EFFECT OF SOIL BUND ON SELECTED SOIL PROPERTIES AND ASSESSING FARMERS´ ADOPTION OF PHYSICAL SOIL AND WATER CONSERVATION TECHNOLOGIES; A CASE STUDY OF FANTA WATERSHED GENA BOSSA WOREDA, SOUTHERN ETHIOPIA

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In Partial Fulfillment of the Requirements for the Degree of Masters of Science in Soil and Water Conservation Engineering

By

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We, the undersigned, members of the Board of Examiners of the final open defense by **WONDIMU BEKELE GOBA** have read and evaluated his/her thesis entitled **"Effect of Soil Bund on Selected Soil properties and Assessing Farmers' Adoption of Physical SWC technologies*;* A Case Study of Fanta Watershed Gena Bossa District, Southern Ethiopia."**, and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the MSc degree in SWC Engineering.

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Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the School of Graduate Studies (SGS) through the School Graduate Committee (DGC/SGC) of the candidate's department.

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Abstract

Land degradation is one of the major challenges in agricultural production in Ethiopia. To combat the problem various Soil and Water Conservation (SWC) measures were introduced in the country. Soil nutrients assessment is valuable for evaluating agro-ecosystem sustainability, soil degradation and identifying land management practices. This research aimed i) to evaluate the effect of soil bunds on selected soil properties (soil texture, soil organic carbon, phosphorus, potassium and nitrogen); ii) to assess the adoption of farmers and factors influencing physical soil and water conservation (SWC) technologies in the Fanta watershed. Twenty-seven soil samples at 3 slope positions were collected from soil bund and 9 soil samples at 3 slope positions were collected from no bund plots. Samples were taken at 0-20 cm, depth. Analyses were done for soil texture, soil organic carbon (SOC), available phosphorous (AP), available potassium (AK) and total nitrogen (TN). In addition, 128 households were selected from three kebeles for interview to evaluate soil and water conservation (SWC) measures adoption. The results showed that SOC, AP, and AK were significantly ($p \leq 0.05$) increased and decreased by the soil bunds and slope positions. Sand and clay fractions significantly varied with both soil bunds and slope gradient but silt and TN, was not significantly differed in no-bund plots within its slope and adjacent conserved plots. The highest values of most parameters were recorded in lower slope positions both in bund and no-bund plots and near soil bund at upslope side. Farmers differ in their willingness and ability to adopt new practices. Adoption of physical SWC was negatively correlated to age of head of household, family size, farm size, plot numbers and livestock numbers while education level, location of land, extension service and access to training were positively and significant difference. Thus, it can be concluded that soil bunds retain essential plant nutrients but its adoption was limited due to some socio-economic factors in the Fanta watershed. Therefore, Structures were not regularly maintained thus, there should be a continuous awareness creation mechanism on stakeholders and prevent cropland from open grazing. In addition, emphasis should be required on variables which negatively affecting adoption of physical soil and water conservation technologies.

Keywords: Soil Erosion, Soil Fertility, Soil and Water Conservation sustainability.

Acronyms

CSA	Census Statistics Agency
EEPFE	Environmental Economics Policy Forum for Ethiopia
FAO	Food and Agricultural Organization of United nations
FFW	Food For Work
GBDANRDO	Gena Bossa District Agriculture and Natural Resource Development Office
GDP	Gross Domestic Product
HHs	Household Heads
IFPRI	International Food Policy Research Institute
MoARD	Ministry of Agriculture and Rural Development
NGO	Non-Governmental Organization
PAs	Peasant Association
PSNP	Productive Safe Net Program
SCRP	Soil Conservation Research Project
SIDA	Swedish International Development Co-operation Agency
SLM	Sustainable Land Management
SNNPR	South Nation Nationalities and Peoples Regional State
SOM/C	Soil Organic Matter/Carbon
SSA	Sub-Sahara Africa
SWC	Soil and Water Conservation
UNCCD	United Nations Convention to Combat Desertification
WFP	World Food Program

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1. INTRODUCTION

1.1 Back Ground

Land degradation caused by soil erosion remains one of the environmental problems worldwide, threatening both developed and developing countries and it has been a major global agenda because of its adverse impact on environment and food security and the quality of life (Slegers, 2008). At global scale, an estimate to about 1960 million hectares of land are prone to erosion, which represents about 15% of the earth's total land area, of which 50% is severely eroded, and much of that is being abandoned (Lal *et al*., 2004).

Estimates in sub-Sahara Africa (SSA) show that 320 million hectares of land were affected by human induced soil degradation and this is estimated to cause a damage of US $26 billion annually on the continent (Lal, 1994). Tenywa and Bekunda, (2008) report that the underlying cause of land degradation is as a result of the destructive, over-exploitation and inadequate conservation of soil and water resources. This has continued to threaten agricultural productivity, biodiversity and water quality Scherr and Yadav, (1995) as well as the livelihoods of the poor, of whom 90% depend on the natural environment for their survival World Bank, (2008). Land degradation and consequent decline in soil fertility has become a serious threat to agricultural productivity in SSA (Smaling and Storvogel, 1990).

Land degradation in Ethiopia is also exacerbated by soil nutrient depletion arising from continuous cropping together with removal of crop residues, low external inputs and absence of adequate soil nutrient saving and recycling technologies (Bojo and Cassels, 1995). Bekele and Drake, (2003) described Ethiopia is the most seriously affected soil erosion area in the world. Both wind and water erosion selectively have removed the fine organic particles in the soil and left behind large particles and stone. In Ethiopia soil, erosion by water significantly contributes to food insecurity among rural households and poses a real threat to the sustainability of existing subsistence agriculture (Haile *et al.*, 2006). In addition, the Ethiopian highlands have been experiencing declining soil fertility and severe soil erosion due to intensive farming on steep and fragile land (Aklilu Amsalu, 2006). Although land provides a means of livelihood, farmers poorly invest in protecting the land, which resulted in increased land resources degradation mainly due to erosion (FAO, 1986). Land degradation in the form of soil erosion, soil fertility depletion, deforestation through clearance for cultivation and overgrazing is among the basic problems facing farmers in the Ethiopian highlands. Land degradation reduces soil fertility of farmlands and limits its ability to increase crop production and reduce poverty and food insecurity. Soil fertility decline and soil moisture stress is well recognized as crop production problem in the study area. Fertilizer application alone has limited impact when moisture is limiting and soil is eroding (Brady and Weil, 2002).

The government of Ethiopia has made several interventions like mass mobilization on soil and water conservation campaigns that have resulted in terraces, soil bunds, area closures, and planted with millions of tree seedlings. Nevertheless, the country still loses tremendous amount of fertile topsoil, and the threat of land degradation is broadening alarmingly (Teklu and Gezahegn, 2003). Soil conservation work in Ethiopia has been closely associated with food for- work (FFW) since the Wello drought of 1972-74 when world food program (WFP) provided food as an incentive for participation in communal labour (SIDA, 1987). Therefore, soil and water conservation (SWC) practices are increasing food production without further depleting soil and water resources, adding high amounts of biomass to the soil, causing minimal soil disturbance, conserving soil and water, restoring soil fertility, and increasing the resilience of farming systems to climatic risk (FAO, 2009). The soil conservation measures adapted well to the local conditions and protected the soil from being eroded. Eleni, (2008) also indicated that introduced SWC measures, fanya-juu and soil bunds, were widely acknowledged as being effective measures in arresting soil erosion and having the potential to improve land productivity.

The structures are designed to intercept and reduce runoff velocity, pond and store runoff water, convey runoff at non-erosive velocities. It traps sediment and nutrients, promote formation of natural terraces over time, protect the land from erosion, improve water quality, enhance biodiversity of downstream water, prevent flooding of neighboring lands, reduce sedimentation of waterways, streams and rivers, improve land productivity and provide diverse ecosystem services (Blanco and Lal, 2008). Belay, (1992) observed that the greater the bank height (i.e. the height of the structures along the riser slope) the better the terrace development, lie also pointed out that the bank height is increased tremendously and the structural slope reduced considerably from the very beginning of the construction. Generally, the soils above the bunds receive more moisture and fertile soil materials and are more productive than the other segments of the interstructural positions of the slope. Therefore, SWC can change the physical conditions of the soil like soil organic matter content, soil structure, water holding capacity, soil bulk density, soil porosity, soil pH and its workability (Gete, 2000). Degraded soils has to be controlled by different conservation structures, it improve soil physical properties such as structure, aggregate formation and stability, and porosity, which, in turn, increase AWC and reduce soil erodibility and susceptibility to crusting and compaction (Hudson, 1994). It also improves soil chemical properties including CEC, thereby enhancing the retention of essential crop nutrients such as N, P, and other macro and micronutrients by reducing losses through leaching and volatilization (Daniel, 2015**)**. Physical and biological soil conservation measures and soil fertility improvement activities implemented in Wolaita conserved the soil and improved soil fertility (Safene *et al.,* 2006).

Despite its benefits, in Ethiopia, soil conservation has been carried out with limited success. There is less-willingness to accept and maintain the extensively introduced practices of soil conservation. Ervin, (1982) declared that farmers' perception positively affects the adoption and efforts of soil conservation. Farmers' perception to use soil conservation measures, especially in low income countries, can be influenced by a complex set of socio-economic, demographic, technical, institutional and biophysical factors (Fender *et al.*, 1985). Various studies Ervin, (1982); Bekele and Holden, (1998) have identified the factors that affect farmers' adoption of practices that control erosion and enhance long-term production and productivity. To reduce rural poverty and maintain food security, soil fertility need to be maintained, agricultural systems need to be transformed to increase the productive capacity and stability of smallholder crop production. Greater attention is thus being given to alternative means of intensification, particularly the adoption of soil and water conservation practices cited in (Mulugeta, 2014).

In Fanta, watershed land degradation is serious because of densely population coupled with rugged and rolling topography, making the area vulnerable to soil degradation. In addition, land fragmentation and having small farm size per household in the study area has forced the farmers to conduct continuous cultivation which reduced fallow period. Similarly, many farmers subjected to continuous cultivation of steeply slope lands without any adequate soil fertility amendments and soil and water conservation measures. Recently, the problem in the study area was clearly observed as much of the extensively grazing cultivated lands. The productive safety net program (PSNP) was launched in 2005 Gena Bossa District Agriculture and Natural Resource Office (GBDANRO, 2010). Stone bund, soil bunds, fanya juu, cut off drain; area closure and plantation have been the major program activities on the watershed. In the study area in relatively SWC, measures have achieved considerable success in coverage. However, a part from monitoring and evaluation reports, no substantive studies made on their performances of improving soil properties so far. Hence, it is valuable to assess adoption and factors affecting adoption of physical SWC measures and to assess the effects of soil bunds on selected soil properties. Thus, the main objective of this study was to evaluate the effects of soil bunds on selected macronutrients and assess farmers´ adoption and factors influencing adoption of physical SWC measures in study area.

1.2 Statement of the Problem

Ethiopia is a relatively large country with a variety of soil types and climatic conditions. It has abundant water resources, diversified flora and fauna, and substantial underground resources. Yet, the standards of living of the people remain at a dismal level. Moreover, studies show there is substantial mismanagement of our natural resources in the form of over utilization of soils (Dessalegn and Taye, 2006). Soil erosion is one of the major threat for soil quality and thereby had detrimental effects on productivity and soil nutrients since the majority of soil nutrients and soil organic matter are stored in the topsoil that is most affected by erosion. The consequences of runoff and erosion are the impairment of the quality and productivity of the land.

In the study area, the combined effects of deforestation, overgrazing, cultivation on steep slopes without implementing adequate physical soil and water conservation practices and integrating biological measures have resulted in severe land degradation. This is mainly due to the increase in population pressure and ever-rising demand for food forcing the rural community to cultivate more erosion prone lands. During the rainy season, the soil is washed away by runoff in areas where soil and water conservation measures are not implemented. In the area under study, soil fertility problems relate with poor crop cultivation practices including cultivation on steep slopes, removal of crop residues and overgrazing. Runoff and erosion takes place in the study area in which slope steepness is the dominant factor where the water removes the finer soil particles including soil organic matter and plant nutrients thus adversely affecting the soil physicochemical properties and crop productivity. All these factors reduce to soil fertility which is not adequately redressed through fertilizer application and agronomic measures.

There are several techniques sensitized by the government to prevent soil erosion in different parts of the study area, which are from 2005 largely driven by productive safety net program (PSNP). However, soil loss remains a critical shortcoming, mainly due to low adoption levels and much of the extensive grazing on cultivation lands. Lack of awareness for high loss of soil fertility is believed to be one reason for limited adoption of soil and water conservation measures.

1.3 Objectives

1.3.1 The general objective

To evaluate the effects of soil bund on selected soil properties and assessing the adoption of farmers on physical Soil and Water Conservation measures.

1.3.2 The specific objectives were:

- To evaluate the effect of soil bunds on selected soil properties (Soil Organic Carbon, Nitrogen, Phosphorus, Potassium and textures) of soil when compared with no bund adjacent fields and in between bunds in different slope locations.
- To assess the farmers´ adoption of physical soil and water conservation technologies.
- To assess factors that influence adoption of physical soil and water conservation measures in the study area.

1.4 Research hypotheses

The hypotheses tested in this study were:

a) The soil bund improves soil physical and chemical properties.

b) Slope gradients affect effectiveness of soil bund.

c) The different variables of socioeconomic and physical characteristics of house hold heads affects the adoption of physical soil and water conservation technologies.

1.5 Research Questions

1) What is the effect of soil bund on selected soil properties?

2) Is there a difference between conserved farm plots and non-conserved farm plots in terms of the selected soil properties?

3) What are the farmer’s adoption on physical SWC structures and factors affecting adoption of introduced physical SWC?

1.6 Significance of the study

The study aims at assessing the variability of soil properties between the conserved farm plot and non-conserved area. Soil fertility decline is well-recognized as crop production problem in the study area. Fertilizer application alone has limited impact when soil is eroding (Brady and Weil, 2002). The outcome will benefit farmers, through supporting the adoption of SWC practices, restore degraded land, and improve soil fertility and potentially leading them to higher yields. It will provide important inputs to policy makers and insights into soil management options and livelihood strategies for farmers. It is also believed that, this study will inform and assist government agencies, extension workers, researchers, planners, and NGOs, which support sustainable land management project (SLM), and productive safety net program (PSNP). To have an insight on the implication of the ongoing SWC practices to inform them about the positive implication of SWC practices on soil nutrient and identifying factors affecting adoption of SWC practices. It will also make bridge on knowledge gaps that hinder further expansion of SWC practices. Planners working on agriculture and natural resource management will also use to it. It can create awareness for households that how SWC practices are the corner stone to improve available soil nutrient thus raise crop yield. Furthermore, this study will be used as a source material for further studies.

1.7 Scope of the study

Since it is not possible to cover the whole aspects of the study area with the available time and resources, it is advisable to limit the study size and the scope of the problem to a manageable size. Hence, the study focused on the representative sites in Fanta watershed Gena Bossa woreda. It also tried to see the selected soil properties with the difference between the conserved farm plots and the non-conserved farm plots with the catchment. It also assessed the farmers’ adoption and factors influencing of physical SWC measures on the cultivation land.

1.8 Limitation of the study

Ignoring the effect of other factors, this paper assumes that conservation with structure play a major role in enhancing soil properties. However, the truth is that soil fertility can be maintained because of combined factors, not because of soil bund alone. Because of the constraints of time and budget, the researcher does not think that enough number of soil samples is taken for making comparisons between soil parameters of conserved and non-conserved farm plots with the different land use and different age of the soil bunds with different slope range and soil depth.

1.9 Organization of the thesis

This thesis is structured in five chapters. The paper tries to address what expectation to achieve by the end of the study. The first chapter includes introduction, problems, objectives, research question, significance, scope, and limitation of the study. Chapter two includes the literature review, which related to practices and challenges of soil and water conservations and their adoption to conserve soils and water were dealt in depth. Chapter three that presents the study area and issues related to climate, geology, population, socio-economic etc. situation of the study area and methodologies used to collection of the data, sampling techniques and in the analysis of data for the study. Chapter four includes the results and discussion of the study based on the results of laboratory and questioners of determined sampled size. Chapter five presents the conclusions and recommendation of the study based on finding of the research.

2. LITERATURE REVIEW

2.1 The Concept of Soil Fertility

Soil is the most fundamental resource on which the production of food, feed, fuel, and fiber depends. Humans cannot survive without soil because it is the basis of all terrestrial life. It underpins food security and environmental quality, both essential to human existence. Essentiality of soil to human well-being is often not realized until the production of food drops or is jeopardized when the soil is severely eroded or degraded to the level that it loses its inherent resilience (Blanco and Lal, 2008).

Soil fertility can be defined as the nutrient supplying ability of the soil, which is the ability of a soil to sustain plant growth, i.e. to provide plant habitat and result in lasting constant yields of high quality (Follet *et al.,* 1987). Although the term soil fertility is normally confused with soil productivity, there is a clear-cut difference between the two, in that soil productivity is the soil's ability to produce a crop. Productivity is a function of a soil's natural fertility and nutrients added as fertilizer, organic residue and other sources; soil physical and biological properties; climate; management and other non-inherent factors used to produce crops (Follet and Wilkinson, 1985). Soil fertility is mainly related to top soil characteristics. Soil fertility largely depends on soil organic matter content, which besides supplying nutrients, ensures good physical conditions necessary for water infiltration, supply of soil moisture, aeration and plant root development. Organic matter is important for maintaining soil structure and maximizing nutrient retention. A fertile soil is rich in nutrients necessary for basic plant nutrition, including nitrogen, phosphorus and potassium (Blanco and Lal, 2008). Soil organic matter is a major reservoir of soil nutrients. Availability of water and nutrients for plant uptake, stability of soil aggregates, water infiltration rate, moisture holding capacity and activities of soil microorganisms are strongly influenced by soil organic matter (FAO, 2005). Therefore, variation of soil organic matter content across a given spatial area can have a significant influence on soil fertility status, and then on crop yield performance. Nitrogen is one of the soil nutrients that are required by plants in large amount. Differences in the nitrogen content of a soil, therefore, can have a strong impact on the productivity of crops in general and on the productivity of highly nitrogen demanding crops, such as maize, in particular (Hall, 2008). Available phosphorus is derived both from inorganic (rock minerals) and organic sources (Lal, 2006). Higher soil erosion and soil nutrient mining could be the other possible causes. Soil fertility is rich in nutrients necessary for basic plant nutrition, including nitrogen, phosphorus and potassium. It contains sufficient minerals (trace elements) for plant nutrition, including boron, chlorine, cobalt, copper, iron, manganese, magnesium, molybdenum, sulfur, and zinc (Blanco and Lal, 2008).

2.2. Soil Fertility Depletion

Soil fertility decline is used as a short term to refer to what is more precisely described as deterioration in soil physical, chemical and biological properties. Soil fertility decline is a major effect of erosion, the term is used here of cover effects of processes other than erosion (Stoorvogel and Smaling, 1990). Soil fertility decline is the major environmental challenge that threatens agricultural productivity and the livelihoods of millions of rural households in Ethiopia (Mitiku *et al*., 2007). When the overgrazing of livestock, land development or farming reduces the amount of forestation, erosion occurs at an accelerated rate. Because of human activity, soil erosion occurs at a much faster pace than soil formation. It occurs whenever the natural balances in the landscape are changed by human activity through misuse or overuse of soil. Degraded soils that result in poor or no production are also called problem soils. Topsoil depletion occurs when nutrient-rich organic topsoil, which takes hundreds to thousands of years to build up under natural conditions, is eroded of its original organic material (Bjonnes, 1997). Heavily degraded soils are incapable of supporting a large plant biomass because of low or depleted nutrients and soil organic matter (SOM).

Soil fertility depletion has major economic consequences, particularly in populated areas. Soil fertility depletion causes economic loss because of crop destruction and reduced crop productivity (Whitmore *et al.*, 1994). Continuous cropping of cereals, removal of crop residues, low levels of fertilizer usage and unbalanced application of nutrients can led to leaching, especially for N and K. Loss of nitrates (N), phosphates (P) and potash (K) from the soil in available form for plants results in stunted growth and low crop yields IFPRI, (2010). In terms of nutrient depletion, Haileslassie *et al*., (2005) estimated Ethiopia's nutrient rates of 122 kg N, 13 kg P and 82 kg K ha-1 yr-1. Similarly, Adimassu *et al*., (2012) estimated 47.8 kg N, 0.60 kg P_20_5, and 0.40 K_2O ha -1 yr-1 through soil erosion alone in the central highlands of Ethiopia. Because of both soil erosion and nutrient depletion, more than 30,000 ha of croplands are estimated to become out of production annually (Grepperud, 1996).

