



**TECHNICAL EVALUATION, IMPACTS OF PHYSICAL SOIL AND WATER
CONSERVATION STRUCTURES AND SLOPE GRADIENTS ON SELECTED SOIL
PROPERTIES THE CASE OF HAWASSA ZURIA WOREDA, SOUTHERN ETHIOPIA**

MSc THESIS

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HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

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**A THESIS SUBMITTED TO THE DEPARTMENT OF BIOSYSTEMS ENGINEERING,
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We, the undersigned, members of the Board of Examiners of the final open defense by Bandira Belachew Dogiso have read and evaluated his thesis entitled “technical evaluation, impacts of physical soil and water conservation structures and slope gradients on selected soil properties the case of Hawassa Zuria Woreda, 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 degree of Masters of Soil and Water Conservation Engineering.

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ACRONYMS AND ABBREVIATIONS

ANOVA:	_____	Analysis of variance
BD:	_____	Bulk density
CEC:	_____	Cation exchange capacity
CP:	_____	Conserved plots
CSA:	_____	Central Statistical Agency
DAs:	_____	Development agents
EB:	_____	Exchangeable base
FAO:	_____	Food and Agriculture Organization
Ha:	_____	Hectare
HH:	_____	Household
HZWAO:	_____	Hawassa Zuria Woreda Agriculture Office
HZWFaED:	_____	Hawassa Zuria Woreda Finance and Economic Development
MOARD:	_____	Ministry of Agriculture and Rural Development of the Federal Democratic Republic of Ethiopia
NCP:	_____	Non-conserved plots
NGOs:	_____	Non-Governmental Organizations
NMA:	_____	National Meteorological Agency
PH:	_____	Soil reaction
SLMP:	_____	Sustainable Land Management Project
SNNPR:	_____	South Nation, Nationalities and Peoples Region
SOC:	_____	Soil organic carbon
SOM:	_____	Soil Organic matter
SPSS:	_____	Statistical Packages for Social Sciences
SWC:	_____	Soil and Water Conservation
TN:	_____	Total nitrogen
USDA:	_____	United States Department of Agriculture.
WTCER:	_____	Water Technology Centre for Eastern Region

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ABSTRACT

*This study was aimed on technical evaluation, impacts of physical soil and water conservation structures and slope gradients on selected soil properties. For the purpose of the study Hawassa Zuria Woreda was selected and Kejima Unibulo, Ounbulo Wacho and Shamena Gerimama kebeles were selected purposively from woreda. Total of 60 structures; 20 soil bunds, 20 fanya juus and 20 micro basins were randomly selected and their dimensions were evaluated according to the standard recommended. 18 soil samples (two treatments * three slope classes * three replications) were collected at a depth of 0-20 cm from kejima unibulo. 364 households were interviewed. Data were analyzed using paired samples T-test, one way analysis of variance and descriptive statistics. In the study area soil bunds, stone bunds, fanya juus and micro basins were implemented. Technical evaluation showed that only vertical interval of soil bund was constructed according to the standard. The result revealed that physical soil and water conservation structures had no impacts on soil texture and had significant impacts on bulk density. Slope gradients had significant impacts on sand soil and silt soil. physical soil and water conservation structures and slope gradients had significant impacts on chemical properties of soil. Farmers were preferred to practice soil bund, fanya juu and micro basin, respectively. Farmers were perceived the benefits of physical soil and water conservation structures as soil fertility improvement, increase crop productivity and restoration of degraded lands. The problems in implementation of physical soil and water conservation structures in the study area were small land size, labor cost, lack of technical skills, inaccessibility of construction materials, lack of interest for young generation to participate in agricultural activities, lack of field guide line for soil and water conservation practices, weak interaction among stakeholders, food insecurity and lack of awareness, respectively. Generally, physical soil and water conservation structures implemented had poor technical quality. There should be awareness creation and trainings for the farmers and development agents. There should be integration of physical conservation measures with agronomic and biological conservation measures and implementation of slope reducing structures along steep slopes in order achieve objectives of erosion reduction.*

Key words: - technical evaluation, physical soil water conservation structures, slope gradients, soil properties, farmers' perception.

1 INTRODUCTION

1.1 Background of the study

Land degradation is a broad, composite and value-laden term that is complex to define but generally refers to the loss or decline of biological and economic productive capacity (Tesfaye, 2017). Land degradation remains one of the biggest 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 (Afro *et al.*, 2016).

Land degradation is all about any diminishment of biodiversity and ecosystem functioning that negatively impacts the provisioning of ecosystem services and ultimately impedes poverty eradication and sustainable development effort. Land degradation is a temporary or permanent decline in the productive capacity of the land or its potential for environmental management (Tesfaye, 2017).

Soil degradation is the loss of soil productivity quantitatively or qualitatively through various processes like erosion, acidification, salinization, nutrient depletion and deterioration of soil physical properties. Soil erosion is the most contributing process to unsustainable agricultural productivity in most developing countries (Negessa and Tesfaye, 2021). Land degradation in the form of soil erosion and nutrient depletion threatens food security and the sustainability of agricultural production in Sub-Saharan Africa (Ejegue and Gessesse, 2021). Soil erosion is the most dangerous ecological process observed in Ethiopia, degrading the precious soil resources (Negessa and Tesfaye, 2021).

Soil erosion is identified as the foremost cause of land degradation mainly in the rainfed agricultural landscapes of Ethiopia (Masha *et al.*, 2021). Soil erosion induced by water had an impact on national food supply, deteriorate soil fertility and reduce agricultural productivity, downstream flooding and reservoir sedimentation and loss of valuable plant nutrients (Ejegue and Gessesse, 2021). The problem is predominantly severe on cultivated sloping lands as these areas are highly vulnerable to easy removal of the uppermost soils by running water (Tadesse and Belay, 2004).

Agriculture is the main source of livelihood for more than 75% of the Ethiopian population (Mohammed *et al.*, 2020). Some of the factors that cause decline of soil fertility are clearing of forests, the removal of crop residues from the fields, land fragmentation, reduction of fallowing, low fertilizer inputs, inadequate soil and water conservation measures, cropping of marginal lands and poor soil management (Pound and Ejigu, 2005). Soil fertility depletion due to erosion is one of the most important challenges of Ethiopian farmers that led to very low productivity of agricultural lands (Mohammed *et al.*, 2020). The annual rate of soil loss in Ethiopia is estimated to be 12 tons/hectare/year (Hurni, 1986), and can be even higher on steep slopes with soil loss rates greater than 300 tons/hectare/year or about 250 mm/year where vegetation cover is inadequate (Grag, 2019).

In Ethiopia, SWC interventions were started since the mid-1970s and 80s to alleviate both problems of erosion and low crop productivity (Yonas *et al.*, 2016). As a result, government implemented soil and water conservation practices to reduce erosion-induced land degradation (Hurni, 1993; Bekele and Holden, 1999). Various mechanical (bunds, terraces, check dams, cutoff drains and waterways) and biological (homestead and communal tree plantations and enclosures) SWC measures have been implemented in drought-prone areas (Amsalu and de Graaff, 2007).

Physical SWC structures had been implemented in Ethiopia for last five decades through public participation. The implementation was targeted to reduce severe soil erosion from farm land and associated effects of land degradation. Moreover, it was focused to maintain soil fertility and improve agricultural productivity. To this end, a lot of effort has been done to conserve soil at private and communal lands while the success has found to be less comparable with the effort done so far (Berhanu, 2019).

The SWC practices improve the biophysical change by reducing soil and water loss, discharge of springs, improved micro climate, greening the area, supplying grass for cut and carry, modifying terrain, improving soil depth, stabilizing active gullies (Ademe *et al.*, 2017). It could be evaluated with technical quality and effectiveness on improving soil properties. Technical evaluation was done

by measuring different dimensions and comparing those with recommended standards (Tsegaye and Awdenegest, 2018). Physical SWC structures were evaluated by its technical viability; fitness of the layout of the structures with standards, appropriateness, management and maintenance (Berhanu, 2019). Quality of physical SWC structures could be evaluated using technical characteristics for measurements and comparing them with the recommended standards (Demissie, 2016). Evaluation against design specifications includes vertical interval and length, gradient, embankment compaction, embankment height and width, channel depth and width in accordance with guideline recommended (Engdayehu, *et al.*, 2016). Most of the existing physical SWC structures were not constructed according to the standards. Evaluation on the quality of Physical Soil and Water Conservation Structures was conducted in Wyebila Watershed, Northwest Ethiopia. Physical SWC structures were constructed, only 20.58% (bund gradient and vertical intervals) were designed based on the package specifications (Walie, 2016).

Evaluation of the effectiveness of physical SWC structure on improving soil properties were conducted in Wonago district, Southern Ethiopia. The findings showed that soil P^H , K^+ , P, TN, SOC, %clay and CEC were significant ($p \leq 0.05$) for SWC practices. The sand and silt fractions were not significant ($p < 0.05$) for SWC practices. P, SOC, %silt and CEC were significantly different for landscape position. The study indicated the effectiveness of SWC practices in improving the soil properties (Ademe *et al.*, 2017). Impact of Physical Soil and Water Conservation Structures on Selected Soil Physicochemical Properties were conducted in Gondar Zuriya Woreda. The results showed that soil organic carbons (SOC), total nitrogen (TN), Available P, K^+ and Bulk density (Bd) were significantly ($p \leq 0.05$) affected by the soil conservation measures. Sand and clay fractions significantly varied with both soil conservation measures and slope gradient. Soil organic carbon and TN were higher while bulk density was lower in conserved fields compared to fields without conservation structures. No significant difference was observed in SOC and TN along the slope but the mean value of SOC and TN increased with decrease in the slope percent and decrease in bulk

density. Similarly, CEC, EC, and Ca^{2+} and Mg^{2+} did not show any significant differences with respect to SWC measures and slope gradient (Hailu, 2017).

The study area is susceptible to land degradation by soil erosion due to its nature of topography and human induced factors such as intensive agriculture and inappropriate management of the land (HZWAO, 2015). In order to reduce the degradation of land which results low agricultural productivity, Hawassa Zuria Woreda Agriculture Office implemented physical, agronomic and biological measures through safety net program and community participation (HZWAO, 2015).

