ADDIS ABABAUNIVERSITY

SCHOOLOFGRADUATESTUDIES

COLLEGE OF SOCIAL SCIENCES

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DEPARTMENTOFGEOGRAPHY ANDENVIRONMENTALSTUDIES

CONTRIBUTION OF SUSTAINABLE LAND MANAGEMENT PRACTICES TOSOILORGANICCARBONSEQUESTRATIONINYESIRWATERSHED, BURE ZURIA WOREDA, ETHIOPIA

.

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JUNE,2023

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A THESIS SUBMITTED TO THE COLLEGE OF SOCIAL SCIENCES, ADDIS ABABA UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREEOFMASTEROFARTSINGEOGRAPHYANDENVIRONMENTALSTUDIES SPECIALIZATION:CLIMATE CHANGE AND ADAPTATION

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This is to certify that the thesis prepared by GirmaKibret, entitled: contribution of sustainable land management practices to soil organic carbon sequestration in yesir watershed, bure zuria woreda, Ethiopia, submitted in partial fulfillment of the requirements for the Degree of Master of Art in Geography and Environmental Studies, specialization: Climate change and adaptation complies with the regulations of the university and meets the accepted standards with respect to originality and quality.

Signedbytheexaminingcommittee:

Signedbytheexamining committee:

Advisor ________________________Signature ________________Date ____________

Internal Examiner ________________Signature________________Date ____________

External Examiner _______________Signature________________Date ____________

Chair Person ______________________Signature ______________Date____________

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Aabstract

The sustainable land management program (SLMP) of Ethiopia aims to improve livelihoods and create resilient communities and landscape to climate change. Soil organic carbon (SOC) sequestration is one of the key co-benefits of the SLMP. Thus, understanding a change in different land management measures and improved agronomic practices with its relation in Carbon stock change is crucial to understand the potential of different SLM practice i.e., soil bund, pastureland management, afforestation/reforestation, and area closures will create resilient landscape to climate change.The objective of the study was to assess the impact ofSLM practice on SOC in Yesir watershed, Bure zuria District, NW Ethiopia. A total of 98 soil sampleswerecollectedin2010andthesamenumberofsamplescollectedfromthesamelocation in 2018. The study followed both qualitative and quantitative method of analysis to assess the SOC change between the two years. The study conducted on three land use types, i.e., Cultivated land, Grassland and Shrub-land. In addition, two Agro-ecological zones, i.e., Highland (above 2300m asl and Mid-highland (between 1500-2300m) were considered in the study area. The resulthighlighted thatwhenmeasuringthe spatialSOCstbetweenthetwo AEZ in thestudyarea, more SOC quantity was observed in the Highland as compared to the Mid-highland up to 0- 20cm depth. The differences were not statistically significant, however, as demonstrated by the test of 95% of confidence interval of one way ANOV that did not provide significant differences between the two AEZs. The observed higher SOC values in the highland than in the mid altitude might be due to two factors: i)SOC density may increase in the highlands with increased precipitationasincreasedrainfallenhancesabovegroundbiomassproductionandii)decreases with temperature along increases in altitude lead to occurrence of cold soil temperature which may reduce soil carbon losses via microbial decomposition of soil organic matter. Furthermore, statistical evidence for the paired observations between the baseline and post SLM in the farmland and Grassland highlighted that there was no significant difference observed from zero. This might be due to the fact that the specific SLM technologies ("bunds with vegetations") implemented in the agricultural land were not supported by interventions that supplies different carbon input to the soil (crop residue input and other soil management practices). Under agricultural land, factorsuch as the quantityandqualityof organic matter input, decomposition rate, and land management practices would largely determine its C sequestration potential (Bayer et al., 2006; Cochran et al., 2010). On the other hand, the study showed that, there was significant differences in the shrub-land between the two years in SOC (P<0.005) upto 20cm depth. Similarly, statistically significant variation (P < 0.05) of SOC was observed between the two years at watershed level. The observed differences could be attributed to different factors i.e., the combination of physical and biological interventions (terraces + vegetations + area enclosure) that resulted in the highest SOC. ***The study identified that implementation of SLM interventions can bring significant difference in terms of change in soil Organic carbon. To increase SOC stock in the agricultural land, two possible measures can be suggested, these areintegrationofreducedtillage,Soilfertilitymanagementcombinedwith bio-physicalinterventionsthatincreasecarboninputintothesoil.secondly,increasequality of Soil and water conservation structures and regular maintenance in the farmland.*

Keywords:Watershed,Soilorganiccarbonstock, Soilorganiccarbonstock change

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Acronyms

ADLI	AgriculturalDevelopmentLedIndustrialization
AEZs	AgroEcologicalZones
ARD	AgriculturalResearchandDevelopment
BD	BulkDensity
BDAO	BureDistrictAgricultureoffice
BDARDO	BureDistrictAgriculturalandRuralDevelopment Office
BDOOLEP	BureDistrictOffice ofLandandEnvironmental Protection
CEC	CationExchangeCapacity
CO2	CarbondiOxide
CRGE	ClimateResilientGreenEconomy
CSA	CentralStatistics Agency
DA	DevelopmentAgent
EHRS	EthiopianHighlandsReclamationStudy
FAO	FoodandAgricultural Organization
GDP	GrossDomestic Product
GHG	GreenhouseGas
LULC	LandUse/LandCover
MoA	Ministryof Agriculture
SLMP	SustainableLandManagementProgram
SOM	SoilOrganicMatter
SOC	SoilOrganicCarbon
SOCS	SoilOrganicCarbon Stock
SSA	Sub-SaharaAfrican
UNDP	UnitedNationsDevelopmentProgram
UNESCO	UnitedNationsEducational,ScientificandCulturalOrganization
USDA	UnitedStatesDepartmentofAgriculture
WB	WorldBank
WRDA	WaterResourceDevelopment Authority

CHAPTER ONE

1. INTRODUCTION

1.1 BackgroundandJustification

Agricultural activities are responsible for about one third of the world‟s GHG emissions and this share is projected to grow, especially in developing countries (IPCC, 2007). Smallholder agricultural systems are highly dynamic and heterogeneous environments that may have significantly contributed to greenhouse gas (GHG) emissions over the past number of decades. Furthermore, these systems traditionally suffer from severe soil organic matter depletion due to intense decomposition following soil ploughing, the removal of most crop residue duringharvest, coupled by enhanced soil erosion inherent to these activities (G.Saiz and A. Albrecht, 2016). Yet, they may also offer large mitigation potential through the implementation of good management and sustainable agricultural practices, particularly through land management (Lipper et al, 2011).

Ethiopia has over thirty million hectares of cultivable land and over eleven million ha of cultivated land (Ethiopia CRGE doc, 2011). The agricultural sector contributes about 46.3% of the country„s GDP, employs 83% of total labor force and contributes 90% of exports (EEA, 2012). Historical practices, rapid expansion, and inappropriate agricultural techniques have resulted in poor soil quality. Soil management is therefore a fundamental component of the country‟‟s agricultural initiative to control and manage carbon emission as the country grows. (Ethiopia CRGE doc, 2011).

Agricultural sector in Ethiopia plays a pivotal role to induce the industrialization process in the country. Therefore, enhancing the productivity of this sector is crucial not only for the development of the sector itself but also for the development of other sectors of the country„s economy. Agricultural production relies directly on soil, water, and a variety of biological processes. While it relies on climate conditions, its role in the global carbon cycle makes it a major contributing factor to climate change. Today, more than ever before, it is understood not only the significance that climate has for agriculture, but also the eno rmous significance that agriculturehasfortheclimate(WB,2012).Furthermore,Ethiopiafacesawidesetofsoilfertility lossissues.Theproblemismoreseriousinthehighlandswheremostofthehumanandlivestock population is found (Assefa et al., 2005). The agricultural sector in the country is characterized by small-scale and subsistence-oriented farming system due to an adverse combination of land resource degradation, climatic variability, and demographic, economic and institutional constraints and shocks. (Negra C et all., 2014).

Ethiopiaisinvestinga hugeresourcetotacklelanddegradationthroughlandrestorationunderits various initiatives such as Food for work, Managing Environmental Resources to Enable Transitions (MERET), and the sustainable land management program (SLMP). In the lastdecade, Ethiopia has invested more than US$1.2 billion annually in restoring landscapes in its major regions (Adimassu et al., 2018). Some of the Sustainable Land Management (SLM) practices implemented include physical measures (soil/stone terraces, trenches, micro basins, percolation bonds, and gully treatments); biological measures (area closure, tree/forage planting on terraces, bamboos); or a combination of the two. The full list of SLM practices implemented in Ethiopia are detailed in Nedessa et al. (2015). SLM interventions have been implemented across the country to achieve multiple aims such as (i) reducing soil erosion and surface water sediment loads (Tamene and Vlek, 2007), (ii) reducing surface water runoff and enhancing groundwater recharge (Woldearegay et al., 2018), and (iii) promoting revegetation and soil fertility, thereby increase agricultural productivity (Abera et al., 2020). In addition to improving livelihoods, the land restoration efforts also support the government of Ethiopia to achieve its regional and international commitments such as the “4 per 1000” initiative and the Land Degradation Neutrality programme (Chabbi et al., 2017). It is also expected to contribute to the achievementofboth thenationalREDD+programmeandthe ClimateResilientGreenEconomy (CRGE) strategy.

Land management practices implemented in many parts of Ethiopia showed positive impacts on restoring degraded landscapes and enhanced soil fertilities (Abdalla et al., 2018). Abera et al. (2020) conducted a meta-analysis to summarize how different land restoration practices and interventions affect ecosystem services. Other studies also investigated the effect of land restoration on various ecosystem and livelihood benefits in Ethiopia (Balehegn et al., 2019; Adimassu et al., 2018; Araya et al., 2011). Despite these efforts, there is however a knowledge gap about the impacts of land management practices on sequestration of soil organic carbon (SOC;seee.g.,Namirembeetal.,2020).SOCplaysakeyroleinvariousagriculturaland ecological processes related to soil fertility (Abdalla et al., 2018), carbon cycle and soil-atmosphere interactions including CO2 sequestration (Ramesh et al., 2019; Xu et al., 2019; Murty et al., 2002). As SOC is the largest pool of carbon in the terrestrial ecosystems (Schlesinger and Bernhardt, 2013), any effort to sequester SOC is a key mechanism to reduce CO2 in the atmosphere due to humans and contribute to mitigate climate change (Paustian et al., 2016; Smith et al., 2016; Zomer et al., 2017). Thus, our knowledge about the relationship between land management practices and SOC will be crucial to facilitate informed decision making and also contributes to the global and regional knowledge pool.