2.3. Soil Erosion in Ethiopia

Much of the world has been facing increasingly serious soil erosion of various degrees caused by both natural and human factors as well as its consequent environmental deterioration. The loss of soil through land degradation processes particularly by erosion is one of the most serious Environmental problems (Pimentel, 2006). Ethiopia is one of the Sub-Saharan Africa countries most severely affected by soil erosion. Soil erosion particularly by water erosion, is an important factor in both the long-term decline and the seasonal reduction in food crop production in Ethiopia (FAO, 1986). The removal of soil particles by the action of water is known as water erosion. One important feature of soil erosion by water is the selective removal of the finer and more fertile fraction of the soil (Michael & Murnaghan, 2000).

Soil erosion poses a serious threat to national and household food security Bekele and Holden, (1998) and therefore its management is essential for improving food security in seriously affected areas of Ethiopia (Awdenegest and Holden, 2006). Soil erosion is a severe problem in sloping areas, especially in the northern and central highlands where vegetation cover is very low and soils are already very shallow (Jabbar *et al*., 2000). Soil erosion mainly occurs in the highlands, which have erratic rainfall that generate erosive runoff. According to Oldeman *et al*., (1991) more than 50% of the northern Ethiopian highlands suffer from sheet and rill erosion. Consequently, more intensive farming and farming on steep slopes undermined soil fertility while increasing the incidence of soil loss from erosion (Woldeamlak, 2003).

Soil erosion has major ecological and economic consequences, particularly in populated areas. Soil erosion causes economic loss because of crop destruction and reduced crop productivity. Erosion also leads to shortened investment life of water management infrastructures, and greater flood frequency caused by sedimentation and dimensioned infiltration capacity of soil (Whitmore *et al*., 1994). Slope gradient is one of the important topographic factors that influence the process of drainage; runoff and soil erosion thereby affects physicochemical properties (Farmanullah, 2013). Soil loss would normally be expected to increase with increase in slope gradient, because of respective increase in velocity of surface runoff and decrease in infiltration rate (Luk *et al*., 1993). Amuyou and Kotingo, (2015) reported that slope gradients have marked influence in soil properties as expressed in the distribution in soils along slope positions. Usually in study area; soil erosions of sheet erosion (a more or less uniform removal of a thin layer of topsoil); rill erosion (small channels in the field); or gully erosion (large channels, similar to incised rivers) was seen.

2.4. SWC measures Implemented in Ethiopia

Soil and water conservation (SWC) measures are activities, which maintain or enhance the productive capacity of the soil through prevention or reduction of erosion, conservation of soil moisture, and maintenance or improvement of soil fertility. SWC measures reduce soil and land degradation whether it is caused by physical (winds, runoffs, soil sealing, etc.) or chemical (nutrient leaching, loss of organic matter, etc.) factors. If sustainably managed, the soil will ensure the provisioning of land and ecosystem services (UNCCD, 2012).

In Ethiopia, the problem of intolerable soil erosion and its adverse effects has been repeatedly reported for many watersheds. The traditional physical SWC measures, such as stone terraces, have been practiced in a few areas for several hundred years (e.g. Konso area) for which awareness and experience have been confined in that particular area. The structures having certain technical designs and specifications have been introduced to many new areas, assuming that land users can adopt it eventually. Since, the 1970s, pilot projects, campaign work, food for work programs (grain and edible oil support), etc. were initiated and are ongoing by both government and nongovernmental organizations (Berhe W/Aregay, 1997). A watershed treatment approach was adopted for the program and three major conservation activities were undertaken. These are: physical conservation measures on farm lands which included tied ridges, soil or stone bunds and various types of terraces; soil conservation on grazing land which combined area closure and re-vegetation with fodder trees or shrubs and soil conservation on forest land which included hillside terracing, planting of multipurpose tree species and fruit (Aklilu, 2006). The implementations of the SWC measures are largely determined by economic status, public awareness, and educational level of the stakeholders. The main prerequisite for attaining sustainable agricultural development is the formulation of appropriate resource management policies, which are supported by the farming community to which they are willing and able to respond (Aklilu, 2006). The major benefits of erosion control are conserving water and retaining of soil nutrients and organic matter, as well as maintaining soil depth and soil structure (Pimentel, 1993). This makes the issue of soil conservation not only necessary but also a vital concern if the country wants to achieve sustainable development of its agricultural sector and its economy at large (Abera, 2003). Absence of integrating indigenous SWC**:** for centuries, Ethiopian farmers have indigenous and traditional knowledge and skills to manage their farm land. In Southern Ethiopia, there are ample indigenous soil and water conservation techniques that enable farmers to manage and use their land. Farmers have typical agronomic soil and water conservation practices to conserve the soil, moisture and to enrich soil fertility. Some of the known agronomic practices are crop rotation, contour ploughing, mulching, manuring, strip cropping, agro-forestry practices and life tree planting. The failure to integrate these rich practices to exotic soil and water conservation is one of the main constraints exist in woina- dega and dega agro-ecological zones (Abera, 2003).

The Soil Conservation Research Project (SCRP) was initiated in Ethiopia in 1981 with main development objectives of providing the Ethiopian soil conservation efforts with necessary basic data for the proper implementation of soil conservation measures, testing the applied and planning adapted measures, and training local as well as international personnel in this field of study (SCRP, 2000). The SCRP has developed a number of soil conservation techniques and several studies have been conducted on the adoption and profitability of these techniques.

A variety of SWC measures have been popularized among the farming community. According to Rauch, (1998) the main types of these practices are physical measures (also termed mechanical or technical measures), Biological measures (also termed vegetative measures) and Agronomic measures (sometimes called best management practices). Its practices can be subdivided into annual practices and one-time investments. Annual SWC practices form part of ploughing and cultivation practices, and requires an effort within each cropping season. Annual SWC practices are mulching, contour ploughing, organic fertilizers, cover crops, crop rotation among others. One-time investments are mainly mechanical practices. They require a one-time investment of labor and capital, and afterwards recurrent maintenance activities. Efficiently soil management is necessary, not only for agriculture but also in development as it can be a huge impact on addressing issues of poverty and food security. Therefore, it is substantial to exercise environmental rehabilitation, such as reducing soil erosion, for survival and development by implementing appropriate approaches and technology.

2.4.1. Physical conservation measures

Physical or structural (also termed as engineering or mechanical) measures are essentially designed to reduce soil and water losses by reducing the length and the gradient of slopes and thus increasing water infiltration into the soil and making the soil on those slopes less vulnerable to erosion by the forces of rainfall and runoff (MoARD, 2005). Slope gradient is one of the important topographic factors that influence the process of drainage; runoff and soil erosion thereby affects physicochemical properties (Farmanullah, 2013). Soil loss would normally be expected to increase with increase in slope gradient, because of respective increase in velocity of surface runoff and decrease in infiltration rate (Luk *et al*., 1993). For this reason, physical conservation measures are mostly recommended for steep slope hillsides with slope gradients > 15percentage. The aim of SWC is preventing or at least reducing the effects of soil erosion while maintaining the soil quality (Graaff, 1993). SWC consists of any set of measures and practices in order to ensure the soil functions for long-term use by humans and nature (Grohs, 1994). Ethiopia, mainly through the world food programmed (WFP) for food for work (FFW) programmer, played a significant role in the development of soil conservation programmer (SIDA, 1993).

Since 2011, the government of Ethiopia instituted a national physical SWC construction campaign that runs for two months (January and February) every year throughout the country. The campaign is aimed at mobilizing the community to construct the necessary structures following watershed conservation principles. To implement the programmer, a watershed is selected from every kebele (the smallest administrative unit) by the local development committee, the Development Agents (DAs), and the community. Then the necessary SWC structures are constructed by the community of the kebele under the supervision of the local DAs. However, the achievement is below the anticipated (Asnake, (2014). These express the management practices of soil erosion, which have been introduced to farmers.

The physical SWC measures are considered as investment for which significant benefit are expected later and for years to come. However, practical models and empirical equations are less available to estimate effect of SWC structures, as they touch many parameters and create complex interactions. In addition, the offsite role is less feasible to estimate and commonly ignored even in existing estimation and computation. The short term effects of bunds are reduction of slope length and the creation of small retention basins for runoff and sediment to reduce the quantity and eroding capacity of the over land flow Nyssen *et al.,* (2007) the medium and long term effect of bunds include the reduction in slope angle by forming bench terrace (Alemayehu *et al*., 2006). In the long term, slow forming terrace included by bunds are often associated with a high variability in soil fertility and crop response, which is due to water and tillage erosion in between structure (Nyssen *et al*., 2007). Previous studies indicate that soil bunds can reduce soil erosion with 48% to 84% Tesfaye, (2008); Teshome *et al*., (2012) and stone bunds can reduce soil erosion with 64% to 73% in different parts of Ethiopia (Vancampenhout *et al.*, 2006; Meshesha *et al.*, 2015).

2.4.1.1. Soil bunds

Soil bunds act on slopes up to 15 to 30% (depending on rainfall, soil type and land use) both by interrupting slope length and by reducing its gradient and with proper maintenance, eventually lead to terrace formation. The horizontal distance between two successive soil bunds was determined based on the vertical interval (HI) between bunds (usually 1 m for Ethiopia) and the slope angle. The dimensions of the bund were 1.2 m bottom width, 0.3 m top width, 0.5 m height and 1:2 side slope (MoARD, 2005). All the soil bunds were constructed in such a way that a trench was excavated to a depth of 50-60 cm and 40-50 cm wide along the contour at 1% gradient towards the waterway and the soil were thrown downhill. Grasses and shrubs were planted on the riser of the bund during the main rain season. Soil bunds are ridges and ditches made of soil, dug across the slope along the contour. Thus, they reduce soil erosion and increase the amount of water the soil can hold. Contour bunds can be used both on cultivated and uncultivated land. Contour bunds are appropriate for fields with permeable soils of gentle to moderate slopes Franzluebbers, (2010) and it is not recommended to build bunds on steep slopes more than 30% slopes. Vanlauwe *et al.*, (2013) indicated that contour bunds are among the recommended soil erosion control techniques in some moderate hills lands. A guideline by the Ethiopia ministry of Agriculture estimates 150-250 person per day for the construction of one kilometer of soil bund structure.

In study area from the physical SWC techniques soil bunds and stone bund are more dominant. This type of structure and its interval decided based on topography's and other parameters by the DAs of the watershed who trained natural resource management experts. However, there are different problems with the selection of appropriate types of the conservation structures and techniques and design of the technology based on their slope variation and intervals of one bund with the others (GBDANRO, 2010).

2.5. Effects of SWC Measures on Soil physical and chemical properties

Soils and waters are supports the growth of most of our food and fiber; so, its productivity is a major factor in the overall development of all nations of the world. In general, SWC techniques reduce sediment transport, including soil organic matter, which also contains nutrients like nitrogen (N), phosphorus (P), and potassium (K), from cultivated lands (Zougmoré *et al*., 2009; Adimassu *et al*., 2014). The fundamental roles of SWC structures are to significantly reduce soil loss and its consequences. The SWC measures are identified as the first line of defense that mostly acts as barrier due to the creation of obstacles against surface runoff. Most structures gradually develop into bench terrace and decrease the slope gradient and velocity of runoff.

Most of studies in Ethiopia confirmed positive impact of soil and water conservation measures on soil physical and chemical properties (bulk density, soil moisture content, organic matter, total nitrogen, plant available phosphorus and exchangeable bases) and crop yields. Soil conservation structures tested in Dalocha Woreda significantly influenced the soil physical and chemical properties and maize crop yields (Mesfin, 2004). Tenge *et al*, (2004) reported that grass strips, bench terraces and fanya juu reduced soil loss by 40, 76 and 88%, respectively, compared to the land without those structures. SWC practices are important so that the soil nutrient has to be preserved and the environment kept neat, tidy, and productive in order to preserve our human health and nutrition. The roles of SWC practices in increasing agricultural productivity have been indicated in many studies. Joyce & Musiwa, (1999) confirmed that the benefits of SWC practices in agriculture is proven and it can enrich available soil nutrient via reducing soil erosion, controlling nutrient leaching, safe guard the land and reduce the risks of total crop failure in drought years.

The short-term effects of soil bunds were the reduction of slope length and the creation of small retention basins for runoff and sediment. Therefore, it reduces the quantity and eroding capacity of the overland flow. These effects appear immediately after the construction of the soil bunds and reduce soil loss. In Ethiopia on farmers' perceptions about the contour bunds showed that approximately 94% of the farmers believed the potential of bunds to improve cropland productivity (Bewket, 2006). The majority of the farmers observed an improvement in crop yield in less than two years after the construction of the bunds (Wolka *et al.,* 2016). However, the effect of stone bunds on crop yield takes more time than for soil bunds, which is probably because a newly built stone bund is porous, which is less effective in trapping runoff, but eventually the pore spaces clog and runoff is effectively slowed down and sediment is trapped behind the stone bunds (Wolka *et al.,* 2013).

2.5.1 Soil Physical Properties

Soil physical properties largely determine the soils, water and air supplying capacity to plants. Many soil physical properties change with changes in land use system and its management such as intensity of cultivation, the instrument used and the nature of the land under cultivation, rendering the soil less permeable and more susceptible to runoff and erosion (Sanchez, 1976). As a result, soil bunds influence soil properties by changing soil erosion and deposition processes. Accordingly, there existed significant difference in soil properties with implementation of soil bund SWC measures in the study area. Soil texture contributes to crop productivity as they affect soil physical fertility (Rasool *et al*., 2007). According to these authors, the soil physical properties influence soil water movement, crop root penetration and nutrient uptake. Erosion and deposition processes also modify soil physical characteristics (Chen *et al.*, 1997; Vancampenhout *et al*., 2006).

2.5.1.1 Soil texture

Soil texture determines a number of physical and chemical properties of soils. The performance of selected SWC measures, pointed out that the complete removal of topsoil at the soil loss zone causes the subsoil dominated by clay material while moving down slope and deposited on the top of the fertile accumulation zone (Herweg and Ludi, 1999). It affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, tillage and irrigation practices (Foth, 1990; Gupta, 2004). Quraishi, (1977, 1980) evaluated the effects of structural land modifying measures on physical properties of soil and found higher content of silt and clay in terraced soil, which indicates that it has been least affected by erosion. The rate of increase in stickiness and the moisture content increases depend on the content of silt and clay, the degree to which the clay particles are bound together into stable granules and the OM content of the soil (White, 1997). With steep landscapes, transportation and translocation of fine particles are expected. This result also confirms the presence of higher clay fraction in the lower slope gradient due to deposition from the upper slope and also on the steep cultivated hill slope, the most noticeable changes were a decrease in clay and a corresponding increase in sand and silt fractions as the slope gradient increases (Hailu, 2012).

2.5.2 Soil Chemical Properties

Soil chemical properties are the most important among the factors that determine the nutrient supplying power of the soil to the plants and microbes. The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up. Minerals inherited from the soil parent materials over time-release chemical elements that undergo various changes and transformations within the soil (Lilienfein *et al*., 2000).

2.5.2.1 Soil organic carbon (SOC)

Soil organic carbon is the main constituent of SOM and its importance as a soil quality indicator both as a single soil or compound (SOM) attribute was reported (Yemefack *et al*., 2006). The total organic carbon is the carbon stored in soil organic matter; organic carbon enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota (Nelson and Sommers, 1996; White, 1997). Soil organic matter (SOM) or soil organic carbon (SOC) is commonly recognized as one of the key chemical parameters of soil quality, yet quantitative assessment of its contribution to soil quality is often lacking. Through its role in aggregate stability, it influences soil porosity, and thus gas exchange reactions and water relations. The soil organic carbon is one of the most important constituents of the soil due to its capacity to affect plant growth as both a source of energy and a trigger for nutrient availability through mineralization. Humus participates in aggregate stability, and nutrient and water holding capacity (Kahn, 2014). Farming practices resulted in loss of OC (Eylachew, 1999). According to FAO, (1978) soil organic matter (SOC), total N, and available phosphorous (P) found to be significantly different ($p = 0.05$) between conserved and non- conserved watersheds. The non - conserved micro - watershed had the lowest soil organic matter (SOC), total N and infiltration rate compared to the conserved twin-catchment. The values of organic carbon, nitrogen, phosphorus, and potassium were found significantly higher under terrace than unprotected land (Quraishi, 1980). They findings reveal that upslope areas had lower nutrient concentrations than lower areas because of erosion of top soil and subsequent deposition on lower slope positions. The organic carbon losses in upslope shoulder slope positions, while lower slope positions undergo organic carbon accumulation, which is attributed to erosion and depositional processes was reported (Wang *et al.,* 2001, Gregorich *et al.,* 1998). On the other hand, an insignificant difference in soil organic carbon between upper and lower slope positions under various soil and water conservation measures (Hao *et al.,* 2002).

2.5.2.2. Total nitrogen

In tropical environments where forest ecosystems are usually converted to agricultural systems, total nitrogen content of soils tends to turn down quickly. Intensive cultivation of soil, which led to high rate of OM turnover, accelerates its decomposition, makes the soil more susceptible to erosion, and decreases its water holding capacity at saturation (Wakene, 2001, Solomon *et al.*, 2002). This governs low total nitrogen content to be a characteristic feature of the highly disturbed weathered soils in the humid and sub humid tropics. Siriri *et al.*, (2005) noted that lower nitrogen values are recorded on the upper terrace section and moderately increases down the individual terrace. Though cultivation causes decrease in the total nitrogen content of soils in different agro ecosystems, the rate of decline is found to be rapid during the first few years of cultivation. However, after 10 years of cultivation soil total nitrogen content had increased due to fertilization. Field research indicated that the mean total nitrogen content of the terraced site with the original slope of 15, 25 and 35% were higher by 26, 34 and 14%, respectively, compared to the average total nitrogen contents of their corresponding non-terraced sloping lands (Million, 2003). The farm plots treated with SWC measures within the watershed was found to exhibit higher TN than the non-conserved watershed (Abay Challa *et al*., 2016). The variation in TN was also significant with slope gradient, where TN was, higher in the lower slope than in the higher slope gradients. This might be due to the removal of OM from the higher or steep slopes because of soil erosion and leaching to the down slope (Abay Challa *et al*., 2016). Wadera, (2013) found relatively higher average TN and available phosphors for bounded farm plots on average ground slops of 3%, 8% and 13% compared to the corresponding values on adjacent non-bounded farm plots on similar slope ranges.

2.5.2.3. Available phosphorus

Phosphorus (P) is known as the master key to agriculture because lack of available P in the soils limits the growth of both cultivated and uncultivated plants (Foth and Ellis, 1997). Following N, P has more wide spread influence on both natural and agricultural ecosystems than any other essential elements. It is the most commonly plant growth-limiting nutrient in the tropical soils next to water and N (Mesfin, 1996). Erosion tends to transport predominantly the clay and OM fractions of the soil, which are relatively rich in P fractions. Thus, compared to the original soil, eroded sediments are often enriched in P by a ratio of two or more (Brady and Weil, 2002). In the finding of Mulugeta and Karl, (2010) who reported that, AP was observed to be significantly different between the conserved and non-conserved fields. The variation is due to the soil organic matter content difference. AP was significantly high ($P < 0.05$) in no terraced croplands adjacent to level soil bund aged 4 year, stone bund aged 6 year and stone bund aged 8 year (Wolka *et al*., 2011). The main sources of plant available P are the weathering of soil minerals, the decomposition and mineralization of soil OM and commercial fertilizers. Most of the soils in Ethiopia particularly Nitsols and other acid soils are known to have low P contents, not only due to the inherently low available P content, but also due to the high P fixation capacity of the soils (Murphy, 1968; Eylachew, 1987). Oxisols, Ultisols, Vertisols and Alfisols are generally low in total P while Andosols are generally high in P content (Mesfin, 1996). Brady and Weil, (2002) reported that SWC practices are essential to enhance available soil phosphorus, soil potassium and soil nitrogen. It is also reported that, deficiency of available soil phosphorus and potassium enhances with soil and water conservation measures (Shober *et al*., 2013).

2.5.2.4. Available Potassium (K)

Potassium (K) is the third most important plant growth-limiting nutrient just next to N and P. Its behavior in the soil is influenced primarily by soil cation exchange properties and mineral weathering rather than by microbiological processes. Unlike N and P, K causes no offsite environmental problems when it leaves the soil system. It is not toxic and does not cause eutrophication in aquatic system (Brady and Weil, 2002). Vimpany, (1999) according its finding increasing applied rate of K fertilizers displaced both exchangeable Ca and Mg into the soil solution from where they could be lost by leaching. The variation in the distribution of K depends on the mineral present, particle size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material from which the soil is formed. For instance, soils formed from sedimentary materials are generally low in K content, while soils formed from crystalline rocks contain relatively high K (Mokwunye, 1978). The relatively higher AK on no terraced cropland adjacent to soil bund aged 8 year was most likely because of the difference in weathering process and past erosion (Wolka *et al*., 2011). It is also reported that, deficiency of available soil phosphorus and potassium enhances with soil and water conservation measures (Shober *et al*., 2013).