The physical SWC structures implemented were not achieved their objective, impacts of physical soil and water conservation structures and slope gradients were not evaluated. Therefore, the objective of this study was technical evaluation, impacts of physical SWC structures and slope gradients on selected soil properties.

1.2 Statement of the problem

The current trend of soil degradation in the country particularly in the highlands is a major constraint to the anticipated improvement of the livelihood of people and the economic development of the country as a whole. SWC measures and efforts have been undertaken to address the issue in the country and most of these structures weren't achieved the objective (Berhanu, 2019).

In the study area conservation work has been started since 2010 by support from the government, SOS Sahel, SLM project, safety net programs and community participation. After the support activities from NGOs about five years, the conservation work responsibility was left to the local community believing that the farmers have enough awareness, adopted and experienced about the benefits of conservation works as well as practiced implementation (HZWAO, 2015).

Due to highly expose of the erosion problems as well as reduction of crop productivity the woreda government had given attention to reduce the problem of soil erosion and increase agricultural productivity. The woreda Agriculture and natural resource office decided to implement physical SWC structures each year at Woreda level. In the Woreda erosion problem area were selected and

physical SWC structures were implemented yearly via community participation. Implemented physical SWC structures were found with less effectiveness in erosion reduction. This requires evaluation of physical SWC structures, impacts of physical SWC structures and slope gradients on soil properties.

Farmers have less awareness on impacts of physical SWC structures and slope gradients on soil properties some farmers were removed the structures from their farm lands. To advance awareness on physical SWC structures evaluation of its impact is needed. Impacts of slope gradients would be evaluated to give attention for steep slope area residents. Therefore, this study was aimed to technical evaluation, impacts of physical SWC structures and slope gradients on selected soil properties.

1.3 Objectives of the study

The general objective of this study was; technical evaluation, impacts of physical SWC structures and slope gradients on selected soil properties.

1.3.1 Specific objectives

- To evaluate the effectiveness of physical SWC structures.
- To evaluate impacts of physical SWC structures and slope gradients on selected soil properties.
- To investigate the farmers' perception and the problems in implementation of physical soil and water conservation structures.

1.4 Research questions

The following research questions have been considered as guide to focus the study;

- How effective are the physical SWC structures?
- What impacts has the physical SWC structures and slope gradients on selected soil properties?
- What is the farmers' perception and the problems in implementation of physical SWC structures?

1.5 Scope of the study

This study was undertaken in Hawassa Zuria Woreda, Sidama national regional State. It covers three kebeles of woreda namely; Kejima Unibulo, Ounbulo wacho and Shamena Gerimama. It was focused on evaluation of technical quality, impacts of physical soil and water conservation structures and slope gradients on selected soil properties. This study was limited to three kebeles under Hawassa Zuria Woreda due to shortage of time, finance and other constraints. Therefore, the result was revealed to selected kebeles and it is necessary to undergo further study to have findings for evaluation of technical quality, impacts of physical SWC structures and slope gradients on soil properties.

2 LITERATURE REVIEW

2.1 Physical soil and water conservation structures in Ethiopia

Physical soil and water conservation structures are permanent features made of earth, stones or masonry designed to protect the soil from uncontrolled runoff and erosion and retain water where needed (SUSTAINET EA, 2010). Selection and design of structures depend on climate and the need to retain or discharge the runoff, farm sizes, soil characteristics (texture, drainage and depth), availability of an outlet or waterway, labor availability and cost and adequacy of existing agronomic or vegetative conservation measures (Lakew *et al.*, 2005, SUSTAINET EA, 2010).

2.1.1 Soil bund

A level bund is an embankment along the contour made of soil and/or stones with a basin at its upper side. The bund reduces or stops the velocity of overland flow and consequently soil erosion (Hurni *et al.*, 2016). Soil which is eroded between two bunds is deposited in the basin behind the lower bund. Soil bunds reduced soil losses and runoff by 35% and 15% respectively (Amare *et al.*, 2014).

Graded bunds are slightly graded sideways with a gradient of up to 1% towards a waterway or river. They can retain normal amounts of runoff in their basins, but they can drain excess runoff from heavy storms which would cause overflow and downslope destruction on level bunds. Most of the soil eroded between two bunds is deposited, while some will be drained sideways during heavy storms and lost from the land. However, graded bunds are more effective than level bunds in wet and moist areas with clay soils. Some studies showed that graded soil bund reduced runoff, soil and nutrient losses (Negessa and Tesfaye, 2021). Soil bund brought about significant reduction in average annual runoff and soil losses. Consequently, Soil bund reduced losses of soil organic carbon and soil nutrients like N, P and K (Zenebe *et al.*, 2014).

2.1.2 Fanya juu

A level fanya juu ('throw uphill' in Swahili language) is an embankment along the contour, made of soil and/or stones, with a basin at its lower side. Level Fanya Juus are embankments to retain runoff between two bunds. Runoff is retarded behind them and the overflow is collected in the ditch below the embankment. Runoff in the ditch flowing sideways is stopped by the tied ridges. Soil eroded between two fanya Juus is deposited behind the lower one (Hurni *et al.*, 2016).

A graded fanya juu is slightly graded sideways towards a waterway, with a gradient of up to 1%. This gradient is for surplus runoff to be drained if the retention of the fanya juu is not sufficient. Graded fanya juu retains small amounts of runoff above their wall and they drain excess runoff from heavy storms through the ditch below. Some of the soil eroded between two fanya juus is deposited above the wall, some is deposited in the ditch and the rest is drained sideways (Negessa and Tesfaye, 2021). The fanya juu reduces or stops the velocity of overland flow and consequently soil erosion. Soil eroded between two fanya juus is deposited behind the lower one. This deposition of soil behind the fanya juu can increase crop yield (Negessa and Tesfaye, 2021).

2.1.3 Micro basin

A micro basin is a small structure with the shape of a half or a full circle excavated to obtain a small basin for planting a tree. Micro basins vary in size according to their designation to conserve water. They are small in moist agroecological zones and large in dry ones. In dry areas they are used to harvest water from a larger area (2–3 m diameter) on gentle slopes sometimes with additional water collection ditches. The micro basins are prepared in rows always one micro basin in the lower row between the two micro basins in the higher row (Hurni *et al.*, 2016).

2.2 Technical Evaluation of physical soil and water conservation structures

2.2.1 Vertical interval and spacing

Level soil bund can be evaluated by technical aspects such as spacing, vertical interval and layout on the contour. Spacing and vertical interval are dependent one over the other. Spacing is the ground distance between two consecutive bunds and vertical interval is the height difference between two consecutive bunds. In principle spacing is decided by the steepness of the slope and the runoff expected to generate in the area (Tsegaye and Awdenegest, 2018).

In principle the spacing should decrease when slope gradient increases (Gizaw *et al.*, 2009). According to WTCER (2011) the basic principles for determining the spacing of bunds are seepage zone below the upper bund should meet the saturation zone of lower bund, the bunds should check the surface runoff at the point where flow attains an erosive velocity and the bund should not cause inconvenience in agricultural operations.

Only 20.58% SWC structures were constructed based on the packages. The problem was serious mainly on bund vertical intervals where there was not observed any similarity between existing physical SWC structures and the recommended one. As per discussion with the farmers the main reason for the failure to achieve physical SWC structures based on the package is knowledge and skill gap on SWC practices. This was not only for farmers but also for DAs (Demissie, 2016).

The spacing between existing terraces ranged from 8 to 50 m with an average of 23 m on 3–19% slope lands, 78% were not fulfill the minimum technical standards of vertical interval. Similar vertical interval and bund spacing were used at different slopes. 92% of the bunds constructed were on slopes greater than 9%. They were not fulfilling the technical standard. Some wider spacing has reduced the effectiveness of bunds since the concentrated run-off causes breakage through weak terrace segments (Engdayehu *et al.*, 2016).

2.2.2 Gradient and length of bunds

Fanya juus retain small amounts of run-off above the embankment and drain excess run-off through the ditch causing overflow and topping the embankment down slope with drainage problems. In some areas there is also risk of over topping and breakage during high run-off in fragile soils (Haile *et al.*, 2006 and Lakew *et al.*, 2005). Length of all physical SWC structures were significantly less than the standards (Berhanu, 2019).

2.2.3 Embankment compaction and height

These are dimensions related to the soil bund and fanya juu embankment and their appropriate design. These dimensions need special technical care because usually there is less participation of farmers in the field in their modification (Tsegaye and Awdenegest, 2018). Assessment of embankment height of soil bund and fanya juu terraces showed that bunds constructed in 2013 have an approximate average height of 0.42 m which meets 70% of the technical recommendation but such terraces shrink gradually due to poor compaction. Lack of compaction is creating quality problem on physical SWC structures (Engdayehu *et al.*, 2016).

2.2.4 Embankment width, channel depth and width

The depth and width of the ditch for level fanya juu for farmlands with slope steepness up to 10% is about 0.55 m and it is 0.6 m for farmlands of 10% to 20% slope steepness (Tsegaye and Awdenegest, 2018). Embankment width of all bunds was within the range of the technical standard but only 81 and 83 % of the top width for fanya juu and soil bund respectively were met the technical standard. Bunds had about 0.4 m depth and 0.43 m channel width in which 85 and 90 % were met the standard respectively (Engdayehu *et al.*, 2016).

2.3 Impacts of physical SWC structures on Physical Properties of Soil

Various studies conducted to evaluate the impacts of physical and biological soil and water conservation on physical soil properties. According to those studies, the percentage of clay content of soil increased and sand particles of soil decreased with a soil treated with SWC

structure. The decrease in soil BD due to SWC practices that would result in greater water infiltration rates which in turn minimize runoff velocity, sediments and organic matter removal. As a consequence, OM accumulation improves a soil physical structure which promotes crop root abundance, crop stand, crop production and better crop residues at the conserved plot. The land that treated with SWC measures improves the soil moisture content which is a key factor affecting agricultural production in water limited environments (Tadele, 2019).

