THE EFFECTS OF FANYAJUU, DRAINAGE DITCH AND HOME GARDEN AGROFORESTRY PRACTICES ON SOIL PROPERTIES AND MAIZE CROP YIELD PRODUCTIVITY IN ALETA CHUKO WOREDA, SIDAMA, SOUTHERN ETHIOPIA

By

Deginet Ayele

Advisor: D/r Ambachew Demessie (Associate Prof.)

Co-advisor: D/r Tesfaye Abebe (Prof.)

Thesis Submitted to the School of Plant and Horticultural Sciences, Hawassa University, College of Agriculture in the partial Fulfillment of the Requirements for the Degree of Master of Sciences in Agroforestry

June 2022
Hawassa/Ethiopia

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Advisor’s thesis approval sheet

The effects of fanyajuu drainage ditch and home garden agroforestry practices on selected soil properties and maize crop yield productivity in Aleta Chuko Woreda, Sidama Southern Ethiopia has been carried out by Deginet Ayele Dangiso Id. No GpAgFoR/0001/11, under my/our supervision. Therefore, I/we recommend that the student has fulfilled the requirements and hence hereby can submit the thesis to the Graduate Program of the School of Plant and Horticultural Sciences, College of Agriculture, Hawassa University, Ethiopia.

Ambachew Demessie (PhD)	______________	______________
Name of advisor	Signature	Date

Approval Sheet –I

This is to certify that the thesis titled “The effects of fanyajuu, drainage ditch and home garden agroforestry practices on selected soil properties and maize crop yield” in Aleta Chuko Woreda, Sidama, Ethiopia.” submitted in partial fulfillment of the requirements for the degree of Masters of Science, specialization in Agroforestry of the Graduate Program of the School of Plant and Horticultural Sciences, College of Agriculture, Hawassa University is a record of original research carried out by Deginet Ayele, under my supervision, and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the course of this investigation have been duly acknowledged. Therefore, I recommend that it to be accepted as fulfilling the thesis requirements.

D/r Ambachew Demissie (Asso.Prof) ______________ ________________

Name of Major Advisor Signature Date

D/r Tesfaye Abebe (Prof) ________________ ________________

Name of Co-Advisor Signature Date

Approval Sheet –II

We, the undersigned members of the boarded of the examiners of the final open defense by Deginet Ayele have read and evaluated his thesis titled “the effects of fanyajuu, drainage ditch and home garden agroforestry practices on selected soil properties and maize crop yield in Aleta Chuko, Sidama Ethiopia” examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Agroforestry.

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the Council of Graduate Studies (CGS) through the department graduate committee (DGC) of the candidate’s major department.

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Name of Chairman	Signature	Date
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Name of Major advisor	Signature	Date
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Name of Co-Advisor	Signature	Date
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Name of Internal Examiner	Signature	Date
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Name of External Examiner	Signature	Date

Dedication

This thesis work is dedicated to all of my family members for their unconditional love and support during the research and writing up process.

Statement of the Author

I declare that this thesis is my own work and all sources of materials used are duly acknowledged. I declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate. This thesis has been submitted in partial fulfillment of the requirement for the degree of the degree of Master of Science, specialization in Agroforestry of the Graduate Program of the School of Plant and Horticultural Sciences, College of Agriculture, Hawassa University, Ethiopia.

Name of the Author	Signature	Date
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Date of Submission: ----------------------------------

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Abbreviations and Acronyms

AvP	Available Phosphorous
ACTADO	Aleta Chucko Town Agricultural Development Office
BD	Soil Bulk Density
CEC	Cation Exchange Capacity
FPSE	Farmers Perceptions for Soil Erosion
ITK	Indigenous Technical Knowledge
OM	Organic Matter
PSD	Soil Particle Size Distribution
SE	Soil Erosion
SEI	Soil Erosion Indicator
SOC	Soil Organic Carbon
SOCS	Soil Organic Carbon Stock
SWC	Soil and Water Conservation

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The Effects of Fanyajuu, Drainage Ditch and Homegarden Agroforestry Practices on Soil Properties and Maize Crop Yield Productivity in Aleta Chuko Woreda, Sidama, Ethiopia.

Mr. Deginet Ayele, Ambachew Demissie (Associate Prof.), Tesfaye Abebe (Prof.)

Abstract

*Resource degradation, particularly soil erosion coupled with poor soil and water loss control practices are few of the major causes for the decline of agricultural crop production. In Aleta Chuko Woreda, soil erosion and water logging triggered by vegetation clearance, land fragmentation and population growth, are very common. Thus, this study was carried out in Dongora Morocho and Elelcho kebeles of Aleta Chuko Woreda on Fanyajuu, drainage ditch and home garden agroforestry (HgAF) conservation practices (1) to assess soil physical properties; including soil bulk density, soil moisture content and soil texture. (2) to assess soil chemical properties including cation exchange capacity (CEC), available phosphorous av. P, and soil pH (3) to assess soil carbon sequestration (soil organic carbon (SOC), soil organic matter (SOM) and soil organic carbon stocks (SOCs) (4) to assess maize crop productivity; including crop yield and total biomass 5) to assess farmer's perception on the effect of soil erosion and water logging control practice. Soil samples in three replicates were collected at 0-10 and 10-20 cm depth for the analysis of texture, Av. P, CEC, pH and OC. Separate core samples were collected at the same spot for bulk density determination. For each treatment a 20*20 m main plot was assigned and the grain yield was collected in 3 replicates from 2*2m sub plots within the main plot. Sampling size of 195 respondents was calculated from the entire population (4616) of two kebeles. Then 195 respondents were randomly selected from the two Kebeles to the collect data, through questionnaire. The data on soil bulk density and soil moisture content show no significant differences in all conservation treatments at ($P>0.05$) in the 0-10 and 10-20cm depth. Soil bulk density (BD) ranged from 1.1 g cm^{-3} (drainage ditch, Fanyajuu and HgAF) to 1.3 g cm^{-3} (un-conserved crop field). Sand in soil under lower fanyajuu (28.3%) is significantly higher compared with that of un-conserved crop field (20.3%).Silt under un-conserved crop field is significantly greater than all other conservation practices. Clay under upper Fanyajuu is significantly higher compared with lower fanyajuu, lower drainage ditch and un-conserved crop field while clay under lower fanyajuu is significantly lower than the rest of conservation practices. Over all the textural class is clay soil for all conservation practices. Soil pH among SWC treatments and non-conserved land varied between, 5.7 to 6.6. The lowest pH (5.7) was recorded in soils under homegarden agroforestry plots. CEC in soils under un-conserved farm plots is significantly lower at ($p < 0.05$) compared with all of the other SWC treatments. Available P (22.7 $mgkg^{-1}$) in soils under homegarden agroforestry plots is significantly higher than any of the SWC treatments and is within the levels of healthy range. SOC concentration ranges between 1.1 and 1.3 % and is in the order of home garden agroforestry (1.3%), upper and lower drainage ditch (1.25%) and upper and lower fanyajuu (1.22 %). The grain and stover biomass yield of maize under SWC treatments is in the order of Fanyajuu >Drainage ditch >Homegarden agroforestry >Un-conserved field p lots. The evidence recorded under this study attests that the majority of farmers fairly understand about the benefits of soil and water conservation practices to improve soil productivity. Generally the data suggests that SWC practices are crucially important to reduce soil erosion and augment crop yield and farmers should be advised to apply conservation practice on farm lands of their possession.*

Keywords: Bulk density, Degradation, Organic carbon, Organic Matter, Phosphorous, Soil Erosion

1. Introduction

1.1. Background

Soil degradation, particularly soil erosion is one of the causes for the decline of agricultural crop production (Teklu and Williams 2018) . The soil degradation's potential threat to crop productivity is huge but few people have a clear understanding of what soil degradation is and what its subsequent consequences are (Chizana, et, al 2007).

In Ethiopia erosion is recognized as one of the onsite factors for reduction of yield and increased production cost of the society (Bekele and Holden, 1997; Woldeamlak, 2006). Impacts of soil erosion on productivity and nutrient depletion are mainly due to on-site effects: a decline in soil fertility, soil organic carbon and moisture availability and off-site effects such deposition of sediments in irrigation dams (Stroosnijder, 2009).

The national average yield of major crops for small holder sectors is less than 1.2 ton/ha (CSA, 2007) and this is considered as among the lowest in the world. One of the reasons for the low yield is huge loss of top soil, which is estimated to be 1.2 tone/ ha /year and it can be higher in steep slope and any barren lands (Hurni, 1993). SWC activities maintain or enhance the productive capacity of land in areas affected by or prone to soil erosion. Soil erosion, on the other hand, is the movement of soil from one part of the land to another through the action of wind or water. Some soils are too erodible and are difficult to be cultivated (Adimassu, (2014) . Water logging is another problem which results in crop failure or yield reduction by reducing the amount of oxygen available to the roots (Easton and

Bock, 2016). Water logging is a drainage problem that results in high water inflow caused by rain, runoff, interflow, rise in ground water, over irrigation or flooding. Soil type particularly heavy clay soils and soils prone to surface sealing, hold moisture for long periods is one of the many causes that permits water logging easily in a given site (Tadele and Yihenew (2011). Hence such condition calls for soil and water conservation strategies to be administered.

In Ethiopia, farmers locally apply indigenous technical knowledge (ITK) such as stone bunds, water ways, diversion ditches, and cultural practices that includes (adding compost, manure, chemical fertilizers, growing of legume crops) to combat soil erosion , remove waterlogging condition and maintain soil fertility in place respectively (Bewket, 2011). Biological and Physical SWC technologies such as agroforestry, fanyajuu, and drainage ditch have been proposed to combat soil erosion and water logging problem but only a few, if any, are implemented by farmers to support their indigenous technical knowledge (ITK) on a long-term basis (Tolera, 2011). 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. The Fanya juu reduces or stops the velocity of overland flow and consequently soil erosion. Whereas, a drainage ditch is an artificially created or modified watercourse that drains surface or groundwater from low-lying areas, fields, roadways, or plant irrigation (Eshetu and Alemayhu, 2016).

Agroforestry is a deliberate mixture of trees crops and or animals in the same land unit. The components enhance land cover and intercepts rainfall, anchors the soil through their root system and increase the soil resistance to detachment through the addition of soil organic matter (Tesfaye and Wiersum, 2010). Soil conservation in Ethiopia, is not only closely related with the improvement and conservation of the environment, but also sustainable development of agricultural sector and the country’s economy at large (Wegayehu and Drake, 2003). Efforts towards the soil and water conservation goals were started since the mid-1970s and 1980s (Bekele and Holden, 1999).

1.1 Statement of the Problem

Soil erosion and water logging triggered by vegetation clearance and land fragmentation stemmed from population growth, is very common in Aleta Chuko woreda. Soil erosion water logging led to loss of production capacity of farm lands, leaving crop cultivation and livestock husbandry to resist the impacts of the changing climate variability.