2.6 Farmers Adoption of physical soil and water conservation technologies

Adoption is the process of accepting, implementing and sustainable use of soil and water conservation measures by the farmers of an area through experts and development agents (Solomon, 2016). The adoption of improved physical SWC technologies in developing countries has attracted much attention from scientists and policy makers mainly because land degradation is a key problem for agricultural production (Graaff *et al.*, 2008). There are three phases in the adoption process: the acceptance phase, the actual adoption phase and the continued use phase (Graaff *et al.,* 2008). The acceptance phase generally includes the awareness, evaluation and the trial stages and eventually leads to starting investing in certain measures. The actual adoption phase is the stage where by efforts or investments are made to implement SWC measures on more than trial basis. The third phase of continued use or final adoption is the stage in which the existing SWC measures are maintained over many years and new ones are replicated on other fields. Adoption of soil and water conservation measures has been very limited. Knowledge among farmers about integrated soil conservation, water, and nutrient management measures are very low (Girma, 2001). People were already aware of the negative consequences of soil erosion on agricultural production and the environment centuries ago. Adoption is often a continuous process, and may occur in a gradual or stepwise manner, sometimes ending in only partial adoption (Hailu Birara, 2011). The traditional physical SWC measures, such as stone terraces, have been practiced in a few areas for several hundred years (e.g. Konso area) for which awareness and experience have been confined in that particular area. In this study, adoption of soil and water conservation means that the degree of acceptance and use of different SWC technologies/practices partially or fully by household farmers.

2.7 Factor Affecting Adoption of Soil and water Conservation technologies

The poor adoption of soil and water conservation practices is common in the developing countries. Factors such as income level, labor and education level, farming experience, conservation attitude and family size are factors, which influence adoption of SWC practices (Addisu, 2011). Severe erosion can be attributed to weak knowledge dissemination and limited enforcement of land management guidelines, rather than a lack of identified technologies and practices. For example, Ethiopian government designed national conservation strategy launched in 1997 was comprehensive, covering management guidelines for soil, forest, and water resources, but implementation through extension has proved difficult and has largely stalled (IFPRI, 2010). Economic constraints such as wealth status of the farmers, off -farm income, annual income, cost of the fertilizers and debt status are factors, which tends to increase or reduce incentives for soil-water conservation (John, 2008). Lack of proper awareness among policy makers of the extent and impacts of land degradation, lack of awareness of the nature and technical requirements of SWC practices, top-down planning approach to technical assistance, weak linkage during technology generation and dissemination, limited capacity to plan and implement SWC practices. At all levels, poor networking of information on SWC practices were also the challenges influence implementation of successful SWC practices in Ethiopia (EEPFE & IFPRI, 2006). As discussed earlier, the projects and programmers implemented which are PSNP in study area for more than ten years poorly repaired and adopted by farmers. Few exemplary achievements of SWC based watershed management have attracted the government. With the intention of replicating these achievements a roughly thirty day, public campaign undertakes SWC based rural watershed management has been considered as a strategy and was lunched early 2011. The activity has been well publicized and polities in some regions including SNNPR of our zone. However, the programs give less attention on maintenance of the watershed and on the farmer level, which was done by them. Sands, (1986) explain that farmers have rejected many introduced technologies since they are simply in appropriate for the specific condition of small farm systems.

Farmers' decision to adopt soil conservation measures is not only influenced by their perception of erosion hazard but also by the types of structures and their attributes. Respondents removed the soil conservation structures partially or totally, because of mole rat, running grass and difficulty of plowing across the field were the main reasons for removing the soil conservation structures. Other important reasons for removing structures partially or totally include, the belief that the farmland was relatively flat, the potential loss of land to conservation structures, which occupy part of the scarce productive land, and proximity of the plot, from which the structures were removed (Tadesse, and Belay, 2004). Raes *et al*., (2007) in the central high land of Ethiopia, the soil bund reduced the yield of barley by 1.7% when the space occupied by the structures area taken into account and otherwise increased yield by 1.7% (Adimassu *et al.*, 2012). The government and experts might have accumulated sufficient technical and theoretical lessons and experiences. However, it appeared that building the structures with any approach is no the challenge, but shifting farmers minds or convincing them to replicate and adopt the technology are still much further behind than they should be. In many watershed, reports and field observations confirm that structures are rarely maintained when damaged or broken by livestock, floods, etc. the campaign work annually focuses on building new structures by not auditing or monitoring the previous labor and time investment of similar activities (wolka *et al*., 2018). Improved physical SWC practices with the system of agriculture are the issue of sustainability for many countries, particularly for developing countries whose economy largely depend on agriculture (Fikru, 2009). However, the adoptions of soil and water conservation measure are not satisfactory. To these effects, many studies have been conducted in different parts of world including Ethiopia to identify the determinant factors that affect the adoption of soil and water conservation practices. These include demographic, socio economic, institutional and physical factors (Mulugeta *et al*., 2001; Bekele & Drake, 2003).

3. RESEARCH METHODS AND OF STUDY AREA

3.1 Description of the Study Area

3.1.1 Location of the study area

Gena Bosa is one of the five woredas of Dawuro Zone. The woreda has 37administrative units of which 34 are rural Administrations Kebeles while three are municipals administrative kebeles. Karawo is the capital town of the woreda, which is located at 508 km southwest of Addis Ababa, 329 km from Regional Capital City Hwassa and 27 km from Zonal capital Tercha town. Geographically, it is located between 6^{0}57´27´´N-7^{0}21´21´´N Latitude and 37^{0}9´49´´E-37^{0}31´48´´E Longitude and the study watershed is located 7^{0}16´54´´-7^{0}19´34´´Nand37^{0}17´29´´-37^{0}19´22´´E.

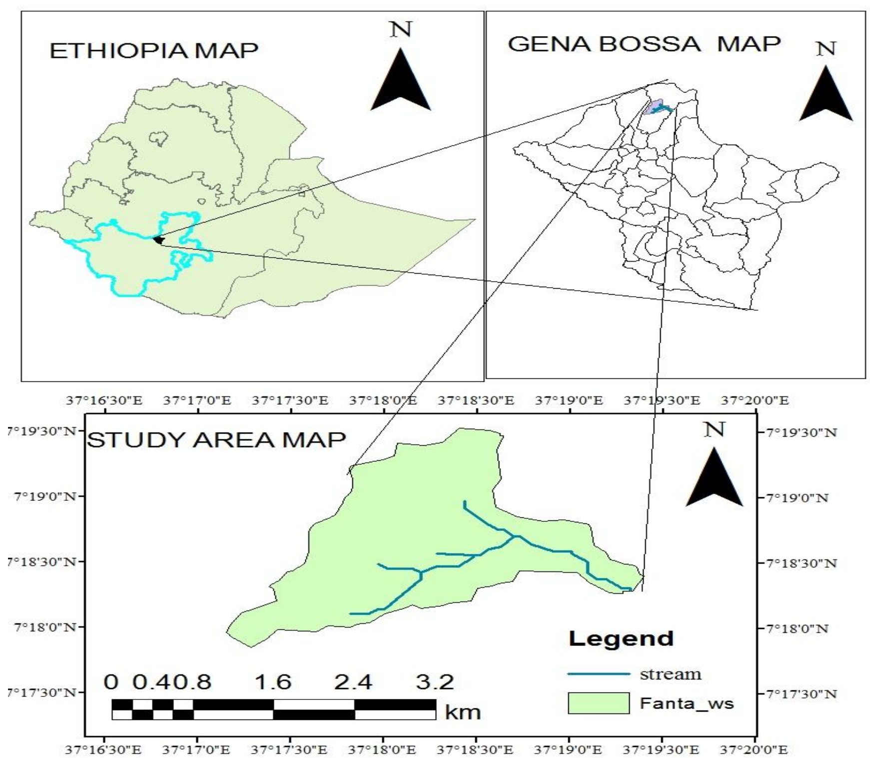


Figure 1: Study Area Map

Relatively, the woreda share a boundary line Loma woreda in the south, Wolaita and Kembata Timbaro zones (Omo River) in the east, Oromiya region in the north (Gojeb River), Mareka woreda and Dawuro zone capital Tercha town in the west. The woreda has a total area of 92,249 ha, which accounts for 21% of the total area of the Zone, with an elevation ranging 501-2860 m above sea level (GBDANRO, 2017).

3.1.2 Topography, Agro ecology and Rainfall

The area has rugged topography and the terrain of the land is sloppy in nature. The mountains and high plateaus have cool temperature moderated by the altitude and abundant rainfall. In contrast, the lowlands near the Omo and Gojeb rivers are dry and hot. Based on the data obtained from study Woreda GBDANRDO, (2017), most of the land is mountainous and characterized by steep slopes, unsuitable for agricultural. According to the land utilization data of the district, 34.8% is cultivated land, 17.5% grazing land, 27.7% forest, bushes and shrub land and 20% covered by others. Gena Bossa district is divided in to three agro-ecology, namely kola, woynadega and Dega, which covers 50%, 38.8% and 11.2%, respectively (GBDANRDO, 2016). The annual mean temperature ranges from 15.1°C- 27.5°C. The rainfall is a bimodal type: the short rainy season is between (February to March) and the long between (May to September). The average annual rainfall ranges from 1201 - 1600 mm

3.1.3 Soil of the study area

There are three major soil types in the woreda such as eutric camisols, dystric nitisols, leptosols and orthic acrisols are commonly seen in the study area repots (GBDANRO, 2016).

3.1.4 Population

According to population growth projection made by Central Statistical Agency (CSA), which was based on 2007 population and housing census, the total population of the woreda increase from 86,565 to 119,070 showing an increment by 32,505 between the years 2007 to 2018. The total population of District are about 119,070 and its HHs is male 11,823 female 1,155 and from this population 59,757 is male and 59,313 is female (GBDFEO, 2017).

3.1.5 Farming System and Land Use

In the study area, agriculture is characterized by subsistence mixed crop-livestock farming. More of the area around the homestead is covered with perennial Enset (*Ensete ventricosum*), which is a staple food and income source. Coffee (Coffee arabica), and fruit trees such as papaya (*Carica papaya*), banana (*Musa species*), avocado (*Persea Americana*) and mango (*Mangifera indica*) are among the widely cultivated crops. Vegetables such as potato, cabbages, onion, carrot, and green pepper are intercropped with these tree species crops. Annual crops such as maize, teff, sorghum, barley, wheat, bean, godere and haricot bean are most commonly cultivated. Livestock production is an essential part of the farming system as nearly all land preparation is done with ox-drawn ploughs. They also provide farmers with transport, manure and fuel. They are an important insurance during hardship times and wealth ranking is mainly based on the ownership of livestock. Oxen, cows, sheep, goats, horse and donkeys are the types of livestock kept by the farmers. It is composed of various indigenous trees, shrubs, and bushes like Dokma (*Strychnos spinosa*), Bisana (*Croton macrostachyus*), Bamboo (*Arundinaria alpine*), Tid (*Juniperus procera*),Wanza (*Cordia africana*), Tikur-enchet (*Prunus*), Kulkual (*Euphorbia candelabrum*), Birbira (*Millettia ferruginea*), and Grawa (*Vernonia amygdalina*). In the forest, farmers have the right to use the forest for their livestock grazing. This land use system is denuded of trees, shrubs, and bushes and open for grazing. Farmers usually use live fence of various tree species around their farmland for shade, firewood, and fodder and soil fertility improvement. Some of the tree species that farmers are usually used to grow for soil fertility improvement are Wanza (*Cordia africana*), Bisana (*Croton macrostachyus*) and Birbira (*Millettia ferruginea*) (GBDANRDO, 2016).

3.2. Data collection and analysis

This study applied methods for both primary and secondary data collection. Secondary data sources, documented materials such as reports, which were obtained from the woreda agricultural development offices. The primary data were obtained through soil sample, field survey, interview, focus groups and questionnaire survey.

3.2.1 Soil Sampling and Laboratory Analyses

3.2.1.1 Soil sampling

Soil sampling, sites were selected from both soil bund and no bund farm plots. In the case of the soil bund, sampling plots refer to the area between two successive soil bunds of equal or greater than seven years old was sampled from upper, middle and lower slope positions. In the case of no bund plots, the sampling plots refer to the area under cultivation, which is found adjacent to soil bund plots. Plots with bunds and adjacent plot without bund had similar history of land management, soil type and slope. In plots with soil bunds, soil samples were collected from three sub-plots, that is, near bund at down slope side, middle point and upslope side from the next bund. This was replicated three times per plots and the plough layer (0-20cm) was considered. Similar procedure was followed to collect soil samples in other three plots. Adjacent to each soil bund, the no-bund field was considered for soil sampling. In no bund fields, soil was sampled from upper, middle and lower slope positions considered. The upper, middle and lower slope positions has slope of >25, 15 – 25 and 3 – 15% slope respectively. The total 36 composite soil samples were 27 in bunds (3 slope positions *3samples in between two bunds*3 replication per plots*1-depth) and 9 in no bund plots (3 slope positions *3 composite sample per slope position*1-depth). The samples were analyzed for Total Nitrogen (TN), Available Phosphorus (AP), Soil Organic Carbon (SOC), Available Potassium (AK), sand, silt and clay soil texture classes.

3.2.1.2 Soil Laboratory Analysis

Collected soil samples were bagged separately with appropriate labels and transported to the laboratories. In the laboratory, soil samples were air dried by in an open air. The air-dried soil samples were crushed to pass through a 2 mm sieve in preparation for laboratory analysis. Soil texture, soil organic carbon, available phosphorus and available potassium was analyzed in Hawassa university Wondo Genet college Forest and NR laboratory section and Total Nitrogen was analyzed under SNNPRS Hawass soil analysis and productivity improvement directorate laboratory section.

Soil texture was determined following the Boycouos hydrometric method Bouyoucos, (1962) after destroying organic matter using hydrogen peroxide (H_2O_2) and dispersing the soils with sodium hexameta phosphate ($NaPO_3$). Soil organic carbon (SOC, %) content was determined following the Walkley and Black method Walkley and Black, (1934). Total N content of the soil was determined by wet-digestion, distillation and titration procedures of the Kjeldahl method as described by (Black, 1965). The available phosphorus content of the soil was determined using Olsen extraction method (Olsen *et al.*, 1954). The available potassium was determined by flame emission spectrophotometer (Black *et al*., 1965).

3.2.2 Farmers perception, adoptions and management of physical SWC practices

In addition to soil analysis, the study applied socio-economic issues related to soil erosion and conservation practices. Thus, qualitative and quantitative data on farmers' opinion on soil erosion, adoption and management of conservation structures and factors affecting adoption of physical SWC in Fanta watershed were acquired using household interviews, key informant discussions and focus group discussions as outlined below.

3.2.2.1 Qualitative Data Sources

3.2.2.1.1 Key Informant Interview

Key informants were selected purposely from the woreda and kebeles agricultural experts of Natural Resource Experts, sampled kebele watershed development committee, and kebele administrator. Based on data saturation, 5key informants were employed. For the sake of in detail understanding on the physical SWC implementation and management practices , effects on soil fertility depend on crop yield, the adoption methods of SWC , well adopted technologies and commitments of farmers to sustainable use and the different factors determine the adoption of conservation practices were open ended question was prepared.

3.2.21.2 Focus Group Discussion

Focus group discussion (FGD) was held with selected model farmers of the sample kebeles, kebele leaders, elder people, religious leaders, agriculture extension workers and woreda SWC supervisor using a supporting checklist. Each group had 8-12 members who were selected purposefully for the study. The farmers were selected based on their perception experience, based on plot location that means those them were continues use of soil and water conservation practices on their farmland. One FGD was conducted per kebele in each of the three sampled kebeles. The focus of the discussion was problems of soil erosion; importance of physical SWC, adoption rates specifically; the objectives and importance of physical SWC structures, the approach by which the conservation structures were introduced, and the effects of physical SWC structures on controlling soil erosion and improving soil fertility. Finally, the different factors determine the adoption of conservation practices, challenges and limitations in building and repairing the structures, and commitment to replicate and repair the introduced structures were evaluated.

3.2.2.1.3 Field Observation

Direct observation is one of the important methods of primary data collection. It helps to generate ideas helpful to modify questionnaire for survey, group discussion and key informant interview and to acquire information about the physical setting of the area. These observations was take farmers to assess what they did to conserve the soil and water, erosion status, the problems face them on their fields and measure they take to mitigate the problems. The data were also being obtained from primary sources mainly related to adoption behavior and assessment of farmers’ awareness to the SWC practice through observation. In the sampled kebeles, household heads that adopted and non-adopted was identified during field observations. Adopters who have physical SWC structures on their farmland and those who have not physical SWC structures on their farmland can be identified as non-adopters.

3.2.2.2 Quantitative Data Sources

3.2.2.2.1 Household interview

Household interview was a typical method to collect primary data from the sample households. A structured interview questionnaire that had involved both closed and open-ended questions were prepared and used to generate data from the respondents. Household survey was conducted through face-to-face interview of the respondent. Household heads were appropriate respondents for the questionnaires designed for the survey. The issues to be addressed in the questionnaire encompass fundamental information that includes socioeconomic characteristics, the cause and consequences of soil erosion, seriousness of soil erosion problems, types of built SWC structures, recognized effects and advantages of built physical SWC structures, and favorable situations at HHs level that support building or rebuilding of the physical SWC structures. In addition, challenges in building and repairing the physical SWC structures, limitations of the SWC structures and the factors that determine the adoption and repair of SWC structures were considered.

3.2.2.2.2 Sample Size Determination

For the assessments of farmers´ adoption of physical SWC and their influencing on adoption based on PSNP report, three kebeles (Beza shota, Mela galda and Bodola Mamado) was purposely selected. They respectively represent best, medium and low performing kebeles with regard to physical SWC (GBDANRO, 2010).

The sample size was determined using a probability proportional to sample size precision technique used hand calculation method Cochran, (1977), which was given by;

$n_o. = \frac{t^2 p(1-p)}{d^2}$ -- equ (1)

$n_1 = \frac{no}{1+\frac{no}{N}}$ -- equ (2)

n_o = the desired sample size when population is greater than 10,000

n_1= No. of samples size when the population < 10,000

t = 95 percent confidence limit i.e1.96

p = 0.1 proportion of population to be included in sample,

N = total number of population

D = degree of accuracy desired (0.05).

The result from above formula 43, 43 and 42 HHs respectively from Beza shota, Mela galda and Bodola Mamado equal distributed and were selected by quota and random sampling technique from a list of Kebele farmers in the watershed and out of watershed.

Table 1: Sample size distribution in (Beza shota, Mela galda and Bodola Mamado)

No	Kebeles	Total number of HHs	Sample size
1	Beza shota	602	43
2	Mela galda	565	43
3	Bodola mamado	547	42
Total		1,714	128

3.2.2.2.3 Selecting factors affecting physical SWC practices

For selecting factors affecting adoption of physical SWC, literature consultation and personal experience in the watershed were dominantly considered. Its data were generated through semi-structured questionnaires administrated to the sampled respondents through face-to-face interviews. Factors expected to influence the adoption of SWC technology such as demographic characteristics (sex, age and family size), socioeconomic variables (education and livestock size), physical variables (farm size, plot numbers and location of plots) and institutional factors (access to training and agricultural extension) were gathered. These variables were selected based on an exploratory survey, literature review, personal observation, group discussions and key informant's interview in study watershed. Previous studies in different part of globe identified factors that determine the adoption of SWC measures included demographic, socio-economic, institutional and physical factors (Mulugeta *et al.,* 2001; Bekele and Drake, 2003; Tenge *et al*., 2003; Eleni, 2008; Fikru, 2009). A set of qualitative and quantitative variables were used to model factors driving adoption of SWC and the response variable was a binary variable, which was assigned by coding. Finally, binary regression modeling, which is also discussed below in detail was used to produce an explanatory model of factors driving adoption of SWC in the study area. All the data were computed using SPSS (Statistical Package for Social Sciences) version 16.0.

3.2.3 Data analysis

Based on data obtained from laboratory Soil and water conservation structure (soil bund) and adjacent non-conserved farm plots and slope gradient was used as independent variables and the soil parameters as dependent variables. The significance difference of parameters of soil property due to effects of soil bund compared with adjacent non-conserved plots was tested by using one sample t-test. The slope gradients and location between bunds was tested using analysis of one way ANOVA at $P \leq 0.05$ level of significance with the aid of using Statistical Package of Social Science (SPSS v. 16). Soil properties with significant differences among the landscape positions and relative location in the watershed were analyzed for the significance of mean differences in relation to landscape positions and watershed locations separated by the Least Significant Difference.