The texture of the soil was dominated by clay fractions in both CP and NCP. The highest mean value of clay content was observed in the CP and the lowest was observed in the NCP. On the contrary, the average sand content of the soil was higher in the NCP than that of CP. The silt content of the soil constitutes the lowest proportion in both CP and NCP, although a relatively slightly higher value was observed in the CP (Mamush *et al.*, 2021). The mean differences of all particle size distributions between CP and NCP were not statistically significant ($P > 0.05$). The maximum sand at Elmo without SWC and minimum sand at Elmo with SWC were observed. The variation may be due to the steep landscapes, transportation and translocation of fine particles. The analysis also showed significant variation of clay for SWC practices with maximum clay at Hobene with SWC and lower clay at Elmo without SWC (Yonas *et al.*, 2017). The non-significant difference in texture may be due to the young age of physical SWC structures that cannot make significant change on soil weathering (Lemma *et al.*, 2015, Tiki *et al.*, 2015). This implies that SWC measures did not easily alter the soil textural classes (Belayneh *et al.*, 2019), instead the parent material in which the soil was formed is more determinant (Mamush *et al.*, 2021). A relatively high clay content observed in the CP were primarily the impact of SWC structures on soil erosion as it reduces the removal of soil particles. On the other side, the removal of fine particulates due to erosion in the NCP can increase the sand content of the soil. The land kept under crop cultivation for a prolonged time

without any management measure could facilitate unrestricted washing of fine soil particles through runoff (Demelash and Stahr, 2010).

Soil particle fraction (%) of sand content was showed significant difference ($p \leq 0.05$) between conserved and non-conserved farmlands. The highest mean was observed under farmland treated with fayna juu. Though, silt and clay content did not show significant difference between conserved and non-conserved farmlands (Sirna and Leta, 2020). The variation in sand content might be due to inherent soil property derived from the parent material since soil texture is not affected by conservation measures within such a short period of time. Regarding slope gradients, soil textural fraction (%) was exhibited significant ($p \leq 0.05$) difference under slope gradients. Sand and clay content (%) was showed a significant difference under gentle slope than a middle and steep slope, while silt content (%) was demonstrated a significant ($p \leq 0.05$) difference between gentle and steep slope (Sirna and Leta, 2020).

The result of the analysis was presented that bulk density did not show significant variation between treatments and slope gradients. However, the higher means were observed under the control plot and middle slope gradient (Sirna and Leta, 2020). Bulk density was higher in the NCP than that of the CP and the difference was statistically significant ($P \geq 0.05$; Mamush *et al.*, 2021). This is due to the existence of high organic matter content in the CP (Siraw *et al.*, 2020). The removal of uppermost soil organic materials by runoff might be the reason for the observed high bulk density value in the NCP than CP (Mamush *et al.*, 2021). Bulk density and moisture content of treated soil is increased (Abay *et al.*, 2016, worku *et al.*, 2012). This result also confirms the presence of higher clay fraction of conserved soil due to deposition from the upper slope (Regina *et al.*, 2004). The recorded percentage of sand is lower for CP while higher percentage of clay. Those results confirm the findings by Lemma *et al.*, 2015. These may be due to soil particles resistance to detachment and susceptibility to transportation. Gebremichael *et al.*, 2005 reported that selective removal of soil particles to steeper slopes leave behind

coarser materials (sand, gravel and stones) while the transported material is deposited as the slope steepness decreases. Sandy soils are less cohesive than clay soils and thus aggregates with high sand content are more easily detached; silty soils derived from loess parent material are the most erodible type of soil (Blanco and Lal, 2008).

2.4 Impacts of physical SWC structures on Chemical Properties of Soil

Several studies recognized that physical SWC structures showed a significant difference on chemical properties of soil between conserved and non-conserved plot of land. According to the study conducted by Abay *et al.*, 2016 the graded stone bunds have shown significant improvement in chemical soil properties such as OM, TN, P^H and CEC. Moreover, the high OM content of farm plots with SWC practices affect more positively the soil properties as compared to the non-conserved farm plots. Variation was also significant along slope gradients for some chemicals properties.

Worku, 2017 indicated that, physical SWC structures (stone faced soil bund and soil bund) is promising in protecting the cultivated land from erosion and the associated nutrient depletion. With regard to analysis of soil characteristics in CP and NCP; SOC and TN were higher while BD was lower under the conserved farm. Yonas *et al.*, 2017 also reported that soil and water conservation improved significantly the soil chemical properties (P^H, K⁺, available P, SOC, TN and CEC) than in the land without SWC treatment. This indicates the positive impacts of SWC practices in improving the nutrient status. OM, TN, P^H, CEC available P and EB also significantly improved by biological SWC measures. Mamush *et al.*, 2021 also reported the same findings in which SOC, TN, Available P, CEC and EB were higher in CP than NCP and they showed significant differences. Alemayehu, 2007 also confirmed in Anjeni watershed in which available P on terraced land was higher than the non-terraced.

Under a continuous cropping system soil acidity increases due to the gradual replacement of basic cations by aluminum (Zougmore *et al.*, 2002). SWC structures are practically used as support for agronomic and soil management and considered as the first defense line (Morgan, 2005). Thus, they alone are less likely to improve soil properties significantly under similar management to non-terraced. Zougmore *et al.*, 2009 has reported that combining stone rows barriers to run-off with the application of compost was significantly controlled erosion and reduced organic carbon and nutrient losses than compost or stone row alone.

2.5 Perceptions of farmers on soil erosion problem

Most of the respondents indicated that they perceived the soil erosion problems in their farmland. Regarding signs with which it can be identified they rightly mentioned visible erosion features such as sheet, rills, gullies and landslides (Sirna and Leta, 2021). Soil erosion is widespread but there is considerable variation in the degree of erosion from place to place. The majority of the farmers reported that they perceived soil erosion problem in their farm land but the severity of the erosion was varied from place to place based on different factors mainly due to slope steepness and soil conservation measures practiced. Generally, perception of soil erosion problem is an important factor to suggest possible solutions and makes decisions on conservation investments (Meseret and Dawit, 2019).

2.6 Farmers' perception and the problems in implementation of physical SWC structures

The participation of different actors at different phases of SWC practices enhances the possibility of achieving sustainable SWC outcomes. Almost all farmers agreed that SWC practice was very helpful for erosion control and better to improve soil productivity. The physical SWC practices mainly soil bund and Fanya juu has been practiced by integrating them with multipurpose biological measures such as vetiver grass (Sirna and Leta, 2021).

Farmers were asked the positive and negative impact of SWC structures on soil physiochemical properties implemented on their land. Most of the farmers perceived the positive impact of SWC structure on their farm land. Farmers addressed that SWC structures improved their land through preventing erosion, increasing land productivity and increasing fertility. This indicates that farmers have good awareness of SWC structure (Meseret and Dawit, 2019).

The change in perception of farmers in soil and water conservation practices in their farmlands directly related with the effectiveness of the structures (Tsegaye, 2018). Farmers have different perception on the factors affecting the effectiveness of the structures and have a detailed knowledge and opinion about what works best where (Tsegaye and Awdenegest, 2018).

SWC work has a number of problems that hinders the implementation of physical SWC structures. According to Getahun *et al* (2021) small land size, lack of labor force, acidic soil, poor access to fertilizer, seed, construction material, lack of technological skill and lack of maintenance were discouraging farmers to apply the standard design for conservation structure.

There are barriers or challenges for farmers to adopt soil erosion control measures in Ethiopia. Some of these challenges include labor unavailability, limited capital, limited incentives and benefits, insecure land tenure policy, inappropriate technology choices, lack of technologies that provide quick returns for subsistent farmers, weak technical support from development agents and officers and poor community participation (Nigussie, 2015). Implementations of SWC measures were influenced by several factors. For instance; poor design construction, maintenance and long-term adoption problems. Farmers in their interview also verified that the involvement of local farmers in the planning, maintenance and selection of conservation measures has been very low (Masha *et al.*, 2021). Challenges for the households to implement SWC practices on their farmlands include lack of awareness on SWC measures, land shortage, labor shortage and wealth status of the farmers. Some farmers failed to maintain adopted soil conservation measures mainly due to the reduced plot size by conservation measures, poor

design, lack of labor and incentives (Belay and Eyasu, 2017). Major constraints that determine the implementation of soil and water conservation in Ethiopia were lack of integrated bio-physical measures, absence of integrating indigenous practices, lack of considering socio-economic profile, low perception and participation of farmers, poor design, improper land use, less maintenance, weak monitoring and evaluation of soil and water conservation practices (Nigatu, 2017).

3 METHODOLOGY

3.1 Description of the study area

The study site is about 20 km south-west of the regional capital Hawassa and 290 km south of Addis Ababa located at 07° 01' 54" to 07° 50' 36" N longitude and 38° 15' 39" to 38° 25' 43" E latitude and the altitudinal range is 1700 m to 1850 m a.s.l. It is bordered by Shebedino and Boricha Woredas to the south, Oromia Region to the west and north and Hawassa town to the East.