Waterlogging affects plant growth and production in the anaerobic conditions, leading to the death of certain crops and plants. Also, plant roots fail to respire as a result of the excess water in the soil profile, making them weak and either die or fall. The soil is critically important resource as it is the bases for life and healthy environment. But it is negatively affected by erosion and water logging condition which limits its ability to support life by the loss of its productive capacity.

Water logging is prevalent in study area which crucially reduce crop yield that seriously affects the livelihood of the farming community. To tackle the soil erosion and water logging problems, biological (agroforestry systems) and physical soil and water conservations practices like fanyajuu terrace and drainage ditch are implemented on the cultivated lands.

Soil degradation negatively affects the lively hood of the community in the study area which necessitates farmers to perceive its severity and the associated yield loss and be prompted to carefully consider implementing appropriate SWC practices. The introduced conservation SWC technologies have not been sustainably used by farmers in the study area. But the community frequently face the resultant effect of soil erosion particularly, runoff, gully, rill, sheet erosion and water logging problem. The effectiveness of the implemented SWC technologies, the rate of adoption, factors affecting it, their relevance to farmers interest, the comparative efficiency of the introduced SWC technologies in comparison to farmers' own ITK, farmers' perception of soil erosion (FPSE) and their attitude towards it are not yet studied.

1.2. General Objective

To Assess the Effects of Soil and Water Conservation (SWC) Practices Such as Fanya juu, Drainage Ditch and Homegarden Agroforestry on Soil Properties and Maize Crop Yield in Dongora Elelcho and Dongora Morocho kebeles of Aleta Chuko woreda, Sidama region, Southern Ethiopia.

1.2.1 Specific Objectives

- To Assess the Effects of SWC Practices on Selected Soil Physical Properties.
- To assess the effects SWC Practices on Selected Soil Chemical Properties.
- To Assess the effect of SWC on Carbon Sequestration
- To Assess the Effect of SWC Practices on Maize Crop Yield
- To Asses Farmers Perception on Soil Erosion, it's Impact on Crop Yield and Sustainable Farm Productivity.

1.3. Research Questions

1. Do Fanya juu, drainage ditch/SWC treatments and home garden agroforestry practices affect soil properties?
3. Do fanyajuu, drainage ditch/ SWC treatments and home garden agroforestry practices affect maize crop yield?
3. How farmers perceive soil erosion, its impact on crop yield and sustainable farm productivity?

1.4. Significance of the Study

Since water logging and soil erosion are serious problems in Aleta Chuko area, this study was important to evaluate the roles of agroforestry system, the physical soil and water conservation structures against their effect on the reduction of soil erosion to enhance soil fertility. The study result can potentially be used to design appropriate intervention aiming at curving the envisaged soil erosion and water logging problem and augmenting soil fertility for sustained production.

1.5. Scope of the Study

Despite the need to carry out this empirical study on wider scale, the scope of this study is limited only to two kebeles in Aleta Chuko woreda. The impacts produced as a result of soil erosion are tremendous in the Woreda. Yet, this study captures impacts related to yield decline, loss of soil fertility, water logging condition and gully formation alone and hence can’t provide an exclusive impact menu. The slope percentage of the studied sites and the spacing between SWC structures should have been measured to be used as an aid to explain the study findings.

1.6. Limitation of the Study

All sites designated for this study should have been with similar topography (flat, undulating, and hilly terrain), slope and soil type. This could increase the strength of statistical inference by avoiding the uncertainty that other factors are not interfering with the outcome of the result

The questionnaire should have been prepared separately for SWC practicing farmers and the vice-versa. Such action could provide valuable information about why some of the respondent farmers are not practicing SWC in farmlands under their possession.

2. Literature Review

2.1. An overview of Soil Erosion problem

Much of the world has been facing increasingly serious soil erosion problem 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. Mitiku and Brigitta, (2006) have claimed that the reduction in water availability due to land degradation and soil erosion is a major global threat to food security and the environment.

Furthermore, croplands are the most susceptible to erosion because of repeated cultivation and the continual removal of plant cover. Some 80 percent of this degradation has taken place in developing countries and most countries lack sufficient resources to repair degraded land (Mitiku and Brigitta, 2006).

2.2. Soil erosion in Ethiopia

Natural resource degradation is the main environmental problem in Ethiopia. The degradation mainly manifests itself on lands where the soil has either been eroded away and/or whose nutrients have been taken out to exhaustion without any replenishment (Assefa, 2009). The majority of the farmers in rural areas of Ethiopia are subsistence-oriented, cultivating impoverished soils on sloppy and marginal lands that are generally highly susceptible to soil erosion and other degrading forces. The Ethiopian highlands have been experiencing declining soil fertility and severe soil erosion due to intensive farming on steep and fragile lands and other factors attributed to population pressure (Borin, 2005). The country’s soil loss through erosion averages 42 metric tons per hectare per year on currently cultivated lands and 70 metric tons per hectare per year on formerly cultivated degraded lands (Zanin, 2005).

About 45% of the total annual soil loss in the country occurs from cultivated fields, which accounts for only 15.3% of the total area (Borin and Zanin, 2005). The latest land degradation estimates indicate that out of the 52 million hectares of land making up the highlands of Ethiopia, 14 million hectares are severely degraded, 13 million hectares are moderately degraded and two million hectares have practically lost the minimum soil depth needed to produce crops. The illustration by Bekele and Drake, (2003), shows that the problem of soil erosion is compounded by the fact that some farmers dismantled the conservation structures built in the past through food for work incentives. Consequently, in Ethiopia, land degradation in the form of soil erosion and declining fertility is serious challenge for agricultural productivity and economic growth (Admassie, 2000) .

Soil erosion by water is by far the greatest land degradation problem. Wegayehu and Drake, (2003) stated that the most ubiquitous cause contributing to agricultural land degradation was soil erosion and also made clear that measures of land degradation usually focus on the severity of soil erosion. Water erosion not only removes nutrients but also reduces thickness and the volume of water storage and root expansion zone. Under extreme gully erosion, farm activities are extremely affected. The magnitude and rate of soil erosion continued to increase despite the considerable efforts made during the past three decades. The role of overgrazing is significant in fueling soil degradation process since it is integrated into a smallholder farming system (Wegayehu and Drake, 2003).

2.3. Resultant Effect of Soil Erosion in Ethiopia

The largest proportion of the degraded land is situated in the Woinadega agro-climatic zone where about 72% of cultivated land of the country is concentrated. Moreover, in the Ethiopian highlands, soil degradation and desertification are major issues since agriculture and deforestation have been practiced here for over 2500 years. Insecure rainfall, low technology levels and an increasing population pressure combined enhance soil degradation and desertification posing a major threat to agricultural productivity.

The living conditions of the rural poor in the highlands have been worsening because of drought and increasing deterioration of the quality and quantity of natural resources, which are the main basis of subsistence agriculture. There is a prediction that serious soil erosion is estimated to have affected 25 % of the area of the highlands to the extent that they will not be economically productive again in the foreseeable future. The capacity of the highland farming communities to sustain production is, therefore, under serious pressure. Wood, (2001) described that soil erosion in Ethiopia as sever and indicated that erosion reduces the countries food production by 1-2 % annually. The annual rate of soil loss in the country is higher than the annual rate of soil formation. Hence, the underlying cause for the excessive rate of soil loss is the unsustainable exploitation of the land resource which is manifested by extensive de-vegetation for fuel wood and other uses and expansion of cultivation and grazing into steep land areas (De graaff, 2006).

Soil erosion is also aggravated by lack of efforts in conservation and largely remains a problem to be tackled at ensuring food security, poverty reduction and sustainable maintenance of healthy environment. Considerable efforts have been made to develop and promote different types of soil and water conservation technologies. However, their acceptance, adoption and sustained use by the land users have not been widespread for various reasons (Alemayehu, 2007).

2.4. Soil and Water Conservation Practices

2.4.1 Home garden agroforestry practice

Home garden agroforestry practice is a special category of agroforestry that deals with the cultivation of multipurpose and multi-storied trees and crops combined with animal husbandry around a homestead (Tesfaye, 2010) in Sidama, Southern Ethiopia. Enset takes the lion share (in terms of coverage) in home garden agroforestry systems compared to other agronomic or horticultural crops. Besides serving as a food plant, it provides mulching for maintenance of soil moisture and protection of soil detachment by the rain drop impact. On the top of this, decomposed mulch material improves or maintain the soil fertility as well.

Hence, the soils are generally good in soil nutrients except the deficiency in phosphorus content. This agroforestry system is a well-known land-use system and supporting a wide range of plant species. The floristically and structurally diverse agroforestry systems can provide habitat and resources for partially forest dependent native plant and animal species that would not be able to survive in a purely agricultural landscape.

Several features of the Enset-coffee agroforestry systems are important for the ecological sustainability, including (1) maintenance of species diversity, which is important for risk spreading and minimization, genetic conservation of native species, efficient resource use and biological pest control; (2) reduced use or elimination of soluble or synthetic fertilizers, increased or improved use of manure and other organic materials as soil ameliorants, and soil conservation; (3) Reduced use or elimination of chemical pesticides, replacing these with integrated pest management practices and system diversity; and (4) self-sufficiency, by using on-farm or locally available ‘internal’ resources and a minimum or conditional use of purchased ‘external’ resources, which contributes to the long-term conservation of the resource base and environmental resilience of the systems (Bongers & Sterck, 2006).

2.4.2. Physical Soil and Water Conservation Practices

2.4.2.1. Stone Bunds

Stone bund is an embankment constructed along the contour to minimize soil erosion and to prevent runoff damage on downstream fields. It is constructed from stone/soil with a ditch at the upper side of the bund for stabilization (Amare, 2014). Stone bunds are widely applied in Tigray and elsewhere in Ethiopia. But relatively limited assessment has been done to determine their effectiveness and efficiency in halting soil erosion hazard. Stone bunds and Fanyajuu bunds are widespread conservation strategies for soil and water conservation (Amare, 2014).

2.4.2.2. Soil Bunds

Soil bund is an embankment constructed from soil along the contour with water collection channel or basin at its upper side. It is constructed in gently sloping terrain by throwing soil dug from basin down slope (Gebreselassie, 2017). It retains the running off water in the watershed and thus helps to control soil erosion. Although soil moisture plays an important role in crop growth, it is highly heterogeneous in space and time even in small catchments (Jemberu,2017). Traditional ditches have different sizes, spacing and gradients and are constructed every season by ox plough to dispose excess water from farm plots between successive bunds. Recently, integration of biological conservation strategies for stabilization of bund structures and gully treatment with plantation of trees like *Sesbania sesban* and grass species has become more popular (Fleskens and Ritsema, 2018).

2.4.2.3. Terracing

Terracing refers to building a mechanical structure of a channel and a bank or a single terrace wall, such as an earthen ridge or a stone wall. Terracing reduces slope steepness and divides the slope into short gently sloping sections. (Wheaton and Monke, 2001). Terraces are created to intercept surface runoff, encourage it to infiltrate, evaporate or be diverted towards a predetermined and protected safe outlet at a controlled velocity to avoid soil erosion (FAO., 2000). For some time, terracing have continually been promoted as among the best management practices for effective soil and water conservation (Amsalu and De Graaff) . The practice refers to building a mechanical structure of soil in form of channel and bank or single terrace wall, such as an earthen ridge or a stone wall. Terraces refers to an earth-embankment, constructed across the slope, to control runoff and minimize soil erosion (FAO, 2000). For slopes with gradients less than 15%, mulch for moisture conservation or application of Level Bund for maximum water conservation is recommend (Adimassu, 2014).