The scientific community has spent considerable efforts in mapping SOC, modelling its spatiotemporal variation and confirming its primary role in shaping ecosystems functioning (Grinand et al., 2017; Ajami et al., 2016; Ratnayake et al., 2014). Accurate estimation of SOC and its dynamics are necessary to support improved carbon management and climate change mitigation, and to identify land management practices with higher SOC sequestration benefits. Good understanding of the spatiotemporal dynamics of SOC in relation to land management practices can also enable us to understand what options placed where can sequester the most carbon, making our interventions more effective and efficient. This can ultimately enable governments to achievetheir NationallyDetermined Contributions (NDCs) within their planning horizons. In CRGE, the contribution of soil as potential for carbon sequestration through land restoration and climate smart agriculture practices is stated.

At a local scale, SOC concentrations are largely governed by soil physical and chemical properties, which determine the SOC stabilization (Cotrufo et al., 2019), environmental conditions and land use changes (Martin et al., 2010; Fantappi`e et al., 2010; Abegaz et al., 2016), intensive agricultural practices (Yan et al., 2012), and shifts in soil management practices (Powlson et al., 2011; West and Post et al., 2002). Conservation tillage practices such as reduced tillage and no-tillage have been proposed, as an alternative to conventional tillage, for their advantages in preserving SOC (Beare et al., 1994; Liu et al., 2014) and improve soil physicochemical properties (Blanco-Canqui and Ruis, 2018; Johnson and Hoyt, 1999).

Therefore, understanding the change in land management and its relationship with Carbon stock dynamics is essential to identifying appropriate measures to tackle associated problems. Therefore,thisstudy aimedtodeterminethechangesinSOCstocksduetoSLMinterventionsin smallholder agricultural system in Yesir watershed, Bure Zuria district, NW Ethiopia. The findings of this study will provide lines of evidences to accurately quantify and monitor SOCstocks and stockchanges existed in complex and multiple land use system occurring at various management intensities.

1.2 Statement oftheproblem

Ethiopia is an ecologically diverse country with an agricultural sector which contributes the major share of Gross National Product and practically almost all export earnings. About four fifthsofthepopulationdependsuponagriculturefortheirlivelihood(FAO,2014).Thequalityof the soil determines the potential of agricultural development and then the capacity of smallholders to attain food security and improve their livelihoods (FAO, 2014).

Soil fertility depletion in smallholder farms is the fundamental biophysical root cause for declining per capita food production in Sub-Saharan Africa (Sanchez etal., 1997). Agriculture in Ethiopia also has many constraints which impede improvements in production and productivity. Among which Land degradation is a major constraining factor not only as an impediment to accelerated and sustainable socio-economic development, but also as a serious obstacle to the wellbeing of its people.

The traditional farming practice that has been carried out for centuries, absence of appropriate soil and water conservation measures, improper land use systems and continuous clearing of forests for cultivation purposes have worsened the situation of soil degradation (Oldman et al., 1993). These have resulted in accelerated soil erosion and depletion of essential soil nutrients for plant, especially in the areas of the highlands and around mountains slopes (Hurni et al., 1993; Gete et al., 2003). This problem may be alleviated through the prevention of further degradation of natural resources, rehabilitation of the degraded lands and preparation of a rational land use planning for agriculture (Betru et al., 2003; Sahlemedhin et al., 1999).

The different land use and land management systems could also significantly contribute to the variation in soil physicochemical properties. Physical and chemical characteristics of the soils on land under continuous cultivation could vary from the land that remains uncultivated for a long period of time (Gebreyohannes et al., 2001; Wakene et al., 2001). Maddonni*et al*., (1999) reported thatlandusesystemaffectsbasicprocessessuchas erosion,soil structureandaggregate stability, nutrient cycling, leaching, carbon sequestration and other physical and biochemical processes.

Soil organic carbon is a result of biogeochemical processes occurring at or near the soil surface, and function as energyflow, mineral cycling and water cycling. It also enhances the processes of absorbing and slowing down water, supporting enormous microbial diversity, retaining minerals for plant use, and improving soil quality.Soil organic matter is one form of the surplus thermodynamic work of the biosphere, the excess of photosynthesis over respiration. Because soils hold more carbon than the atmosphere and vegetation combined, and can hold it longer, people are increasingly looking to soil carbon as an opportunity to both mitigate and adapt to climate change, along with its twin issue, ecosystem function. (Donovan, et al., 2012).

The current ability to quantify GHG emissions and mitigation from agriculture in tropical developing countries is remarkably limited (Rosenstock et al., 2013). Empirical measurement tools and field and laboratory facilities are expensive and inadequately available. Emissions can be estimated for large areas with a combination offield measurement, modeling and remote sensing, but even simple data about the extent of activities is often not available and models require calibration and validation (Olander et. al., 2014).

Multiple factors complicate measurement of agricultural GHG sources and sinks in developing countries and necessitate approaches specific to the conditions common in these countries, including heterogeneity of the landscape, the need for low-cost methods, and the need for improving farmers' livelihood and food security. Heterogeneous landscapes in developed countries are dominated by industrial agriculture, usually monocultures with commonly defined practices. The combination of high research intensity and large-scale agriculture in developed countries creates a homogenous, relatively data-rich environment where point measurements of key sources can be extrapolated with acceptable levels of uncertainty to larger areas using empirical and process-based models (Del Grosso et al., 2008; Millar et al., 2010). In contrast, many farmers (particularly smallholders) in tropical developing countries operate diversified farmswithmultiplecropsandlivestock,withfewersizesoftenlessthan2hectares.

Moreover, when measuring change in soil carbon, the sample or data point is thechangeordifferenceinthecarboncontentatasingleplotoveratimespan.Someofthe statistical discussions in the current literature about measuring soil carbon can be confusing becausetheyareorientedaroundmeasuringcarbonatonepointintime(Donovanet al., 2013).

MostoftheresearchworkaboutQuantificationandassessmentofSOCtillnowhasbeenonly limitedtodevelopedcountries.Itwasalsoobservedthat,hardlyanyextensivestudyhasbeen carried out in Ethiopia to examine about soil organic carbon stock and stock change measured at two-pointintimeisstillinadequateinthecaseofEthiopia. Further,theexistingstudieshave focusedtheirattentionpredominantlyonthemeasurementoftheamountofSOCchange at watershed level and measurement of the level of SOC change at different land usesystem.

Therefore, the study is designed to characterize the soil physical and chemical properties and classify the soils of the study areas using well quantified chemical and physical properties andals to quantify the Soil Organic Carbon (SOC) changes across smallholder agricultural lands measured at two-point time.

1.3 Objective of the study

The main objective of the research aims to evaluate the contribution of Sustainable land management practices on soil organic carbon (SOC) stock change in Yesir watershed, Bure-zuria district. The specific objective includes

- To quantify before (2010) and post SLM (2018) Soil organic Carbon stocks agro-ecologically by land-uses,
- To evaluate the impact of Sustainable Land Management practices on Soil Organic Carbon (SOC) stock change in the study area

1.4 Researchquestions

Therefore, in order to achieve the above objectives, the study attempts to answer the following research questions:

- Are the Land use and land management of the study area variable by AEZ and/or altitudinal differences?
- ArethereanysignificantSOCstocksdifferencebetween land usetypes acrossAEZ?

- HowtheSOCstockischangedbetweenlandusesaftertheimplementationofvarious land management activities in the study area?
- IstheresignificantdifferenceinSOCstockduetoimplementationofvariouslandmanagement practices against the baseline in the study area?

1.5 Significanceofthe study

Soilorganiccarbon contentiscriticalforimprovingproductivityofagriculture;thuscontributing more for alleviating problems of food security. Soil fertility management is an important issuefor small-scale farmer. Different stakeholders (Government and NGOs) involved in rural development are highly concerned with SLMPs to intervene in improving agricultural productivityand to maintaintheexisting soilfertility. So,itis believedto contributeto achieving food security program.

Therefore, the study could provide lines of evidence to extension agents, researchers, non-governmental organizations and policy makers about the role of sustainable land management activities for improving soil organic matter content and hence enable them to developappropriate technologies and design effective policies and strategies that enhance soil fertilityand productive land use. The research will contribute to inform policy makers and practitionersto obtain site specific Emission Factor for quantifying soil GHG.

Generally, the findings will be helpful especially for Ministry of Agriculture (MoA) and respective agricultural institutions in planning and decision making in the future. It will also serve as a baseline literature for further study of SOC.

1.6 Scopeof thestudy

This studyhasspatial,temporaland analyticalscopes.Spatiallythisstudyislimitedtowatershed level which was undertaken in Yesir watershed, Bure district, North West Ethiopia. The study is longitudinal considering a-two-time soil data collection (i.e., at base year (2010) and post intervention (2018)., Soil samples for SOC and Bulk density were taken for analysis in a laboratory during both time periods.

1.7 Organization ofthe study

This thesis is organized into five chapters. The first chapter encompasses introduction part and consists of background, statement of the problem, objective of the study, significance of the study,scopeandlimitationofthestudy.Thesecondchapterdealswithreviewofliteraturewhich focuses on Soil Morphological and Physical Properties, soil chemical properties, Carbon sequestration in different land uses, SOC stock along the altitudinal gradient and Factors affecting soil organic carbon (SOC) Storage. The third chapter is devoted to brief description of the studyarea and a thorough explanation of the methodologies employed for data collection and analysis. Chapter four deals with the results and discussion and finally chapter five present conclusion and recommendations of the study.

1.8 Limitationofthestudy

The main limitations were the availability of data for biomass as a main carbon stock due to security issue in the study area. The other limitation was the distribution of samples were not equally distributed across the land uses i.e., 77 samples for farmland, 14 samples for Grassland and 7 sample plots for shrub lands, as the samples were laid randomly in a fixed grid across the watershed.

1.9 DefinitionofwatershedandRelatedTerms;

Soil organic carbon: Soil organic carbon (SOC) is the carbon that remains in the soil after partial decomposition of any material produced by living organisms. It constitutes a key element of the global carbon cycle through atmosphere, vegetation, soil, rivers and the ocean. SOC is the maincomponentofsoilorganicmatter(SOM)andassuchconstitutes thefuelofanysoil (Foth& Ellis, 1997).

Soil organic carbon stock: Soil organic carbon (SOC) stock is the carbon held within soil organic constituents (i.e., products produced as dead plants and animals decompose and the soil microbial biomass).

Soil organic carbon stock change: Soil organic carbon (SOC) stock change is the variation in carbon held within soil organic constituents (i.e., products produced as dead plants and animals decompose and the soil microbial biomass).