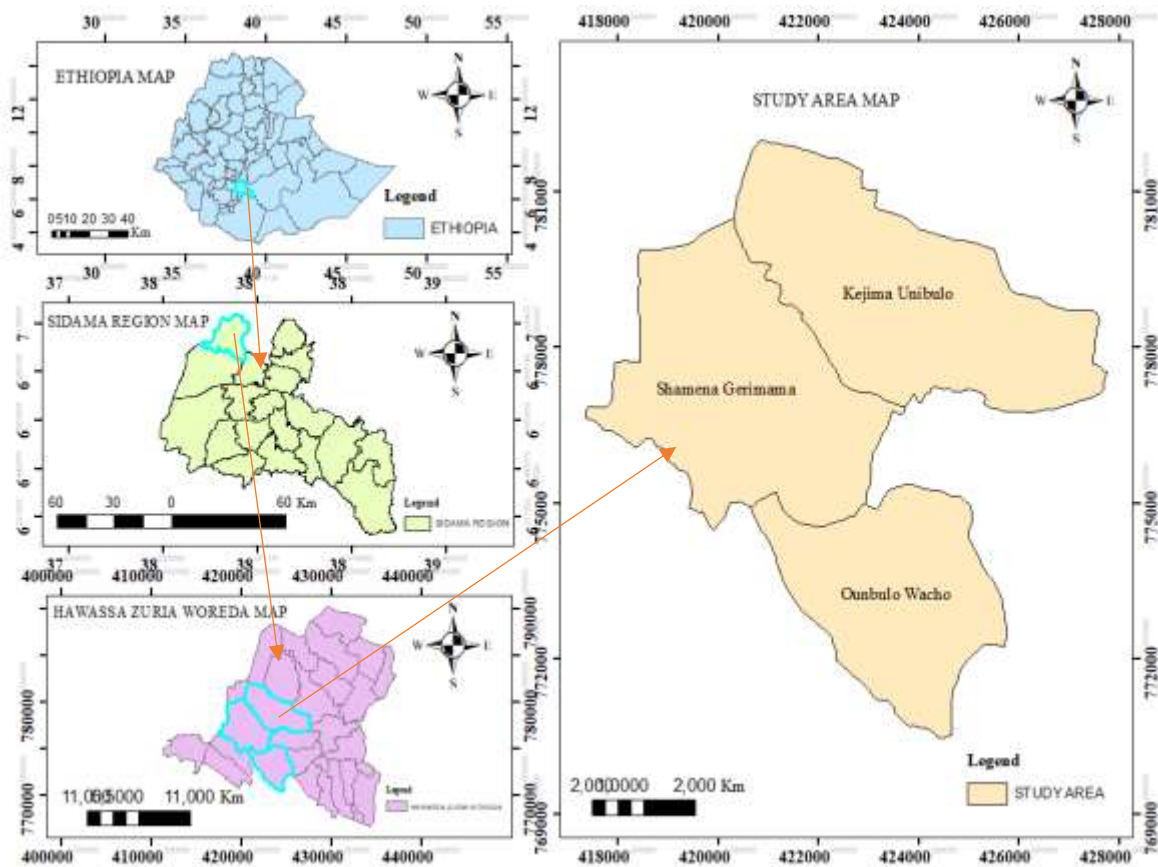


Figure 1. Map of the study area

3.2 Topography

The topography of the area is undulating flat to gentle slope hill bases to steep slope hills. The hills are much degraded as a result of erosion that forms a lot of gullies which start from the hills and extend into the farmlands at the hill bases.

3.3 Soil characteristics

The physical characteristics of the soil at the site are very porous, sandy-loam, shallow at top and along the slope length of the hills and deep at hill base in which augering is done up to 150 cm without difficulty, susceptible to erosion by water and grey in appearance.

3.4 Socio-economy

3.4.1 Farming and trees

Maize (*Zea mays*) is the dominant staple crop in the area which the farmers produce year after year with less chance of crop rotation due to small-sized land holdings. *Ensete ventricosum* and *Eragrostis tef* are also the major crops grown by farmers in the area. Cattle, sheep and goats and equines are the common livestock reared in the area.

Most common tree and shrub species available in the area include *Acacia* species on farm lands and hillsides, *Ficus* species on farm lands, *Croton macrostachyus* on range lands, *Euphorbia turcalli* as live fences, *Cordia africana* on farm lands and home gardens, *Azadirachta indica* at home gardens, *Eucalyptus camaldulensis* on border, woodlots, boundary and home gardens, *Grevillea robusta* at home gardens and farm borders.

3.5 Climate

According to the National Meteorological Agency (NMA), Hawassa Zuria Woreda receives an average annual rainfall of 900 to 1200mm with annual mean temperature of 20°C. In terms of traditional agro-ecology classification, categorized under dry Woina-Dega (Sub-humid weather) and the study area is characterized by bimodal rainfall pattern, i.e., belg (small rainy season that extends from March to May) and kiremt (main rainy season, extends from June to the end of September).

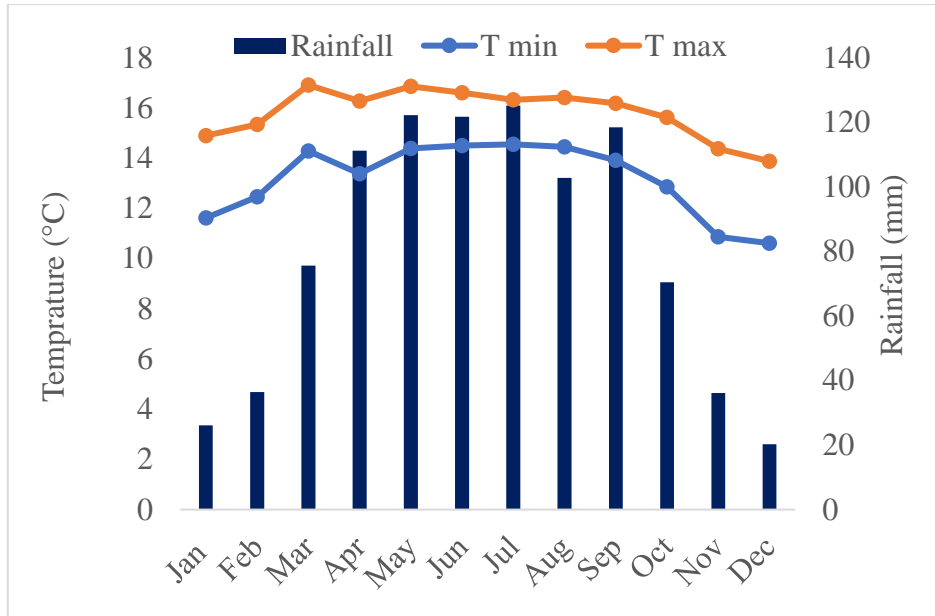


Figure 2. Mean monthly rainfall and monthly maximum and minimum temperature of the study area (1987-2019; Source: ENMA, 2020)

3.6 Research method and sampling methods

This research was followed experimental research method. For this research work mixed method of data collection approach was used. Therefore, both qualitative and quantitative method were used. This research follows simple random sampling technique. Hawassa Zuria Woreda was purposively selected. Three kebeles out of twenty-five kebeles in Woreda namely; Kejima Unibulo, Ounbulo Wacho and Shamena Gerimama were selected purposively due to the susceptibility of the area for erosion and availability of implemented physical SWC structures. From selected kebeles four sites were selected namely; site 1 and 2 from Kejima Unibulo, site 3 from Shamena Gerimama and site 4 from Ounbulo Wacho were selected based on availability of the structures.

3.7 Data Collection and sampling

The data for this study were gathered from primary and secondary sources. In this research; observation, field measurement, soil samples, questionnaires and interview were the major

sources of primary data. Secondary sources of data for this study were publications, books, journal articles and internal records.

3.7.1 Measuring dimensions of the structures

The data were collected through measuring the dimensions of physical SWC structures implemented in the area. The dimensions' measurement was done on the implemented structures. Field measurement was carried out on the ditch depth, ditch width, vertical interval, embankment height, embankment width and berm size for soil bund and fanya juu structures, respectively. Diameter, spacing, vertical interval, pit width and pit depth for micro basin were measured.

3.7.2 Sampling the structure for technical evaluation

The Structures were selected randomly from the sites of selected kebele. Soil bund, fanya juu and micro basin with the age of five months were selected for technical evaluation. The main reason of the selection of these structures were the widely availability, easily applicability and accessibility for implementation by the community. Total number of the structures selected were 60. Simple random sampling techniques were used to measure the dimensions of the structures. Based on this; 20 soil bund, 20 fanya juu and 20 micro-basin dimensions were measured.

3.7.3 Soil sampling

Reconnaissance field survey was carried out in the study area to select appropriate site for soil sampling. Kejima Unibulo were selected purposively and soil sample were taken from CP where fanya juu had been constructed with age of 6 years and NCP. Both farm lands have similar land form and land use. From CP soil samples were collected from the area between the two successive fanya juus. In the case of NCP soil samples were collected from the area in between successive farm boundaries. The slope gradients were divided into three slope ranges

of which 3-15% as gentle slope, 15-30% as moderately steep and 30-50% steep slope (Yirga and Hassan, 2008). Soil samples were collected from each slope classes.

A total of 18 soil samples from CP and NCP, three slope gradients (upper, middle and bottom slopes) and three replications were taken at one depth (0-20 cm). Therefore, 2 treatments×3 slope gradients×3 replications were collected by using auger from a depth of 0-20 cm at four corners and center of a plot of 10m x 10m size using “X” sampling design as described by (Markesan and Schinner, 2005) with sharp edged and closed, circular auger pushed manually down the soil profile.

3.7.4 Preparation and laboratory analysis

Soil analysis were undertaken in south agricultural research institute soil laboratories. The samples were mixed thoroughly in a plastic bucket to form a composite sample. Except for soil bulk density collected soil samples were air-dried at room temperature, homogenized and passed through 2 mm sieve before laboratory analysis. For determination of soil organic carbon and total nitrogen, the samples were passed through 0.5 mm sieve. Moreover, undisturbed samples were taken with a core sampler of height (10 cm) and diameter (7.2 cm) for soil bulk density determination. Selected soil physical and chemical properties that were determined in the laboratory include soil texture, bulk density, P^H , organic carbon, available phosphorus, total nitrogen, CEC and exchangeable bases (Na^+ , K^+ , Ca^{2+} and Mg^{2+}). The soil texture was analyzed with the help of the hydrometer method (Bouyoucus, 1962). The bulk density of the soil was estimated from undisturbed soil samples collected by using a core sampler (which is weighted at field moisture) after drying pre-weighted soil core samples in an oven at 105 °C (Blake, 1965). Determination of soil P^H was conducted using P^H meter in the supernatant suspension of 1:2.5 soils to water ratio. Organic carbon of the soils was determined following the wet digestion method (Walkley and Black, 1934). While percentage of organic matter of the soils was determined by multiplying the percent of organic carbon value by 1.724. Available P was

determined by the Bray II extraction method (Bray and Kurtz, 1945). Total nitrogen was determined following the Kjeldahl method (Jackson, 1958). The ammonium acetate method was employed to determine the CEC and exchangeable bases (Na^+ , K^+ , Ca^{2+} and Mg^{2+}). The exchangeable bases Ca^{2+} and Mg^{2+} in the leachate were determined by atomic absorption spectrometer, whereas Na^+ and K^+ were measured by flame photometer (Rowell, 1994).