In higher rainfall areas, application of Level Fanyajuu is recommended if cattle are excluded all year. Continuous maintenance on constructed terrace is necessary during rainy season. The vertical interval is 1 meter for all measures on this slope. All structures require careful maintenance by the farmer and continuous building up until Bench Terrace is developed after several years.

2.5. Effect of Fanyajuu Terraces on Soil Physico-Chemical Properties.

Fanya juu is SWC structure to control erosion hazard. It is constructed by digging a trench and throwing the soil uphill to form an embankment and over time creates sloping bench-like terraces (Woldeamelak B. 2003:, 2003). The term was coined from Swahili language; meaning “throwing up-hill. Fanya juu is usually applied in cultivated land with slopes above 3% and below 16% gradient and uniform terrains with deep soils. Moreover, it has a potential to increase and sustain crop productivity (Desalegn, 2016). It improves the soil chemical properties such as soil pH, available phosphorous, CEC etc. Fanyajuu terraces across the contour lines create barriers that minimize soil erosion and runoff, through a filtering process. Silt builds up in front of the strip, and with time, benches are formed. The spacing of the strips depends on the slope of the land (Alemayehu, 2007).

On gentle sloping land, the strips are made with a wide spacing (20-30 m), while on steep land the spacing is about 10 to 15 m (Gemechu, 2016). All soil depths of more than 50 cm are possible. For slopes between 15 and 50%, conservation tillage combined with contour structures is recommended. On soil with good infiltration (sandy to silt texture), level bund or level fanyajuu combined with cutoff drain should be applied between every 10 to 15 structures. The vertical interval between two bunds is two-and-a-half times the depth of the soil. For clay soil, waterway should be constructed in the first year followed by Graded Bund or Graded Fanyajuu afterwards. Stone bunds and Fanyajuu bunds are widespread conservation strategies for soil and water conservation (Tadele, 2016).

2.6. Effects of Drainage Ditches on Soil Physico-Chemical Properties.

Drainage ditches are one of the widely used SWC practices and also known as traditional ditches. These are micro- channels constructed on cultivated farms to drain off excess water and control soil erosion. These are low cost measures in which construction is part of the normal ploughing activity. However, unlike the plough furrows, the ditches are made wider and deeper in dimension and usually run diagonally across the field. Locally, it is said to be drainage ditches “Boye” (Lakew, 2005). The location of the outlet of a drainage system is important to the proper water-removal function of the system. The outlet should be chosen with care to allow free flow (un-submerged) most of the time. Drainage is important to improve soil pH by reducing over flow of lateral water and stabilize the soil erosion. Improving drainage of agricultural fields can be achieved by three primary means: (1) installing subsurface, artificial “tile” (perforated pipe) drains at some depth below the soil surface; (2) surface ditching; and/or (3) land shaping (usually used with either ditching or subsurface drainage) (Asrat and Yitayew ,2005).

Both the subsurface tile drainage and ditch-type systems function to lower the water table in the soil below the crop’s root zone, while land shaping prevents water ponding on soils with very low infiltration capacity by building a crown or convex surface to direct surface flow from the field. These practices are usually used in combination; tile lines and/or surface-shaped fields need to drain to a ditch. Selection of a drainage system depends in part on the drainage problem that exists and the particular soil characteristics causing the problem (Tadele and Yamoh, 2011). The occurrence of surface runoff has been schematically illustrated by Steenhuis, (2010) who divide basins in the hill slopes and the lower relatively flatter areas. Precipitation on the hill slopes can partly infiltrate and partly flow downslope as (sub-) surface flow. Areas in the landscape where run on and rain depth are greater than runoff and infiltration become saturated during the rainy season.

The differences in flow discharge along the slope are due to differences in slope gradient, concavity of the area, depth to an impermeable layer in the soil transmissivity James and Roulet (2009) and rainfall characteristics (Ziadat Taimeh ,2013). Saturation of the soil and jointly its effect on surface runoff is often seasonally bound Ngatcha, (2011) amongst others studied erosive effects of overland flow due to soil saturation during the rainy season in Ethiopia, Cameroon and India respectively. Shallow soils, if occurring in the middle and lower parts of the slopes, get saturated more quickly and hence rill and gully initiation is more likely in these areas (Steenhuis , 2010).

2.7 Effects of Physical SWC on Crop Yield

The construction of fanyajuu takes less space than soil bunds and accelerate bench development, thus, complaint about space can be greatly reduced with fanya juu terraces (Bewket and Sterk, 2003). The aim is to reduce and stop erosion and increase water holding capacity of the soil so as to enhance crop yield. The main benefit of fanya juu is its capacity to become bench terrace within few years than soil bunds, yet it has overtopping and breakages (Lakew, 2005).

Overall, the drainage ditch should be designed to lower the water table from the upper parts of the effective root zone (top 6 to 12 inches) no later than 24 hours after becoming saturated to avoid significant crop yield loss that will generally occur due to poor aeration. Therefore, proper drainage ditch is vital to prevent crop damage due to excess water. Farmers in Ethiopia especially those who operate farming in high potential areas and sloppy terrain are aware of the negative consequences of soil erosion on agricultural production. As a result, SWC measures such as stone bunds, hillside terraces, and different types of crop and soil management activities exist as an indigenous knowledge for centuries (Awulachew, 2010). However, farmers view some of the physical SWC measures as showing limitations as they were not getting immediate returns (Amsalu and De-Graaff, 2007).

2.8. Effects of Homegarden Agroforestry Practice on Soil Physico-Chemical Properties

Under home garden agroforestry system, soil organic matter ranges between 45percent, CEC from 21-25 (meg/100gsoil), nitrogen between 0.3-0.5 per cent, pH between 5-6, and phosphorous 1-4 ppm. The Enset cohort substantially contributed to the simulated total biomass C stocks. The shares of Enset and coffee are insignificant compared to trees for C sequestration, in the indigenous agroforestry systems. Enset has exceptional ability to suck up lot of water in rainy seasons and store it in the stem to use it in drier season. The water from Enset will be distributed to nearby crops such as coffee and others. Moreover, Enset system significantly increase soil available total nitrogen (TN) available phosphorus (av.P) and organic carbon (OC) than annual cropping system (Bogale, 2007).

2.9 Effects of Homegarden Agroforestry Practice on Crop Productivity

The home garden agroforestry system aims to increase or maintain the production and productivity of farming system; reduce agricultural inputs, production costs and increase the diversity products. Home garden agroforestry system mainly consists of coffee, Enset, trees (both woody and non-woody components) intercropped with annual crops (Bogale, 2007). The Enset-coffee system is believed to be a bio-diversity hotspot to the extent that some people consider it as a museum for genetic resources.

The key components of this agroforestry practice are the perennial crops, Enset and coffee, with mean coverage of over 60% of the farm areas (Tesfaye ;Wiersum & Bongers, 2010). The two crops are grown in an intimate association with several herbaceous and woody crops as well as trees in multistory configurations. The majority (more than 50%) of the land in this agro ecological zone is occupied by coffee followed by Enset. Animal husbandry is also another activity in this belt. Lack of grazing land and limited spaces inhibits the involvement of farmers in this agroforestry system in animal rearing in a wider scale. This region supports a large number of populations, and hosts diversified flora and fauna.

2.9.1 Grass Strips

Grass strips are the least costly and least labor-demanding soil conservation structures. They combine characteristics of both biological and structural measures. Grass strips are a popular and easy way to terrace land, especially in areas with relatively good rain fall (Thomas, 1997). The grass is planted in dense strips, about 0.5-1 m wide, along the contour at intervals equivalent to calculated terrace spacing. Grass strips have been widely used in Tanzania in the Kondoa area of Dodoma, also in Arusha, Iringa and Kilimanjaro regions (Christianson,1993). In Kenya, they are commonly found in the highlands of Central and Rift valley where there is good rainfall. Surface runoff with severe soil erosion has been the main factor enhancing nitrogen loss from agricultural fields. As documented by Thomas, (1997) grass strips reduce s t soil loss by 59% and nitrogen by 42% compared to the loss from the plots without conservation measures in India.

2.9.2 Stabilization of SWC Structures and Reforestation of Degraded Lands

Bund stabilization with vegetation, and homestead plantations help to enrich soil organic matter content and restore vegetation cover and biodiversity (Asefa and Colman, 2003). Restoration of vegetation cover improves the accumulation of organic matter that enhance the resistance of soil particles to detachment impact of raindrop and transportability by surface runoff (Lesschen, 2005). Hence, vegetation cover controls soil erosion and maintain soil fertility. An add-on of SWC measures to vegetation cover play a considerable role in improving the water supply through a better recharge.

The vegetation cover enhances the infiltration capacity and reduces loss of water through surface runoff (Jemberu and Gebreselassie, 2017). Thus, the on-site and off-site impacts of SWC measures can lead to efficient use of soil and water resources and ultimately to sustainable land management (Baptista, 2016). The crown cover of the vegetation is highly responsive to rainfall and can easily form a dense cover during the rainy season. SWC measures constitute an important component of farming activity in the Ethiopian highlands and farmers apply various traditional and introduced SWC measures (Fleskens and Ritsema, 2018) .

Soil erosion is regarded as one of the forms of soil degradation, which involve deterioration of physical, chemical and biological properties of soil; all of which require attention. Soil erosion is highly related to the slope angle and it causes considerable deterioration of soil fertility and crop yields (Asefa and Oba 2003). On steep slopes; barriers have to be closely spaced if they are to reduce soil erosion to tolerable levels. When trees are arranged along the contours with close spacing, they form an effective barrier to soil erosion.

In addition to this, over time, a natural terrace would be formed upslope; the barrier further reducing soil erosion rates. Agronomical, *Calliandra* and *Leucaena spp* are good colonizers of denuded areas; tolerating soils that are heavily compacted and poorly aerated, and can persist in poorly drained soils. A system in which the land users continuously increase land productivity using measures that are ecologically sound, economically viable and culturally acceptable is key for sustainable development. The management and conservation of land resources such as soil, water and vegetation in such a manner ensure the attainment and continued satisfaction of human needs for present and future generations.

2.9.3 Vegetation Cover

The vegetative cover reduces the soil erosion via canopy intercepts rain drops and reduces the erosive energy of the rain drops. Dense canopies that cover much of the soil surface intercept a large proportion of the rain fall. Vegetation cover, a key factor in ecosystems health and environmental and land resources planning. Vegetation cover is affected by climate change, soil and nature of the topographic surface. Human-induced climate change may create new changes in the spatial-temporal distribution pattern of climate factors, such as precipitation, temperature, and sunlight (Amare, 2014).