CHAPTERTWO

2. Review literature

2.1. Factorsdetermining Soilorganicmattervariation

Organic matter (OM) includes all materials of organic origin present in the soil regardless oftheir origin and status of decomposition. It includes fresh and highly decomposed crop residues and animal excretions as well as decomposing bodies of soil flora and fauna. The OM content of the soil is an indication of its fertility because it is the dominant reservoir and source of plant nutrients mainly N, P and S. Generally, soil OM serves as storehouse of plant nutrient elements, holds and conserves soil moisture, binds soil particles together, improves soil aeration, protects nutrients against leaching and provides favorable environment for various microorganisms(Desta et al., 1982; Colman *et al*., 1989). In general, soil OM influences soil physical, chemical and biological properties related to soil quality. It also supplies a large number of micronutrients, which are normally not supplied by inorganic fertilizers. Under similar climatic conditions, the OM content in fine textured soils is two to four times higher than that of coarse textured soils (Prasad and Power, 1997). Most cultivated soils of Ethiopia are poor in their OM content due to low amount of organic materials applied to the soil and complete removal of the biomass from the field (Yihenew et al., 2002). The same author reported that continuous and intensive cultivation practices might be attributed for the deterioration of soil aggregates and low return of plant biomass to the soil system in the cultivated lands.

Biological degradation is frequently resulted in the depletion of vegetation cover and OM in the soil, but also denotes the reduction of beneficial soil organisms that is important indicator of soil fertility (Oldman et al., 1993). The building up of OM level on mountain slopes is attributed to luxurious growth of vegetation favored by rainfall (Sehgal *et al.*, 1985; Singh and Prakash,1985). Soil OM content decreased with a decrease in altitude and down slope position. The cultivated soil on the upper slope exhibited high OM and total N when compared to the less eroded cultivated soil on the foot slope and toe slope areas (Belay et al., 1996). The relatively high OM and total nitrogen (N) contents of the soils probably resulted from frequent fallowing and addition of organic manure (Belay et al., 1996).

2.1.1. Soilorganic matterasaffectedbyLULC

Land use change is the major problem that affects the physicochemical properties of soils in the highlands of Ethiopia (Bahrami et al., 2010; Admasu et al., 2014; Aredehey et al., 2019). Changes in land use types, mainly the conversion of natural forests to agricultural land and settlement, are the most widely practiced activities in northwest Ethiopia (Molla et al., 2010). Continuous use of land for cultivation and grazing purposes results in the loss of soil nutrients, particularlyin the highland areas where erosion is more severe (Molla et al., 2010; Gebreselassie and Ayanna, 2013).

Land-use conversions are practiced by different agents at different scales to satisfy specific needs, which in most cases lead to soil degradation. Since 1850, roughly 35% of anthropogenic CO2 emissions have occurred (Foley et al., 2005), much of which was a direct result of SOC stock losses caused by land-use changes (World Bank, 2012). This loss is a threat to the climate because it increases atmospheric carbon dioxide (CO2) and greenhouse gas (GHG) emission(Lal, 2014). Murty et al. (2002) have reported that, globally, 24% of SOC stock has been lost throughtheconversionofforestlandstocroplands.FAO(2007)hasalsoreportedthatconversion of natural ecosystems to croplands and pasturelands resulted in losses of 20–50% of the soil carbon stocks in a meter of the top soil depth. Various studies have reported the impact of land- use changes on SOC at different areas of the highlands of Ethiopian (Miheretu andYimer, 2018; Guteta andAbegaz, 2017;Abegaz et al., 2016; Emiru and Gebrekidan, 2013; Moges et al., 2013; Tsehaye and Mohammed, 2013; Demelash and Stahr, 2010; Chibsa and Ta, 2009; Yimer et al., 2007; Haileslassie et al., 2005).

Cultivated lands have relatively low SOC compared to other land use types. However, they have goodpotentialtosequestermoreatmosphericCO_2throughimprovedland managementpractices. Under agricultural land, factors such as the quantity and quality of organic matter input, decomposition rate, and land management practices would largely determine its C sequestration potential(Bayeretal.,2006;Cochranetal.,2010). Thisislargelybecauseproper managementof agricultural lands (e.g. application of farmyard manure) would increase C storage (Mosier et al., 2003). Further, plantation of trees along agriculture field boundaries would also enhance C storage under agricultural land (Wani et al., 2012).

Grass lands stores relatively higher SOC compared to Agricultural use types and have good potential to sequester more atmospheric CO2. High SOCst in the grazing land use related to the high amount roots of grass and high grass root biomass turnover rate, which is important as protection **from** erosion and lack of tillage. High grass root biomass turnover rateand also lack of tillage was reported (Guo and Gifford, 2002; Urioste et al., 2006; Qi et al., 2012; Yoseph et al., 2017). Similarly, Girmay and Singh (2012) reported that higher mean SOCst was observed in northern Ethiopia due to animal excrement. Controlled grazing land use types accruesignificantly higher soil organic carbon stock than cultivated and fallow land use types (Yusuf, 2018).

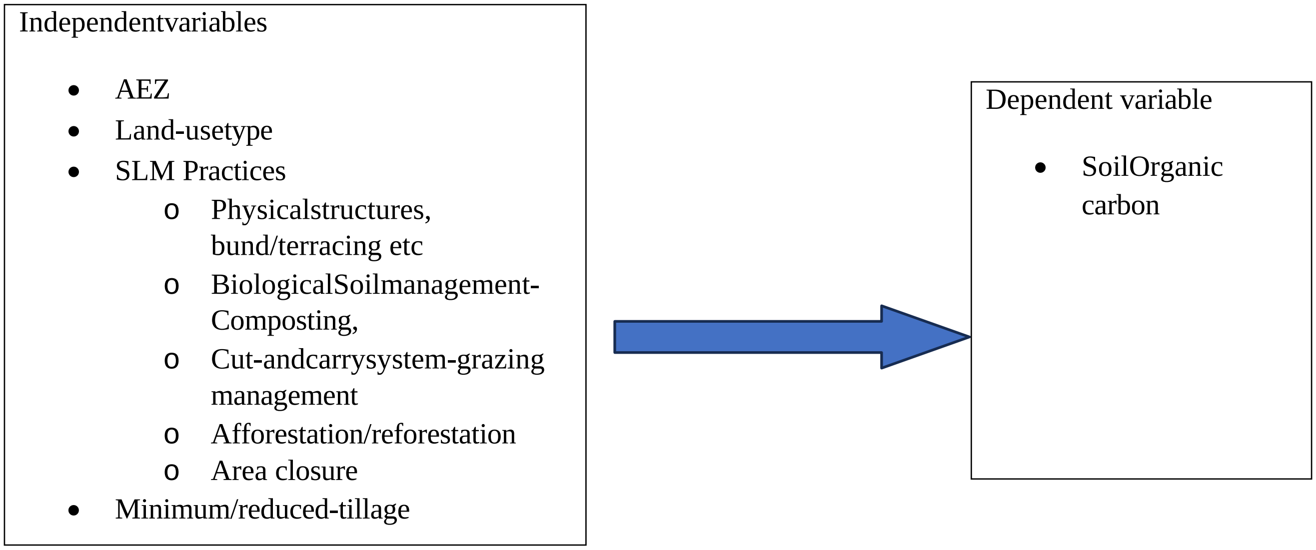
2.1.2. SoilOrganicMatterasaffectedbyaltitude andclimaticzones

Soil C sequestration is the uptake of atmospheric CO2 by terrestrial ecosystems through plant photosynthesis and its conversion and long-term storage in the soil. However, differences in soil type, above-ground vegetation, and climate result in significant differences in soil C storage capacity across regions (Stockmann et al., 2015). Spatial patterns in SOM at different latitudes globallyrevealed that terrestrialSOM levels increase progressivelywith latitude and areaffected by vegetation, temperature, and precipitation (Minasny et al., 2017). Similarly, changes in altitude are associated with changing climate factors, which, in turn, alter SOM.

Altitude is known to have greater impacts on diversity, biomass, and C stock in forestecosystems (Alves et al., 2010). SOC stock trend along the altitudinal gradients is mostly controlled by temperature and precipitation. As pointed out by Jobbagy and Jackson (2000),SOC density increases with precipitation and decreases with temperature. These changes in climatic factors along the altitudinal gradient influence vegetation composition, consequently affecting the quantity and turnover of soil organic matter (Quideau et al., 2001). Therefore, increasing trend of SOC stock with altitude was reported in forestland (Wolde et al., 2014). Similar trend was reported in agricultural field at Ladakh (Charan et al., 2012).
Climate, especially temperature and precipitation, largely determines vegetation cover, quantity and quality of organic residues entering the soil, and the rate of SOM mineralization and litter decomposition;consequently,italsodeterminestheturnoverofSOM(Davidsonetal.,2000).

Many studies have reported a significant negative correlation between the MAT and SOM content (Ganuza and Almendros, 2003; Lemenih and Itanna, 2004). Chao Li et al., (2002) reported that Changes in SOM with altitude were significant among different climate zones. Specifically, SOM content increased with altitude in tropical and subtropical regions, but decreased with altitude in temperate and plateau regions. Moreover, on comparing the slope of SOM content with changes in altitude for different climate zones, the slope displayed a decreasing (positive to negative) trend from tropical to plateau regions.

Fig 1 presents conceptual framework that shows the dependability of SOC buildup at the studysite on the agro-ecology zone and land management practices.



CHAPTERTHREE

3. Descriptionofthestudyarea,ResearchMethods,Materialsand Procedures.

3.1. Descriptionofthestudy area

3.1.1. LocationandClimate

Geographically the study area, Yesir watershed, is located in Bure Zuria District, West Gojam Zone of the Amhara National Regional State (ANRS), NW Ethiopia. It is situated 400 km away from Addis Ababa to northwest, on the wayleading to Bahir Dar town, the capital of the ANRS. Yesir watershed is located at 37^{0}2‟30‟‟‟‟E to 37^{0}10‟0‟‟‟‟and10^{0}35‟00 N to 10^{0}47‟30‟‟‟‟ (Figure 1). This watershed has 13 sub watersheds within four kebeles (Jibgedel- has 5 sub watershed; Adel agata- 3 sub watershed; Wadra-2 sub watershed and Gulm- 3 sub-watershed), and has an altitude of between 713 to 2,691meter above sea level (masl).