3.7.5 House hold Sampling

Sample households were selected from each kebele proportionally by using simple random sampling techniques. Total population was 4039, out of these 364 sample respondents were selected. 111, 148 and 105 sample respondents were selected from Kejima Unibulo, Ounbulo Wacho and Shamena Gerimama, respectively (Table 1).

The sample size was determined by using the formula proposed by Yemane (1967) by considering precision level to be 5% with confidence interval of 95%, total population (N) in selected three kebeles was 4039.

$$n = \frac{N}{1+N(e)^2}$$

Where: N is the total number of households in the study area, e is the margin of error, n is the sample size of households in the study area. Thus, $n = 4039 / 1 + 4039(0.05)^2 = 364$. Therefore, 364 households were sampled.

Table 1. Sampling population

No	Name of Kebele	Total household	Sampled household
1	Unibulo Kejima	1228	111
2	Ounbulo Wacho	1645	148

3	Shamena Gerimama	1166	105
	Total	4039	364

3.7.6 Field observation

Field observation were carried out to identify the type of physical SWC structures implemented. A group of seven people (four farmers, two development agents and the researcher) were involved in the transect walk. During the transect walk the types of physical SWC structures were identified and coded by features in the farms and owner of the farmland recorded using a format developed for this purpose.

3.8 Data Analysis

The researcher was used Statistical Package for Social Science (SPSS) version 25 statistical software to analyze collected data. Technical evaluation of physical SWC structures was analyzed using paired samples t-test, impacts on soil properties were analyzed using mean comparison and one way ANOVA. Socioeconomic characteristics, HH interview, farmers' perception and problems in implementation of physical SWC structures were analyzed using descriptive statistics.

4 RESULTS AND DISCUSSION

4.1 Identification of physical SWC structures

Several physical SWC measures with the purpose of reducing surface runoff thereby increasing infiltration were implemented in the study area. Majority of SWC measures in the study area were directed to control soil loss from cultivated lands. The main physical SWC structures constructed in the study area were soil bund, stone bund, fanya juu and micro basin. The results showed; 37.9% soil bund, 3.3% stone bund, 34.6% fanya juu and 24.2% micro basin were implemented (Table 2). These structures were implemented because the objective was to reduce the soil loss from the cultivated land and improve the properties of the soil in cultivated lands.

Table 2. Physical SWC structures implemented in the study area

Physical structures	Frequency	%
Soil bund	138	37.9
Stone bund	12	3.3
Fanya juu	126	34.6
Micro basin	88	24.2
Total	364	100

4.2 Technical evaluation of physical SWC structures against standards

4.2.1 Comparison of measured and standard soil bund dimensions

The t-test for ditch depth, ditch width, embankment height, embankment width and berm size showed significant ($P < 0.01$ and $P < 0.05$) variation. This shows the implementation of structure

was not according to the standard recommended except for vertical interval (Table 4). This finding was in contradiction with (Tsegaye and Awdenegeest, 2018) finding where the vertical interval maintained between the consecutive bunds is significantly higher than the recommended one and wider spacing. This finding was in line with (Yericho, 2019) who found all measured parameters, except top embankment width, in the private land were not as the standard. Except few dimensions, the majority of physical SWC structures both at private and public land were not constructed according to the standard. This indicates that the implemented physical SWC structures were not technically viable. According to response of farmers the reason for poor construction were lack of skills and lack of awareness for the design. In contradiction to this finding, labor cost and lack interest to construct structure in their farm land were the main reason for poor construction of the structures (Yericho, 2019). All dimensions except vertical interval lacks technical quality. As a result, it was poorly constructed and were not effective against to the standard recommended.

Table 3. Soil bund standard and measured dimensions

Sites		Standards (Hurni <i>et al.</i> , 2016)							Measured					
	Structure	Ditch depth(m)	Ditch width(m)	Vertical interval (m)	Embankment height(m)	Embankment width(m)	Berm size(m)	Structure	Ditch depth(m)	Ditch width(m)	Vertical interval (m)	Embankment height(m)	Embankm ent width(m)	Berm size(m)
1.00	1	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.3	0.4	1	0.4	1	0.25
1.00	2	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	2.00	0.4	0.4	1	0.4	1	0.25
1.00	3	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	3.00	0.4	0.4	1	0.4	1.25	0.25
1.00	4	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	4.00	0.35	0.5	1	0.4	1.25	0.25
1.00	5	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	5.00	0.4	0.5	1	0.4	1.25	0.2
2.00	1	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.45	0.5	1.25	0.4	1	0.2
2.00	2	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	2.00	0.4	0.4	1	0.4	1	0.25
2.00	3	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	3.00	0.4	0.35	1	0.4	1	0.25

2.00	4	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	4.00	0.4	0.45	1	0.4	1	0.25
2.00	5	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	5.00	0.4	0.45	1	0.45	1.50	0.3
3.00	1	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.35	0.4	1.5	0.45	1.50	0.25
3.00	2	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	2.00	0.45	0.4	1	0.4	1.50	0.25
3.00	3	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	3.00	0.3	0.45	1	0.4	1	0.25
3.00	4	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	4.00	0.45	0.3	1	0.5	1	0.25
3.00	5	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	5.00	0.45	0.3	1	0.5	1	0.25
4.00	1	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.45	0.3	1	0.5	1.25	0.25
4.00	2	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.45	0.3	1	0.4	1.5	0.25
4.00	3	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.45	0.4	1	0.4	1	0.2
4.00	4	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.4	0.3	1	0.45	1	0.3
4.00	5	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.4	0.3	1	0.45	1	0.3

Table 4. Paired samples test of soil bund dimensions for four sites in Hawassa zuria Woreda

Dimensions	Std. Deviation	Std. Error	df	P
Ditch depth	0.9	0.2	19.0	0.00
Ditch width	1.4	0.3	19.0	0.00
Vertical interval	0.5	0.1	19.0	0.19
Embankment height	0.8	0.2	19.0	0.01
Embankment width	0.5	0.1	19.0	0.03
Berm size	0.6	0.1	19.0	0.00

t, df, P denotes t-statistics, degree of freedom and significance, respectively

4.2.2 Comparison of measured and standard fanya juu dimensions

The t-test analysis showed that fanya juus in the study area showed ($P < 0.01$ and $P < 0.05$) variation from the standard for all its' dimensions (Table 6). In contrary (Tsegaye and Awdenigest, 2018) found shallower ditch depth than the recommended ones and the ditch width was maintained around values recommended for such kind of farmlands in middle and down parts of the watershed. The height of the embankment maintained smaller than recommended values. Therefore, there might be an overtopping problem in the farm plots constructed with the fanya juu terrace due to the short embankment height. This could be due to lack of skills and lack of awareness for the design. This shows all the dimensions were lacks technical quality. As a result, it was poorly constructed and were not effective against to the standard recommended.

Table 5. Fanya juu standard and measured dimensions

Sites	Standards (Hurni <i>et al.</i> , 2016)							Measured						
	Structure	Ditch depth(m)	Ditch width(m)	Vertical interval (m)	Embankment height(m)	Embankment width(m)	Berm size(m)	Structure	Ditch depth(m)	Ditch width(m)	Vertical interval (m)	Embankment height(m)	Embankment width(m)	Berm size(m)
1.00	1	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.4	0.4	1.5	0.5	1	0.25
1.00	2	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	2.00	0.4	0.4	1	0.5	1	0.25
1.00	3	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	3.00	0.4	0.4	1	0.5	1.25	0.25
1.00	4	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	4.00	0.35	0.45	1	0.5	1.25	0.25
1.00	5	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	5.00	0.45	0.45	1	0.5	1.25	0.25
2.00	1	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.4	0.45	1	0.5	1	0.3
2.00	2	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	2.00	0.4	0.4	1	0.5	1	0.25
2.00	3	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	3.00	0.45	0.35	1	0.5	1	0.2
2.00	4	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	4.00	0.45	0.35	1.5	0.6	1	0.25

2.00	5	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	5.00	0.45	0.35	1	0.6	1.5	0.25
3.00	1	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.45	0.45	1	0.5	1.5	0.25
3.00	2	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	2.00	0.45	0.35	1	0.6	1.5	0.25
3.00	3	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	3.00	0.4	0.35	1	0.6	1	0.25
3.00	4	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	4.00	0.45	0.45	1	0.5	1	0.2
3.00	5	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	5.00	0.4	0.5	1	0.5	1	0.25
4.00	1	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.45	0.5	1	0.6	1.25	0.2
4.00	2	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.4	0.5	1.25	0.6	1.5	0.2
4.00	3	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.4	0.45	1.5	0.6	1	0.25
4.00	4	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.4	0.45	1.25	0.6	1	0.25
4.00	5	0.5	0.5	1-1.5	0.5-0.75	1-1.5	0.25	1.00	0.35	0.45	1.5	0.6	1	0.25

Table 6. Paired samples test of fanya juu dimensions for four sites in Hawassa zuria Woreda

Dimensions	Std. Deviation	Std. Error	df	P
Ditch depth	0.7	0.1	19.0	0.00
Ditch width	1.1	0.2	19.0	0.00
Vertical interval	0.8	0.2	19.0	0.01
Embankment height	0.5	0.1	19.0	0.00
Embankment width	0.8	0.2	19.0	0.00
Berm size	0.4	0.1	19.0	0.00

df, P denotes degree of freedom and significance, respectively

4.2.3 Comparison of measured and standard micro basin dimensions

Micro basin in the study area showed significant ($P < 0.01$) variation from the standard for all its' dimensions (Table 8). Results revealed that measured values of micro basin dimensions were higher than the standard. This variation in all dimension of micro basin during construction could

be due to lack of skills and lack of awareness for the design. As a result, it was poorly constructed and were not effective against to the standard recommended.