Drought with the effect of precipitation deficit is a multi-scalar and complex phenomenon. It is often characterized by drought indices, such as standardized precipitation index and reconnaissance drought index (RDI) and during the last decades, the frequency, severity, and duration of droughts have been showing a clear upward trend in Iran and elsewhere in the world (Jemberu and Gebre Selassie, 2017). Therefore, monitoring and assessment of drought is of vital importance.

2.10. Farmers' Perception towards SWC Measures in Ethiopia

Farmers' perception on soil degradation is necessary to evaluate whether they distinguish between indicators of erosion and fertility loss. For instance, studies conducted in different areas have shown that farmers have knowledge of soil conservation measures (De-graaff, 2006). The paradox is farmers not apply SWC Measures to combat the devastating effect of soil erosion. Understanding farmers‟ perception about soil erosion and its impact is important in promoting soil and water conservation technologies (Chizana and Giller, et al, 2006). Soil erosion is an insidious and slow process therefore farmers need to perceive its severity and the associated yield loss before they can consider implementing soil and water conservation practices (Awdenegest and Holden, 2006).

Different farmers may have different attitudes towards soil conservation. Those attitudes may also affect the selection of soil conservation practices. Sometimes, farmers who have good attitudes also may not practice soil conservation due to the socio-economic failures. Zanin, (2005) combined economic and psychology theories and argued that conservation decisions were influenced not only by context variables, such as tenure, income and farm terrain, but also by their attitudes towards SWC technologies.

Perceiving the soil erosion problem and positive effect of soil conservation measures also provides stimulus to and shapes opinions about the adoption of conservation practices that stop the erosion problem. Perception of erosion problem is not a sufficient condition for adoption of soil conservation practices though it is a necessary one (Woldeamelak, 2003). For some valid reasons practicing of traditionally known soil conservation methods tends to be influenced by some factors. For instance, farmers recognize the importance of crop residues in enhancing soil fertility and resistibility of soil particles for rain drop impact through the addition of OM. However, crop residues and animal dung is used for fuel energy and other home use despite that the removal of plant materials impoverishes the soil, as it is no longer possible recycle the nutrients present in the residue.

3. Materials and Methods

3.1. Description of the Study Area

The study was conducted in Dongora Elelcho and Dongora Morocho in Aleta Chuko woreda found in Sidama Regional State Ethiopia. It is bordered with Lokka Abaya Woreda in the west; Dalle Woreda in the north; Aleta Wondo in the east and Dara in the south direction. It is located 62 km south of Hawassa, the regional capital of Southern Sidama region and 339 Km south of the capital Addis Ababa along Addis Ababa Moyale highway ACTDO, 2012

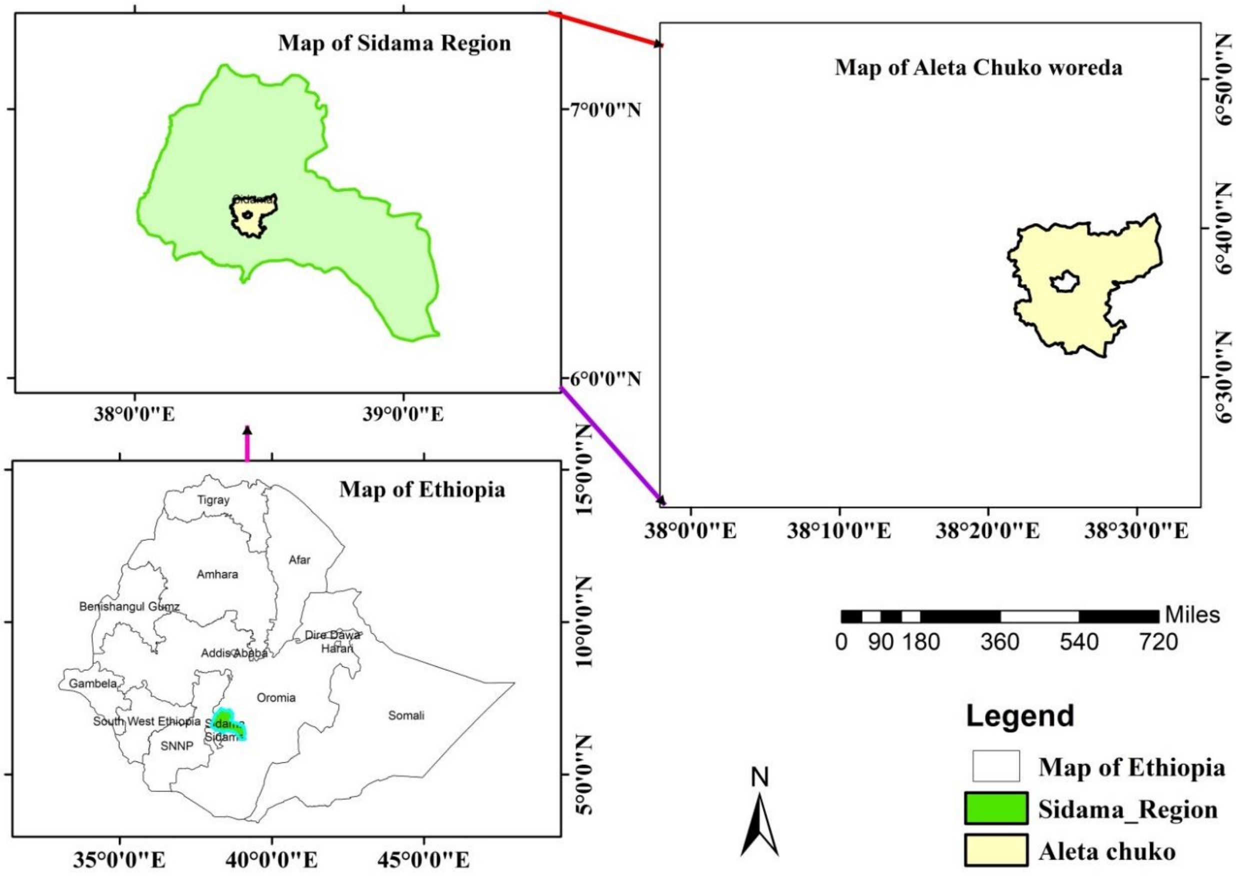


Figure1: Map of the study area.

3.2. Soil Property of the Study Area

The soil type in Dongora Elelcho and Dongora Morocho of Aleta Chuko woreda is vertisol (ACTADO 2012). Vertisols are clayey soils that shrink and swell extensively upon changing soil moisture conditions. Vertisoils exhibit unique morphological properties such as the presence of slickensides, wedge-shaped aggregates. Shrink-swell phenomena are the dominant pedogenic processes in vertisols and are attributed to changes in interparticle and intraparticle porosity with changes in moisture content. This is in contrast to the commonly invoked process of clay interlayer hydration-dehydration to explain shrink-swell phenomena (Coulombe et al., 1996).

Vertisols are often vulnerable to surface sealing, hold moisture for long periods is one of the many causes that permit waterlogged easily in a given site. Water logging is prevalent in study area which crucially reduce crop yield that seriously affects the livelihood of the farming community in the area. So the farmers at the study area manage the soil by using the soil and water conservation practices like Fanya juu terrace and drainage ditch in order to remove unwanted lateral water movement. This is because these conservation measures can improve the physical condition of soil like bulk density, soil porosity and workability (ACTADO, 2012).

3.3. Topography and Climate

It has an altitudinal range of 1400-2300 m.a.s.l with an annual average rainfall of 1100-1400 mm and mean annual temperature of 10-26°C. (ACTADO, 2012). The slope of the study Kebeles ranges from 0 - 5% to 75-85%. The altitude of the

Kebele ranges from 180 - 244 meters above mean sea level (Aleta Chuko Woreda Finance and economic development annual report, 2010).

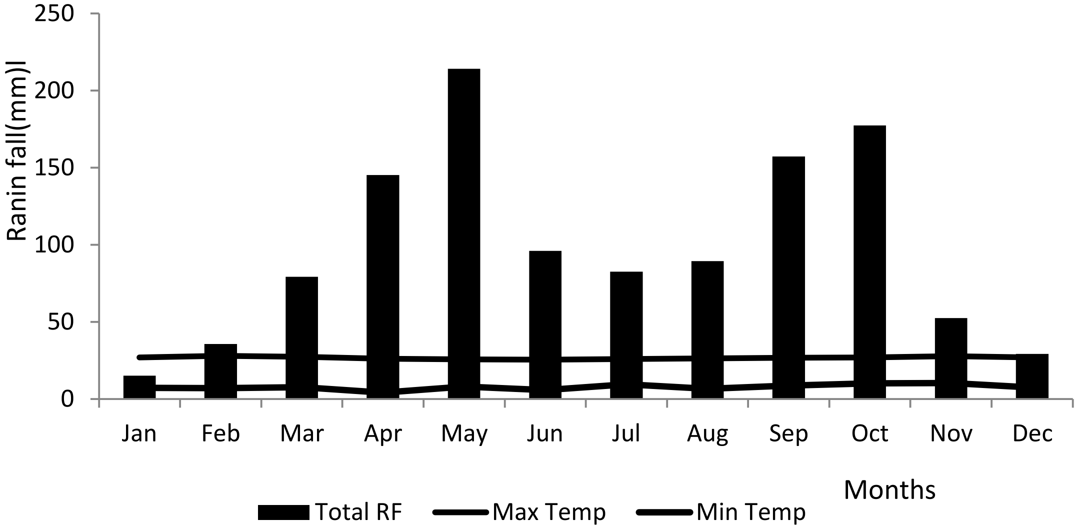


Fig.2: Monthly rainfall (mm) and mean monthly maximum and mean minimum Temperature (0c) for the period of 2009 -2021

3.4 Population size of the Study Area

The population size of the study Kebeles (Dongora Elelcho and Dongora Morocho) in Aleta Chuko woreda, Sidama Regional State, Ethiopia is grouped as shown in Table 1.

Table 1: Population size of the study area

Kebele		Population Size	Female	Male	Households
Dongora Morocho		2124	860	1264	90
Dongora Elelcho		2492	994	1498	105
	Total	4616	1854	2762	195 (4.2%)

3.5. Vegetation

Many indigenous tree species with very limited abundance are existing in the area. They are occurring on some farmer's farmlands, around churches homesteads and the community woodlot. Major indigenous tree species in the study area are Yeabesha Girar (*Acacia abyssinica*), Weyra (*Olea africana*), Bisana (*Croton macrostachyus*) and Gesho (*Rahmnu sprinoides*). Exotics species Nech Bahir Zaf (*Eucalyptus globulus*), Deccurence (*Acacia deccurens*) and Sesbania (*Sesbania sesban*) are also found in the study area. (ACTADO, 2012).