The data collected in the HH survey was analyzed by one sample t- test to know the relationship between the dependent and independent variables. That was helpful to compare the mean of adopters and non-adopters of soil and water conservation measures with respect to continuous variables such as age, farm size, farm slope, numbers of farm, education and number of livestock farmers owned, access of training and access to extension services.

A binary logistic regression was computed for the analysis of determinant factors for SWC practice. Descriptive statistics such as percentage was used to analyze farmers' response on SWC practices. Results were presented in tables and figures.

4. RESULTS AND DISCUSSION

4.1 Effects of soil bund on soil properties

4.1.1 Effects of soil bund on selected soil physical properties

The texture analysis showed that plots without soil bund showed higher sand and silt fractions compared to those plots treated with soil bund (Table: 2). The percent of clay was significantly higher ($p<0.05$) in plots with bunds than no-bund plots (Table: 2). Silt was not significantly ($p>0.05$) differed in soil bund of compared with adjacent of no-bund plots. This indicates that soil erosion selectively removed soil particles. The sand materials are heavier to transport and remains behind while silt and clay being fine materials, easier to transport by water erosion. In addition, it indicated to speculate erosion intensity of the Fanta watershed as significant variation in proportion of soil particles observed in seven or more years old soil bund.

Bezabih *et al.*, (2016), similar reported in Gojeb Sub- Basin of Dedo District, Southwest Ethiopia and Mengistu, (2015), reported that Soils treated with soil bund have relatively higher clay fractions compared to the no-bund plots. In addition, Demelash and Stahr, (2010) reported significantly higher silt content in non-conserved than conserved lands in, northwestern highlands of Ethiopia. In contrary, Hailu *et al.*, (2012), reported in Goromti Watershed sand and clay was no significant variations were observed with the treatments.

Table 2: Effects of soil bund on soil texture at 0-20 cm depth under three-slope position in Fanta Watershed (mean ±SD).

		Soil-bund	No-bund	
Variables	Slope Position	Mean ± SD, n = 9	Mean ± SD, n = 3	P_value
Sandy (%)	Upper (>25%)	36.44 ± 0.84a[a]	45.67 ±3.05a[b]	0.000
	Middle (15 – 25%)	30.89 ± 1.69b[a]	42.33 ±0.577ab[b]	0.000
	Lower (3 – 15%)	24.33 ± 5.0c[a]	40.00 ± 1.00b[b]	0.000
	Average	30.55 ± 5.92[a]	42.67 ± 2.96[b]	0.000
	P_value	0.000	0.028	
Silt (%)	Upper (>25%)	26.66±5.27a[a]	25.33±3.06a[a]	0.233
	Middle (15 – 25%)	28.1±0.78a[a]	26.67±0.58a[b]	0.016
	Lower (3 – 15%)	19.9±5.12b[a]	27.0±0.00a[b]	0.043
	Average	24.85 ± 4.655[a]	26.33± 1.73[a]	0.361
	P-Value	0.000	0.553	
Clay (%)	Upper (>25%)	36.89 ± 1.69a [a]	29.00 ± 0.00a[b]	0.000
	Middle (15 – 25%)	41.11 ± 1.17a [a]	30.67 ± 1.53a[b]	0.000
	Lower (3 – 15%)	55.78 ± 9.64b[a]	33.00 ± 1.00b[b]	0.003
	Average	44.59 ± 9.90[a]	30.89 ± 1.96[b]	0.000
	P-Value	0.000	0.010	

***Note**: Mean and SD followed by different small letters in the subscript indicate significant difference (p<0.05) between slope positions and the variation between bund and no-bund shown by the superscript letters, different letters again indicate significant difference.*

The proportion of sand and silt was less but clay was high in lower slope position compared to upper and middle slope positions in plots with bunds as well as in no-bund plots (Table 2). This indicates that the proportion of sand and silt was progressively increasing from lower slope position to middle and upper slope in plots of soil bund but silt was decreasing from lower slope position to upper slope in no-bund plots. The structures that reduce surface runoff and soil loss retain water that enhances crop growth and contributes to soil fertility. Due to this, the texture classes varied significantly among slope position. The proportion of clay was decreased from lower slope position to upper in both soil bund and no-bunds plots. That means the fine particles including clay are removed from upper slope position and deposited in low slope area.

Similarly, finding Hailu *et al., (*2012), reported significant variation in clay and sand contents among landscape positions**.** In addition, Tugizimana, (2015) reported that the clay and silt amounts increases within both of conserved and non-conserved land from upper to lower slopes and decreases in sand particles and Laekemariam *et al.,* (2016) in Wolita zone southern Ethiopia, reported that within slope increasing the percentage of silt should be decreases. On contrary; Wolka *et al.,* (2011) in Bokole watershed reported that the clay fractions at 4 and 9 years old level soil bund was showed no significant difference in any fractions compared to adjacent-no terraced cropland . In addition, Herweg and Ludi, (1999) pointed out that the complete removal of topsoil at the soil loss zone causes the subsoil dominated by clay material.

4.1.2 Effects of soil bund on selected soil chemical properties

4.1.2.1 Soil Organic carbon (SOC)

The SOC was significantly higher ($p<0.05$) in plots treated with soil bund compared to the no bund plots in upper, middle and lower slope positions of the watershed (Table:3). The variation in SOC between bunds and no bunds was slightly increases from upper slopes position to lower, where the plots with soil bunds in upper, middle and lower slope positions were higher respectively by 18.9, 28.2 and 29.4% of SOC in soil bunds plots than no bunds. This implies reduced erosion of soil where soil bunds retained fine soil particles along with organic matter in plots treated with soil bunds.

The similar studies in different parts of the country Million, (2003), Mekuria *et al*., (2011) and Hailu *et al.*, (2012) also showed higher SOC in plots with soil bunds compared to no bund. However, a study in Bokole watershed reported no significant difference on SOC (Wolka *et al*., 2011). Since the SOC is central indicator of soil quality (example, high nutrient retention, water transmission and retention), the soil bunds appeared to contribute for retaining soil quality. This is highly important to maintain food security in challenging climate and increasing population. It is important in reducing erosion related agricultural land degradation.

Table 3: Effects of soil bund on soil organic carbon (SOC %) at 0-20 cm depth under three-slope position in Fanta Watershed (mean ±SD).

	Soil-bund	No-bund	
Slope position	Mean ±SD, n=9	Mean ± SD, n=3	p-value
Upper (>25%)	$1.58\pm0.04a^{a}$	$1.269\pm0.018a^{b}$	0.000
Middle (15-25%)	$1.77\pm0.03b^{a}$	$1.27\pm0.02bc^{b}$	0.000
Lower (3 - 15%)	$1.97\pm0.12c^{a}$	$1.39\pm0.041c^{b}$	0.000
Over all mean	$1.77\pm 0.18a^{a}$	$1.03\pm0.46b^{b}$	0.000
P-Value	0.000	0.000	

Note*: Mean and SD followed by different small letters in the subscript indicate significant difference (p<0.05) between slope positions and the variation between bund and no-bund shown by the superscript letters, different letters again indicate significant difference*.

The concentration of SOC was significantly (P<0.05) different among the slope positions of both soil bund and no-bund plots (Table: 3). It was progressively increased from upper slope position to middle and lower both in plots with soil bunds and in no bund plots. This is likely due to higher erosion in upper slope position and higher deposition in lower slope (foot slope) areas, which mainly due to slope of the land. This result agrees with the finding of Million, (2003) in that SOC in soil under three terraced sites of similar slopes, Worku *et al.*, (2012) also reported the dependence of SOC with land slope positions where fertile soil deposition at lower slope position would favor soil water content, high crop biomass production and in turn enhance SOC.

4.1.2.2 Total Nitrogen (TN)

Plots with soil bunds had significantly higher (P<0.05) total nitrogen content compared to that of no bund plots, however; there was no significant difference between middle and lower slope positions (Table: 4). The variation in TN between bunds and no bunds was slightly increases from upper slopes position to lower, where the plots with soil bunds in upper and middle was higher but become less in lower slope positions respectively by 0.08, 0.09 and 0.05% of total nitrogen than the no bund plots. This was 29.6, 33.3 and 18.5 % higher TN in soil bunds plots than no bunds. This was perhaps due to high fertile soil particles that removed from upper slope position and deposited in lower slope of open cultivation and the bund without integrating biological mechanisms it a loan could not significantly influences.

The result agreement with finding of e.g. Hailu *et al*., (2012), Mulugeta *et al*., (2010) that found higher TN content in farm plots with physical conservation measures (soil bund) as compared to the no-bund lands. In contrary, finding of Wolka *et al., (*2011) in Bokole watershed, was not significantly varied in cropland with level soil bund of 4, 6 and 8 years old compared to no terrace**.** Also Daniel, (2015) reported that the difference in the TN concentration of soils between conserved and non-conserved sub-watersheds was not statistically significant.

Table 4: Effect of soil bund on total nitrogen (TN %) at 0-20 cm depth under three-slope position in Fanta watershed (mean ±SD).

	Soil-bund	No-bund	
Slope position	Mean ±SD, n = 9	mean ± SD, n = 3	p-value
Upper (>25%)	0.22 ± 0.05a[a]	0.14±0.03a [b]	0.01
Middle (15 – 25%)	0.29±0.04bc[a]	0.20±0.07ab[a]	0.18
Lower (3 – 15%)	0.31±0.05c[a]	0.26±0.05b[a]	0.21
Over all mean	0.27 ±0.06[a]	0.20 ±0.07[b]	0.01
P-Value	0.01	0.11	

Note*: Mean and SD followed by different small letters in the subscript show significance difference (p<0.05) between slope positions and the variation between bund and no-bund shown by the superscript letters, different letters again indicate significant difference*.

Total nitrogen content was increased from upper slope position to middle and lower slope position both in soil bunds and in no bund plots (Table: 4). However, non-variation in total nitrogen was observed along slope gradient, in no-bund plots but higher mean value was observed in the lower slope than in the upper slope gradients. This might be due to their downward movement with runoff water from higher slope gradient and accumulation there at the lower slope gradient.

Similar trend was reported by Million, (2003) who observed 26, 34 and 14 % higher TN contents in terraced plot than in non-terraced sloping lands slopes of 15, 25 and 35% respectively. In additional; Belay, (2016) reported less total nitrogen at upstream in both treated and non-treated plots than lower stream of selected watersheds. However; Daniel, (2015) and Shiene, (2012) reported concentration of TN did not show significant variation across the landscape positions, relative location in the sub-watershed and their interaction effect.

4.1.2.3 Available phosphorous (AP)

Table: 5 shows that the soil bund had significantly higher ($p<0.05$) AP than no bund plots. The variation of AP between bund and no bund was observed in upper, middle and lower slope position of the plots. This was perhaps due to availability of higher organic matter at treated section because of sediment depositing areas, which is the main source of organic phosphorus. This is highly important to increasing soil fertility that is used to improve crop yield by reducing soil erosion.

The result agrees with the finding of Mulugeta and Karl, (2010) and Demelash and Stahr, (2010) who reported a significantly higher available P in soils of the conserved than non-conserved lands. Also finding of Hailu *et al.*, (2017) in Goromti Watershed, reported that the AP in soil under conserved plots was relatively better than in the non-conserved plots. In contrast, Wolka *et al*., (2011), Hailu *et al*., (2012) and Assefa, (2007) reported that AP was significantly high ($P < 0.05$) in no terraced croplands adjacent to level soil bund 4, 6 and 8 years old soil bund and stone bund.

The result show that highest amount of AP at lower slope position of the soil bund and no bunds while the lowest amount were recorded at the upper slope positions (Table: 5) with in both conserved and non-conserved plots. This is due to the downward movement of nutrients with runoff water from the high slope and builds up at the low slope position. Yimer, (2017) in the Main Rift Valley area and Asnake, (2016) reported the available phosphorus in both treated and non-treated plots along slop gradient; where it was low in upper stream compared to lower stream of studied watersheds. However, Daniel, (2015), Hailu *et al*., (2012); Shiene, (2012), who reported non-significant variation in the available P among the landscape positions.

Table 5: Effect of soil bund on total soil available phosphorous (AP mg/kg) at 0-20 cm depth under three-slope positions in Fanta watershed (mean ±SD).

	Soil- bund	No- bund	
Slope position	Mean ±SD, n = 9	Mean ± SD, n = 3	p-value
Upper (>25%)	146.91±6.74a[a]	69.467±40.81a[b]	0.000
Middle (15 – 25%)	193.35±15.85b[a]	121.467±2.31bc[b]	0.000
Lower (3 – 15%)	405.68±201.0c[a]	130.467±5.13c[b]	0.045
Over all mean	248.65±160.7[a]	107.13±35.18[b]	0.014
P-Value	0.000	0.015	

Note: *Mean and SD followed by different small letters in the subscript show significance difference (p<0.05) between slope positions and the variation between bund and no-bund shown by the superscript letters, different letters again indicate significant difference*.

4.1.2.4 Available potassium (AK)

The AK was significantly high ($p<0.05$) in plots treated with soil bund compared to the no bund plots in upper, middle and lower slope positions of the watershed (Table: 6). The variation in AK between bund and no bund was higher by 47.0% than no bund plots. This is where soil bund retained fine soil particles on structure and difference in weathering process and water erosion factors were different.

Similar finding of Hailu *et al.*, (2017) in Goromti Watershed, reported that AK in soil under conserved plots was relatively better than in the non-conserved plots. In contradict finding of Wolka *et al*., (2011) in Bokole watershed, reported that the relatively higher AK on no terraced cropland adjacent to stone bund 8 year old was most likely because of the difference in weathering process and past erosion.

The AK was increased from upper slope position to middle and lower slope positions in plots with soil bunds as well as in no bund plots (Table: 6). When we compare mean AK in both treated and non-treated plots along slope gradient, it was low in upper slope position compared to lower slope positions of the watersheds. This is due to high runoff or erosion affects upper slope position and deposited in lower slope position of the plots due to gradients of the slope.

Table: 6 Effect of soil bund on Available potassium (AK) (Cmol (+)/kg) at 0-20 cm depth under three-slope positions in Fanta watershed (mean ±SD)

	Soil bund	No bund	
Slope position	Mean ±SD, n = 9	mean ± SD, n = 3	p-value
Upper (>25%)	0.278±0.018a^{a}	0.118±0.0549a^{b}	0.000
Middle (15-25%)	0.327±0.018a^{a}	0.201±0.0166bc^{b}	0.002
Lower (3-15%)	0.429±0.059b^{a}	0.231±0.008c^{b}	0.000
Over all Mean	0.345±0.0735^{a}	0.183±0.058^{b}	0.000
P-Value	0.000	0.040	

***Note**: Mean and SD followed by different small letters in the subscript indicate significance difference (p<0.05) between slope positions and the variation between bund and no-bund shown by the superscript letters, different letters again indicate significant difference*.

Similar finding of Belay, (2016) in Guba-Lafto where the mean Potassium was lower in upper stream compared to lower stream of the watersheds. In addition, Assefa, (2007) in Anjeni Area, West Gojam reported similar finding in which AK increases down the individual terrace and hill-slope position. Wadera Lemma, (2013) reported that implementation of SWC (soil bund) practices enhances the available soil potassium.

4.1.3 Spatial variation of soil properties between bunds

The soil analysis result show that in between consecutive bunds sand, silt, clay, SOC, AP and AK were significantly varied that means highest sand, silt, clay, SOC, AP and AK were observed near soil bund at upslope side in three slope positions of land this is due to water and tillage erosion that moves fertile soil to down slope. Consequently, the water retained behind the embankment would have adequate time to deliver the sediment and infiltrate into the soil. Siriri *et al.*, (2005) noted that lower nitrogen values are recorded on the upper terrace section and moderately increases down the individual terrace. Assefa, (2007) reported the average organic matter value of terraced farm plots increases down a hill-slope position as well as relatively down individual terrace. They noted that the lower section of the terrace is usually more productive than the upper one. This might be due to the reason that the upper section has lower organic matter content than the lower section and such nutrient including others could also be washed away from the upper part of individual terrace and settle on the lower one. That is, the upper is erosional while the lower is depositional.

Table 7: Treatment results of soil parameters in location between bunds

Slope	soil parameters	Location between bunds				
		Erosion	Middle Bund	Deposition	Total	P_value
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
Slope, ≥25%	sand	38.0 ± 1.0a	37.0 ± 0.0a	34.3 ± 1.53b	36.4 ± 1.88	0.01
	silt	27.0 ± 0.0a	26.0 ± 0.0b	26.7 ± 5.77a	26.6 ± 5.27	0.03
	clay	35.0 ± 1.0a	37.0 ± 0.0b	38.7 ± 0.58c	36.9 ± 1.69	0.002
	SOC	1.51 ± 0.03a	1.56 ± 0.02ab	1.67 ± 0.03b	1.58 ± 0.03	0.001
	TN	0.19 ± 0.03a	0.22 ± 0.05a	0.25 ± 0.03a	0.22 ± 0.04	0.239

	AP	139.5 ±2.52a	148.1 ± 4.62b	153.1 ± 3.21b	146.9 ± 6.74	0.009
	AK	0.26 ± 0.01a	0.28 ± 0.00b	0.29 ± 0.01b	0.28 ± 0.02	0.007
15-25%	sand	33 ± 0.0a	30.3 ± 0.56b	29.3 ±0.58c	30.9 ±1.69	0
	silt	27.3 ± 5.77a	28.7 ± 5.77b	28.3 ± 5.77ab	28.1 ± 7.83	0.07
	clay	40.0 ± 0.0a	41.0 ± 0.0a	42.3 ± 1.15b	41.1 ± 1.16	0.015
	SOC	1.74 ± 0.01a	1.76 ± 0.01ab	1.81 ± 0.04b	1.77 ± 0.03	0.04
	TN	0.26 ± 0.04a	0.28 ± 0.04a	0.32 ± 0.03a	0.29 ± 0.04	0.29
	AP	177.13 ± 8.14a	193.47± 12.42ab	209.47 ±0.56b	193.36 ± 15.85	0.011
	AK	0.31± 0.01a	0.33 ± 0.01b	0.35 ± 0.00c	0.33 ± 0.02	0
3-15%	sand	28.3 ± 1.12a	25.7 ± 1.12a	19.0 ± 5.29b	24.3 ± 5.00	0.03
	silt	25.7 ± 2.08a	19.3 ± 1.12b	14.7 ± 3.06c	19.9 ± 1.72	0
	clay	46.0 ± 2.65a	55.0 ± 2.00b	66.3 ± 7.02c	55.78 ± 9.64	0.004
	SOC	1.86 ± 0.04a	1.95 ± 0.01a	2.10 ± 0.12b	1.97 ±0.12	0.018
	TN	0.27 ± 0.03a	0.31 ± 0.03ab	0.35 ± 0.04b	0.31 ± 0.05	0.069
	AP	221.47 ±2.31a	360.13 ± 138.8a	635.47±103.57b	405.69 ± 202.01	0.006
	AK	0.37 ± 0.01a	0.43 ± 0.02b	0.49 ± 0.04c	0.43 ± 0.06	0.006

Note*: Mean and SD followed by different small letters in the subscript indicate significance difference ($p<0.05$) location between bunds in slope positions.*

4.2 Farmers' adoption and management of physical SWC measures

Based on discussion with focus group and obtained from key informants in the study area, PSNP was launched in 2005; provide support for technical SWC measures, and incentives food, and cash for workers. Training was given for experts and administrative leaders. The household heads were also participated in training in kebele level. They have to be aware of the problem (recognizing erosion symptoms and experiencing the negative effects). They have to know about possible solutions (knowledge and skills to install erosion control measures, belief in benefits). Increasing fertilizer requirement of croplands and decreasing yield per unit of land were the main indicators of soil fertility decline in annual and perennial cropland, respectively. Nevertheless, Farmers differ in their willingness and ability to adopt new practices. Adoption describes the farmers' commitment to utilize the technologies sustainably with confidence. However, the adoption of SWC practices are low and even the adopted are not utilized in sustainable manner. Some farmers are reluctant to manage the conserved resources, and even some farmers have removed or dismantled conservation technologies and not practices in the absence of incentives like food-for-work or cash-for-work. There are similar reports that SWC structures after some time are partially or totally removed (Shiferaw and Holden, 1998; Tadesse and Belay, 2004).