Table 7. Micro basin standard and measured dimensions

Site	Standards (Hurni <i>et al.</i> , 2016)						Measured				
	Structure	Diameter(m)	Spacing (m)	Vertical interval(m)	Pit width (m)	Pit depth(m)	Diameter(m)	Spacing (m)	Vertical interval(m)	Pit width (m)	Pit depth(m)
1.00	1	1	2-5	2-5	0.25	0.4	0.8	6	7	0.25	0.3
1.00	2	1	2-5	2-5	0.25	0.4	0.8	6	6	0.2	0.3
1.00	3	1	2-5	2-5	0.25	0.4	1	6	6	0.5	0.4
1.00	4	1	2-5	2-5	0.25	0.4	1	6	6	0.5	0.3
1.00	5	1	2-5	2-5	0.25	0.4	0.8	7	6	0.5	0.35
2.00	1	1	2-5	2-5	0.25	0.4	0.8	6	6	0.5	0.3
2.00	2	1	2-5	2-5	0.25	0.4	0.7	6	6	0.5	0.35

2.00	3	1	2-5	2-5	0.25	0.4	1	6	7	0.4	0.3
2.00	4	1	2-5	2-5	0.25	0.4	0.8	7	6	0.25	0.25
2.00	5	1	2-5	2-5	0.25	0.4	1	7	7	0.3	0.4
3.00	1	1	2-5	2-5	0.25	0.4	1	7	6	0.4	0.3
3.00	2	1	2-5	2-5	0.25	0.4	1	7	6	0.4	0.4
3.00	3	1	2-5	2-5	0.25	0.4	1	7	7	0.3	0.4
3.00	4	1	2-5	2-5	0.25	0.4	1	6	6	0.25	0.3
3.00	5	1	2-5	2-5	0.25	0.4	0.7	6	5	0.3	0.35
4.00	1	1	2-5	2-5	0.25	0.4	0.8	6	6	0.25	0.4
4.00	2	1	2-5	2-5	0.25	0.4	0.8	6	7	0.3	0.3
4.00	3	1	2-5	2-5	0.25	0.4	0.7	6	6	0.4	0.3

4.00	4	1	2-5	2-5	0.25	0.4	0.7	5	7	0.3	0.4
4.00	5	1	2-5	2-5	0.25	0.4	0.7	5	6	0.3	0.3

Table 8. Paired samples test of micro basin dimensions for four sites in Hawassa zuria Woreda

Dimensions	Std. Deviation	Std. Error	df	P
Diameter	0.8	0.2	19.0	0.00
Spacing	0.6	0.1	19.0	0.00
Vertical interval	0.6	0.1	19.0	0.00
Pit width	1.2	0.3	19.0	0.00
Pit depth	1.0	0.2	19.0	0.00

df, P denotes degree of freedom and significance, respectively

4.3 Socio-economic characteristics of the respondents

The data for socio-economic characteristics were obtained by interviewing the 364 households in the study area. It was known that any programs implemented should consider the livelihood status of the society to be sustained and solving their problems. Socioeconomic data were collected to identify the relation of their livelihood and physical SWC structures implemented.

4.3.1 Sex of the respondents

The result showed that; out of total household interviewed 88.7% were male and 11.3% were female (Table 9).

Table 9. Sex of the respondents

Sex	Frequency	%
Male	323	88.7

Female	41	11.3
Total	364	100

4.3.2 Marital status of the respondents

The result showed that 2.7% were single, 95.1% were married, 1.4% were divorced and 0.8% were widowed (Table 10).

Table 10. Marital status of the respondents

Marital status	Frequency	%
Single	10	2.7
Married	346	95.1
Divorced	5	1.4
Widowed	3	0.8
Total	364	100

4.3.3 Age of the respondents

The age of the respondents was classified in to two age groups. The result showed that 20% of the respondents were aged <30, 25% of the respondents were aged between 30-40, 35% of the respondents were aged between 41-50 and 20% of the respondents were aged between 51-65 (Table 12).

Table 11. Age of the respondents

Age	Frequency	%
<30	73	20
30-40	91	25
41-50	127	35
51-65	73	20
Total	364	100

4.3.4 Land size of the respondents

The result showed that 32% of the respondents has 0.25 ha, 28% of the respondents has 0.5 ha, 20% of the respondents has 0.75 ha, 10% of the respondents has 1 ha, 7% of the respondents has 1.25 ha and 3% of the respondents has 1.5ha (Table 13).

Table 12. Land size of the respondents

Land size(ha)	Frequency	%
0.25	116	32
0.5	102	28
0.75	73	20
1	36	10
1.25	26	7

1.5	11	3
Total	364	100

4.3.5 Land use of the respondents

Major land use types were crops, grazing and agroforestry. The result showed that 50.8% were crops, 3.6% were grazing and 40.6% were agroforestry, respectively (Table 14).

Table 13. Major land use of the respondents

Land use types	Frequency	%
Crops	185	50.8
Grazing	13	3.6
Agroforestry	166	45.6
Total	364	100

4.4 Impacts of physical SWC structures and slope gradients on physical and chemical properties of soil

4.4.1 Soil physical properties

Soil texture

Table 15 provides the soil particle size proportion under CP and NCP. The texture of the soil was dominated by sand fractions in both CP and NCP. The highest mean value of sand content was observed in the NCP (39.17%) and the lowest was in the CP (38.32%). On the contrary, the average clay content of the soil was higher in the CP (16.72%) than NCP (14.03%). The average silt content of the soil was higher in the CP (24.67%) than NCP (21.28%). The mean differences of soil textures between CP and NCP were not statistically significant ($P > 0.05$; Table 15). This implies that SWC measures did not alter the soil textural classes (Belayneh *et al.*, 2019). A short period under SWC treatment can not affect the weathering process to create a statistically significant variation on soil texture, Instead Parent material determines soil formation (Mamush *et al.*, 2021).

Table 16 provides the soil texture proportion under slope gradients. The higher mean value of sand content was observed in lower slope (40.88%) and the lower mean was observed in upper slope (36.62%). The higher mean value of silt content was observed in lower slope (24.08%) and the lower was in upper slope (19.17%). The result revealed that the content of sand and silt were significantly ($P < 0.01$ and $P < 0.05$) influenced by the slope gradients (Table 16). This could be due to the fact that the high rainfall in the area and steepness of the slope.

Bulk density

The mean value of BD in CP and NCP was 0.95 g.cm^{-3} and 1.26 g.cm^{-3} , respectively. This showed that the BD was higher in NCP than that of the CP and the difference was statistically significant ($P < 0.05$; Table 15). The higher BD values in NCP may be caused by the exposure

of the sub-soil by erosion and the removal and oxidation of the organic carbon from the top soil. Soil erosion due to runoff and the decomposition of relatively small amount of organic carbon resulted in the decline of soil structural properties increased bulk density (Muktar *et al.*, 2019). These finding was also in line with Muktar *et al.*,2020, Worku, 2017 and Mamush *et al.*,2021 who reported the significant difference in mean value of BD in which higher value was recorded in NCP than CP.

BD showed non significance ($P>0.05$) along slope gradients (Table 16).

Table 14. Impacts of physical SWC structures on physical properties of soil

Treatments		Sand (%)	Clay (%)	Silt (%)	BD (g.cm ⁻³)
Conserved	Mean	38.32	16.72	24.67	0.95
	Std. Deviation	2.41	5.51	4.97	0.14
non-conserved	Mean	39.17	14.03	21.28	1.26
	Std. Deviation	2.57	5.25	3.67	0.32
P		0.48	0.31	0.12	0.02

Table 15. Impacts of slope gradients on physical properties of soil (N=6)

slope gradients		Sand (%)	Clay (%)	Silt (%)	BD (g.cm ⁻³)
Upper (>30%)	Mean	36.62	14.08	19.17	1.09
	Std.	2.33	6.34	3.93	0.26
	Deviation				
Middle (15-30%)	Mean	38.73	14.55	25.67	1.04
	Std.	1.71	4.97	2.36	0.11
	Deviation				
Lower (10-15%)	Mean	40.88	17.50	24.08	1.19
	Std.	1.13	5.09	4.78	0.43
	Deviation				
P		0.00	0.52	0.03	0.684

4.4.2 Soil chemical properties

Soil reaction (P^H)

The mean soil P^H in NCP was lower (5.04) and higher (5.78) in CP (Table 17). The soil P^H was significantly ($P < 0.01$) varied within CP and NCP. The lower mean value in NCP may be related to excessive rainfall coupled with dissected topography, leaching and discharge of important soil nutrients. Whereas, the greater P^H value in CP is related to the reduction of removal of important minerals (Mamush *et al.*, 2021). The higher amount of soil loss due to erosion might have removed the top soil and exposed the sub-soil to lower soil P^H values. The result was in agreement with Melku *et al.*, 2020 who reported significant ($P < 0.05$) variation in CP and NCP.

The result also revealed that there was significant ($p < 0.05$) difference of soil P^H mean values along slope gradients. The result indicated that soil P^H value showed significant ($p < 0.05$) difference from 4.94 to 5.8 when the slope gradient is $>30\%$ and 3-15%, respectively (Table 18). This could be due to the fact that the high rainfall in the area and steepness of the slope increased soil erosion and leaching of basic cations leading to decreased P^H values. This finding is in line with Muktar *et al.*, 2019 who reported the significant ($P < 0.05$) difference of soil P^H mean values along slope gradients.

Soil organic matter (SOM)

The NCP showed significantly ($P < 0.05$) lower (1.60%) organic matter content than mean value (1.85%) in CP (Table 17). This might be attributed to accumulated and retained OM due to physical SWC structures undertaken in the plots, whereas the lowest SOM may be attributed to the loss due to absence of physical SWC structures. The result was in agreement with the finding of Mamush *et al.*, 2021, Melku *et al.*, 2020 and Muktar *et al.*, 2020 who reported that soil organic carbon content of CP was higher when compared to the NCP.

The soil organic matter content showed significant ($P < 0.05$) variation from 1.5-1.93% when slope gradient is $>30\%$ and 3-15%, respectively (Table 18). Soil organic matter accumulation might be higher at the bottom of hills for the fact that it would be transported to the lowest point in the landscape through run off and erosion. This finding was also in line with Muktar *et al.*, 2020 who reported significant variation of organic carbon along slope gradients.

Total nitrogen (TN)

The average total nitrogen content in CP (0.4%) was higher than NCP (0.3%). The difference in the average total nitrogen value between CP and NCP was statistically significant ($P < 0.01$; Table 17). This might be attributed to the effect of physical SWC structures as it reduces the loss of finer soil particles, increases soil organic carbon and total nitrogen in the CP. This finding was in agreement with Muktar *et al.*, 2020 and Mamush *et al.*, 2021 who reported significant difference of average total nitrogen value between CP and NCP with higher average total nitrogen content in CP than NCP.