3.6. Agriculture

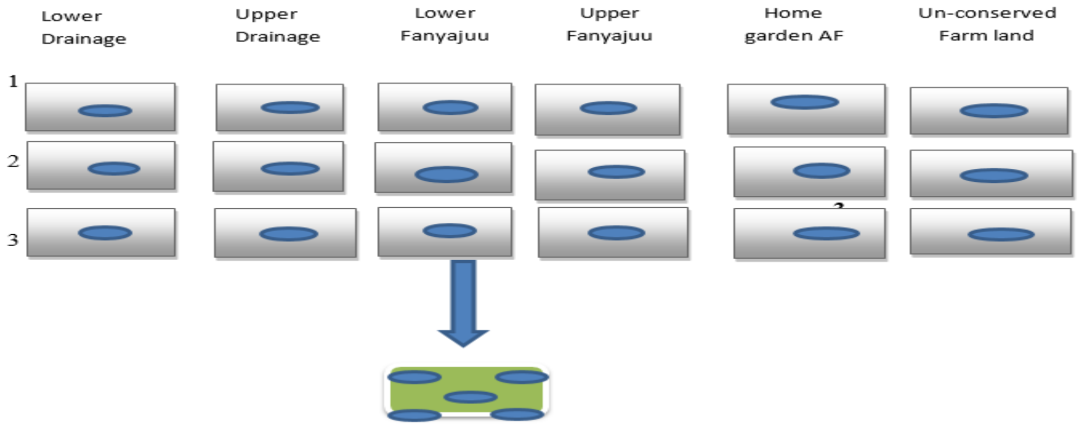
The dominant farming system in Aleta Chuko Woreda is coffee, Enset- trees (both woody and non-woody components) based agriculture intercropped with annual crops (both cereal and root crops). Rain-fed crop production during summer season is mostly practiced in the catchment area where intensive cultivation, sowing, weeding and other activities are performed. The livelihood of the community is mainly based on mixed farming system. The dominant crops produced in the area are cash crops such as coffee, pineapple, chat, avocado and mango, and other food crops like cereals, sweet potato, cassava and enset. Moreover, livestock production plays a significant role in the livelihoods of the people in the study area. Livestock is also a source of food and cash as well as the major source of draft power, fuel and fertilizer for crop production.

3.7. Site Selection

The availability and types of soil and water conservation and agroforestry practice were considered as criteria for site selection within the study area. To this effect, reconnaissance survey through transect walk was carried out to identify sites where samples are to be collected. GPS was used in the process to determine site locations. The transect walk was carried out from east to west and from north to south direction which has resulted in the identification of Dongora Morocho and Dongora Elelcho.

Dongora Morocho predominantly practice two types of physical structures (Fanya juu, drainage ditch) and enset based home garden agroforestry to control soil erosion and water logging respectively. These sites along with farmland without any of SWC were considered for soil physical and chemical properties evaluation. All sites are located adjacent to each other in much closer proximity.

3.7.1 Soil Sampling Layout



3.7.2. Soil sampling design

In Dongora Morocho, farms with SWC practice explicitly fanyajuu, drainage ditch; home garden Agroforestry system and farm without SWC practice here after named as treatments were assigned for soil sampling. Two main sampling plots of 20 by 20m were laid out in 3 replicates one in the lower and one in the upper portion on drainage ditch and fanyajuu treatment. Five sub sampling plots were assigned in the four corners and one in the center in each of the two main plots and were bulked together. In each of the sampling plots of each treatment, a total of 10 soil samples were taken from 0-10 and 10-20 cm depth. The 10 soil samples from each of the sampling plots were then bulked reducing them to 1 and placed and were placed in plastic bag. The collected composite soil samples were taken to the forestry module laboratory where they were air dried, crushed and passed in 2 mm sieve. A total of eighteen composite soil samples were used to determine the soil texture and chemical properties explicitly Soil pH, Cation Exchange Capacity (CEC), Available Phosphorous (P), Soil organic matter (SOM), Soil organic carbon (SOC) and Soil organic carbon stock (SOCS).

Separate core sample was drawn from the same sampling spots up to a depth increment of 0-10 and 10-20 cm depth for Bulk density (BD) and Soil moisture content determination. These were achieved by manually forcing a sharp aged still cylinder with the height of 5cm and a diameter of 5cm into the soil. The same core sampler was used one at a time and emptied it into a plastic bag. Then the core samples were taken to the soil laboratory at College of Agriculture Campus and the fresh weight was taken using electronic balance and oven dried at 100 ^{o}c for ≥ 24 hrs until constant weight is achieved.

3.7.3. Laboratory Analysis for Soil Physical Properties

Soil bulk density (g/cm3) , Percent moisture (wt. %) and Soil texture were analyzed and measured as described in (Kim, 2005). Soil pH was measured in a 1:2.5 (w/v) soil to water suspension (Jackson, 1973; Thomas (1996). Cation Exchange Capacity (CEC) was measured as described in (Peverill,1999). CEC was expressed as centimols of positive charge per kilogram of soil (cmol/kg) and by NH4.

Available P was determined by using Olsen *et al*., (1954) method and expressed as mg of Available P/Kg of soil (mg/Kg) while Organic Carbon (OC) was analyzed by the wet oxidation method (Walkley, Black 1934).

3.7.4. Measurements and Calculations

3.7.4.1 Calculations for Physical Properties

1) Bulk Density (g/cm3) was calculated by using equation1as described in (Kim, 2005)

   BD (g/cm3) = dry weight of soil/volume of soil…..………… (Equ.1)

Where:

   BD (g/cm^3) = Bulk density

2) Percent moisture (wt. %) was calculated by using equation 3 as described in (Kim, 2005)

   SMC=$\underline{\text{Mw-MD}}$ * 100……………………………………… (Eq.2)

Where:

   Mw = mass of wet

   Md = mass of dry

3) Soil texture was calculated using equation 1,2,and 3 as described in Sahilemedihin and Taye, 2000).

   Sand = 100-[(d1 + 1 - 2) x (100/50]……………………….. (Eq.3)

   Clay = [(d2 - 0.5 -2) x (100/50]…………………………………………. (Eq.4)

   Silt = 100 - (% sand + % clay)]……………………………………………. (Eq.5)

3.7.4.2 Calculations for Chemical Properties

1) SOM was calculated by using equation 2 as described in (Demessie , Singh Rattan Lal, 2012b)

SOM (Mg/ha) =SOC*1.725………………………………… (Eq.6)

Where:

SOM = Soil organic matter   SOC= Soil organic carbon

2) Soil organic carbon stock (SOC stock) was calculated by using equation 3 as described in (Demessie, Singh Rattan Lal 2011)

SOC stock (mg/ha) = C_{cons}*BD Mg m^{-3}* T (m) *CF coarse *10000 m^2/ha*0.001Mg/kg …………………………………………… (Eq.7)

Where:

SOCS = Soil organic carbon stock (Mg/ha)
C_{conc} = carbon concentration (kg /Mg)
BD = Bulk density (Mg/ m^3)
T = Depth or thickness (m)
CF = Correlation factor (1 - (Gravel % + Stone %) /100)

3.7.6. Crop Yield and Biomass Sampling Design

Harvesting was done manually after maturation and the harvested crop of each plot was collected in sack separately and tugged properly. The harvested samples were sun dried. Finally, the grain yield and the biomass of the Stover weights were recorded separately for each treatment.

$$\text{Grain yield (kg ha}^{-1}\text{)} = \frac{10{,}000\ m^2 * \text{Weight of grain (Kg)}}{\text{Harvested area } (m^2)} \text{ ……………..Eq.8)}$$

$$\text{Stover biomass yield (kg ha}^{-1}\text{)} = \frac{\underline{10{,}000\ \text{m}^2 * \text{Weight of grain (Kg)} \ldots\ldots}}{\text{Harvested area (m}^2\text{)}} \ldots\text{Eq.9)}$$

3.7.7. Assessment of Farmers Perception on SWC Practice

The farmer's perceptions of those residing in Dongora Morocho and Dongora Elelcho on the chosen SWC practices were assessed through questionnaires. There were 195 farmer selected in both kebeles. The, sample size was determined from a total number of households as described in (Yemane (1967) using the equation shown below.

n=N/1+N (e) 2……………………………………………………………. (Equ. 9)

Where:

n=Sample size

N=Total population of a study area e= Marginal error

3.7.8. Data Analysis

The laboratory results of soil sample, crop yield and biomass data were subjected to the analysis of variance (ANOVA) using SAS version 20. The data distribution was checked using Shapiro wilk normality test. Mean separation was carried out using least significance difference LSD comparison test at 5%. Descriptive statistics was employed to analyze the data collected through questioner vis-à-vis perception of farmers on the importance of agroforestry and SWC practices using SPSS version 26. Moreover, correlation matrix was also carried out to determine the nature and degree of relationship between soil physicochemical properties Correlation coefficient values (r) and test of significance were analyzed using Pearson correlation procedure using SPSS.20 software.

4. Result and Discussion

4.1. Effects of SWC treatments on Soil Physical Properties

4.1.1 Soil Bulk Density

Soil bulk density is an indicator of soil compaction and soil health (Shah et al., 2017). It affects infiltration, rooting depth/restrictions, available water capacity, soil porosity, plant nutrient availability, and soil microorganism activity, which influence key soil processes and productivity. Bulk density is influenced by the amount of organic matter in soils, their texture, constituent minerals and porosity (Keller & Håkansson, 2010).

High bulk density is an indicator of low soil porosity and soil compaction. It may cause restrictions to root growth, and poor movement of air and water through the soil. Bulk density increases with compaction and tends to increase with depth (Abu-Hamdeh, 2003 ; Demessie et.al, 2011). Conversely, soils with low bulk density are generally more suitable for agriculture, since the high pore space has a greater potential to store water and allow roots to grow more readily. Bulk density depends on soil type. For clay soils, dry bulk densities of 1.0 g/cm3 indicate a loose soil, whereas 1.2 – 1.3 g/cm3 indicate a much more compact soil. However for a sandy soil 1.2 g/cm3 would indicate a loose soil and 1.5 to 1.6 g/cm3 a more compact situation (Eluozo, 2013).

The bulk density data in Table 2 does not show significant difference between SWC treatments. The similarity in soil texture (Table 2) and SOM among all treatments may explain the non-significant difference of BD under all SWC practices. Bulk density ranges from 1.1 to 1.3 g cm^{-3} (Table 2). As documented by Murphy, (2007) the range of soil bulk density data shown in Table 2 is classified as low. However, for clay soils (Table 2), dry bulk densities of 1.2 – 1.3 g/cm3 indicate a much more compact soil (Eluozo, 2013). Soils with low bulk density are generally more suitable for agriculture, since the high pore space has a greater potential to store water and allow roots to grow more readily. Bulk density increases with compaction and tends to increase with depth (Abu-Hamden, 2003; Demessie et.al, 2011).

4.1.2. Soil Moisture Content

Soil moisture is the water stored in the soil and is affected by precipitation, temperature, soil characteristics and more.