More specifically, those respondents who retained the soil conservation structures built on their land through FFW incentives and/or had introduced the physical SWC measures on their own the time of the survey were considered them as adopters. Whereas those respondents who did not have physical SWC structures at the time of the survey were determined, they were low with in each kebeles and considered them as non-adopters. The interview result showed that new physical soil and water conservation techniques were adopted by 74.2 % of respondents whereas 25.8% did not practice any conservation measures in their farms.

Table 8: Adoption of physical SWC technologies

Kebeles	Beza Shota, n = 43	B/Mamado, n =42	Mela Galda, n =43	Total, n = 128
SWC* adoption	Percentage	Percentage	Percentage	Percentage
Yes	79.1	69.0	74.4	74.2
No	20.9	31.0	25.6	25.8

4.2.1 Demographic, Socio-Economic, Physical and Institutional Characteristics of Households

4.2.1.1 Demographic characteristics of the households

The total numbers of sample households used for this study were 128.The survey result confirmed that 94.5% of the respondents were male, which implies male dominance in the participation of soil and water conservation activity. They were categorized into non- adopters 33 (25.8%) and adopters 95 (74.2%). From sample households, 121 (94.5%) were male and 7 (5.5%) were female household heads (Table: 9). Based on the survey, 98.9% of the adopters were male-headed households and 1.1% was female household heads. On the other hand, out of the non-adopters, 81.8% were male and 18.2% were female-headed households. From total female HHs 85.7% were non-adopters. According to group discussion, there were limited participation of women in the adoption of SWC practices and were highly involved in regular household activities than men.

Household age is one of the most important demographic characteristics for farmers’ adoption of physical SWC practices. The awareness about soil erosion and controlling mechanisms is influenced by age. In terms of age, results show that non-adopters were significantly older than adopters were (mean of adopter=2.89years and non-adopter = 4.12 years old (Appendix: 8)) and the age of the household head influenced the adoption of introduced SWC practices.

The majority of the headed households (46.9%) were found between 45-65 years. From the categorized age of <25, 25-35, 35-45 and >65 years found 9.4, 14.1,25 and 4.7% was ranked respectively. Non-adopters of the respondents were not found less than 35 years of the age this shows that young household heads were more likely to adopt SWC measures than adult.

Table 9: Demographic profile of respondents

Kebeles	Bezashoth (n=43)	Bodolmamado (n=42)	Mela galda (n=43)	Total (n=128)
Respondents characteristics	(%)	(%)	(%)	Percentage
Sex				
Male	93	95.2	97.6	94.5
Female	7	4.8	4.7	5.5
Age distribution				
< 25	9.3	7.1	11.6	9.4
25 – 35	9.3	14.3	18.6	14.1
35 – 45	18.6	26.2	30.2	25.0
45 – 65	60.5	45.2	34.9	46.9
> 65	2.3	7.1	4.7	4.7
HH Family size				
1 – 3	16.3	21.4	14.0	17.2
3 – 7	67.4	50.0	55.8	57.8
8 – 10	14.0	21.4	25.6	20.3
≥ 11	2.3	7.1	4.7	4.7

The household size of sampled household heads was classified as 1-3, 4 - 7, 8 – 10 and greater than or equal to 11, so that, the result shown that sizes were ranked under its classes as 17.2%, 57.8%, 20.3% and 4.7% respectively. From the total respondents 57.8% of households were 3 to 7 family size (Table: 9). Physical conservation measures are labor-intensive technologies. However, households with more number of family sizes were less likely to adopt SWC measures than households with small family size. The mean family sizes of the non- adopters were about 2.39 whereas the adopters were about 2.03 (Appendix: 8). Thus, it can be concluded that the non-adopters had relatively larger family size than adopters. From sampled kebeles high ratio of non-adopter and more family size (7.1%), in ≥11 family size HHs has found in Bodola Mamado kebele compared with rest.

4.2.1.2 Socio-Economic Characteristics of the Households

From socio-economic characteristics of household heads, education is playing a significant role to ensure farmers awareness and appropriately use information to adopt SWC measures. Among the respondents 41.4% of the respondents are illiterate; 32% have completed primary school; 18.8% of the respondents were completed secondary (5 – 8) school; 4.7% of the respondents were completed general secondary school 9 – 10 , also 0.8% of the respondents were completed preparatory and 2.3% of the respondents had diploma and above. Better education level of the HHs had strong and positive relationship with adoption of SWC because of their ability to find new information. From sampled farmers 47.6% in the Bodola Mamado kebele was illiterate compared with other kebeles, thus may have little access to information about newly introduced soil and water conservation practice. The similar finding of Wolka *et al*., (2018), reported that they indicate that a higher proportion of respondents should remain in agricultural activities for their economic and livelihood needs.

The most important components in farming system are the breeding of livestock for different purpose such as; farming activity, source of income, means transportation and source of food. The livestock production in study area were Cattle, sheep, goat, donkey, horse, mule, chicken, bee hive, production were accounted from house hold head 100.0%, 25.8%, 68.8%, 21.3%, 8.9%, 11.7%, 54.7 % and 13.3% respectively. This implies that large percent of livestock resources were highly influential on soil degradation and these higher produced livestock’s were more friendly relationship with natural ecosystem and physical structure.

Table 10: Socio-economic characteristics of the household

Education level	Bezashoth (n=43)	Bodolmamado (n=42)	Mela galda (n=43)	Total (n=128)
None/Illiterate	39.5	47.6	37.2	41.4
Primary (1-4)	27.9	35.7	32.6	32.0
Secondary (5-8)	23.3	14.3	18.6	18.8
S/secondary (9-10)	4.7	2.4	7.0	4.7
preparatory (11-12)	0.0	0.0	2.3	0.8
Diploma and above	4.7	0.0	2.3	2.3

The mean livestock populations of the non-adopters respondents were relatively more (1.88) as compared with the number of livestock of adopters (1.83) (Appendix: 8). This refers that farmers with large number of livestock did not adopted SWC measures because they freely graze on their farms and it destroy the structures. Free and open grazing on cultivation land is common in study area. When cattle and goats are allowed freely on sloppy lands, it aggravates soil erosion. Cultivation and Communal land is mainly utilized free and uncontrolled grazing exposing the top soils to be washed away easily. This was the cause for soil erosion and the damage of soil bunds on both farm plot and grazing land as well as the degradation of soil of the study area.

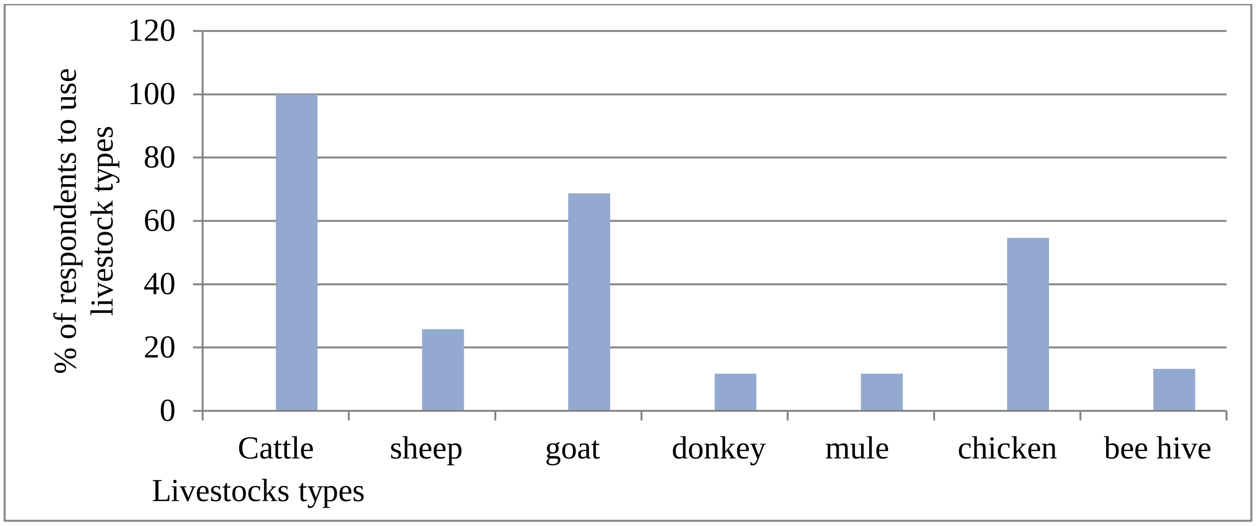


Figure 2: Types of Livestock production

Crop and livestock production were the main farming practices in the study area. The results confirmed that the livestock feed in community grazing land (31.3%), forested area (19.5%), cultivated fields (35.9%) and private grazing field and cut and carry system showed below figure: 3. During the group dissuasion in dry period, most of the livestock was feed on cultivated land on open grazing. As they reported and confirmed on their dissuasion these methods of grazing livestock leads the land become loss essential nutrients; therefore open grazing with in cultivated land was negatively affects the fertility of cultivation land (Figure: 3). A higher livestock-grazing land ratio may result in overgrazing, which, in turn, results in erosion. A being the case, a higher livestock-grazing land ratio is a less adoption for the introduce conservation measures both on their cropland, which is the main source of animal feed, and grazing-land.

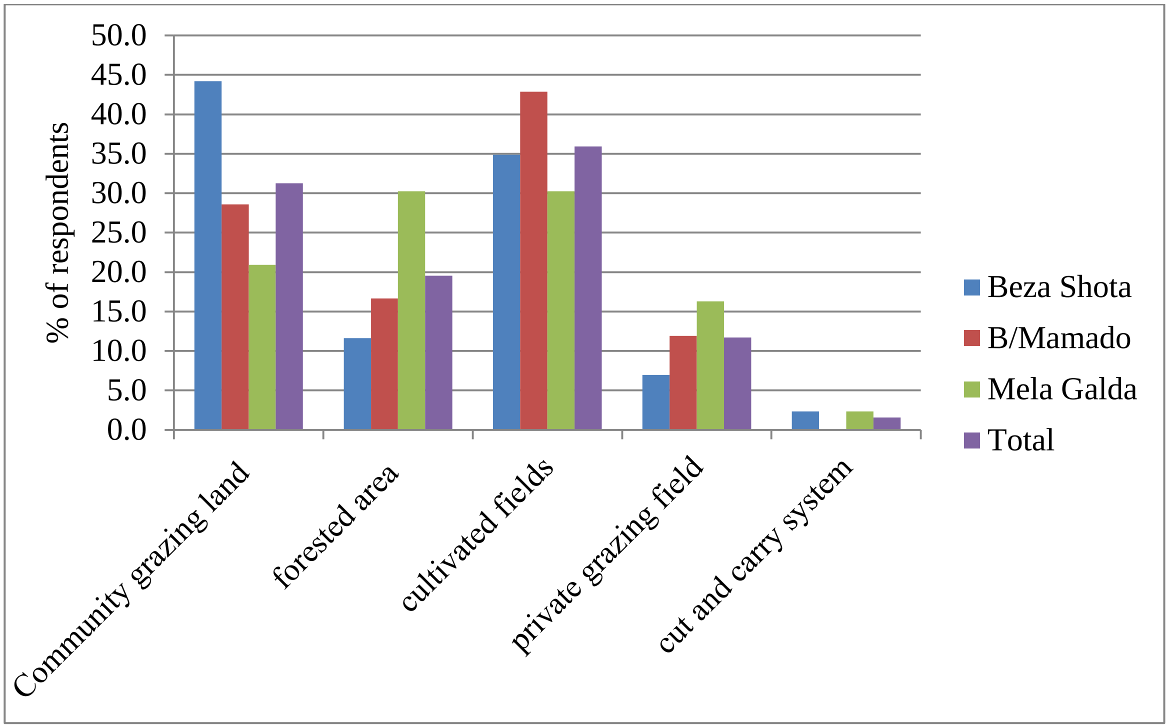


Figure 3: Grazing places of livestock

4.2.1.3 Physical characteristics of the household

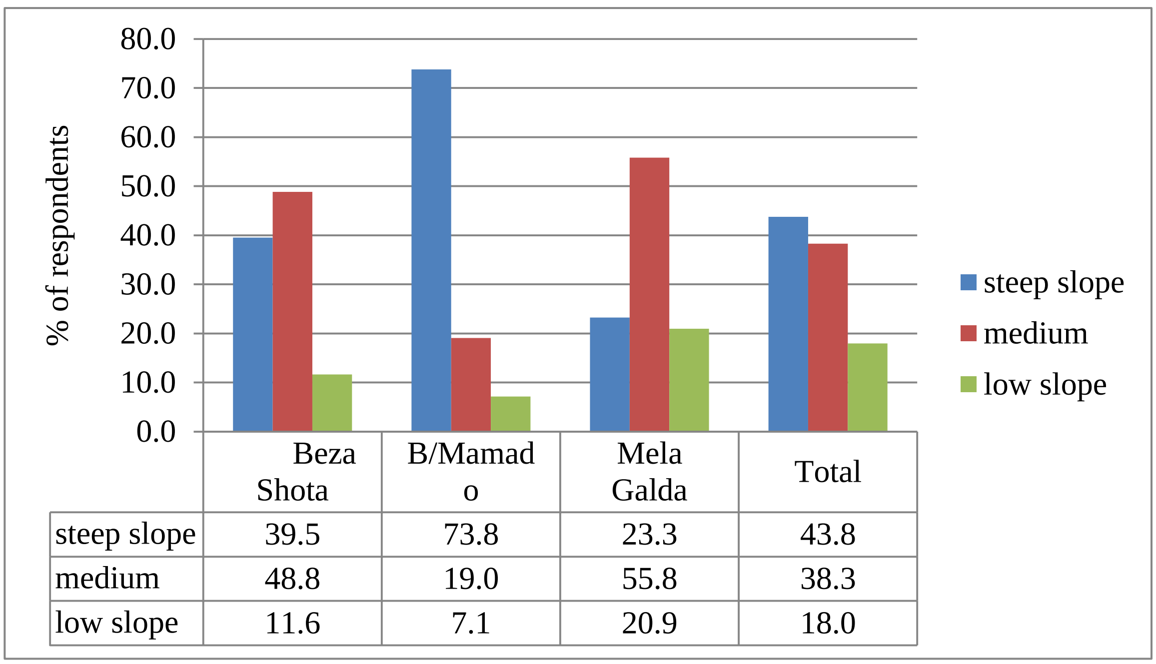
Farm size was one of the physical factors that determine farmers' decision in the adoption of physical SWC practices. The current study revealed that the (46.1%) respondents had holds 0.5 ha to 1 ha cultivated land and 22.7% and 18.0% were ranged 0.25 ha to 0.5 ha and 1.0 to 5.0 ha respectively (Table: 11). The mean size of farmland owned by the non-adopter and adopter were 2.91 and 2.87 hectare respectively (Appendix: 8). This indicates that more proportion of non-adopters have large size of farm land. From selected kebeles high ratio of (7.1%) of Bodola Mamado kebele respondents has, greater than 5ha land holds this is because in this kebele high proportion of non-adopters compared with rest kebeles.

Numbers of farm plot of household heads is one of the major physical factors that determine the adoption of physical SWC measure. According to interview result 75.8% of the respondents replied their farm plot number was one and 18.8% and 5.5% were two and three numbers of plots respectively. The farmland of Bodola mamado kebele household heads have more numbers of farm plots compared with others. This means 9.3%of household heads was have three farm plots, but Beza shota kebele 88.4% household heads has one farm plot. This means number of farmland owned by the non-adopter and adopter were 0.52 and 0.22 respectively (Appendix: 8). Therefore, the number farmland low, farmers' gives attention to manage their land and sustainable use adopted technologies.

Table 11: Land holding and number of plots of household heads.

kebeles	Bezashoth (n=43)	Bodolmamado (n=42)	Mela galda (n=43)	Tota (n=128)
cultivated land	(%)	(%)	(%)	Percentage(%)
Land hold in Ha				
<0.25Ha	14.0	7.1	4.7	8.6
0.25 - 0.5 Ha	32.6	19.0	16.3	22.7
0.5 - 1 Ha	39.5	47.6	51.2	46.1
1.0 -5.0 Ha	11.6	19.0	23.3	18.0
> 5 Ha	2.3	7.1	4.7	4.7
No. of farm plot (parcels)				
1	88.4	69.0	69.8	75.8
2	9.3	26.2	20.9	18.8
3	2.3	4.8	9.3	5.5
4	0.0	0.0	0.0	0.0

According to the interview of respondents, 45.3% of the household heads were located on steep slope farmland (Figure: 4). Bodola kebele was highly steep slope than from Beza shota and Mela galda kebeles. This shows that the majority of sample respondent's farm plot is found on steep slope, which is susceptible to erosion. The high ratio of non-adopter farmlands was located along gentle slope compared with adopter farmers because the mean of non-adopter and adopter was 1.45 and 1.82 (Appendix: 8). Slope of a field affects the rate and amount of soil loss from fields. They discussed that, frequent conservation practices formulated on steeply sloping lands, which showed the desire of farmers to control loss of soil from highly erodible soil.



	Beza Shota	B/Mamado	Mela Galda	Total
steep slope	39.5	73.8	23.3	43.8
medium	48.8	19.0	55.8	38.3
low slope	11.6	7.1	20.9	18.0

Figure 4: Farm plot slope characteristics of study area

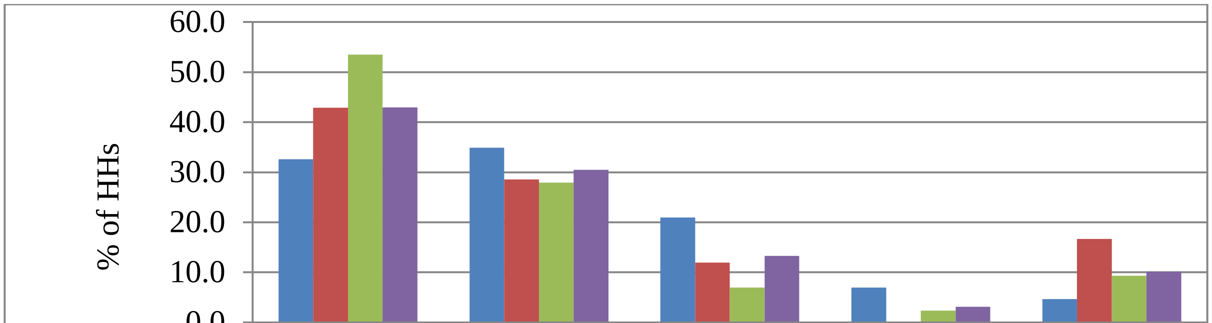
4.2.1.4 Institutional characteristic of the household

Farmers did not have information about new physical SWC technology it should not be expected to adopt the technologies. Based on review results the 83.6% of sampled farmers replied yes to accesses training (Table: 12). Accurate information had a positive influence on farmers' adoption of soil and water conservation measures. In Bodola mamado kebele high ratio (23.8%) of households was do not got access of training compared with rest kebeles.

Table 12: Training accesses of farmers

Kebeles	Beza Shota (n=43)	B/Mamado (n=42)	Mela Galda (n=43)	Total (n=128)
Do You Get Training Accesses	Percentage	Percentage	Percentage	Percentage
yes	88.4	76.2	86.0	83.6
no	11.6	23.8	14.0	16.4

One of the widely used means of addressing information to the rural farmers is public extension service. Development agents are responsible to disseminating the information for each farmer to provide extension services. In the study area, DAs at kebeles level provides agricultural extension because of Agricultural extension is having high importance to introduce better agricultural practices and improved technologies to smallholder farmers. The agricultural extension services in the study area mainly focused on providing basic agricultural education, teaching, and demonstration about the use of agricultural inputs, forestry development, soil conservation and livestock production aspects those whom are assigned considering three departments, which are Natural Resource, Plant science and animal science. The survey result indicated that 89.8% of the respondent has access to agricultural extension agents. As far as frequency of extension contact is concerned, it is apparent from the figure: 5 that about 43.0 % had extension contact once per month, and about 30.5%, 13.3% and 3.1% had extension contact twice per month, three per month and four times per month and the rest 10.2% has no contact with extension workers (Figure: 5). In Beza shota kebele, HHs was high frequency contact with extension services compared with rest kebeles.



	Once per month	Twice per month	Three times per month	Four times per mounth	Has no contact
Beza Shota	32.6	34.9	20.9	7.0	4.7
B/Mamado	42.9	28.6	11.9	0.0	16.7
Mela Galda	53.5	27.9	7.0	2.3	9.3
Total	43.0	30.5	13.3	3.1	10.2

Figure 5: Contact with extension services

4.2.2 Farmers perception about Soil erosion, its causes and consequences in Fanta watershed

4.2.2.1 Perceived soil erosion in Fanta watershed

About 75% of respondent reported that extent of erosion on their farm are severe while 22.7% and 2.3% perceived as moderate and low erosion problems respectively (Table:13). In interviews, key informants and focus group discussions, farmers commonly indicated that they have sensed the loss of soil fertility from cultivated fields and the reduction of the depth of the topsoil through time. They reported during an interview that the most important top soil for crop production activity were deteriorated over time due to occurrence of sheet, rill and gully erosion in their farms. Hence, they should perceived frequently how the loss of fertile soil from cultivated fields has been determined the depth and fertility of the topsoil through time in their farmlands to be reduced. The majority of the farmers reported that the occurrence of sheet and rill erosion was common problem and gully erosion was ranked by 34.9% of respondents (Figure: 6).