The variation in total nitrogen content was significant ($P < 0.05$) with slope gradients. It was higher (0.41%) in the area with slope between 3-15% than with slope $>30\%$ where (0.3%) was recorded (Table 18). This could be due to transportation of nutrients from upper to the lowest point in the landscape through run off and erosion. This finding was in agreement with Melku *et al.*, 2020 and Muktar *et al.*, 2020 who reported significant variation of total nitrogen contents along slope gradients.

Available phosphorous (P)

The mean value of available phosphorous content under CP was higher (14.87ppm) than the value recorded (11.5 ppm) in NCP (Table 17). It showed significant ($P \leq 0.01$) variation of means between CP and NCP. This might be due to intensive application of P-containing fertilizer by the farmers and effects of physical SWC structures. Similarly, Yonas *et al.*, 2017,

Muktar *et al.*, 2020 and Mamush *et al.*,2021 reported the higher available phosphorous in CP than NCP and significant variation of available phosphorous.

The mean value of available phosphorous showed significant ($P \leq 0.05$) variation along the slope gradients (Table 18). The higher (15.13 ppm) value of available phosphorous content was recorded on lower 3-15% slope than the area with slope $>30\%$ (10.97 ppm). This could be due to transportation of nutrients from upper to the lowest point in the landscape through run off and erosion. This finding was in agreement with Yonas *et al.*, 2017, Muktar *et al.*, 2020 and Melku *et al.*, 2020 who reported significantly different available phosphorous along slope gradients with higher mean value at lower slope and lower mean at higher slope.

Cation exchange capacity (CEC)

CEC of the soil of the study area showed significant ($P < 0.01$) variation between CP and NCP. The mean value of CEC content in CP was higher (28.5 cmol (+) kg^{-1}) than the value recorded (25.73 cmol (+) kg^{-1}) in NCP (Table 17). This could be due to the effect of physical SWC structures that reduced the removal of top soil and limited leaching in the CP. This finding is in line with Muktar *et al.*, 2020 and Mamush *et al.*,2021 who reported similar finding in which significant variation of CEC with respect to treatments and higher mean value of CEC in CP than NCP.

The mean CEC content of the soil also significantly ($P < 0.05$) varied from 25.65-28.43 cmol (+) kg^{-1} when the slope is $>30\%$ and 3-15%, respectively (Table 18). This value indicates inverse proportion of slope gradients and CEC of the study area. Higher rate of detachment and transportation of solid materials from steep sloped site than gentle sloped sites. Similar finding was reported by Muktar *et al.*, 2020 where mean value of CEC was significantly varied along slope gradients and the higher mean value of CEC was found at lower slope.

Exchangeable basic cations (Ca²⁺, Mg²⁺, K⁺ and Na⁺)

The average values of all exchangeable calcium, magnesium, potassium and sodium contents of the soil were higher in CP than NCP. The mean values of exchangeable Ca²⁺, Mg²⁺, K⁺ and Na⁺ contents were (13.7, 6.34, 2.7 and 2) and (12.54, 5.59, 2.36 and 1.38) in CP and NCP, respectively (Table 17). The lower exchangeable basic cations value in NCP could be due to leaching and higher rate of soil erosion compared to CP. All the mean variations between CP and NCP were statistically significant (P<0.01 and P<0.05; Table 17). The relative abundance of the exchangeable basic cations content of the soil under the CP and NCP were Ca²⁺ > Mg²⁺ > K⁺ > Na⁺. This finding is relatively in agreement with Muktar *et al.*, 2020 and Mamush *et al.*, 2021 who reported exchangeable basic cations with significant (P<0.05) variation in K⁺ and Ca²⁺.

The highest exchangeable basic cations of soil were observed in the area with slope between 3-15% and the lowest exchangeable basic cations of soil was recorded in the upper (>30%) slope position and the mean variation of exchangeable basic cations were statistically significant (P<0.01 and P<0.05; Table 18). The significant differences along slope gradients could be due to erosion, deposition and leaching processes. This result was in line with Muktar *et al.*, 2020 who reported the same result on effects of exchangeable basic cations.

Table 16. Impacts of physical SWC structures on chemical properties of soil

Treatments		p ^H	OM (%)	TN (%)	Av.P(mg kg ⁻¹)	CEC (Meq/100 g)	Exchangeable basic cations (%)			
							Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
Conserved	Mean	5.78	1.85	0.41	14.87	28.50	2.00	2.70	13.69	6.34
	Std. Deviation	0.26	0.27	0.07	3.33	1.87	0.26	0.30	1.09	0.80
non-conserved	Mean	5.04	1.60	0.30	11.50	25.73	1.38	2.36	12.54	5.59
	Std. Deviation	0.58	0.16	0.04	1.48	0.86	0.39	0.29	1.17	0.63
P		0.00	0.03	0.00	0.01	0.00	0.00	0.03	0.05	0.04

Table 17. Impacts of slope gradients on chemical properties of soil

slope (%)	gradients	pH	OM (%)	TN (%)	Av.P(mg kg ⁻¹)	CEC (Meq/100 g)	Exchangeable basic cations (%)			
							Na ⁺	K ⁺	Ca ²⁺	Mg ²⁺
>30%	Mean	4.95	1.49	0.31	10.97	25.65	1.39	2.27	12.13	5.23
	Std. Deviation	0.65	0.11	0.06	1.22	1.19	0.45	0.21	1.22	0.58
	Mean	5.47	1.77	0.35	13.47	27.27	1.65	2.61	13.33	6.02
15-30%	Std. Deviation	0.41	0.18	0.06	2.61	1.64	0.38	0.21	1.03	0.64
	Mean	5.80	1.93	0.41	15.13	28.43	2.02	2.71	13.88	6.65
	Std. Deviation	0.32	0.23	0.07	3.56	2.21	0.34	0.41	0.91	0.47
3-15%		0.02	0.03	0.04	0.05	0.04	0.05	0.05	0.03	0.00
P										

4.5 Farmers' perception on soil erosion and physical SWC structures

4.5.1 Farmers' perception on soil erosion

Farmers' perception on soil erosion is the most important factor for their adoption of conservation measures. Theoretically those farmers who perceive soil erosion as a problem having a negative impact on productivity and who expect positive returns from conservation are likely to decide to favor of adopting available conservation technologies. When farmers do not acknowledge soil erosion as a problem, they will not expect benefits from controlling erosion and it is highly likely that they will decide against adopting any conservation technologies (Gebremedhin and Swinton, 2003). All of the surveyed households responded that there existed soil erosion problem ranging from severe to minor in their lands (Table 19). Out of the total households, 40% responded as severe, 35% responded as moderate and 25% responded as minor soil erosion problem in their farm lands and none of the households responded that soil erosion doesn't exist in their farm lands.

Table 18. Severity of soil erosion problems

Severity	Frequency	%
Severe	146	40
Moderate	127	35
Minor	91	25
Total	364	100

4.5.2 Farmers' perception on preference of physical SWC structures

The survey showed that all the farmers in the area know the existence of improved physical SWC structures and properly understood the importance of conservation measures. In the study area as the farmers' response indicated that 55%, 30% and 15% of the household were preferred to practice soil bund, fanya juu and micro basin, respectively (Table 20). They preferred these structures because they conserve soil and water that helps to reduce soil erosion and enhance production. In addition to this they preferred due to easily applicability and better understanding they have about these structures than others.

Table 19. Farmers' perception on preference of physical SWC structures

Types of structure	Frequency	%
Soil bund	200	55
Fanya juu	109	30
Micro basin	55	15
Total	364	100

4.5.3 Farmers Perception on benefits of physical SWC structures

As the survey result on benefit of physical SWC structures indicated that 51.9% were responded soil fertility improvement, 25.5% were responded increase crop productivity and 22.5% responded restoration of degraded lands (Table 21).

Table 20. Farmers Perception on benefits of physical SWC structures

Benefits	Frequency	%
Fertility improvement	189	51.9
Crop productivity	93	25.5
Restoration of degraded lands	82	22.5
Total	364	100

4.5.4 Farmers' perception on profitability of physical SWC structures

As the survey result (Table 22) indicated that almost all the farmers' response shows investment in physical SWC structure is much more profitable in a long period of time as they observed in a different experience sharing and implementation of physical SWC practices on their land. 95% perceived as profitable and only 5% perceived as not profitable.

Table 21. Farmers' perception on profitability of physical SWC structure

Profitability	Frequency	%
Profitable	346	95
Not profitable	18	5
Total	364	100

4.5.5 Farmers' participation on physical SWC structure implementation

In Hawassa zuria woreda, farmers have been used to practice introduced SWC measures to conserve and maintain their farm land. The physical measures mainly soil bund, stone bund, Fanya juu and micro basin have been practiced.

Constructions of the physical SWC measures are costly and highly labor-intensive task to accomplish only by the effort of subsistence farmers. During field work, we observed that farmers were involved in physical works in mass, while development agents were working as facilitators and woreda agricultural officers were working as superintendent. It is realized that farmers were not allowed to be absent otherwise they would be subjected to serious punishment. The conservation effort is truly meritorious only if it is really effective and can be sustainable. To be effective it has to be carefully engineered and to be sustainable committed participation of the stakeholders and the farmers are crucial.

The descriptive statistics on farmers' participation in SWC activities in Hawassa zuria woreda was shown the majority of respondents (93%) were participated in the SWC activities and only 7% of them were not participated. Accordingly, most of the respondents (88%) were participated voluntarily while the remainder 12 percent of them participated simply because they were forced to do so by the kebele administration and development agent (Table 23).

Table 22. Farmers' participation on physical SWC structure implementation

Participation	Frequency	%
Participated	339	93
Not participated	25	7
Total	364	100
Voluntary	298	88
Enforced	41	12
Total	339	100

4.6 Problems in implementation of physical SWC structures

As shown in (Table 24) there were several problems that farmers faced during the implementation of physical SWC structures. The response of the respondents showed problems in the study area in which 25% were small land size, 12.1% were labor cost, 19.8% were lack of technical skills, 6.9% were inaccessibility of construction materials, 7.7% were lack of interest for young generation to participate in agricultural activities, 7.7% were lack of field guideline for SWC practices, 13.5% were weak interaction among stakeholders, 2.7% were food insecurity and 4.7% were lack of awareness.