Table 2: Soil physical characteristics under SWC treatments

Variables	Upper Drainage	Lower Drainage	Upper Fanyajuu	Lower Fanyajuu	Homegarden Agroforestry	Un-conserved crop field
			Soil Texture 0-20cm depth			
Sand %	25.0 ab	26.3 ab	23.0 ab	28.3 a	24.3 ab	20.3 b
Silt %	18.3b	17.0 b	17.0 b	19.0 b	15.6 b	27.6 a
Clay %	58.0 ab	51.6 b	58.6 a	52.0 c	58.0 ab	53.3 bc
T. class	Clay soil	Clay soil	Clay	Clay soil	Clay soil	Clay soil
			BD and SMC 0-10 and 10-20 cm depth			
BD (g/cm3)	1.1± 0.03 ^{a}	1.2±0.028 ^{a}	1.2±0.1^{a}	1.1±0. 0 ^{a}	1.1±0.0 ^{a}	1.3 ±0.0 ^{a}
	1.2± 0.06 ^{a}	1.1± 0.0 ^{a}	1.3±0.4^{a}	1.2 ±0.0 ^{a}	1.1±0.0 ^{a}	1.2±0.01^{a}
MC %	44.9± 4.3^{a}	47.6 ±1.63^{a}	37.8± 4 ^{a}	43.2±0.6^{a}	47.6±2.9^{a}	33.4±2.9^{a}
	49.0 ±2.9 ^{a}	43.2 ±0.64^{a}	37.9 ±1 ^{a}	48.9 ±1 ^{a}	43.2±0.6^{a}	41.8±4.0^{a}

Means within rows followed by the same letters are not significantly different to each other (p<0.05, Where: BD=- bulk density, MC=-moisture content, T=Texture

These same factors help to determine the type of biome present, and the suitability of land for growing crops. The health of crops relies upon an adequate supply of moisture and soil nutrients.

Similar to BD, no significant difference is recorded on SMC in plots under all SWC treatments. SMC ranges from 33.4 to 49% in soils under all SWC treatments (Table 2). Soil moisture content in most of the plots under SWC treatments is within the range of 10 to 45 % satisfying as the moderately high classification by (Furr & Reeve, 1945).

4.1.3. Soil Texture

Soil texture is the relative proportion of sand, silt, and clay in a soil (Hillel, 2003). Soil texture is a permanent feature unless soils are subjected to rapid erosion, deposition or removal. Moreover, much of the reactivity of soils is related to the amount of surface area available. As the average particle size decreases, the surface area per unit weight increases (Hiemstra et al., 2010).

The texture of a soil is important because it determines soil characteristics that affect plant growth (Hillel, 2003b). Three of these characteristics are water-holding capacity, permeability, and soil workability (Belachew & Abera, 2010). Data regarding particle size distribution revealed that clay is the dominant feature in Dongora Elelcho and Dongora Morocho kebeles. The textural class of soils in plots under SWC treatments is clay soil (Table 2).

4.2. Effects of SWC treatments on Soil Chemical Properties

4.2.1. Soil pH

The soil pH measures active soil acidity or alkalinity. Natural soil pH reflects the combined effects of the soil-forming factors (parent material, time, relief or topography, climate, and organisms (Zhang et al., 2019). In the natural environment, soil pH has an enormous influence on soil biogeochemical processes. Soil pH is, therefore, described as the “master soil variable” that influences myriads of soil biological, chemical, and physical properties and processes that affect plant growth and biomass yield (Penn & Camberato, 2019a).

Soil pH is crucially important to plant growth because it determines the availability of almost all essential plant nutrients (Neina, 2019). At a soil pH of 6.5, the highest numbers of nutrients are available for plant use. In higher rainfall areas the natural pH of soils typically ranges from 5 to 7, while in drier areas the range is 6.5 to 9. A pH of 6.9 or less is acid. Soils with a pH of 7.0 are neutral; values higher than 7.0 are alkaline. Under normal conditions, the most desirable pH range for mineral soil is 6.0 to 7.0 and 5.0 to 5.5 for organic soil. However, the optimum pH range for most plants is between 5.5 and 7.5; though, many plants have adapted to thrive at pH values outside this range (Neina, 2019).

When the pH is too high, the soil will be alkaline. Alkaline soils pose problems for plant health and growth. For many plants, soil that is high in alkalinity makes it harder for plants to absorb water and dissolved in it nutrients from the soil, which can limit their optimal growth. At a low pH, many elements become less available to plants, while others such as iron, aluminum and manganese become toxic to plants. Aluminum, iron and phosphorus also combine to form insoluble compounds. Low pH in soil can be caused by a loss of organic matter, removal of soil minerals when crops are harvested, erosion of the surface layer, and effects of nitrogen and sulfur fertilizers (Läuchli & Grattan, 2017). The data in Table 3 shows that the soils under upper Fanyajju and homegarden agroforestry is acidic than the rest of SWC treatments. The lowest pH (5.7) was recorded in soils under homegarden agroforestry plots. Soil pH among SWC treatments and non-conserved land varied between, 5.7 to 6.6. Most of the soil pH under SWC treatments is neutral with the exception of soil pH under homegarden agroforestry and upper fanyajuu.

4.2.2. Soil Cation Exchange Capacity

Cation exchange capacity, CEC is defined as the maximum quantity of total cations (both acid and base) that soil can hold at a given pH, which are available for exchange with other cation species present in the soil solution (Soga, 2005) .

Cations retained electrostatically are easily exchangeable with cations in the soil solution so a soil with a higher CEC has a greater capacity to maintain adequate quantities of Ca2+, Mg2+ and K+ than a soil with a low CEC (Ross & Ketterings, 1995). The soil with a high CEC can retain more number of cations owing to the large number of exchange sites available on the clay mineral surface. The strength of cation retention by soil particles increases with increasing ion charge and decreasing hydrated ion radius (Penn & Camberato, 2019).

However, a soil with a higher CEC may not necessarily be more fertile because a soil's CEC can also be occupied by acid cations such as hydrogen (H+) and aluminum (Al3+). However, when combined with other measures of soil fertility, CEC is a good indicator of soil quality and productivity (Penn & Camberato, 2019a).

The cation exchange capacity (CEC) of soils depends on the amount and composition not only of clay minerals but also of soil organic matter (Kaiser et al., 2008). Soil OM will develop a greater CEC at near-neutral pH than under acidic conditions (pH-dependent CEC). Thus, addition of an organic material will likely increase a soil's CEC over time. On the other hand, a soil’s CEC can decrease with time as well, through e.g. natural or fertilizer-induced acidification and/or OM decomposition (Ross & Ketterings, 1995).

Soil CEC is normally expressed in one of two numerically equivalent sets of units: meq/100g (milliequivalents of charge per 100g of dry soil) or cmolc/kg (Miller et al., 1994) (Kim, 2005). CEC in soils under un-conserved farm plots is significantly lower at ($p < 0.05$) compared with all of the other SWC treatments. The higher CEC in soils under conservation treatments could be attributed to clay soil texture and reasonably moderate amount of SOM that ties up exchangeable bases due to the greater amount of negative charge available in the soil surfaces.

4.2.3 Available Phosphorous

Phosphorus is one of the essential elements required by the plant next to nitrogen to complete its life cycle than other essential elements (Khan et al., 2009). While most soils have adequate phosphorus (P), the amount of available phosphorus is low as mineralization of this nutrient is slow. Phosphorus moves very little in the soil and does not leach even with large amounts of precipitation (Miller et al., 1994).

Table 3 Soil Chemical Properties

Variables	upper Drainage	Lower Drainage	Upper Fanyajuu	Lower Fanyajuu	Homegarden Agroforestry	Un-conserved
SOC %	1.25 ± 0.02 a	1.25 ±0.02 a	1.22 ± 0.01 a	1.22 ± 0.03 a	1.3 ± 0.02 a	1.22±0.01b
SOM %	2.1 ± 0.02 a	2.2 ±0.0 3 a	2.1 ± 0.02 a	2.1 ± 0.05 a	2.1 ± 0.03 a	2.0±0.03 b
CEC (cmol kg^{-1})	52.0 ±0.57 a	50 ±1.10 ab	50 ± 2.3 ab	51.0 ± 2.1 b	52.6 ± 1.7 a	43.3±5.6 b
av.P (mgkg^{-1})	17.7 ± 1 b	18.5 ±1.80 b	19.3 ± 1.6 b	20.2 ± 3.2 b	27.2 ± 1.1 a	16.3±2.2 b
pH H_2O	6.6±0.14 a	6.3 ±0.13 ab	6.3 ± 0.2 a	6.5 ± 0.3 a	5.7 ± 0.1 b	6.5±0.4 a

Means within rows followed by the same letters are not significantly different from each other at $p \leq 0.05$, n=3.

Where:

SOC = Soil Organic Carbon, SOM = Soil Organic Matter, CEC = Cation Exchange Capacity,
av.P = Available Phosphorous, cmol kg=$^{-}$centimoles of charge per kilogram of dry soil).
mgkg^{1} = milligram per kilogram

Available phosphorous (av.P) is associated with the amount of organic matter found in soil (Brady, 1990).Hence, soil organic matter management may ameliorate soil pH and improves the availability of phosphorus. Healthy levels of P in soil ranges from 25 to 50 ppm. Optimum soil pH between 6 and 7 will result in maximum phosphorus availability. At low pH (acidic soils), soils have greater amounts of aluminum and iron, which form very strong bonds with phosphate making it unavailable to plants (Penn & Camberato, 2019b).

The finding of this study shows that av. P (22.7 mgkg^{-1}) in soils under homegarden agroforestry plots is significantly higher than any of the SWC treatments and is within the levels of healthy range. Under such circumstances, homegarden agroforestry plots requires slight maintenance through slight phosphorous fertilizer application annually. Nevertheless, the av.P of soils under physical SWC treatment plots falls below the healthy range and demands careful application of phosphorous fertilizer for the healthy completion of the crops life cycle.

4.3. Effects of SWC treatments on Soil Carbon Sequestration

4.3.1. Soil Organic Carbon

Carbon sequestration is the process of capturing and long-term storage of atmospheric carbon dioxide to mitigate global warming and to avoid dangerous impacts of climate change. Soil organic carbon (SOC) is a natural energy storage, derived from soil organic matter and is considered as a highly valued earth's biopolymer (Hazlegreaves, 2021). It is one part in the much larger global carbon cycle that involves the cycling of carbon through the soil, vegetation, ocean and the atmosphere (Horwath, 2007).

The SOC pool stores an estimated 1500 PgC in the first meter of soil depth, which is more than that contained in the atmosphere (roughly 800 PgC) and terrestrial vegetation (500 PgC) combined (Shapkota & Kafle, 2021). Sequestering soil carbon provides other important benefits for soil, crop and environment quality, prevention of erosion and desertification and for the enhancement of bio-diversity (Sanz et al., 2017).

Soil carbon sequestration is accomplished through soil conservation practices that enhance the storage of carbon such as restoring and establishing new forests, wetlands, and grasslands or reducing CO^2 emissions through minimum agricultural tillage.

The evaluated SWC practices for carbon sequestration under this study depicts that the soil under non conserved farm plots accrue the significantly lowest at ($p < 0.05$) carbon concentration (Table 3).Nonetheless ,no significant difference is recorded among the rest of SWC treatments tested.