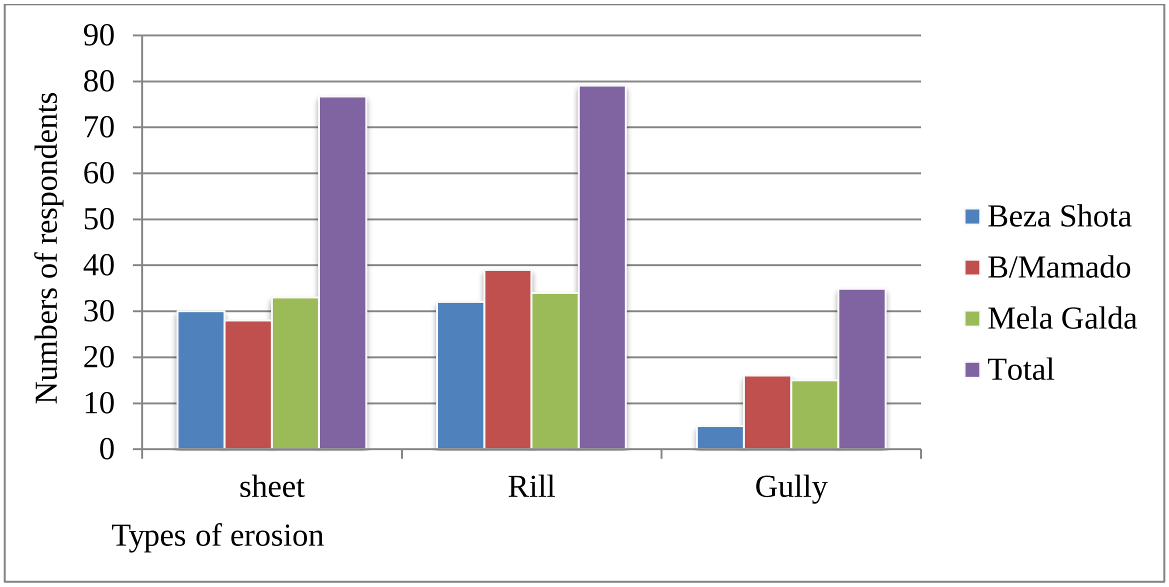


Figure 6: Type of soil erosion on study area

Majority of respondents considered rill erosion problem as the highest as sheet and gully erosion features. Bodola kebele, was hilly areas compared with others and which mass movement of land occurred as observed in the field. Gully erosion was observed at farm boundaries, waterways and roadside specially road constructed in URAP. Amsalu and de Graaff, (2006) also indicated that 91% of farmers in Ethiopia confirmed that sheet and rill erosion to be predominant in Ethiopia.

In sampled three kebeles, the all farmers perceived incidence of erosion in their farmland. This indicated that farmers experience to identify the problem. The erosion appeared moderate to severe as perceived by more than 97% of the respondents in the three kebeles. According to the interview, their severities were determined by reduction of top soil depth, difficulty to ploughing, happening of mass movements and gully formation. According to the reports of group discussion, three decades ago, the soil in the study area was generally fertile in nature and more productive but currently, it does not provide yields without the application of fertilizers. The majority of the local farmers believed that the technologies had important to control runoff and improving soil fertility, but the implementation of new technologies should be under problems. The level of adoption should separate with place-to-place and different with in different farmers.

Table 13: Perception of Respondents for Soil Erosion as a Problem

Kebeles	Beza Shota n=43	B/Mamad n=42	Mela Galda n=43	Total N=128
Respondents characteristics	Percentage	Percentage	Percentage	Percentage
Occurrence of soil erosion				
Yes	100	100	100	100
No	0	0	0	0
Extents of soil erosion problems				
Severe	74.4	83.3	67.4	75
Moderate	23.3	16.7	27.9	22.7
Slight	2.3	0.0	4.7	2.3
Indicator of erosion and its severity by sampled respondents				
Reduction Soil depth	81.4	61.9	90.7	78.1
Mass movement of soil	4.7	11.9	2.3	6.3
Difficulty during plowing	30.2	40.5	20.9	30.5
Fertility decline	95.3	88.1	76.7	86.7
Gully formation	53.5	45.2	27.9	42.2

Extents of soil erosion before use new SWC				
Severe	76.7	90.5	65.1	77.3
Moderate	23.3	9.5	30.2	21.1
Slight	0.0	0.0	4.7	1.6
Extents of soil erosion after use new SWC				
Severe	7.0	11.9	7.0	8.6
Moderate	34.9	45.2	37.2	39.1
Low	58.1	42.9	55.8	52.3

This soil erosion adversely affected soil by reducing thickness of top soil together with fertility as perceived by majority of respondents. Similar finding by, Zegeye *et al.,* (2010) reported that the most important top soil for crop production activity was deteriorating over time due to erosion. Hence, they frequently observed how the loss of soil-cultivated field has been reducing the depth of the topsoil and increasing the number of stones in their farmlands over time. Rill erosion is a result of surface runoff and associated sheet wash, which selectively moves fine material and organic matter that are very important determinants of land productivity (Bewket and Sterk, 2003).

Figure 7: Stoniness in the Farmlands which Affected by Erosion.

4.2.2.2 Farmers perception about Causes of soil erosion

The farmers' perception on the causes of soil erosion reflects that farmers well understood the problem and able to evaluate if their actions are mitigating the right causes. Thus, farmers who declared soil erosion as a key problem were they asked to list and ranked the main causes of it. Most of the respondents 81.3% and 79.7% of the farmers reported over grazing and cultivation of steep slope land respectively as major causes. While 78.1% and 60.9% respectively sated as land slope and deforestation are responded respectively as the main cause of soil erosion.

A daily human activity was the major causes of soil erosion problems when mentioned by farmers and natural resource experts. Their interaction with the natural environment resulted in the loss of precious topsoil that contains important minerals for plant growth, which could reduce the ability of the land to support the increasing productivity. However, it is clear that the extent and factors of erosion varies with time and place. The population increase leads to a higher demand for both food and cash crops that make land exploitation continuously. In study area, the livestock's should be feed freely on cultivated land and these make destroying the structure and trampling the cultivation land, which exposes for water erosion. During the rain time most of it forms into runoff without entering into soil profiles. These was similar with the finding of Wolka *et al*., (2018) who reported in Bokole watershed perceived damage of the SWC structures by free grazing, overtopping surface runoff, and tillage activities. According to the results of study area reported 75% were stated a severe erosion due to the 45.3% area covers steep slope; so that land slope of the area are exposed to erosion and the farmers practices the cultivation activity may increases soil erosion. Considering that, many parts of arable land areas are located on steep slope, coupled with high rainfall, leading to the soil erosion and soils being transported down streams. These also imply that natural factors alone less influenced than the human induced change in the watershed. Natural factors include soil, climate, vegetation, relief and other eco regional characteristics (Lal, 2001). In addition, removal of land cover through deforestation and overgrazing causes soil erosion and land degradation. This process leads to the loss of biodiversity as explained in many parts of the world (Hurni, 1988; Houghton, 1994; Rao and Pant, 2001; Zeleke and Hurni, 2001; Zeleke, 2002). This indicates that most of them have an understanding that soil erosion is caused by combined factors, which include both natural and manmade factor. As can be observed from the field, sheet and formation of rills erosion caused for decline in productivity and limited perception other than gully erosion could influence their participation in the conservation activities.

Regarding the status of the soil erosion before and after introduction of physical SWC, most farmers had their own mechanisms to identify this status (severe, moderate and slight). During focus group discussion and key informants the farm face high removal of top soil, high distribution of sand with shallow depth, less productivity and large gully formed in the farm, which are erosion is considered as severe before introduction of SWC measures. It is possible to conclude based on field observation and interview results and feedback from group discussion that the runoff and soil loss value were reduced after the introduction soil bund in the catchment. In other words, keeping other factors constant, conserved fields with appropriate measures are expected to reduce soil erosion.

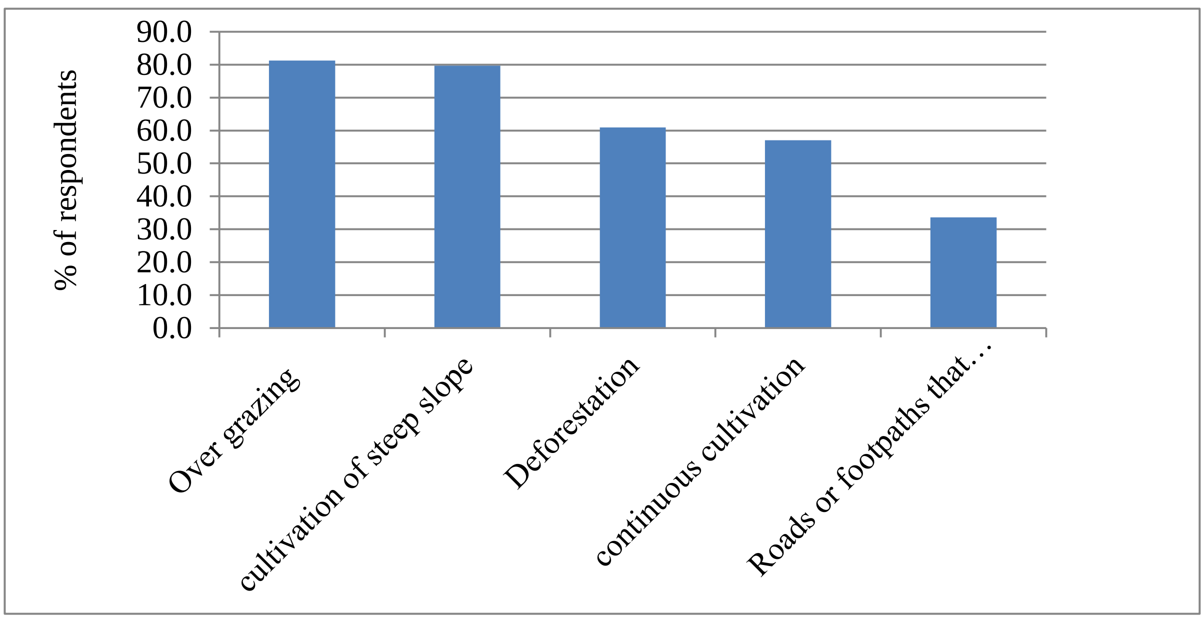


Figure 8: Causes of soil erosion

4.2.2.3 Farmers perception about Consequences of soil erosion

According to the result of the questionnaire, interview of respondent's show that soil erosion was affects the declines of the soil fertility by 94.5% respondents ranked, and this declines of the soil fertility consequences the reduced crop yield (Figure: 9). Soil erosion was caused by different factors practiced in the farm and these factors affect the farmers' livelihoods due to decaling soil fertility and crop productions. The effects decline in the content of soil nutrients, water holding capacity and fertility problems, tillage difficulties, etc. according results of group discussion. This leads to the reduction of productivity of the soils. On the other hand, it affects flooding, reduction in water quality, increase in suspended sediment on the down slope side. Soil erosion changes fertility status of the soil by removing top soils rich in soil nutrients and organic matter. Soil undergoes compaction that reduce soil aeration, permeability hence change in physical, chemical and biological properties of the soil. The similar finding with Mwakubo *et al.*, (2004) who reported that 3 mm top soil lost due to soil erosion each year caused an annual decline in maize yield of 22 kg and 15 kg for beans. In addition, erosion has long been recognized to be a major reason for the poverty and food insecurity in the Rwanda as reported by (Byiringiro and Reardon, 1996).

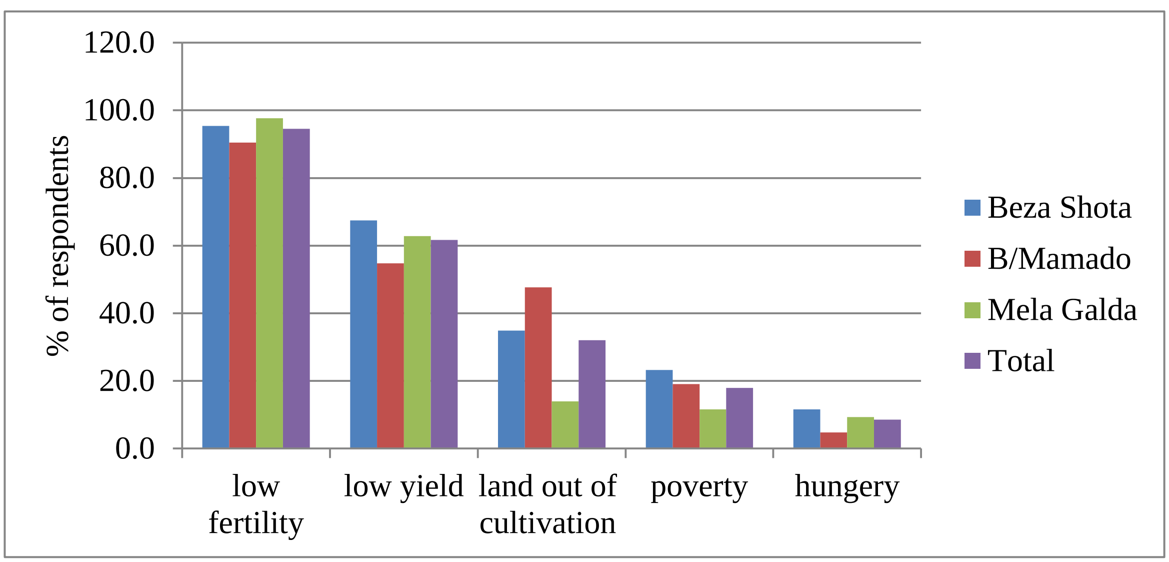


Figure 9: Consequences of soil erosion

4.2.3 Farmers perception about Soil and water conservation in Fanta watershed

4.2.3.1 Traditional soil and Water Conservation Practices

In the study area, there were adopters and non-adopters who practice a traditional conservation structures those were not a traditional measures but they used in traditional ways in their farmlands. According to the group discussion those a several traditional soil fertility maintenance techniques have been identified in the area. These include fallowing, crop rotation, manure, traditional cut-off drains, contour cultivation and mixed cropping as replied by 42.2%, 76.6%, 44.5%, 82.8%, 55.5% and 78.1% of the respondents respectively. Traditional cut-off drains or ditch and mixed cropping were most likely used by farmers in the study area for erosion control in the farmlands. It was a small ditch constructed on cultivated fields using ox-plough. It is used to protect the soil, nutrient and seeds from erosion. Traditional cut-off drains are constructed to allow excess water to drain out of cultivated land to artificial or natural waterway. In the catchment, traditional cut-off drains are dug on the upper side of the cultivated lands to act as cut-off drains by protecting the fields from runoff that comes from higher parts of the terraces.

Soil erosion is not a new phenomenon in the study area. It is often claimed that farmers do not fully understand the causes and consequences of land degradation. A smaller proportion of the farmers appeared to be less aware of below-ground processes of soil degradation by processes such as leaching, nutrient mining and soil acidity. Nevertheless, farmers frequently undertake traditional methods of soil and water conservation such as simple diversion ditches across their fields to divert runoff and therefore prevent their land from becoming waterlogged (Lakew*et al*., 2006). For the question of why they could not practices a soil bund on their farm; they replied from the given alternative reasons 57.6% and 42.4% of respondents rating limited knowledge and shortage of labor as main reasons; while 36.4% and 15.2% of them also shortage of land and poverty as reasons reported respectively (Table: 14).

Table 14: Traditional soil and Water Conservation Practices in study area.

Kebeles	Beza Shota	B/Mamao	MelaGalda	Total
Respondents characteristics	Percentage	Percentage	Percentage	Percentage
Do you practices soil bund on your farm				
Yes	79.1	69.0	74.4	74.2
NO	20.9	31.0	25.6	25.8
If No, the reasons				
Poverty	0	23.1	18.2	15.2
Limited knowledge	66.7	53.8	54.5	57.6
Lack of equipment's	44.4	15.4	9.1	21.2
Land shortage	33.3	46.2	27.3	36.4
Labor shortage	44.4	38.5	45.5	42.4
If No, by what methods they conserve their farm				
Fallowing	30.2	52.4	44.2	42.2
Crop Rotation	81.4	69.0	79.1	76.6
Mannuring	44.2	50.0	39.5	44.5
Traditional Waterway	83.7	78.6	86.0	82.8
Contour Cultivation	67.4	54.8	44.2	55.5
Mixed Cropping	72.1	85.7	76.7	78.1

4.2.3.2 Physical soil and water conservation measures

According to the survey, most of the respondents of household respondents said that, the implemented soil bund on their farmland used to increase soil fertility by protecting soil erosion and collecting rainwater (Figure: 10). The survey result showed that 92.1% of adopter used soil bund at least one of their plots. The proportion of soil bund is larger than that of the other structures in the study area. The possible reason could be for high proportion of soil bund to the other SWC practices is effective since to reduce runoff velocity of steep slope farm lands, are the absence of stone and the soil bund requires less labour input because the excavated material from the ditch is thrown downhill. Similar findings of Anley *et al., (*2006) in Dedo district, western Ethiopia which showed that, soil bund was the most widely and intensively used soil conservation structures than the other. Physical SWC measures are structures, which were built on farm and rangelands for soil and water conservation as well as to increase the time of concentration of runoff, to increase infiltration rate, reducing the amount velocity of surface runoff (MoARD, 2005).

Figure 10: Soil Bund on Study Area

Soil bunds act on slopes from 0-30% (depending on rainfall, soil type and land use) both by interrupting slope length and by reducing its gradient. With proper maintenance, this may eventually lead to terrace formation by moving and compacting soil downhill (FAO, 1986).

Soil bund is constructed with water collection channels at the upper side of the farmland along the contour. That the erosion washed away the top soil together with the applied fertilizer leaving behind the poor and eroded soil. This method was important in controlling soil loss, enhancing soil moisture retaining capacity and ultimately increasing productivity of farmland (WFP, 2005).

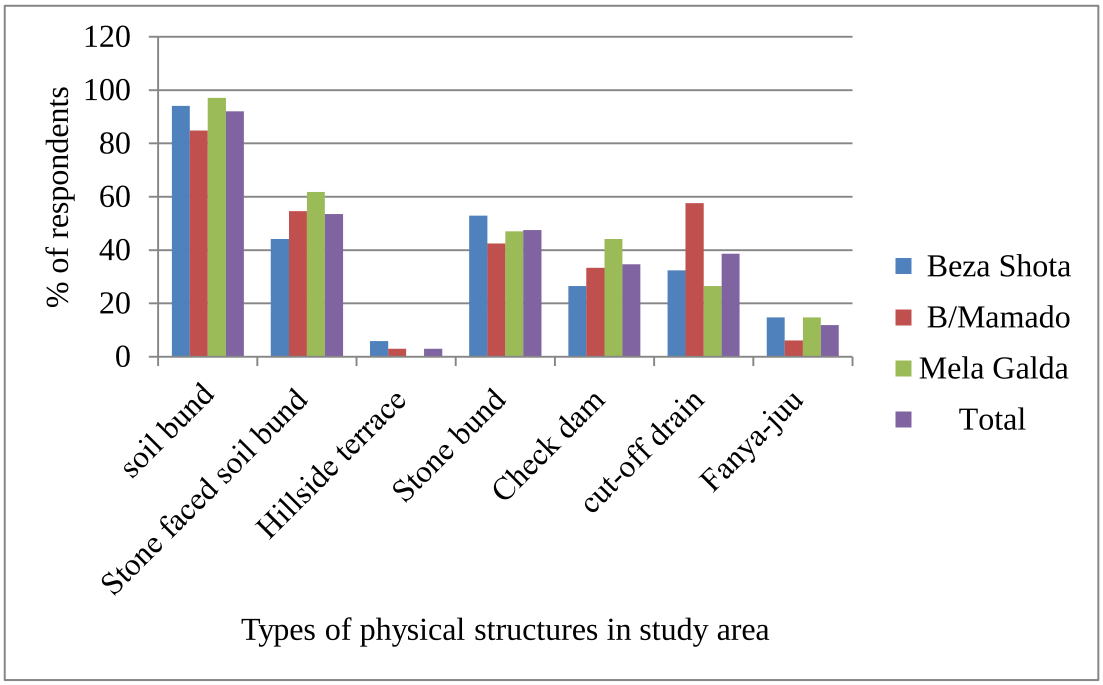


Figure 11: Types of physical SWC structures practices in study area

4.2.4 Perceived benefit of soil and water conservation

Farmers were asked the advantages of conservation while respondents ranked 93.0% that conservation structures improve soil fertility, 71.1% improves crop yield and 65.6% of the respondents mentioned reduce soil losses (Figure: 12). In addition, focus group was agreed on the positive roles of SWC structures in reducing soil erosion and improving crop yields. As perceived, the soil fertility was increased due to the effect of soil conservation techniques on soil that was barriers or protects the soil washed away from top of the soil, which also replied during discussion. As the report of focus group, discussion structures in reducing soil erosion and improving crop yields by reducing slope length and thus reduce the volume of surface runoff, which lowers the sediment transport capacity.

