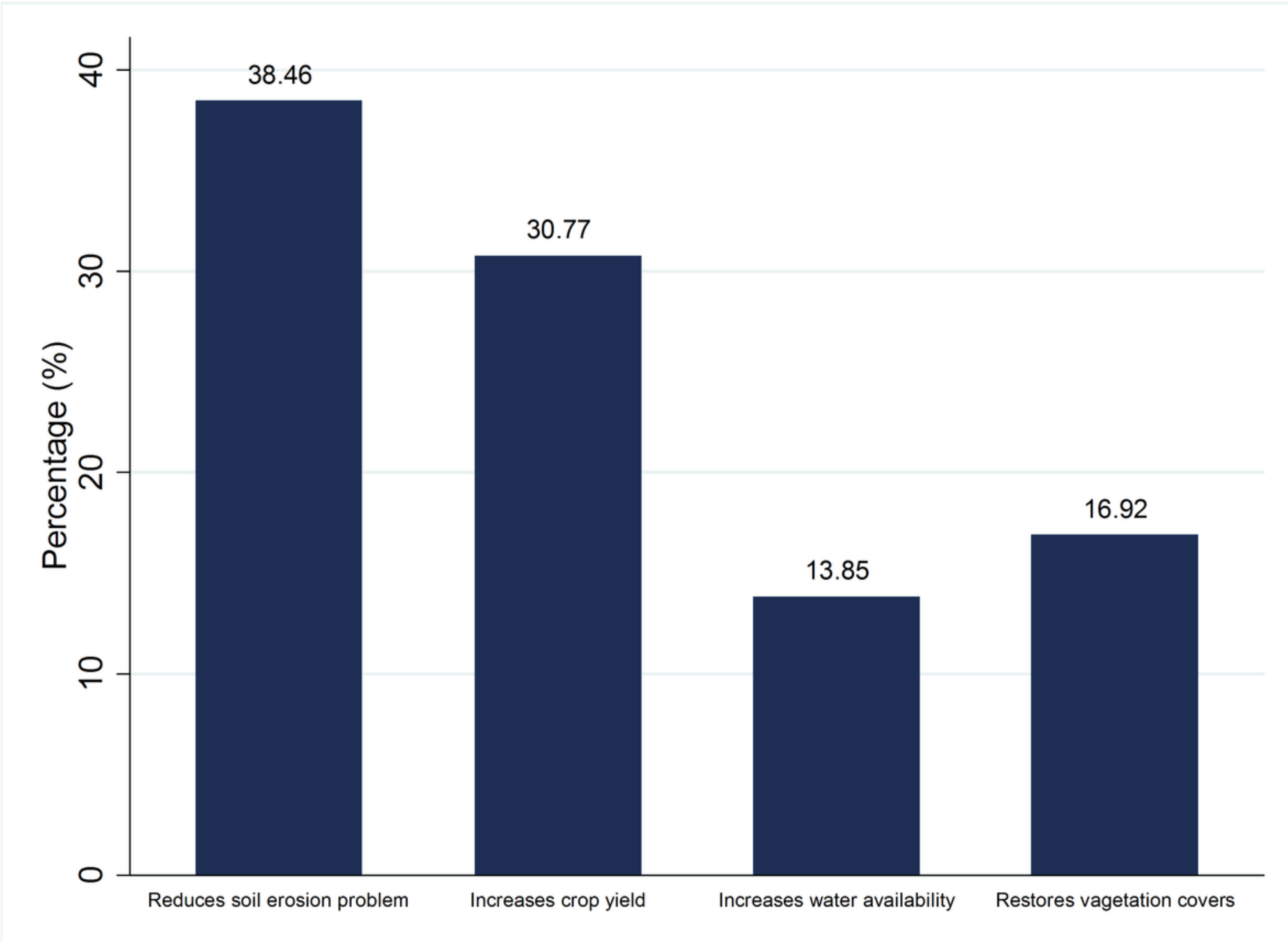

Figure 3

The advantages obtained from adopting physical SWC practices

Source: Own surveyed result 2021