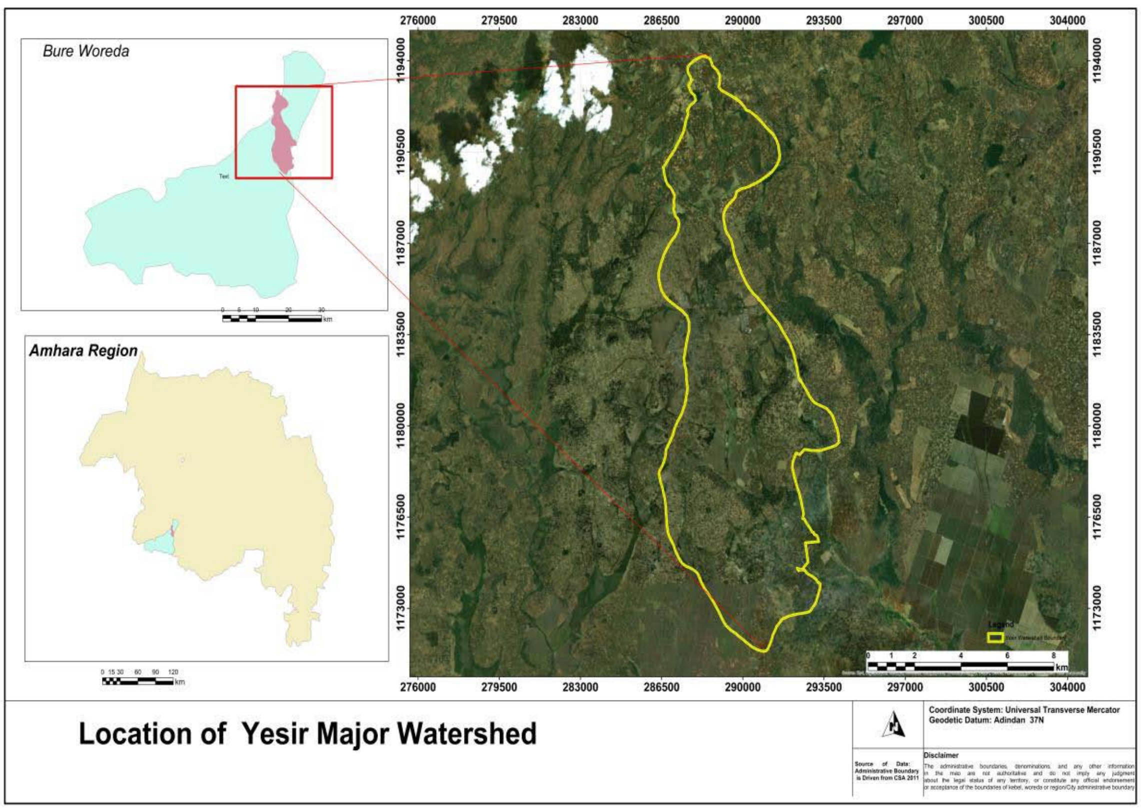


Figure2. Location ofthestudyareainBurezuriaDistrictof AmharaRegional State

Figure3. Landscape of thestudy area

The area is characterized by uni-modal rainfall pattern, with rainfall uniformly distributed over the growing season, which extends from mid-May to mid-September and increases gradually in frequency to reach the maximum in July and decline rapidly after peak starting in August. The variation in the precipitation between the driest and wettest months is 214 mm. The cessation of the rain is much more abrupt compared to its onset and abnormal cessation of the rain can have impact on crop yield (Physical Planning Department, 1985). The mean annual rainfall is 1505 mm of which 80% falls during the four-month period, early June to September. The average annualtemperatureis20.0^{0}Candthemeanmonthlyminimumandmaximumtemperaturesare 13.65^{o}Cand25.30^{o}C,respectively(Figure 3). Ithasthehighestonaverage temperatureinMarch (21.4^{0}C), and July has the lowest average temperature (18.3^{o}C) of the year. During the year, the average temperatures vary by 3.1oC.

The meteorological site from which these records were obtained is around 10-12 km from the studyareawithan altitude of2230 masl. As itwas real to the otherparts of Ethiopia,rainfall and temperature conditions depend on altitude. In reference to the Ministry of Agriculture (MOA) (1998),theagro-ecologyofthedistrictfallswithin tepidsub-humid midhighlands andoneofthe most extensively cultivated landscapes.

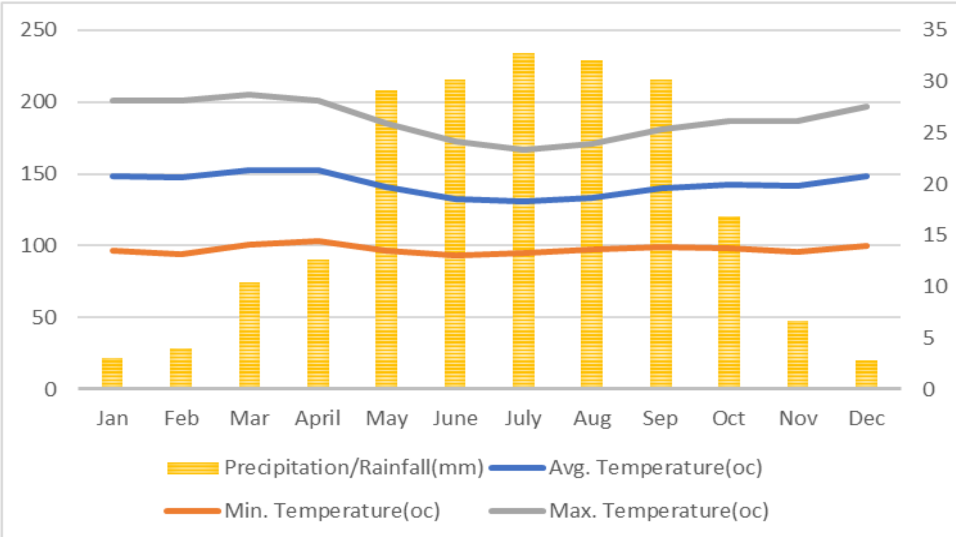


Figure 4: Average monthly precipitation and temperature of the study area
Source:NationalMeteorologicalServiceAgency,BahirDarBranchOffice;

Agroecology

The entire study area is divided into two altitudinal/Agroecological zones (Fig 4) The upper landformoccupies a sizeable portion of the watershed with concentration in the northern parts of the Bure town. The altitude of this land forms ranges from 2300 to 2550 masl. These landforms arecharacterized bypredominantlyundulating torolling slope ranging from5 to15%. Thelower slope occupies extensive area in the southern parts of the town. It is characterized by flat to gently undulating plain with slopes ranging from 0 to 5% and an altitude range of 1750-2300 masl. Poorly drained and annually flooded are some problems of the lower slopes during the rainy season.

Table:-2 Detail of Studied watershed, number of sample plots and selected physical characteristics.

watershed	Noofsample location	Slope class	slope form	Meanaltitude (masl)	AEZ
Yesir	16	0-2%	level	2018	Mid-Highland
	38	2-5%	gentlysloping/	2007	Mid-Highland
	22	5-8%	Undulated/Sloping	2042	Mid-Highland
	12	8-15%	Rolling/stronglysloping	2264	Mid-Highland
	5	15-30%	Moderatelysteep	2025	Mid-Highland
	4	30-60%	Steep	2334	Highland
	97				

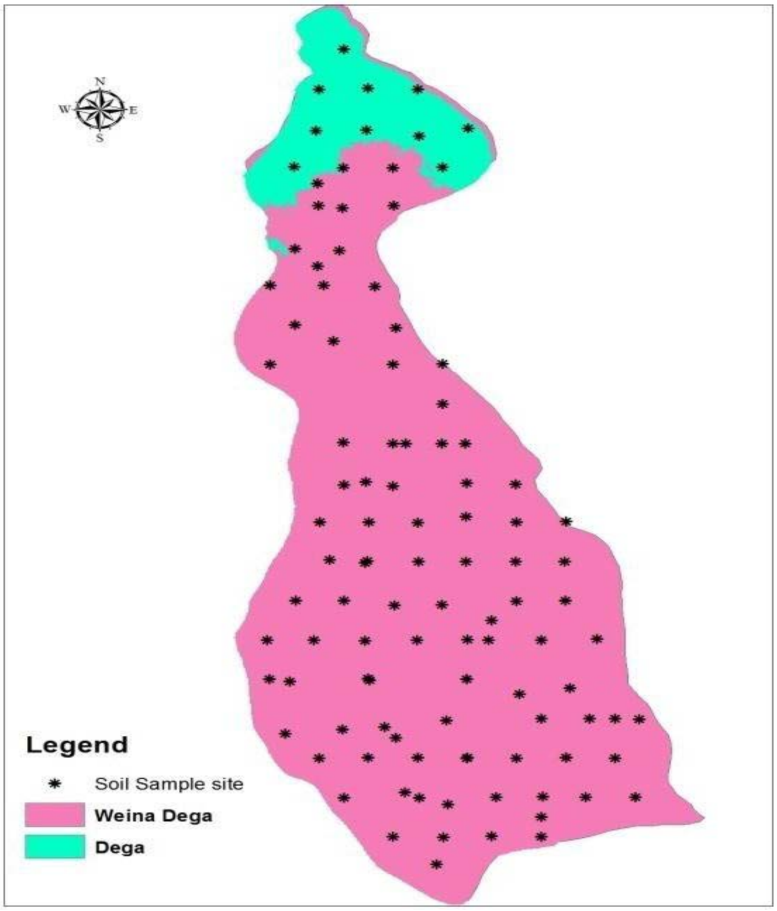


Figure5:-MapshowingtraditionalAgro-ecologicalzonesandsoilsamplesitedistribution

Soilsofthestudy area

Geology

Geologically, the study area is covered with thick trap series volcanic rocks which were erupted from fissures during the early and middle tertiary and from choke shield volcanic mountain center during the Miocene and Pliocene. Trap volcanic series, which consists mainly of weathered and both massive and jointed basalt bed and some pyroclastic layers are identified in two groups within the study area, the Ashngie and Shield group. The Ashengie group comprises the older volcanic rock which were formed from lava and debris ejected from fissural volcanic eruptions. This rock group consists predominantly of alkaline basalt with inter-beddedpyroclasticand rare rhyolites.The eruptiontook placeatintervalswithrelativelylongtimelapses causingformationofpaleosolsasinterbeddinginmanylocations.Theshieldvolcanicrocks consist mainly of pyroclastic basalt and rare petrographically similar to the Ashengie group.