This was agreed with the finding of Hailu *et al.*, (2012); Wolka *et al*., (2018) who reported that the adoption of soil and water conservation increased soil fertility and consequently improved crop yield. Abdul-Hanan *et al.*, (2014) also confirmed that SWC increase Maize yield in Ghana as the result from soil fertility improved by SWC techniques.

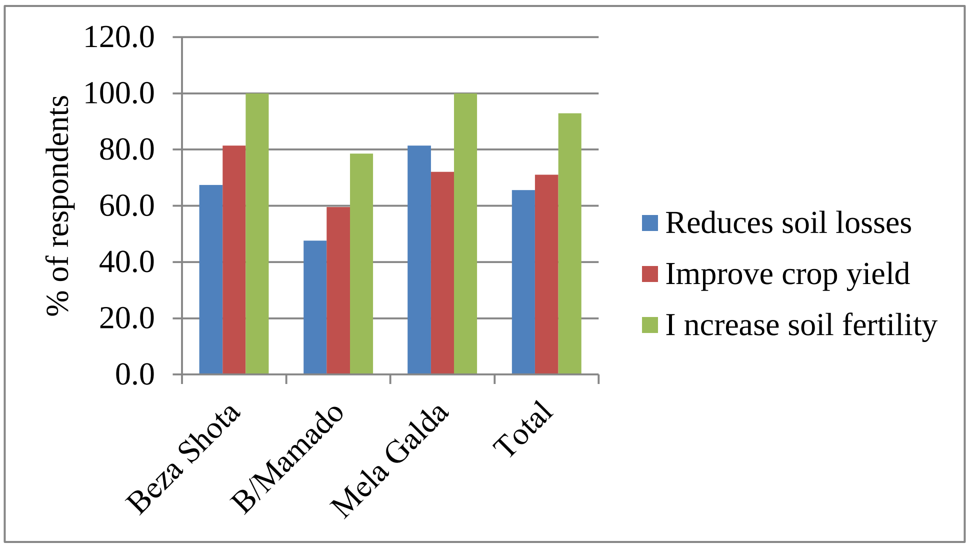


Figure 12: Advantages of new SWC measures

According to the result of the respondents and focus group, discussion increasing of soil fertility; the crop production and vegetation coverage dependent of plots affected by erosion or eroded farms should be high after the adoption of new SWC technologies. Nevertheless, before introducing new technologies their crop production and vegetation coverage should be 69% and 31% low and medium respectively due to usable top soil washed by runoff (Table: 15). After the adoption of introduced technology, the vegetation coverage was 55% and 34% high and medium respectively based on eroded farm levels. However, within less managing practices and other factors there are no changes as replied by 11% respondents. In the focus group discussion farmers explained that the vegetable leaves decomposed as residue, which increases soil productivity, and the soil water holding capacity improved and these makes the crop yield increases but the effects varied based on farmers management activity. The result of observation and key informant interview confirmed that because of deforestation and agricultural land expansion the overall vegetation coverage in the area has been decreasing. However, because of project intervention some degraded hillsides are covered by some indigenous and exotic tree species.

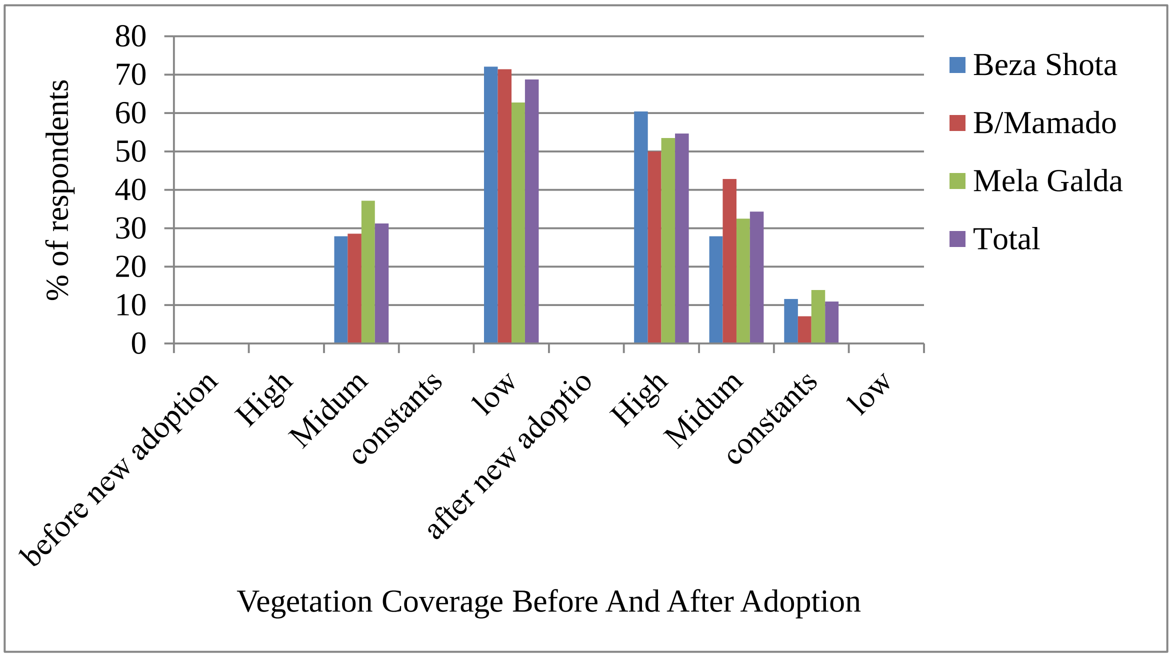


Figure 13: Before and after vegetation coverage in study area

4.2.5. Sustainability of physical SWC

4.2.5.1 Challenges in sustaining physical SWC structures

All farmers (100%) reported having experienced soil erosion in their farmland (Table: 13). In the causes of soil erosion, farmers practiced different soil conservations measures, which are either biological or mechanical special the most common structures in study area was soil bund and stone bund. The results from the study revealed that the challenges faced in sustaining structures of SWC techniques were free grazing, rainfall, lack of vegetation, slope of the land, sever water erosion and not repaired the constructed structures (Table: 13). From these factors, free grazing and failure to repair were major challenges to sustainability of structure as reported by 92.2% and 88.3% of respondents respectively (Figure: 13). Also, during group discussion rose that most of the farmer's soil tillage activities in inter-bund areas can damage the structures that means closely cultivating to embankments of the SWC structures can gradually reduce their thickness and make the structures susceptible for further break down. Addisu Damtew, (2011) also reported livestock damage of built structures in Goromti Watershed, Central Ethiopia, in the cultivated lands.

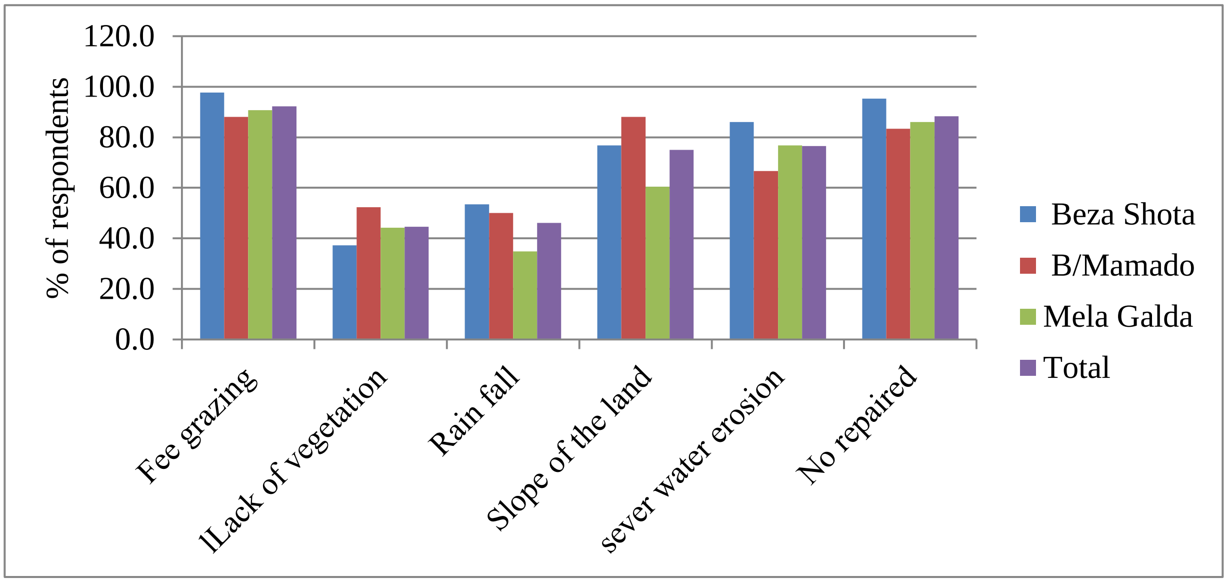


Figure 14: challenges of affects the sustainability of structures

4.2.5.2 Repairing physical soil and water conservation

All farmers (100%) and focus group discussion assures the constructed structures were destroyed (Table: 15). The interview results show that the farmers showed that natural rainfall, livestock and landowners destroyed as perceived by 67.3%, 90.1% and 18.8% respectively. As mentioned earlier, farmers possess comparatively large number of livestock in the area, especially cattle and goats that highly affect the structure. Cultivation land is exposed for intensive grazing and more susceptible for the damage of structures. This challenges sustainability of built structure. That they would destroy every other structure to reclaim the “lost land” for cultivation, and some others stated that they would destroy some of the structures in order to use the fertile sediments retained behind it, like stone bunds. Regarding farmers attempt to repair the damaged structure, 62.1% of the respondents expressed their commitment to repair the destroyed parts but 37.9% stated that they would not maintain the structures. Within group discussions, they stated that, the introduced SWC measures were widely acknowledged and accepted as effective measures and as having the potential to improve land productivity. Nevertheless, their sustainable adoption on the farm level appears to be less likely. These are because based on their responses and confirmed with key informants they are requires other incentive to maintain it and the owners of farm themselves allow their cattle for free grazing in cropland with structures. However, they simply plan to maintain but they could not implement that plan and already challenges the development agent to got incentive from PSNP to build new structures. Also the issue of sustainability in terms of monitoring and evaluation with maintenance of the constructed structure on time is under question because the plan and construction activity mainly focused more on constructing new physical structures than integrating or maintaining the earlier.

Table 15: The experiences of maintaining of constructed structure and its reasons

Kebeles	BezaShota		B/Mamado		Mela Galda		Total	
Respondents characteristics	Respondents	Percentage	Respondents	Percentage	Respondents	Percentage	Respondents	Percentage
Is there any destroyed soil bunds? (from out of adopted 95 respondents)								
Yes	34	100.0	29	100.0	32	100.0	95	100.0
NO	0	0.0	0	0.0	0	0.0	0	0.0
If ‘Yes’, what destroy it? (n = 95)								

Land owners by itself	7	20.6	9	31.0	3	9.4	19	20.0
High rainfall	29	85.3	21	72.4	18	56.3	68	71.6
Livestock	32	94.1	28	96.6	29	90.6	89	93.7
Do you experiences to maintain (from out of answer Yes, 95respondents)								
Yes	25	73.5	17	58.6	17	53.1	59	62.1
NO	9	26.5	12	41.4	15	46.9	36	37.9
If yes, how did you maintain it? (out of 59 experienced to maintain respondents)								
Digging drainage ditches across plots	3	12.0	5	29.4	4	23.5	12	20.3
Planting bushes or trees along the bunds	6	24.0	9	52.9	3	17.6	18	30.5
Stabilizing by leaving the riser slope with grass cover	8	32.0	4	23.5	7	41.2	19	32.2
Redeveloping the terrace bunds	19	76.0	16	94.1	14	82.4	49	83.1
Stabilizing the damaged bunds with stone and soil	23	92.0	17	100.0	17	100.0	57	96.6
If No, why did you not maintain it? (out of 36 no experiences to maintain respondents)								
Because of non-existence of erosion	0	0.0	0	0.0	0	0.0	0	0.0
Because of only slight erosion	0	0.0	0	0.0	0	0.0	0	0.0
Because of the difficulty of up	8	88.9	9	75.0	12	80.0	29	80.6

and down ploughing								
Because of the unavailability of labour	8	88.9	10	83.3	13	86.7	31	86.1
Because of loss of cropland	9	100.0	8	66.7	15	100.0	32	88.9
Because of lack of knowledge	9	100.0	12	100.0	14	93.3	35	97.2

Based on results of interview; the most common maintaining practices are stabilizing damaged bunds with stone and soil redeveloping the bunds are ranked 96.6% and 83.1% respectively. The main source of labor for maintenance of terraces is family members. The farmers those who did not experience to maintain their constructed structure covers out of (adopted-95) respondents 37.9%. They are rating the reasons for these; lack of knowledge 97.2%, losses of cropland 88.9%, shortage of labor 86.1% and the structures difficult to up and down poughing 80.6% (Table: 15). The poor knowledge about the benefits of SWC could be the limiting factor to adopt such techniques (Okoba and de Graaff, 2005).

4.3 Factors affecting adoption of physical SWC measures in study area

Most of the local farmers acknowledged the introduced new physical SWC technologies as effective measures in controlling soil erosion and for improving land productivity. However, most of them did not appear to have intentions or plans to continue construction in their own field and maintaining the constructed structures. Farmers with no-bund in their field did not initiate to build by themselves, which implied that there was a very little chance for the farmer-to-farmer diffusion. Once farmers perceive soil erosion as a problem having negative impacts on soil quality, land productivity, and expect positive returns from soil and water conservation measures, it is highly likely that they will decide in favor of adopting available conservation measures.

Table 16: Binary logistic regression model results for factors influencing adoption of SWC practices.

Variables	B	S.E.	Wald	Df	Sig.	Exp(B)
Sex	3.448	2.807	1.509	1	.219	31.430
Age	-3.118	1.486	4.404	1	.036	.044
Education level	2.779	1.290	4.642	1	.031	16.106
Family size	-.729	.538	1.836	1	.175	.482
Plot number	-1.487	.988	2.263	1	.132	.226
Land size	-.587	.518	1.288	1	.256	.556
Location of land	.575	.630	.833	1	.036	1.778
Contact with extension	1.807	.636	8.087	1	.004	6.095
Accesses to training	2.995	1.202	6.207	1	.013	19.991
Livestock number	-.927	.668	1.926	1	.165	.396
Constant	8.722	6.120	2.031	1	.154	6.1373

a. Variable(s) entered on step 1: sex, age, education level, family size, plot number, land size, location of land, contact with extension, accesses to training, Livestock number.

Based data obtained from interview and discuss with focus group lack of farmer's participation in problem identification, planning, and further decision-making process on new technologies of soil and water conservation. As they conformed they uses of food-for-work as an incentive; without considering the socio-economic characteristics of farmers were the main reasons for no adoption of SWC and the adopted could not use in a sustainable manner. These were demographic, socio-economic, institutional and physical factors (Mulugeta *et al.*, 2001; Bekele and Drake, 2003; Tenge *et al*., 2003; Eleni, 2008; Fikru, 2009). The major factors that determine household heads to adopt physical SWC measures of the dependent variables were analyzed with 10 explanatory variables those selected from the previous studies and interviewing HHs and with key and group should be analyzed by using binary logistic regression test of model coefficient.

4.3.1 Demographic characteristics and adoption of physical SWC practices

Sex of the household heads is positively correlated with the adoption of introduced physical SWC practice but statistically insignificant ($p = 0.091$). The result of Wald statistics (1.509), which showed that male-headed households are more likely to be engaged in implementation and maintenance of SWC practices than female-headed households. The odds ratio of logistic regression showed that male household heads adopted the introduced SWC practices by the factor of 31.43 than female-headed households because they spent their time in domestic activities and limited support other than their children. The similar finding, Asfaw and Neka, (2017), Krishna *et al*., (2008) and Eleni, (2008) indicated that male headed household have a higher chance to involve in continued use of physical SWC measures than female headed households because most women spent their time in domestic activities and responsibilities. Contrary to this, a research conducted by Fikru, (2009) in Koga Watershed in Northern Ethiopia reported that gender did not have any relationship with the adoption of introduced physical SWC structures.

Age of the household had negative coefficient and significance ($p<0.05$) influenced adoption of physical SWC in Fanta watershed (Table: 16). The result of binary logistic regression analysis, household head age is significant at ($p<0.05$) level of significant ($B = -3.118$, $df = 1$, P-value = 0.036) that is, it is negatively correlated with farmers adoption decision. The result of Wald statistics (4.404), showed that old-headed households are more unlikely to be engaged in implementation and maintenance of SWC practices than younger- households headed. The odds ratio also revealed that young- household farmers adopted the introduced SWC practices by the factor of 0.044 than old-household farmers. These imply that older farmers are more unlikely to adopt SWC technologies in comparison to younger farmers. Because they are, more often educated and they are more aware of soil erosion problem and its solution. As age of the HHs increases, a farmer becomes unwilling to retain conservation structures. This is perhaps due to the interest to maintain their own experience of managing land including the soil conservation. In addition, when farmers become older they have less labor to build and repair SWC structures. Similar finding are Bekele and Drake, (2003) reported negative correlation of age of farmer in adopting SWC structures. In addition, Bekele and Holden, (1999) confirmed that younger farmers are often expected to invest more in soil conservation practices. Contrary to this, Fikru, (2009); Chomba, (2004) verified that age of household heads had positively influenced adoption of SWC practices.

Family size correlated negatively and insignificantly with the adoption of introduced physical SWC practices (B = -0.729 df; 1; p –value 0.175). This described that small sized household family is highly likely to involve in retaining of soil and water conservation practices than larger sized household family. Because there is competition for labor between food generating off-farm activities and investment in maintenance of soil and water conservation practices. Similar finding of Fikru, (2009) and Aklilu, (2006) stated that farmers with larger family sizes are less likely to continue using introduced soil and water conservation practices. Bekele and Holden, (1998) indicated that physical conservation practices occupy a large area and compete for the scarce productive land resource. Thus, households with large family sizes tend to remove constructed physical conservation structure from their farmlands. On oppositely; Geoffer, (2004), who found that HHs size, was associated positively with adoption of conservation practice.

4.3.2 Socio-Economic characteristics and adoption of physical SWC practices

4.3.2.1 Education level

In terms of education, adopters were shown to have more years of formal education. Statistics show that adopters, 41.2 years mean show of formal education, compared to the 49.6 year non-adopter and logistic regression result (B = 2.779, df = 1 and p = 0.031). The Wald statistics (4.642) also revealed its significant association with the adoption of SWC practices (Table: 16). This showed that relatively better-educated farmers are engaged in the adoption of the newly introduced SWC practices. The odds ratio also revealed that educated household farmers adopted the introduced SWC practices by the factor of 16.106 than non-educated (illiterate) household farmers. These findings were agreed with the findings of (Fikru, 2006 and Melkie Erkie, 2016). On contrary, the finding of Eleni, (2008) shows that there is no significant correlation between education level and adoption of SWC measures.

4.3.2.2 Livestock size

Livestock size was considered to have a negatively correlated and insignificant with the adoption of SWC practices (Table: 16). The binary logistic regression model result indicates that livestock size is insignificant at 5% level of significant (B=-0.927, df =1, P< 0.165). The result of negative logistic coefficient shows that farmers who have more livestock size have less probability to adopt SWC practices than those who have small number of livestock. Because the cattle are allowed to free grazing on cultivated land and may damage the constructed structures, which negatively affects the interest of construction and repairing of the SWC structures. Thus, farmers disregard construction of the SWC structures by anticipating repeated damage of the built SWC structures by cattle, and thus were not willing to construct. Amsalu and De Graaff, (2007), Tesfaye *et al*., (2014), Wagayehu and Lars, (2003) and Wolka *et al.*, (2018) also similar finding that reported a high number of cattle have less concerned about constructing and maintaining of the SWC structures for improving crop productivity. However, Bekele, (1998) found positive association between livestock holding and adoption of SWC practices in the central highlands of Ethiopia.