The soil organic carbon concentration ranges between 1.1 and 1.3 % which is in the order of home garden agroforestry (1.3%), upper and lower drainage ditch (1.25%) and upper and lower fanyajuu (1.22 %).

4.3.2. Soil Organic Matter

Soil organic matter refers to all organic materials found in soil excluding non-decayed plant and animal tissues, their partial decomposition products, and the living soil biomass (Baldock & Nelson, 2000).SOM provides numerous benefits to the physical and chemical properties of soil and its capacity to provide regulatory ecosystem services (Dungait et al., 2012). SOM is especially critical for soil functions and quality (Jangir et al., 2019). The benefits of SOM are derived from a number of complex, interactive, edaphic factors.

A non-exhaustive list of these benefits to soil function includes improvement of soil structure, aggregation, water retention, soil biodiversity, absorption and retention of pollutants, buffering capacity, and the cycling and storage of plant nutrients. SOM increases soil fertility by providing cation exchange sites and being a reserve of plant nutrients, especially nitrogen , phosphorus, and sulfur, along with micronutrients, which the mineralization of SOM slowly releases (Pan GenXing et al., 2015).

SOM also acts as a major sink and source of soil carbon . SOM ordinarily is estimated to contain 58% C, and "soil organic carbon" is often used as a synonym for SOM, with measured SOC content often serving as a proxy for SOM (Naresh et al., 2020). The concentration of SOM in soils generally ranges from 1% to 6% of the total mass of topsoil. Soils whose upper horizons consist of less than 1% of organic matter are mostly limited to deserts, while the SOM content of soils in low lying, wet areas can be as great as 90%. Soils containing 12% to 18% SOC are generally classified as organic soils (Armentano & Menges, 1986).

Nevertheless, 2% SOC (equivalent to ca. 3.4% SOM[1]) is often taken as a threshold below which the soil becomes physically unstable, more susceptible to cultivation damage (Pretty, 1998). Crop yields might suffer due to reduction in the soil's capacity to cycle nutrients. This will, in turn, lead to reduction in the return of SOM to the soil via crop residues and the cycle of deterioration will intensify (Musinguzi et al., 2013;Lal et al., 2015)

Similar to SOC concentration, the organic matter in soils under non conserved plots (2.0%) is significantly lower ($p<0.05$) than the rest of SWC treatments. Meanwhile, no significant difference is recorded among the rest of SWC practices. The mean value of SOM is 2% for all SWC treatments including the non-conserved plots (Table3).

4.2.3. Soil Organic Carbon Stock

The absolute quantity of carbon held in a habitat pool at any specified time is the carbon stock or store (Ford & Keeton, 2017). Soil carbon stocks express a balance between organic inputs and their stepwise decomposition by soil biota (Yigini & Panagos, 2016). The stock (t C ha^{-1}) can be estimated as the sum over annual inputs (t C ha^{-1} $year^{-1}$) multiplied with mean residence time (year) similar to tree cover transition (Ciais et al., 2011).

Carbon stock acts as an excellent soil inoculant, feeds and expands the volume and diversity of beneficial soil micro-organisms as a catalyst to improve plant availability of both soil borne and applied nutrients. Organic carbon is driven from organic matter which includes decaying plant matter, soil organisms and microbes, and carbon compounds such as sugars, starches, proteins, carbohydrates, lignins, waxes, resins and organic acids (Naresh et al., 2020). Inorganic carbon is mineral-based with the most common form being calcium carbonate (Evans et al., 2020). Carbon stock is used to estimate CO_2 emissions and removals based on its dynamic changes in the ecosystem predominantly through CO_2 exchanges between the land surface and the atmosphere (Hayes et al., 2012).

The depletion of SOC stock is attributed to numerous factors including: decrease in the amount of biomass returned to the soil, change in soil moisture and temperature regimes (which accentuate the rate of decomposition of organic matter), and high decomposability of crop residues due to differences in C: N ratio and lignin (Lal, 2018). Abiotic soil C sequestration depends on clay content, mineralogy, structural stability, landscape position, soil moisture and temperature regimes. Biotic soil C sequestration on the other hand depends on management practice, climate and activities of soil organisms. Management practices such as SWC improves, soil organic carbon stock microbial activity compared with non SWC treated sites (Ghosh et al., 2021).

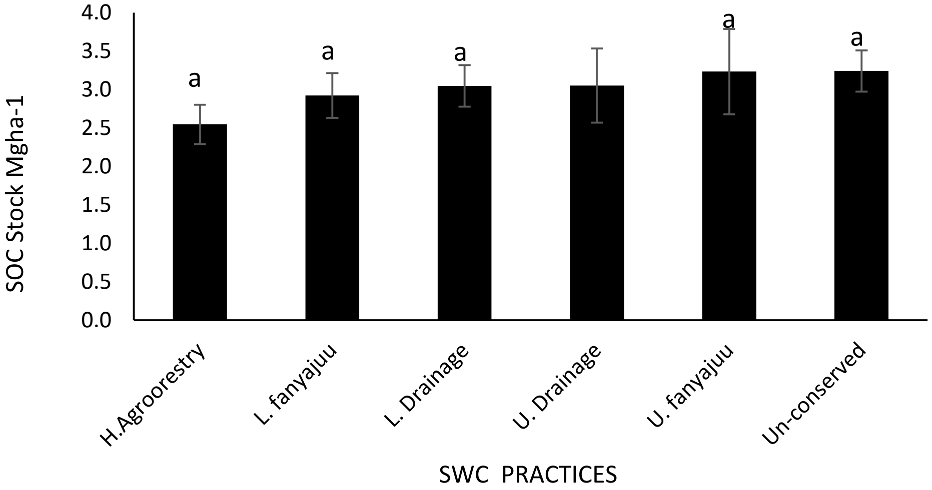


Fig.3: Effects of SWC and home garden agroforestry practices on Soil organic carbon stock in Dongora Elelcho and Dongora Morocho Kebele, Aleta Chuko Woreda

The finding of this study showed that soil organic carbon stock showed non-significant difference at $p<0.05$ in soils between SWC treatments including the non- conserved control plots. The soil organic carbon stock ranged between 2.5 Mgha^{-1} to 3.2 Mgha^{-1} (Fig.3).

4.3.4. Correlation between soil physico-chemical properties

Correlation is defined as a relationship existing between phenomena or things or between mathematical or statistical variables which tend to vary, be associated, or occur together in a way not expected by chance alone. Negative (-) and Positive (+) signs represent negative and positive correlation respectively.

A correlation matrix is a useful tool for figuring out how different variables are related to each other. By looking at the correlation coefficients between two variables, we can learn how they are related and how changes in one variable may affect the other variables.

Table 4: Correlation matrix between soil physico-chemical properties

	CEC *cmol kg^{-1}*	*av.P* *mg kg-1*	*OC* *%*	*OM* *%*	*pH-* *H$_2$O*	*BD* *gcm^{-1}*	*MC* *%*	*Sand* *%*	*Clay* *%*	*Silt* *%*
CEC	1									
av.P	-0.013	1								
OC	-0.079	-0.467	1							
OM	-0.079	-0.467		1						
pH	-0.072	-0.606	0.415	0.415	1					
BD	0.101	0.412	-0.384	-0.384	-0.752	1				
MC	-0.153	-0.076	-0.106	-0.106	0.578	-0.378	1			
Sand	-0.234	-0.328	0.577	0.577	0.479	-0.544	0.1041	1		
Clay	-0.183	-0.297	0.362	0.362	0.110	-0.050	0.042	-0.2432	1	
Silt	0.169	0.417	-0.634	-0.634	-0.379	0.329	-0.180	-0.139	-0.745	1

Where:

The color which approaches to white (zero) represents no correlation

Slightly red color represents low negative correlation

Red color represents medium negative correlation

Slightly green color represents low positive correlation

Green color represents medium positive correlation

Deep green in color represents perfect (strong) correlation

It is used to denote any two or more variables that move in the same direction together, so when one increases, so does the other. The existence of a correlation does not necessarily indicate a causal relationship between variables.

Correlation matrix is important for finding patterns and relationships between variables. It can also be used to make predictions and decisions based on data.

Low correlation coefficients show that the two variables don't have a strong relationship with each other. For example in Table 4 silt shows a medium negative correlation with clay (r = -0.745) and OM (r =-0.634).

4.4. Effects of SWC treatments on maize grain and Biomass Yield.

Soil erosion by water is one of the main causes of land degradation and reduced agricultural productivity in upland areas of Ethiopia. To reverse this problem, various indigenous and recently introduced cross slope barrier soil and water conservation (CSB-SWC) techniques such as *Fanya juu*[1], drainage ditch, vegetative barriers, soil bunds, stone bunds, bench terraces, and tied-ridges etc., have been implemented. Under this study CSB-SWC practice namely *Fanya juu*, drainage ditch, and homegarden agroforestry were evaluated for their effect on crop and biomass yield.

Table:7 Effects of SWC practices on maize grain yield and total biomass

SWC	Grain Yield (Kg/plot)	Grain Yield (tone/ha)	Biomass yield (Kg/plot)	ton/ha
Lower Fanyajuu	1.72 a	4.31	4.39 a	10.90
Upper Fanyajuu	1.70 b	4.20	3.80 b	9.50
Upper Drainage	1.60 c	4.00	3.71 bc	9.30
lower Drainage	1.59 c	3.89	3.72 bc	9.28
Home garden	1.55 d	3.90	3.30 c	8.25
Un-conserved	0.98 e	2.47	2.05 d	5.94

Where: SWC-soil and water conservation

The finding of the study depicted in Table 7 shows that there is strong statistical evidence to claim that CSB-SWC practices positively influenced maize grain and biomass yield compared with the non-conserved mono-cropped field plots. Both grain and stover biomass yield of maize under fanyajuu is significantly higher at ($p < 0.05$) than the rest of conservation practices. The expected lower maize grain and stover biomass yield under homegarden agroforestry practices is attributed to the competition for soil and light resources posed by the associated woody and other components of the system. Given the multiple output fetched from homegarden agroforestry, the overall benefit of the system for sure out ways the obtained yield mono-cropped SWC treated field. The ranking of grain and stover biomass yield of maize under all treatments is in the order of Fanyajuu >Drainage ditch >Homegarden agroforestry >Un-conserved field plots.

The results obtained corroborates with (Alemayehu (2006) ; Abay , (2011) ; Ferede (2018) who found substantial grain yield increment on lands with SWC measures compared to non-conserved land. Similarly, (Eshetu Tadele, Gemechu, Desalegn and Alemayhu 2016) documented up to 87% maize grain yield advantage by using fanyajuu than without treatment. Construction of SWC activities result in a successive increase in grain yield of maize compared to non-conserved plot.

4.5. Farmer's Perception on Causes, Indicators and Effects of Soil Erosion and Water Logging Problems

In this study, farmer's perception is measured through evaluating their understanding about the causes and effects of soil erosion, and water logging problems, soil erosion and water logging indicators, and application of SWC and their effectiveness on improving soil productivity.