Soils

The soils of the study area are developed from the parent materials of tertiary basalt. Themajority of the soils in Bure District in general and the study area in particular are Nitisols and Cambisols (in slope within 8-15%) according to the FAO/UNESCO. These soils are formed in the upper and middle slope positions, with slope range from 2-15%. Acid Nitisols occur widelyin the highlands of Ethiopia where the rainfall intensity is high and the land has been under cultivation for many years (Fikru, 1988). Large area of Vertisolsare also formed in the lower slope positions (2-8%). The clay fraction of these soils is dominated by the 2:1 lattice claymainly montmorillonite. They have clay texture throughout the profile and in most cases the proportion of the clay fraction is very high (more than 60%). The soil cracks widely during the dry season and the cracks close-up again on rewetting. The resulting expansion and contractionis responsible for the formation of slickenside and wedge shaped structure below the surface horizons. They are imperfectly drained. The soils of the watershed are continuously cultivated.

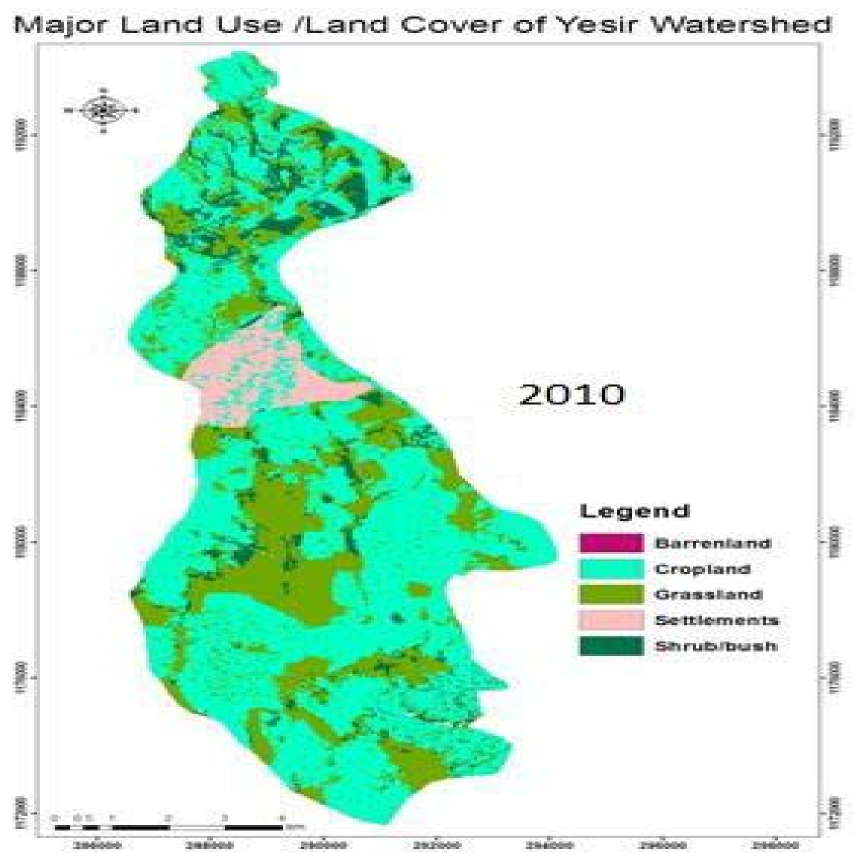
3.1.2. LandUse/LandCover

The land use of the watershed is dominated by traditional rain feed subsistence peasant farming on individual holding and traditional grazing on communal lands (Fig. 5). The effects of this practice on the physical properties of soils and the result attributed to this have not yet been properly quantified.

It was observed that the watershed is characterized by mixed farming where crop and livestock production are interchanging the systems. The overall farming system is strongly oriented towards grain production and it depends on the use of oxen for land preparation. The population generally keeps a number of livestock for production of milk and its by-products and as transferable assets. Crop residues and intensive grazing areas in the watershed are the major contributors to livestock feed resources. Cultivated and grazing lands are the major land usetypesofthewatershed. Thedominantannualcropsgrowninthestudyareasare maize(*Zeamays* L.),fingermillet(*Eleusinecoracona*),teff(*Eragrostistef(*Zucc)Trotter)andPepper(BDAO).

The fairly large share of croplands planted with pepper (Capsicum annuum) can be attributed to its promotion as a cash crop.

Based on the information obtained from farmers, many years ago, the watershed was covered with forest. The natural woodland vegetation of the study area since then gradually disappeared due to overgrazing, increased demand for fuel-wood and charcoal, as well as land which brought into cultivation. There are also small patches of remnant acacia wood and bush lands, which survived on farm boundary and around churches. Without intervention, the remaining wood and shrub lands will probably be destroyed soon. In addition, scattered trees like Crotonmacrostachys and Faiderbia albida are left on cultivated lands. These need to be protected and managed so that they make the maximum contribution to soil and watershed protection. Thereare also Species commonly planted around the homestead are Eucalyptus camaldulensis, and Cupressuslusitania.Acaciadecurrensplantationsarereplacingthebackyards,streambanksand



gullysides.

Figure6.Majorland-use/landcoverofthestudy area

3.1.3. Demographiccharacteristics

Based on the 2007 national census conducted by the central statistical Agency of Ethiopia(CSA), Human population of the woreda is 101,788 of which 96,239 (94.6%) and 5,565(5.4%) live in rural and urban areas respectively.

Table3:-humanpopulationof theBurezuriaworeda

Human population of the woreda	101,788	Rural=96239		Urban=5565	
		Male	Female	Male	Female
		47910	48,329	2577	2,988

3.1.4. Livelihood of the population

Themainsourceoflivelihoodforfarmersinthisdistrictisfarming.ThePeopleofthearea practice different livelihood and income generating activities mainly crop production and animal husbandry.Inadditiontotheseactivities,thepeopleengageinpettytrading,constructionand dailylabor. Crop production plays a major role in income generation in the area and cereals such as Maize, Teff and Millet are the major crops grown. (Bure district Office of Agriculture, 2015). Becauseofthelonghistoryofcultivation,thesoilswereexposedtoslighttomoderatesheet erosionandreducedproductivityofthelandingeneral.Theconditionresultinginlow agriculturalproductioninthewatershedcouldberelatedtovariousfactorsincludingthe dependencyofagricultureonrainfall,lackofmoderntechnology,inappropriateland managementpracticesandmostimportantlyanabsenceofproperinformationonsoilcharacteristics and properties for their sound management practices.

3.1.5. Landmanagement

At baseline, soil and water conservation activities have been applied covering about 15% of the agricultural land of the study site (Bure district Office of Agriculture). These structures were implemented with government initiatives by mobilizing the community. Application of farmyard manure was the conventional practices that farmers were practicing around home gardenand close distance of the homestead. While, in farmlands, where farm plots were far from the settlementarea,theseactivitiesareveryminimal(BuredistrictOfficeofAgriculture).The population generally keeps a number of livestock for production of milk and its by-products and as transferable assets. Crop residues and extensive grazing areas in the watershed are the major contributor to livestock feed resources.

The list of SLM technologies implemented in the study site were collected at each sampling location using appropriate template. Bunds, terraces are the most common interventions in the study area. A combination of physical (Bund, or terraces) and biological was also found in some sites. In the farmland, there are some soil management practices such as crop residue management and compost application.

In this study, the impacts of two categories of SLM practices were evaluated: i) the impacts of biophysical intervention existed at the landscape level particularly bunds/terraces; and ii) the impacts of Integrated soil fertility management particularly composting, crop residue management and traditional conservation tillage on the SOCst sequestration and recommend optimal practice that optimize SOC stock in the study watershed.

3.2. SoilSampling andlaboratory analysis

Soil samples were collected in 2010, before SLMP interventions, and in 2018, after 4 years implementation period and 4 years capitalization phase. The former was collected by the SLMP project as baseline data while in 2018 the SLM Program team collected samples from correspondinglocations of2010.Thesoilsamples werecollectedfroma1kmgrid inboth years. This sampling design was chosen to give an unbiased estimate of SOC contents and SOC stocks in the areas. A total number of 97 soil sample locations were surveyed both in 2010 (before scenario) and in 2018 (after scenario). The distributions of number of soil samples across the study watershed is presented in Appendix 7. The sampling depth is the topsoil (0–20 cm). The same laboratory analyses and methods were used for both years (2010 and 2018). During the field survey, the land uses/covers types corresponding to each sampling point of each site were recorded.Withineachindividualsamplingplot,foursub-plotswereestablished,oneinthecenter and three on a radial arm with 120 angles between them (Vågen et al., 2013; Abegaz et al., 2016) and four equal subsamples were used for a composite sample. Composite samples were produced byhand-mixing after removing unwanted materials like dead plants, roots, and organic piles.Thesoilsampleswereair-dried,crushed,andpassedthrougha2-mmsieveforlaboratory analysis. SOC content was determined using the Walkley-Black oxidation method (Schnitzer, 1982), Bulk density was determined using oven-dry and SOC stock ha-1 was quantified for the 0–20 cm soil depth according to

Eq.(1)(Aynekuluetal.,2011).

SOCst = SOC*BD*D

where SOCst is the soil organic carbon stock (Mg C ha−1), SOC is the soil organic carbon concentration (g C g− 1 soil), BD is the bulk density(g cm− 3), D is soil sampling depth (cm), in this case 20.

3.2.1. StatisticalAnalysis

One of the key objectives of this study was to evaluate if the SOCst varied between before and after the SLM interventions in the yesir watershed covering two agro-ecological zones. After the data were grouped according to the AEZ/altitudinal zone and Land use type, Statistical differences were tested with the help of statistical package for social science (SPSS) version 20 for Windows. Independent t-test was used to measure whether SOC stock mean difference betweenhighlandandmid-highlandissignificantornot.One-way analysisofvariancewas used to test whether mean differences byland uses are significant or not.Paired mean difference t-test was used to determine whether the mean change results (in $tCha^{-1}$) between before andafter SLM intervention were significantly different from zero.

CHAPTERFOUR

4. ResultsandDiscussion

4.1. SoilPhysical Properties

4.1.1. Bulkdensity

The variation in dry bulk density were related to the contents of OM, particle size distributions, slope position and other soil parameters such as depth of soils. Soil bulk density (BD) indicates the soil density per unit volume and is required for estimating the SOC stock.