4.3.3 Physical characteristics and adoption of physical SWC measures

4.3.3.1 Farm size and number of plot

The analysis, report show that land size was not significance influences the adoption of the SWC practices because of the mean of non-adopter was 3.04 and adopter was 2.84 and result of regression (B = -0.587, df = 1 and p = 0.256). This imply that the size of land increases less attention to implement the new SWC also with in group discussion as they approved farmers of large area owners should not want to construction on their farm land because of they were used by changing the fallowed land for seasonal purposes and then after two/three years cultivation make rest. Similarly, Asfaw D., and Neka M., (2017) reported a negative relationship between the size of farmland holding and the probability of adopting soil and water conservation practices. On contrary, Fikru, (2009) and Abera, (2003) they affirmed that farm size is associated positively and significantly with the adoption of introduced soil and water conservation practices.

The number of plots is negatively related with adoption of SWC technologies in the catchment and not significant. The result of binary logistic show that (B = = -1.487 df = 1 p- value = 0.132) and this indicates that the number of farm plot increases the adoption of SWC to become decreases. Those non-adopters had a higher mean number of land compared to the adopters. Similar finding with these was stated as the number of farm parcels of a farmer increase, the attention and care given to proper farming practices reduces drastically, affecting adoption of improved technologies and maintenance of existing structures it was also reported by (Long, 2003; Kessler, 2006; Ertiro, 2006). On contrary, studies that positive effect of plot size on adoption of conservation practices (Yohannes, 1992 and Shiferaw & Holden, 1998).

4.3.3.2 Slope of land

The binary logistic regression analysis revealed that the location of land was positively and significantly correlated with the adoption of improved technologies (B = 0.575 DF, = 1 P-Value = 0.036). This implies slope of land influence adoption and use of SWC technologies positively. This is because slope is an indicator of soil and water loss from the farmland. This forces farmers to control or mitigate the impact of erosion on fields that are situated in steep slopes and hence slope influences the decision of farmers to undertake conservation measures. Wagayehu and Lars, (2003) and Bekele, (1998) also reported that slope affects farmers' decision to adopt conservation structures positively. However, Alemu, (1999) found statistically significant and negative relationship between slope and participation in conservation investment. He argued the returns from investment on steep sloped plots might be low, hence less adoption on such plots.

4.3.4 Institutional characteristics and adoption of physical SWC measures

4.3.4.1 Access to Extension Services

The result of respondents between contact with development agents and adoption of soil conservation depict that there is a positive and significant relation between contact with extension agents and adoption of soil conservation methods (B =1.807 df, 1 p- value = 0.004). Based on results of binary logistic Wald statistics (8.087) also indicated that highly significant association and the factor of 6.095 than those who have no access to extension services (Table: 16). This is because farmers who receive better information from extension agents are willing to implement new soil and water conservation practices and maintain the existing practices. But low frequency of contact between farmers and extension agents result in insignificant effect. The research conducted by Bekele and Drake, (2003) and Shiferaw & Holden, (1998) stated that as farmers are supported by extension workers and knows well about the benefit of conservation practices. The probability of using and maintaining the introduced soil and water conservation practices will increase. However, Fikru, (2009) found that access to extension service did not affect significantly the adoption rate of SWC practices.

4.3.4.2 Training in soil erosion control

Table: 12 show that the 83.6% of sampled farmers replied yes to accesses training and it is correlated positively and significantly with the adoption of soil and water conservation practices (B = 2.995 df, 1 p-value 0.013). The Wald statistics (1.202) also indicated highly significant association and the odds ratio of farmers who have access to training is greater by the factor of 19.991 than non-trained farmer household heads to the adoption of introduced soil and water conservation practices. Less awareness of the nature and technical requirements of SWC practices as well as lack of awareness on agricultural knowledge and SWC measures are the major challenges, which are limiting households to adopt and implement SWC practices at their farmlands. It is believed that farmers did not have information about SWC practice and cannot be expected to adopt it. Fikru, (2009) reported that training has positive correlation with the adoption of soil or stone bund and tree plantations. According to Tenge, *et al*., (2004); Asrat, *et al*., (2004); Million and Kassa, (2004), better perception and knowledge of farmers about the soil erosion problem contribute significantly to the sustainable use of introduced soil and water conservation practices. However, Bekele and Holden, (1998), revealed that access to training has a positive but insignificant correlation with the adoption of introduced soil and water conservation practices.

5. CONCLUSIOUN AND RECOMMANDATION

5.1 Conclusions

Soil erosion has been aggravated as result of over grazing, cultivation of steep slope and deforestation. This study compared soil properties in plots with soil bunds and no bunds in three slope positions and assessed factors determining adoption of soil bunds in a productive safety net supported watershed.

The results of soil analysis showed that soil texture and most of chemical properties had significant variations with respect to soil bunds and slope gradients. The different content of clay, sand, SOC AP and AK on different slopes indicated the ability of soil bunds to reduce erosion. Generally, the soil bunds had positive impacts on the soil parameters in conserved plots showing higher amounts of nutrients than non-conserved croplands. In addition, lower slope position and close to bund (at upslope position within consecutive bunds) highest value was recorded for most nutrients, clay and silt fractions.

The results from survey indicated that all farmers recognize the negative impact of erosion on soil productivity, 74.2% of farmers adopt physical SWC techniques and the majority of farmers implement the techniques under the support of the PSNP. Among the total sampled households, 93.0% farmers perceived that the adoption of physical soil and water conservation increased soil fertility and consequently improved crop yield.

Majority of respondents and focus group discussion indicated that constructed structures were destroyed due to natural rainfall, livestock and landowners. Livestock's specially cattle and goats highly affect the structure, which were due to free grazing's. The result shows that free grazing and fewer attempts to repair the built structures also appeared bottleneck on sustainability of the conservation technologies.

Binary logistic regression model were used to analyze the important factors with regard to the soil bund. Educational level, location of land, accesses to extension contact and accesses to training were positively and significantly influencing farmers' decision to adopt improved physical SWC practices. Conversely, sex, family size, farm size and number of farm plots and livestock owned were analyzed with binary regression model and showed negative influence on farmers' adoption on SWC practices. It can be concluded that soil bunds were importantly retained essential nutrients but its sustainability suffered from challenges for adoption and repairing in Fanta watershed.

5.2 Recommendation

The physical SWC structures were not regularly maintained. Thus, there should be a continuous awareness creation mechanism on DAs and other stakeholders on the proper management of the structures.

Incentives obtained from Food-for-Work or Productive Safety Net Program should not be considered a way to obtain food or money for survival, rather farmers must be convinced that the incentive assist them in increasing agricultural production through constructing and maintaining SWC measures.

In addition, awareness raising campaign must be intensified for demonstrating the soil nutrient and moisture-enhancing role of the conservation structures. Thus, for adopting and disseminating such techniques farmers' perception and awareness on benefit and risk of introduced SWC techniques should be increased by offering training to farmers.

Prevent cropland from open grazing, and control overstocking of cattle's that leads to overgrazing and further soil depletion.

Continuous intensive cultivation without appropriate SWC practices contribute for lower levels of soil nutrient distribution across the landscape positions. The lower levels of soil fertility indicators across the landscape reveal the need for improved land and water management strategies. Therefore, emphases should be given on promoting site-specific sustainable SWC practices for soil nutrient improvement and thereby better agricultural productivity. Otherwise, the soils are likely to undergo accelerated degradation and rapid productivity losses.

Active participation of all the local farmers in all aspects of technological development is important to strength their capacity and increase motivation to use the newly introduced SWC technologies. Thus, participation of all the stakeholders especially farmers achieve better success for implementing SWC technologies. Although most farmers perceive their soils as being fertile, this was not reflected in the crop yields. There is need, therefore, for further investigation on soil fertility in order to help the farmers achieve expected crop and livestock yields as per their locality.

The selected factors such as, female, large land holders, large family members and more livestock owners of household heads are negatively influences the adoption of SWC activities, the agricultural and rural development offices, NGOs and the concerned bodies could special emphasis on creation of awareness and encourage farmers collaborations in adoption and maintenance of SWC practices.

This study is just a step to pave a way for further study, presenting the above recommendations for more research to validate and expand the result of this study. Thus, further investigations, which include the performance of different SWC practices on nutrient retention, yield improvement under varied conditions of land use, slope steepness, soil type, soil depth to be assessed in order to investigate.

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7. Appendix

Appendix 1: Questionnaire for Household survey

The purpose of this questionnaire is to gather information on farmers 'adoption on physical SWC practices that are being employed by smallholder farmers by PSNP and effects of its on soil fertility and crop production in Gena Bossa Woreda. The study will be used to forward possible solutions, extension and research interventions that favor the farmers. This information will be delivered to those who are extremely confidential and who really want and willing to see your agricultural development to evaluate the implementation of the program.

Date of interview: Day____________, Month____________, Year___________

Appendix 1.1. Respondents General Information

1.1. Name of the respondent…………………………………….

1.2. Age; 1) <25 2) 25-35 3) 35-45 4) 45-65 5) >65

1.3. Sex; 1) male 2) female

1.4. Educational status; 1) Illiterate 2.primary school (1-4),3. Elementary school (5-8), 4.Secondary school (9-10), 5.preparatory school (11-12) 6) diploma 7) degree and above

1.5 Kebele……………

1.6. Occupation (major sources of income): 1) Mixed farming 2) Pastoralist 3) Daily Laborer 4) Agro-Pastoralists 5) Government employee 6) Others (specify the off-farms; selling, bee keeping,) …………………………

2. Assets & family size of the Respondents

2.1 The size of the total area of cultivated land in hectares_____________1) <0.25ha, 2) 0.25-0.5ha, 3) 0.5-1ha, 4) 1-5ha and 5) >5ha

2.2 Numbers of the farm plot. 1) 4 2) 3 3) 2 4) 1

2.2 Number of persons lives in the household 1) 1-3 2) 4-7 3) 8-10 4) >+11

2.3 Total number of animals owned by the household Oxen----------Cows----------Calves----------Donkeys---------Horses------------Mules-----------Sheep-----------Goat-----------

2.4. What crop do you grow?

a) Enset And Godere b) Maize c) potatoes d) teff e) sorghum f) bean g) barley h) Wheat

3 Soil Erosion problems and their perceived solutions.

3.1 Where is your farm located? a) Steep slope b) Low slope c) Marshland d) Medium

3.2 Do you experience soil erosion problems in your farm? a) Yes… b) No… If yes, how serious the problem is? a) High b) medium c) low d) very high

3.3 What do you think contributes to soil erosion or causes it? a) Land slope b) Vegetation removal c) Intensive cultivation d) Rainfall e) Deforestation f) Over grazing g) continuous cultivation h) cultivation of steep slope i) Roads or footpaths that cross plots

3.4 Which are the effects of soil erosion? a) Poverty b) Land become out of cultivation c) Low yield d) Low soil fertility e) Hunger

3.5 Where do you keep your animals? -------------------------------- 1) Community grazing land 2) On forested area 3) On cultivated fields 4) On private grazing field 5) cut and carry system

3.6 Do you practice soil bund conservation measures in your farm? a) Yes... b) No…

If no, what is the reason? a) Poverty b) Limited knowledge c) Lack of equipment’s d) Land tenure e) labor shortage

If yes, who support you? a) NGOs b) Government c) community

If NGOs; 1) PSNP 2) SLM 3) Other

3.7 How was the soil erosion on your farm before the introduction of the SWCM by PSNP? A. No soil erosion B. Moderate soil erosion C. Slight soil erosion D. Severe soil erosion

3.8 Is there any destroyed soil bunds? A. Yes B. No

If your answer is ‘Yes’, what destroy it? a) High rain b) livestock c) land owners by interest

3.9 Do you have the experience of maintaining terraces destroyed by rain or livestock? A) Yes B) No ; If your answer is ‘Yes’, how did you maintain it?

A. Stabilizing by leaving the riser slope with grass cover B. Redeveloping the terrace bunds C. Digging drainage ditches across plots D. Planting bushes or trees along the bunds E. Stabilizing the damaged terrace bunds with stone and soil F. Other (please specify)

If your answer is ‘Yes’, what is the source(s) of labour for maintenance?

A. HHS B. GOV C. PSNP D. Family E. Other (please specify) ______

If your answer for question is ‘No’, why did you not maintain it?

A. Because of non-existence of erosion B. Because of only slight erosion C. Because of the difficulty of up and down ploughing D. Because of loss of cropland E. Because of the unavailability of labour F. Because of lack of knowledge G. All H. Other (please specify)

If your answer for question no 3.8 is ‘C’, why did you destroy it?

A. Because of the reduction of yield B. Because of the narrowing of cropland C. Because it makes farming difficult D. Because of lack of knowledge’s E. All

3.10 What factors do you take first in to account to construct SWC ? 1. Steepness of the slope, 2.soil physical degradation, 3.land use systems, 5.severity of soil erosion, 6. Gully formation.

3.11 What advantages have you realized after adopting soil erosion control in your farm? a) Reduced soil loss b) Improved crop yield c) Increased Soil fertility d) increase soil MC

3.12 What are the challenges that affect the quality and effectiveness of physical SWC structures? 1. Animals free grazing 2.Intensity of Rainfall 3. Slope of the land 4. Lack of vegetation cover, 5.severe water erosion 6. By cultivation 7. No repaired /management's

3.13 What is your plot level crop productivity before adoption of soil conservation?

A. Low B. Medium C. High

3.14 How do you relate your crop productivity after adoption of soil conservation?

A. Low B. Medium C. High D. Constant

3.15 Before lunching PSNP is there any other programs and soil bund conservation exist.

A) Yes B) No, if no what conservation measures do employ for your farm plot(s), which are not terraced? A. Contour cultivation E. Crop rotation B. Fallowing F. Mixed cropping C. Drainage ditches and waterways G. Other (please specify) _____ D. Use of manure

3.16 What are the major constraints you meet in adoption method of soil conservation?

A. Constructing physical conservation B. Lack of incentives C. Labor shortage D. Decrease the size of the plots E. Problem related to drainage F. Difficult to plough and turn the oxen

3.17 What is the extent of vegetation cover after adoption of soil conservation?

A. Low coverage B. Medium coverage C. High coverage D. Constant

3.24 What is the overall coverage of vegetation is before adoption of soil conservation?

A. Low coverage B. Medium coverage C. High coverage D. Constant

3.25 How many times do you contact with soil and water conservation experts (DAs experts) Per a month? A/ None B/ = once C/ two times D/ = three times

Appendix 2: Interview protocol for key informant and experts of NRM

1. When was soil conservation structures introduced in this watershed? What are adopted methods of soil conservation? ____

2. How do you get the effectiveness of soil conservation SWC measures in controlling soil erosion problems?____

3. What are the major factors affecting the farmers for the adoption of SWC practices in the study area?____

4. How do you evaluate the socio economic condition of the village in terms of the level of education, age, family size and other?_____________________________________

5. What is the Extent of community participation in planning designing, implementing monitoring and Executing soil conservation decision? How willing are the village community members to commit resource? How task are assigned to fulfill the responsibility?_______

6. What are the newly introduced methods of soil conservation? Among newly introduced method of soil conservation, what is the type of soil conservation farmers adopted well? And why? ____

7. What is the role of the DAs, SWC and agricultural experts in the conservation intervention?

8. What is the criterion used to select farmers to adopt method of soil conservation? How do you see the perception of farmers in adopting method of soil conservation and soil erosion?

____

9. Are there any types of package that you have introduced farmers to gain additional source of income?____

10. How do you evaluate the degree of empowerment of community towards making decision in regarding to soil conservation?____

11. Do you belief farm size and labor shortage affect adoption of soil conservation? If yes how?____

12, What are the traditional methods of soil conservation in the area? How do you rate farmer's traditional soil conservation in particular?________________________________

13, Do you belief farmers will continue to maintain and undertake soil conservation after the withdrawal of the project?____

14. Do you agree that physical SWC practices are the solution to restore and rehabilitate degraded lands as well as increase soil fertility? A) Agree B) Disagree; if you agree, how? Pleaseputyouropinion.____

15. Do you agree that physical SWC practices are the solution for reducing rural poverty? A) Agree B) Disagree; If you agree how? Please put your explanation._____________________

16. What are the effects of physical SWC practices on crop yields? Please put down your explanation.____

17. Physical SWC practices decrease the rate of soil erosion. 1. Agree 2. Disagree; if agree, please explain, how?____

18. Physical SWC practices increase soil fertility content. 1. Agree 2. Disagree; if agree, please explain, How?____

Appendix 3: Observation Check List

Date of observation_____________ Place of observation (watershed) ______________

Peasant association ____________ House hold code____________

1. The overall condition of soil conservation on farm as well as off farm (conservation history) and Physical conservation structures quality.

2. Availability of adopted method of soil conservation and types

3. Livelihood condition of the areas.

4. House hold initiation in soil conservation measures.

5. The status of treated plot with adopted method of soil conservation. Opportunities (benefits) and Challenges

7. Crop productivity on the farm plot and crop stored around home stead.

8. Erosion extent on farm plot as well as Degree of erosion problem on the plots.

9. Status of soil and water conservation structure at the time of interview.

Thank you for your time and cooperation!

Appendix: 4 ANOVA results of soil parameters on slope location from soil bund plots.

		Sum of Squares	df	Mean Square	F	Sig.
sand conserved	Between Groups	661.556	2	330.778	31.614	.000
	Within Groups	251.111	24	10.463		
	Total	912.667	26			
silt conserved	Between Groups	343.407	2	171.704	18.731	.000
	Within Groups	220.000	24	9.167		
	Total	563.407	26			
clay conserved	Between Groups	1769.185	2	884.593	27.312	.000
	Within Groups	777.333	24	32.389		
	Total	2546.519	26			
TN conserved	Between Groups	.040	2	.020	10.047	.001
	Within Groups	.047	24	.002		
	Total	.087	26			
SOC_ conserved	Between Groups	.703	2	.352	48.332	.000
	Within Groups	.175	24	.007		
	Total	.878	26			
AP_ conserved	Between Groups	.108	2	.054	39.508	.000
	Within Groups	.033	24	.001		
	Total	.140	26			
AK_ conserved	Between Groups	342625.407	2	171312.704	12.504	.000
	Within Groups	328822.000	24	13700.917		
	Total	671447.407	26			

Appendix: 5 ANOVA results of soil parameters on slope location from no-bund plots.

		Sum of Squares	df	Mean Square	F	Sig.
sand_ non-conserved	Between Groups	48.667	2	24.333	6.844	.028
	Within Groups	21.333	6	3.556		
	Total	70.000	8			
silt_ non-conserved	Between Groups	4.222	2	2.111	.655	.553
	Within Groups	19.333	6	3.222		
	Total	23.556	8			
clay_ non-conserved	Between Groups	24.222	2	12.111	10.900	.010
	Within Groups	6.667	6	1.111		
	Total	30.889	8			
TN_ non-conserved	Between Groups	.020	2	.010	3.266	.110
	Within Groups	.018	6	.003		
	Total	.039	8			
SOC_ non-conserved	Between Groups	1.623	2	.812	99.886	.000
	Within Groups	.049	6	.008		
	Total	1.672	8			
AP_ non-conserved	Between Groups	.021	2	.010	9.232	.015
	Within Groups	.007	6	.001		
	Total	.027	8			
AK_ non-conserved	Between Groups	6506.000	2	3253.000	5.751	.040
	Within Groups	3394.000	6	565.667		
	Total	9900.000	8			

Appendix: 6 Mean and SD of Adopter and non-adopters on adoption of SWC practices.

Adoption SWC		sex	age	Education level	Family size	Plot number	Land size	Location of land	Contact with extension	Accesses to training	Livestock number
Non-Adopter	Mean	.82	4.12	.09	2.39	.52	2.91	1.45	.82	.6364	1.8788
	N	33	33	33	33	33	33	33	33	33	33
	Std. Deviation	.392	.485	.292	.933	.755	1.208	.564	.769	.48850	.64988
Adopter	Mean	.99	2.89	1.34	2.03	.22	2.87	1.82	1.84	.9053	1.8316
	N	95	95	95	95	95	95	95	95	95	95
	Std. Deviation	.103	1.026	1.199	.643	.465	.878	.729	.879	.29440	.75305
Total	Mean	.95	3.21	1.02	2.13	.30	2.88	1.73	1.58	.8359	1.8437
	N	128	128	128	128	128	128	128	128	128	128
	Std. Deviation	.228	1.062	1.177	.742	.566	.969	.707	.961	.37179	.72565