4.5.1. Farmers Awareness on Causes of Soil Erosion and Water Logging Problems

Vegetation clearance and land fragmentation is major cause of soil erosion and water logging problem in Aleta Chuko Woreda. Soil erosion and water logging leads to the loss of farm lands productivity. The reduced production capacity of farm lands affect the livelihood of the farming community and directly hamper the climate change mitigation effort.

Land fragmentation caused by population growth contributes to the reduction of the size of farm lands in Dongora Morocho and Elelcho Kebeles of Aleta Chuko Woreda. This study finding reveals that the size of farm lands for households in the area ranges from 0.25 to 3.25 ha (Fig 6).

About 134 (68.7%) of the total respondents reportedly hold an average farm land size below 1 hectare and only 49 (25.1%) of the sampled HHs showed an average land size between 1.01-2 hectares. Thus, the unabated population growth and the continued land fragmentation, reduced food production and threatens the livelihood of farmers in the studied area.

The reduced food production coupled with poor land management warrants that the potential of conversion of forested lands and sloping terrain to open up arable land is inevitable in Aleta Chuko Woreda. Conversion of forested areas into crop fields, poor SWC practice and land fragmentation further aggravates soil degradation.

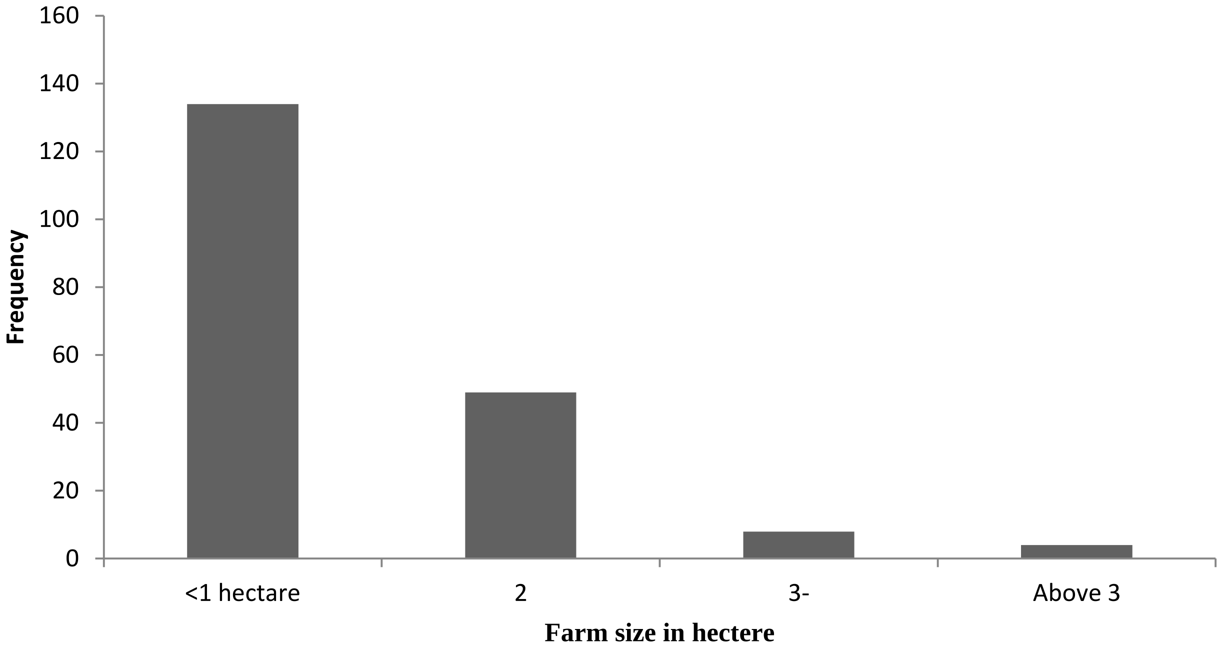


Figure 6: Proportion of respondents based on farm size (N=195)

4.5.2. Farmers Awareness on Soil Erosion and Water Logging Problem

Understanding farmers‟ perception on soil erosion indicators and its impact is important to promote SWC practice (Chizana, et al, 2006). Soil erosion is a crafty and slow process. Therefore farmers need to perceive its severity and the associated yield loss before they can consider implementing soil and water conservation practices (Kibemo and Detamo, 2011).

In the study area, respondent farmers describe the prevalence of soil erosion problem, on their farms as well as in the surrounding landscapes through various indicators depicted in Table 8. Respondent farmers express soil erosion as a sole reason for declining soil fertility (39%), diminishing yield (23.6%), increasing input and management requirement (14.9), declining soil depth (13.3%). Rill and gully formation were reported as the most commonly noticeable indicators of soil erosion.

Tables 8: Farmers awareness on soil erosion indicators (N=195)

SE indicators	Frequency	Percent
Declining soil fertility	76	39
Declining yield	46	23.6
Rill and gully formation	18	9.2
Increasing input and management requirement	29	14.9
Declining soil depth	26	13.3

Where: SE = Soil Erosion

Cognizant of the soil degradation problem, farmers in the studied areas combat soil erosion and water logging problem through the application of SWC practices namely Fanyajju, drainage ditch and homegarden agroforestry as displayed in Table 9.

Table 9: commonly applied SWC methods to combat soil erosion and water logging problems in Aleta Chuko Woreda (N = 195)

Type of SWC applied by farmers	Frequency	Percent
Fanya juu	26	13.3
Drainage ditch	49	25.1
Home garden	51	26.2
Un-conserved	69	35.4
Total	195	100

The most common physical conservation structures widely used in the area include drainage ditches and Fanya juu 25.1%, 13.3 respectively. 26.2% of the respondents used home garden agroforestry practice and the rest 35.4% of the respondents use neither homegarden agroforestry nor physical SWC structures. In other words, they do not use any soil erosion control mechanisms in their farms.

Primarily, conservation structures were introduced with the objectives of conserving, developing and rehabilitating degraded agricultural lands and as well increasing food security through increased food crop production (Adbacho, 1991).Nevertheless a large portion of farmers (35.4%) do not apply SWC to combat the perceived soil erosion problem (Table 9).

4.5.3. Farmers evaluation on the effectiveness of SWC practices on maize grain and stalk yield

Respondent farmers evaluated and ranked SWC practices as Fanayajju (63 %) > D.ditch (46.2 %) > H. agroforestry (26.2%). While 59.5 %, 47.7% and 33.8 % of respondents rate H. agroforestry, D.ditch and Fanyajuu respectively as moderate (Table 9).

Table 10: Farmers evaluation on the effectiveness of SWC practices against crop yield and soil fertility maintenance

	D. ditch		H. agroforestry		Fanya juu		Un- conserved	
F. Response	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
High	90	46.2	51	26.2	123	63.1	65	33.3
Moderate	93	47.7	116	59.5	66	33.8	57	29.2
Low	12	6.2	28	14.4	6	3.1	73	37.4

Where: D = Drainage, H = Homegarden, F= Farmers

On the other hand, 33.3% and 29.2% of respondents consider the un-conserved farm plots as high and moderate respectively with regard to soil fertility and crop yield. In agreement to the lowest grain and biomass yield (Table 7), the larger percentage of respondent farmers (37.4%) rate the un-conserved farm plots as low in both soil fertility status and crop yield performance (Table 9).

4.6. Conclusion

The range of bulk density obtained in this study shows that soil of all sites in Dongora Elelcho and Dongora Morocho kebeles is compact.

Data regarding particle size distribution revealed that clay is the dominant feature in soils of the studied kebeles and plots under SWC treatments.

Most of the soil pH is neutral with the exception of soil pH under homegarden agroforestry and upper fanyajuu SWC treatments.

CEC in soils under un-conserved farm plots is significantly lower at ($p < 0.05$) compared with all of the other SWC treatments.

The av.P of soils under physical SWC treatment plots falls below the healthy range with the exception of homegarden agroforestry field plots and demands careful application of phosphorous fertilizer for the healthy completion of the crops life cycle.

The evaluated SWC practices for carbon sequestration under this study depicts that the soil under non conserved farm plots accrue the significantly lowest at ($p < 0.05$) carbon concentration. Nonetheless, no significant difference is recorded among the rest of SWC treatments tested.

The grain and stover biomass yield of maize under all treatments is in the order of Fanyajuu > Drainage ditch > Homegarden agroforestry > Un-conserved field plots.

The evidence recorded under this study attests that the majority of farmers fairly understand about the benefits of soil and water conservation practices.

Respondent farmers express soil erosion as a sole reason for declining soil fertility (39%), diminishing yield (23.6%), increasing input and management requirement (14.9), declining soil depth (13.3%). Rill and gully formation were reported as the most commonly noticeable indicators of soil erosion.

Cognizant of the soil degradation problem, farmers in the studied areas combat soil erosion and water logging problem through the application of SWC practices namely Fanyajju, drainage ditch and homegarden agroforestry. Nevertheless a large portion of farmers (35.4%) do not apply SWC to combat the perceived soil erosion problem.

4.7. Recommendation

The problem envisaged regarding to the small sized land holding necessitate agricultural intensification through protecting soil erosion and applying agricultural technologies suitable for small sized land holders.

Extension workers should pay due attention to convince and persuade those farmers who do not show effort to combat soil erosion.

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6. Appendix

Questioners prepared to sample households with the objective of assessing and evaluating SWC practices in crop fields of Dongora Morocho and Dongora Elelcho Kebeles in Aleta Chuko Woreda, Sidama Regional State, Ethiopia.

1) Name/ID of HH head_____________

2) Sex of the household head:

   A. Male
   B. Female

3) Farm size (ha):

   A. < 1
   B. = 2
   C. ≤ 3
   D. > 3

4) What type of SWC practice?

   A. Drainage
   B. Fanyajuu
   C. No SWC

5. What are the benefits of Drainage Ditch on soil improvement and crop yield improvement? And how much its benefit on soil and crop yield?

   A. Highly Soil fertility improves
   B. Moderately Soil fertility improves
   C. Lowly Soil fertility improves
   D. Higher soil erosion
   E Higher crop yield improves
   F. Moderately crop improves
   G. Lowly crop yield improves

4. What are the benefits of fanyajuu on soil and crop yield and how much its benefit on both?

A. Highly Soil fertility improves
B. Moderately Soil fertility improves
C. Lowly Soil fertility improves
D. Higher soil erosion
E. Highly crop yield improves
F. Moderately crop yield improves
G. Lowly crop yield improves

5. Is there any benefits on Un-conserved area on soil and crop yield? And how much its benefit on both?

A. Highly Soil fertility improves
B. Moderately Soil fertility improves
C. Lowly Soil fertility improves
D. Higher soil erosion
E. Highly crop yield improves
F. Moderately crop yield improves
G. Lowly crop yield improves

6. What Indicators of soil erosion on your farm?

A. Declining soil fertility
B. Declining crop yield
C. Rill and gully formation
D. Increasing input requirement
E declining soil depth

7. What causes of soil erosion on your farm?

A lack of labor
B. deforestation
C. lack of capital
D. Weak SWC practice