Table4:-Soilbulkdensityg/cm^{3}Agro-ecologicallyforthevariouslanduses

Landuse	Agro-ecologicalzone	
	Highland	Mid-highland
	Mean	Mean
Farmland	1.17[a]	1.16[a]
Grassland	1.23[a]	1.11[a]
Shrubland	1.21[a]	1.13[a]

ThestudyshowedthatthebulkdensityfortheHighlandwashigherascomparedtoMid- highland, indicating that the averagebulk densityof thesurfacesoil layers decreasedpersistently with decreasing elevation. Supporting the result reported by Hanawalt and Whittaker (1976) that bulkdensityandparticledensitydecreasedwithelevation. AccordingtoLandon(1991),forgood plant growth, bulk densities should be below 1.4 g/cm3 and 1.6 g/cm3 for clay and sandy soils, respectively. Thus, the bulk density values observed in the soils studied were within the normal range of mineral soils worldwide.,

4.2. SOC

4.2.1. BaseyearSoilOrganicCarbonbyland-usetypedisaggregatedby AEZ

In the Highland, Shrub land had highest average estimate (85.41tC ha^{-1}) followed by Grassland (50.70 tC ha^{-1}), whilst the lowest for Cultivated land (44.76tC ha^{-1}). Highest variation was recorded within the land uses. and a 95% confidence interval showed that Shrub land had significantdifferencethanGrazinglandandcultivatedland.Atestofsignificanceshowedthere wassignificantdifferenceamongthethreeland-usesintermsofSOCSintheHighland(p=0.002). The highest variation among the samples could be due to variation in the amount of organic matters in different land use type. For higher SOC stock in shrub land could be Un-cultivated soils have higher in soil Organic Carbon than those soils in cultivated for years (Miller and Gardiner, 2001), as frequent cultivation may increase loss of SOC due to enhanced decomposition of SOM.

In the Mid-highland, Soil of the three land-uses was ranked in a sequence of Grazing land > Shrub land > Cultivated land. The difference was not significant, (P=0.359). However relatively higher mean SOC storage observed in grass land than the cultivated land. This might be due to the fact that Grasslands are not tilled annually and are compacted by animal trampling so that there might be minimum oxidization of carbon element to the atmosphere due to the absence of aeration. The result reported by Hanawalt and Whittaker (1976) supporting the result that Soil organic content increased with elevation, but soil litter cover was maximal at upper-middle elevations where plant cover and productivity were highest.

Table5:-Testof Significance(ANOVA)inSOCSfortwoAEZ inthreelandusetypes.

	ANOVA					
AEZ/ACZ		Sumof Squares	df	MeanSquare	F	Sig.
	Betweenthethree land-usetypes	3764.694	2	1882.347	15.934	.000
Highland AEZ	WithinSOCst	1417.603	12	118.134		
	Total	5182.297	14			
Mid-Highland AEZ	Betweenthethree land-use types Within SOCstTotal	467.246 19835.153 20302.399	2 88 90	233.623 225.399	1.036	.359

4.3. SoilOrganicCarbonstockdifferencesbetweentwomeasuredtime periods by land-use

4.3.1. Farmland

In this study, the impacts of two categories of SLM practices were evaluated: i) the impacts of biophysical interventionexisted atthelandscapelevelparticularlybunds,terraces,biologicaland a combination of physical (bunds and terraces) and biological; and ii) the impacts of Integrated soil fertility managementparticularly composting, crop residue management and traditional conservation tillage on the SOCst sequestration, and recommend optimal practice that optimize SOC stock in the study watershed. Under agricultural land, factor such as the quantityand qualityof organic matter input, decomposition rate, and land management practices would largely determine its C sequestration potential (Bayer et al., 2006; Cochran et al., 2010)

The study highlighted that, in the farm land, where 70 (seventy) samples were taken and compared at two measurement time (Appendix Table 8). The mean difference was 1.94 tC ha^{-1}, up to 20cm soil layer. Though, statistical evidence for the paired observations in the farmland revealedthatthemeandifferencedidn'tshowsignificantdifferentfromzero.Thismightbedueto the fact that the combined intervention of physical structures (Soil bund) applied might rather lead to redistribution and deposition of soil particles within the farm area. Bayer and Cochran *et al.*reportedthatunderagriculturalland,factorssuch asthequantityandqualityoforganicmatter input, decomposition rate, and quality of land management practices would largely determine its C sequestration potential (Bayer *et al.*, 2006; Cochran *et al.*, 2010). This is largely becauseproper management of agricultural lands (e.g. application of farmyard manure) would increase C storage (Mosier *et al.*, 2003). Similar results have also been reported by other scientists (Freibaueretal.,2004).Smithetal.(2005,2012)reportedthat inputofcropresidues couldattain thehighestrateofCsequestration(0.7MgChayr^{-1})incomparisonwiththatofmerely0.2Mg Cha^{-1}yr^{-1}withtheinputofmineralNfertilizer.

4.3.2. Grassland

The study highlighted that higher mean difference in SOC stock between the two measurement timesoccurredinGrasslandanddescriptivestatisticsdisplayedinTablebelow.Theresult showed that, from samples allocated for the Grassland (N=17), and analyzed with a means difference test. The actual mean differencewas 6.39 tC ha^{-1} (1.27tC ha^{-1} $year^{-1}$) upto20cmsoil layer and there was no statistical evidence for the paired observations showing significant different from zero, (t_{17} = 1.66)

Table6:pairedsampletestforGrasslandSOCStocktCha^{-1}betweenthebaselineandPost SLM intervention

PairedSamplesTest									
Landusetype-Grassland		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95%Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	T C per ha Post SLM (Grassland)VstCper haatbaseline (Grassland)	6.41824	15.91908	3.86095	-1.76660	14.60307	1.662	16	.116

tC/haProject:meanvalueofCarbonatproject,intonperHectare, **tC/ha baseline**: mean initial Carbon value ton of per Hectare, **Mean**: The average difference between the two variables.

Standarddeviation:Thestandarddeviationof thedifference scores.

Standarderrormean:Thestandarderror,**t**:Theteststatistic (denoted *t*)forthe pairedT test.

df:Thedegrees of freedomfor thistest.

Sig.(2-tailed): The*p*-valuecorrespondingtothegiventeststatistic*t*withdegreesoffreedom*df*.

BeforetheProjectintervention,therewas noSustainableLand Management(SLM) technologies applied in the Grass that are relevant for improving the status of SOC. the reason might be those interventions required much investment and strong institutional arrangement to implement with the capacity of small holder farmers system, like, controlled grazing through banning of free grazing. (Personal observation during sampling and discussion with District experts).

In addition, the introduction of controlled grazing bylaws applied in grassland during the SLM Project intervention might contributed to more sequestration of SOC than before the Project.Yusuf, M et al., 2018 reported that controlled grazing land use types accrue significantly higher soil organic carbon stock than uncontrolled and free grazing system.

4.3.3. Shrub land

As shown in Table 4, the mean SOC Stock difference in the Shrub-land was 11.92 tC ha^{-1} between the two periods (2010 to 2018), which is an annual increase of 2.38 tC $ha^{-1}year^{-1}$. Statistical evidence indicated that the mean difference between the paired observations was significantly different from zero. The reason might be attributed to the various area enclosure applied in the communal shrub land, the different SLM practice as area closure afforestation/reforestation activities implemented during the project period in the study area.

Table-7:**-pairedsampletestfor** Shrubland**between baselineandPostSLMSOCst_tC ha^{-1}**

PairedSamplesTest									
		PairedDifferences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Intervalofthe Difference				
					Lower	Upper			
Pair-shrub land	SOCst_tCha^{-1}-Post SLMandSOCsttCha^{-1} at Baseline	11.93	10.53	3.17	4.86	19.00	3.758	10	.004

tC/haProject:meanvalueofCarbonatproject,intonperHectare, **tC/ha baseline**: mean initial Carbon value ton of per Hectare, **Mean**: The average difference between the two variables.

Standarddeviation:Thestandard deviationofthedifference scores.

Standarderrormean:Thestandard error,**t**:Theteststatistic (denoted *t*) forthe pairedT test.

df:Thedegrees of freedomfor thistest.

Sig.(2-tailed):The*p*-valuecorrespondingtothegiventeststatistic*t*withdegrees of freedom *df*.

4.4. SOCStock changedifferencefor the whole watershed attwopoint in time

AnalysisoftheamountofSoilCarbonchangeofthewatershedlevelwascarriedoutusingpaired sample test. For this particular study, 95% confidence was used, and the result showed the probable range of the mean change in carbon, t at 0.05 is the critical value of t for a 95% confidence interval and 97 degrees of freedom.

The study highlighted that, for the study area, with a paired mean difference the average/mean valueof SoilOrganiccarbonofthere-sampling was3.88tCha^{-1}withaprobablerangeof 1.25to 6.51 tC ha^{-1}(Table 5) during the Eight years of implementation period, up to 20 cm soil layer. Statisticalevidencethatthemeandifferencebetweenpairedobservationsissignificantlydifferent from zero, (t_{97} = 2.1). This might be attributed to the various area enclosure applied in the shrub/bush land as a protected area and afforestation reforestation, including pasture land management particularly applying cut and carry system through community bylaws, as a project activity.

Table8:pairedsampletestforwatershedlevelbetween thetwoyears(SOCStocktCha^{-1}atPost SLM and tC ha^{-1} Baseline)

PairedSamplesTest									
		PairedDifferences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95%Confidence Intervalofthe Difference Lower	Upper			
Pair1	tCha^{-1}PostSLMVstC ha^{-1} at Baseline	3.88	13.67	1.33	1.25	6.51	2.92	105	.004

tC/haProject:meanvalueofCarbonatproject,intonperHectare, **tC/ha baseline**: mean initial Carbon value ton of per Hectare, **Mean**: The average difference between the two variables.

Standarddeviation:Thestandard deviationofthedifference scores.

Standarderrormean:Thestandard error,**t**:Theteststatistic (denoted *t*) forthe pairedT test.

df:Thedegrees of freedomfor thistest.

Sig.(2-tailed): The*p*-valuecorrespondingtothegiventeststatistic*t*withdegreesoffreedom*df*.

The project activities involved construction of soil and water conservation and application of crop residue management and compost application at household level within the boundaryof the watershed.. However, in the study area, the application of such inputs by farmers might more concentrated on near the homestead area, due to this reason, farm plot far from homestead area might have relatively low coverage application of Carbon inputs (Composting and retaining crop residue after harvest).