Table 23. Problems in implementation of physical SWC structure

No	Problems listed	Frequency	%
1	Small land size	91	25
2	Labor cost	44	12.1
3	Lack of technical skills	72	19.8
4	Inaccessibility of construction materials	25	6.9
5	Lack of interest for young generation to participate in agricultural activities	28	7.7
6	Lack of field guideline for SWC practices	28	7.7
7	Weak interaction among stakeholders	49	13.5
8	Food insecurity	10	2.7
9	Lack of awareness	17	4.7
Total		364	100.0

5 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The objective of this study was technical evaluation, impacts of physical SWC structures and slope gradients on selected soil properties. According to the results obtained except vertical interval of soil bund all structures were not constructed according to the standard. The reason for the poor technical quality were lack of skills and lack of awareness for the design.

The result revealed that physical SWC structures had no impacts on soil texture whereas, had significant ($P < 0.05$) impacts on bulk density. There were significant ($P < 0.01$ and $P < 0.05$) impacts on sand soil and silt soil along slope gradients. physical SWC structures and slope gradients had significant impacts on chemical properties of soil. P^H , OM, TN, available P, CEC, Exchangeable basic cations (Na^+ , K^+ , Ca^{2+} and Mg^{2+}) had significant ($P < 0.01$ and $P < 0.05$) variation under treatments and slope gradients. Higher mean value of chemical soil properties recorded in CP and lower mean were recorded in NCP. This could be due to higher rate of detachment and transportation of solid materials from NCP. Higher mean value of soil chemical properties was recorded in lower slope class and lower mean were recorded in upper slope class this could be due to higher rate of detachment and transportation of solid materials from steep slope to gentle slope sites.

All the surveyed households responded that there existed soil erosion problem ranging from severe to minor in their lands. 40% responded as severe, 35% responded as moderate and 25% responded as minor soil erosion problem in their farm lands. Farmers' response indicated that 55%, 30% and 15% of the household were preferred to practice soil bund, fanya juu and micro basin, respectively. They preferred these structures because they conserve soil and water that helps to reduce soil erosion and enhance production. In addition to this they preferred due to easily applicability and better understanding they have about these structures than others.

Survey on benefits of physical SWC structures indicated that 51.9% were responded soil fertility improvement, 25.5% were responded increase crop productivity and 22.5% responded restoration of degraded lands. In Hawassa zuria woreda, farmers have been used to practice introduced physical SWC measures to conserve and maintain their farm land.

The descriptive statistics on farmers' participation in SWC activities in Hawassa zuria woreda was showed the majority of respondents (93%) were participated in SWC activities and only 7% of them were not participated. Accordingly, most of the respondents (88%) were participated voluntarily, while the remainder 12% of them participated because they were forced to do so by the kebele administration and development agents.

The problems in implementation of physical soil and water conservation structures in the area were small land size (25%), labor cost (12.1%), lack of technical skills (19.8%), inaccessibility of construction materials (6.9%), lack of interest for young generation to participate in agricultural activities (7.7%), lack of field guide line for soil and water conservation practices (7.7%), weak interaction among stakeholders (13.5%), food insecurity (2.7%) and lack of awareness (4.7%).

Generally, physical SWC structures implemented in the study area had poor technical quality these should be considered and a responsible body should have to create awareness and give trainings for the farmers and development agents of the area. There should be sustainable maintenance of structures for further benefits. physical SWC structures implemented were improved soil properties in advance but, there should be integration of physical conservation measures with agronomic and biological conservation measures and implementation of slope reducing structures along steep slopes in order to achieve objectives of erosion reduction and improvement of livelihood of the farmers of the area in a sustainable manner.

5.2 RECOMMENDATION

Based on the findings of this study, the following recommendations are forwarded:

- All dimensions of the structures constructed were not according to the standard except vertical interval of soil bund. These should be considered by concerning body and farmers and development agents should have training about design of physical SWC structures.
- In the study area only practices of physical conservation measures were widely used. To have successful conservation there should be integrated practices with physical agronomic and biological measures. So, further investment in conservation work would be needed.
- Young generations should have awareness and understood SWC work and sustainable resource conservation.

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APPENDIX 1

Table 24. Checklist for field measurements of technical parameters of structures

Name of structure _____ : slope class _____

Site	Sampled structures	Slope (%)	ditch depth (m)	Ditch width (m)	Vertical interval (m)	Embankment height (m)	Embankment width (m)	Berm size (m)	Diameter (m)	Spacing (m)	Pit width (m)	Pit depth (m)
1	1											
	2											
	3											
	4											
	5											
2	1											
	2											
	3											
	4											
	5											
3	1											

	2											
	3											
	4											
	5											
	1											
	2											
	3											
	4											
	5											

APPENDIX 2

Table 25. Checklist formats for observation and transect walk

Observation point	Slope			Major land use			Soil depth (cm)				Soil type		
	3-15%	15-30%	>30%	Crop land	Grass land	Forest land	>25	25-50	50-100	>150	Course	Medium	Heavy
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													

13													
14													
15													
16													
17													
18													
19													
20													

APPENDIX 3

I House hold survey questionnaire

1. General information

Region _____

Woreda _____

Kebele _____

Name of site _____

Date of interview _____

Name of interviewer _____

Name of respondent _____

2. Sex

A. Male B. Female

3. Age

A. 0-12 B. 16-64 C. Greater than 64

4. Education

A. 0 grade B. 1-4 C. 5-8 D. 9-12 E. Diploma graduate F. BSc degree G. Above

5. Marital status

A. Single B. Married C. Divorced D. Widowed

II Socio economic characteristics of house hold

1. What is your main agricultural production activity on your farm?

2. In what off/on farm activity you and your family members engaged?

A. Labor hires out B. Petty trade C. Hand craft D. selling of firewood E. Others

3. Can you estimate the income you get from off farm activities?
_____ birr

4. How much birr do you get on average annually from agricultural activity (value in birr)?
_____ birr

5. Land holding, numbers of plot you have? _____

Plot No	Area	Holding status (rent, owned self)	Distance from residence	Major land use (crop, grazing, trees, fallow, crops and trees etc.)	Slope (steep, very steep, medium and flat)	Conservation measures (soil bund, stone bund, fanya juu, micro basin and others)
1						
2						

3						
4						
5						

*Estimated slope category= steep and very steep (30%-60%), moderate (10%-29%) and flat (<10%)

6. Do you have perennial crops?

A. Yes B. No

7. If yes how big the farm is?

I Do you feel that farm land is sufficient to satisfy your family basic needs?

A. Yes B. No

II If your answer is no for question 8, what are the major causes?

III If your answer is no for question 8, how do you overcome food shortage?

IV If your answer is no for question 8, how many months do you experience food shortage in a year?

V What are your main expenditures?

VI Labor availability

I Do you have labor shortage?

II If the answer to question 1 is yes, how do you solve labor shortage?

III If the labor is hired, what type of labor do you hire?

A. Casual B. Permanent C. Both D. NA

IV Can you easily get labor whenever you need?

A. Yes B. No C. NA

V Which family members participate in soil and water conservation works?

A. Men B. Women C. Children D. All of them participate

VI Do you or your family member work on off-farm activities?

A. Yes B. No

VII If your answer is yes, which family members working on non-farming activity?

VII Perception of soil erosion problems

1. Do you think that soil erosion is problem of your farm plots?

A. Yes B. No

2. What do you think about consequences of soil erosion?
 - A. Land productivity decline
 - B. Change in type of crops grown
 - C. Reduces farm plot size
 - D. All

Others _____

VIII Farmers' perception of soil erosion hazards

1. Whether soil erosion was perceived as a problem in own farm?
 - A. Yes
 - B. No
2. Severity of problem, if yes to the above question 1
 - A. Severe
 - B. Medium
 - B. Moderate
3. Have you observed change in soil erosion severity over the past 3 years?
 - A. Yes
 - B. No
4. Extent of impact of soil erosion on farm production
 - A. Severe
 - B. Moderate
 - C. Has no effect
5. Do you believed that soil erosion can be controlled? And how?

IX Farmers' perception on physical soil and water conservation measures

1. Do you know existence of improved soil and water conservation structures?
 - A. Yes
 - B. No
2. If yes, which type do you know?
3. Which of the following types of soil and water conservation measures are efficient to reduce the problem of soil erosion?
 - A. Stone bund
 - B. soil bund
 - C. cut off drain
 - D. water way
 - E. fanya juu all

Other _____

4. Have you participated in community conservation activities?
 - A. Yes
 - B. No
5. Do you believe that investment in soil and water conservation practices is profitable in the long run?
 - A. Yes
 - B. No
6. What is the problem related to each soil and water conservation structures? Hint, choose from 1-7.

No	Problems	Soil bund	Fanya juu	Micro basin	Water way	Stone bund
1	Source of rodents					
2	Reduce farm land					
3	Difficult to turn oxen					
4	Labor intensive					
5	Difficult to implement					

6	Costly					
7	Others					

X Benefit from physical soil and water conservation measures

1. Indicate benefit gained from SWC management using the following indicators:

No	Benefits	Rating			
		Highly increased	Increased To some extent	Decreased	Highly decreased
1	Fertility				
2	Crop Productivity				
3	fodder and grass supply				
4	Wood Production				
5	Livelihood Security				
6	Dependency on aid/ FFW				
7	Water supply (drinking and irrigation)				
8	Water use efficiency				
9	Soil erosion				
10	Number of trees				

11	Restoration of grazing lands				
12	Flooding				

2. If you are dissatisfied, what is the reason?
 A. The benefit is inadequate B. I didn't get any benefit

Others _____

XI Institutional support

1. Do you get extension service?
 A. Yes B. No
 2. If yes for question A, who provides the extension service?

3. How often you have obtained extension advice on soil and water conservation practices?

4. Have you been participated in training of soil and water conservation for the last five years?

A. Yes B. No

5. If yes for question 4, how many days?

6. Was the training useful and what did you get from the training?

7. Do you participate from access of credit?

A. Yes B. No

XII Conclusion question

1. What do you recommend to improve the effectiveness of physical soil and water conservation measures?