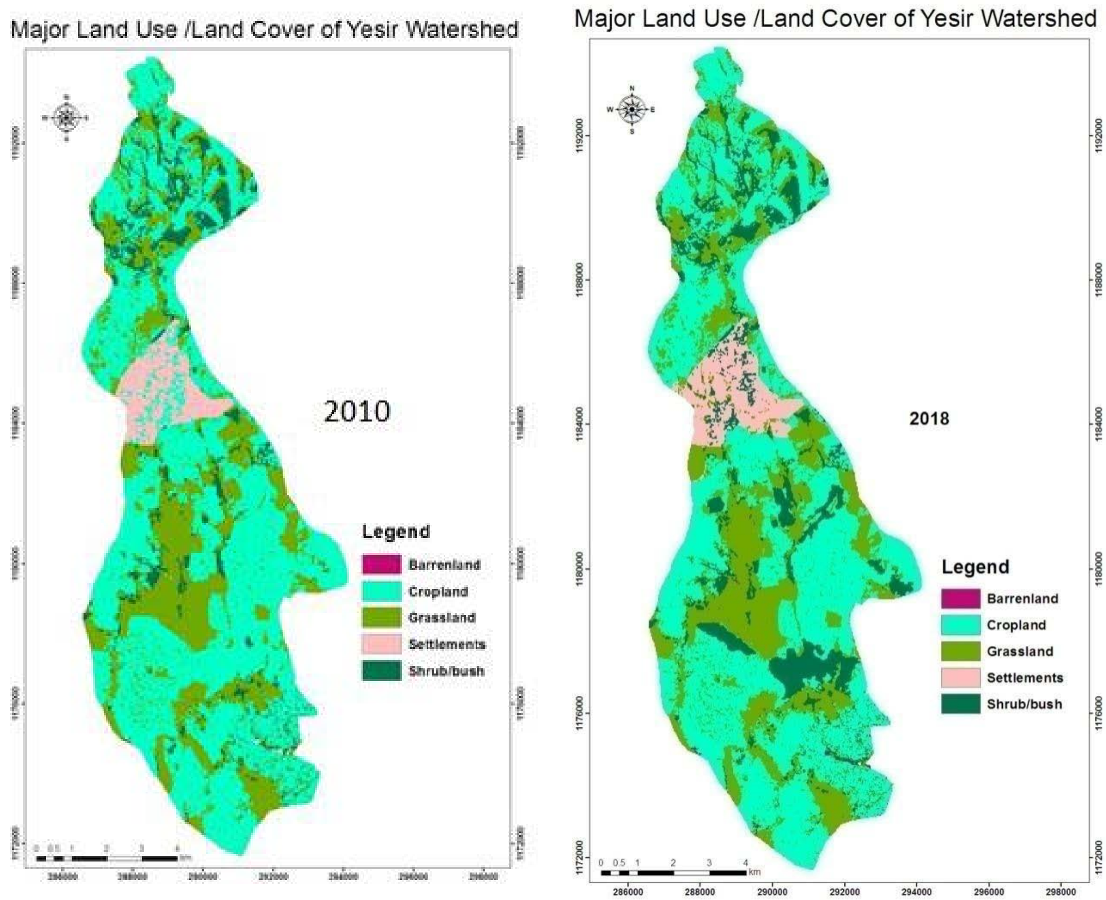


Figure7:- Thecontribution of SLMactivitieson SOCStock changeinthe studyarea

For post SLM intervention, a wide range of Sustainable Land management practices applied inall land uses with technical and financial support from the SLM project. The major SLM practices in the surveyed watershed particularly in cultivated land include different physical conservation structures (e.g. terraces (Hill-side, Fanya-juu, Soil/Stone bunds) + area enclosure) were observed as common practices in the study area, integrated with biological structures for Soil and Water Conservation (SWC)

CHAPTERFIVE

5. ConclusionandRecommendation

5.1. Conclusion

SLM practices have various benefits in arresting land degradation and enhancing soil fertility, generating enabling conditions for food security of small farmers. This study is conducted to studythe impact of SLM practice, implemented in the last 8 years, on SOC stock. The following conclusions are drawn from the results of the study:

- The mean Bulk density for the Highland was 1.20 g cm-3. Conversely, the mean bulk densityforMid-Highlandwas1.13gcm-3bothat0-25cmdepth,Inthepresentstudy,the bulk densities of the highland were higher than that of the mid-highland soils showing a decreasing pattern with a decrease in altitude.
- Shrub land in the Highland, had highest average estimate (85.41tC ha^{-1}) than Grassland (50.70 tC ha^{-1}), while the lowest for Cultivated land (44.76tC ha^{-1}), showing significant difference from zero. On the other hand, in the Mid-highland, Soil of the three land-uses wereranked in a sequence of Grazing land > Shrub land> Cultivated land.
- Thechange inthe amountofSoilOrganicCarbonatwatershedlevelduringthetwo years in time had significant difference from zero.

5.2. Recommendation

In line with this the following recommendation were forwarded to strengthen the government effort so far on practices:

- The poor quality ofSoil and water conservation practices in cultivated landcan be addressedthroughgooddesigningofthephysicalstructuresbeforeapplicationtothefarm andintegrategooddesignstructuresofcutofdrainandwaterways.
- The low coverage of compost application and residue management in the study area can be addressed both through reducing tradeoffs between using crop residue for livestock feed/fuel wood versus applying residue for soil fertility amendment, in addition, the provision of transporting material for compost to apply in area where the farms are far

fromhomesteadmayincreasetheareacoverageofsuchpractices.

- AapplicationofsustainableAgriculturalintensificationthroughcropmix(inter-cropping, crop rotation) increasing the availability of livestock feed and fuel wood through the introduction of improved grass/forage system
- The current Carbon change, particularly at farm level, need to increase beyond the current level. This can be achieved by increasing the carbon input through adequateSoil fertility management. Therefore, it is critical in future connecting researches practice and policy for the effective scaling up of adequate soil fertility management practice in the farming system
- As study result indicated, Small holder farmers aremorecontributingtothereductionof Soil Carbon emission due to the implementation of area enclosure with afforestation reforestationpractices.Andthisshould be connectedtopaymentforecosystemservices to access finance from the different carbon finance initiative in the country and elsewhere to get additional income by establishing a robust national level monitoring, reporting and verification system.
- Provision of continuous training and awareness to the farmers on soil fertility management is advisable to improve the awareness of farmers for sustainable land management.

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Aappendices

AppendixTable1showingaverageSOCstockof thestudy areabylandusetypeand AEZ

Land-usetype	Highland SOCStock (tC ha^{-1})	Mid-highland SOCStock (tC ha^{-1})
Cultivated land	44.76±4.07	6.28±1.90
Grazingland	50.70±4.52	52.36±3.08
Shrubland	85.41±4.22	49.54±4.64
Total	**54.08**±4.97	**47.72**±1.57
Min	24.57	16.32
Max	90.51	84.40
CV	35.58	32.19

CV:CoefficientofVariation,Min:minimum,Max:Maximum

AppendixTable2:watershedleveloverallSOCstdifferencebetween thebaselineandpost SLM intervention

		Mean	Std. ErrorMean
Pairresult watershedlevel	t Cha^{-1} PostSLM	52.31	1.91
	t C ha^{-1}Baseline	48.43	1.53
	Paireddifference	3.88	1.33

AppendixTable3.:Data recordingsheet on applicationof soilmanagementinthe studyarea

							Soilmgmt.-Organicfertilizer used		InorganicFertilizer applied			
Latitude_m	Longitude_m	Slope1.flat2.gentle 3.moderate 4.steep	Slope Aspect 1.Norht 2.east 3.south 4.west	Slope Position 1.summit 2.backslope 3.footslope 4.toeslope	Land cover 1.cropland 2.grassland 3.shrubland 4.forest	Was there landuse change? 1.yes2. No	Compost kg/ha (qunt/ha)	Crop residue management 1.10%2.25% 3.30%4.50%	Urea kg/ha	DAP kg/ha	Lime kg/ha	Physical soil management 1.soil/grass/tree bund strip 2. stonebund 3. drainageditch
1187220	288199	3	1	1	1	2	24Qt/ha	1	200	200		1
1187223	287109	3	1	2	1	2		2	200	200		1and2
1187187	289222	3	3	3	2	2						
1188109	288512	2	1	3	2	2						1
1187717	288075	2	2	1	1	2	10Qt/ha	1	100	100		1
1188153	287621	3	1	1	4	1						1
1183220	288555	1	2	3	1	2		1	100	150		1
1183206	290578	1	1	3		1						
1183206	291065	1	2	3	2	2						
1183206	289849	1	4	3	1	2	8Qt/ha					1
1183205	289593	1	1	3	2	1	10Qt/ha					1
1191006	291030	2	4	2								
1193017	288505	2	3	2	4	1						1
1192000	289999	2	2	2	2	1						1
1192026	289001	2	2	2	2	2						1
1192008	288007	2	3	2	1	1	9Qt/ha	1	100	50	300	1
1190953	287952	3	4	2	1	2		1	50	25		1
1190969	288970	2	3									
1190806	290040	3	3	2	1	1	12Qt/ha	1	100	50		1
1189261	288095	2	2	2	1	2		1	200	200		1
1189190	288568	2	3	3	2	2						1
1189245	289602	2	3	3	2	2						1
1190230	290598	2	4	1	4	2						1
1190237	289581	2	3	1	1	2	10Qt/ha		200	100		1
1190197	288592	2	2	1	2	1						1

1189814	288075	2	1	3	1	2			50	100		1
1190240	287606	2	4	1	1	2	15Qt/ha		200	200		1
1186222	287613	2	2	1	1	2			100	200		1
118527	287107	2	2	2	1	2			100	200		1
1185809	288395	1	4	1	1	2						1
1186170	289649	1	4	1	1	2				100		1
1185248	289603	2	4	2	1	2			100	200		1
1185226	290609	2	4	2	3	2						1
1179997	290983	1	4	1	1	2						1
1180000	290022	1	2	1	1	2	5Qt/ha		200	200		1
1179993	291986	1	2	1	1	2			150	150		1
1179994	292971	2	4	3	2	2						1
1178993	291995	1	2	1	1	2			150	150		1
1178892	290495	1	3	4	2	2						1
1179009	292994	2	3	2	2	2						1
1179968	288941	1	3	4	2	2						
1179007	287531	2	3	4	2	1						1
1179007	288511	1	3	3	2	2						1
1180142	289404	1	3	4	2	2						
1180048	288231	2	3	2	1	2		1	25	50		
1177994	289992	1	1	2	2	2						
1177009	291000	1	1	2	1	2	15Qt/ha	1	60	40		
1178010	291003	1	1	3	1	2	24Qt/ha	1				
1177995	291433	1	2	2	1	2		1	400	400		1
1178499	291500	1	3	4	2	2						3
1181175	290087	2	3	1								
1181200	289103	1	2	2	2	2						1
1181196	288113	3	3	1	1	2						
1182149	288603	3	2	2	1	1			100	100		1
1182235	289042	1	3	2	1	2		1	200	200		1
1182116	289594	1	3	1	3	2						

1181993	290988	1	2	1	1	2	12Qt/ha		400	800		1
1182181	292092	3	2	2	4	2						1
1181230	293098	2	3	2	1	2			200	200		1
1181216	29212	1	4	1	1	2			400	800		1
1181367	291075	2	2	2	2							
1179094	289623	1	3	1	2	2						
1178003	286958	2	2	2	1	2		1	200	200		1
1177995	287912	1	1	1	1	2		1		200		1
1177983	288942	1	2	1	2	2						1
1176978	289031	1	3	1	1	2			200	200		1
1177020	289002	1	3	1	1	2						1
1177007	287013	1	2	3	1	2		1	200	200		1
1176938	287410	1	3	4	2	2		1				1
1175622	287324	1	3	1	1	2	12Qt/ha	1	200	200		1
1175006	288001	1	3	1	1	2						1
1173992	288513	1	3	1	1	2			200	200		1
1174028	290712	2	2	2	1	2	10Qt/ha	1		200		1
1174335	289832	3	2	2	1							
1174198	290129	3	2		2	1						1
1172499	290487	3	4	1	1	2		1	400	400		1
1173194	290605	2	4	1	1	2		2	100	200		1
1173209	289590	1	2	1	1	2		2	200	200		1
1175936	288569	1	3	1	1	2						1
1175999	289418	3	3	2	3	2						1
1176161	290682	4	4	1	4	2						2
1175740	289662	3	3	2	2	2						1
1175242	291080	1	1	1	1	2		1	100	200		1
1175218	290098	2	2	3	1	2			200	400		1
1175217	289098	2	1	2	1	2			400	800		1
1173233	292600	2	2	2	1	2			100	100		1
1173732	292592	2	4	2	1	2		1	200	200		2

1174237	292625	2	2	2	1				200	200		1
1174217	294511	1	3	1	3	2						1
1174226	293500	1	4	1	1	2			200	200		1
1173009	291501	2	2	2	2	2						1
1176006	292510	2	2	1	1	2			200	200		1
1175010	293007	2	3	1	1	2		1	200	400		1
1174996	291999	3	1	1	1	2		1	200	200		1
1174000	291594	3	3	3	1	2			200	200		1
1176619	292066	3	2	3	1	2		2	200	200		1
1191783	288148	2	3	2	1	1		1	100	50		1
		2	2	3	1	1						2
1177989	292501	2	4	2	1	1		1	100	50		1
1178031	293628	1	3	1	1	2		1	200	200		1
1175000	293993	1	4	3	1	2			300	300		1
1176781	293083	1	3	1	1	2			200	200		1
1175991	294490	1	2	1	1	2		1	200	200		1
1176000	293999	1	1	4	1	2			200	200		1

AppendixTable4*SoilAnalysisLaboratoryforpostSLM*

HorticoopEthiopia(Horticulture)PLC						
SoilandWaterAnalysis Laboratory						
SoilAnalysis Results						
Lab.Code	PH-H2O	OC	OM	Available Phosphorus	Available K	Bulk Density
	0-14	%	%	Mg/kg	Mg/kg	g/Cm3
18HAG01	*5.76*	*1.66*	*2.86*	*18.65*		*0.99*
18HAG02	*5.94*	*1.82*	*3.13*	*23.98*		*1.27*
18HAG03	*5.4*	*2.1*	*3.62*	*9.98*	*212.55*	*1.11*
18HAG04	*5.06*	*2.27*	*3.91*	*76.89*		*1.15*
18HAG05	*5.54*	*2.09*	*3.6*	*14.48*		*1.25*
18HAG06	*5.91*	*1.92*	*3.31*	*17.23*		*0.98*
18HAG07	*5.52*	*2.17*	*3.74*	*9.72*		*1.11*
18HAG08	*6.12*	*1.36*	*2.34*	*10.79*		*1.04*
18HAG09	*5.24*	*4.89*	*8.43*	*7.68*		*1.02*
18HAG010	*6.14*	*1.42*	*2.45*	*9.7*		*0.95*
18HAG011	*6.28*	*1.98*	*3.41*	*9.1*		*0.74*
18HAG012	*6.81*	*2.55*	*4.4*	*12.37*		*1.19*
18HAG013	*6.03*	*1.97*	*3.4*	*9.89*	*246.4*	*1.15*
18HAG014	*5.11*	*1.83*	*3.15*	*12.8*		*1.07*
18HAG015	*5.38*	*2.09*	*3.6*	*11.78*		*1.25*
18HAG016	*5.56*	*1.46*	*2.52*	*14.75*		*1.08*
18HAG017	*5.82*	*1.87*	*3.22*	*13.94*		*1.22*
18HAG018	*5.51*	*2.26*	*3.9*	*10.15*		*1.08*
18HAG019	*5.68*	*2.35*	*4.05*	*32.23*		*1.12*
18HAG020	*6.07*	*0.98*	*1.69*	*12.32*		*1.17*
18HAG021	*6.01*	*1.64*	*2.83*	*11.06*	*144.3*	*1.22*
18HAG022	*5.83*	*2.12*	*3.65*	*12.08*		*1.31*
18HAG023	*5.79*	*3.39*	*5.84*	*14.99*		*1.19*
18HAG024	*5.45*	*1.72*	*2.97*	*11.24*		*1.36*
18HAG025	*5.13*	*3.57*	*6.15*	*6.97*	*196.2*	*1.26*
18HAG026	*6.05*	*2.12*	*3.65*	*21.83*	*264.6*	*1.35*
18HAG027	*5.35*	*3.23*	*5.57*	*8.45*		*1.08*
18HAG028	*5.5*	*3.21*	*5.53*	*6.53*		*1.14*
18HAG029	*5.59*	*2.97*	*5.12*	*12.1*		*0.94*
18HAG030	*5.31*	*2.25*	*3.88*	*12.58*		*1.38*
18HAG031	*5.32*	*1.91*	*3.29*	*9.83*		*1.18*

18HAG032	***5.58***	***1.28***	***2.21***	***16.53***		***1.17***
18HAG033	***5.79***	***1.85***	***3.19***	***7.23***		***0.97***
18HAG034	***4.78***	***2.47***	***4.26***	***22.8***		***1.15***
18HAG035	***5.24***	***1.77***	***3.05***	***9.99***		***1.27***
18HAG036	***5.19***	***2.07***	***3.57***	***55.18***	***291.6***	***1.36***
18HAG037	***5.32***	***2.2***	***3.79***	***15.26***		***1.29***
18HAG038	***5.31***	***2.84***	***4.9***	***7.88***		***1.11***
18HAG039	***6.03***	***1.38***	***2.38***	***7.45***		***1.34***
18HAG040	***5.37***	***1.64***	***2.83***	***10.58***		***1.26***
18HAG041	***5.16***	***2.72***	***4.69***	***8.12***		***1.21***
18HAG042	***5.79***	***1.24***	***2.14***	***17.07***		***1.22***
18HAG043	***5.26***	***6.77***	*###*	***8.17***		***1.46***
18HAG044	***5.37***	***2.42***	***4.17***	***12.04***		***1.23***
18HAG045	***5.48***	***1.93***	***3.33***	***11.39***		***1.19***
18HAG046	***5.84***	***1.35***	***2.33***	***7.18***	***134.4***	***1.26***
18HAG047	***5.18***	***3.27***	***5.64***	***7.33***		***0.87***
18HAG048	***5.64***	***2.56***	***4.41***	***39.01***		***1.41***
18HAG049	***5.62***	***2.57***	***4.43***	***19.98***		***1.2***
18HAG050	***4.91***	***4.1***	***7.07***	***7***		***1.18***
18HAG051	***5.56***	***3.13***	***5.4***	***56.68***		***1.16***
18HAG052	***5.05***	***2.29***	***3.95***	***16.93***		***1***
18HAG053	***5.18***	***2.15***	***3.71***	***10.15***		***1.2***
18HAG054	***5.85***	***3.21***	***5.53***	***9.49***		***1.28***
18HAG055	***5***	***1.86***	***3.21***	***10.73***		***1.34***
18HAG056	***4.77***	***2.08***	***3.59***	***22.46***	***245.25***	***1.12***
18HAG057	***5.38***	***2***	***3.45***	***9.78***		***1.62***
18HAG058	***5.23***	***3.57***	***6.15***	***6.77***		***1.06***
18HAG059	***5.04***	***2.93***	***5.05***	***15.46***		***1.26***
18HAG060	***4.91***	***4.6***	***7.93***	***16.35***		***0.95***
18HAG061	***5.05***	***2.35***	***4.05***	***20.99***		***1***
18HAG062	***5.16***	***2.53***	***4.36***	***6.8***		***1.08***
18HAG063	***5.35***	***4.23***	***7.29***	***38.34***		***1.24***
18HAG064	***5.42***	***2.77***	***4.78***	***17.92***		***1.19***
18HAG065	***5.66***	***1.5***	***2.59***	***11.3***		***1.31***
18HAG066	***6.28***	***1.99***	***3.43***	***32.47***	***296.8***	***1.27***
18HAG067	***5.11***	***2.04***	***3.52***	***14.51***		***1.22***
18HAG068	***5.36***	***2.15***	***3.71***	***19.88***		***1.35***
18HAG069	***4.83***	***2.12***	***3.65***	***14.52***		***1.38***
18HAG070	***5.79***	***2.66***	***4.59***	***7.63***		***1.26***
18HAG071	***5.76***	***2.02***	***3.48***	***7.5***		***1.17***
18HAG072	***6.11***	***1.22***	***2.1***	***7.19***		***0.93***

18HAG073	***5.03***	***2.3***	***3.97***	***15.92***		***1.13***
18HAG074	***6.02***	***1.92***	***3.31***	***10.07***		***0.96***
18HAG075	***6.05***	***1.54***	***2.65***	***7.67***		***1.26***
18HAG076	***5.36***	***2.48***	***4.28***	***14.05***	***346.5***	***1.2***
18HAG077	***5.45***	***2.52***	***4.34***	***11.04***		***1.11***
18HAG078	***4.96***	***1.73***	***2.98***	***10.67***		***0.98***
18HAG079	***5.34***	***2.31***	***3.98***	***11.23***		***1.51***
18HAG080	***7.23***	***0.79***	***1.36***	***10.86***		***1.15***
18HAG081	***5.64***	***1.46***	***2.52***	***16.19***		***0.93***
18HAG082	***5.72***	***2.17***	***3.74***	***10.57***		***1.53***
18HAG083	***5.96***	***1.75***	***3.02***	***11.8***		***1.4***
18HAG084	***5.51***	***2.35***	***4.05***	***19.67***		***0.92***
18HAG085	***5.2***	***2.33***	***4.02***	***12.4***		***1.11***
18HAG086	***5.58***	***3.49***	***6.02***	***19.91***	***268.8***	***0.92***
18HAG087	***6.03***	***1.7***	***2.93***	***10.21***		***0.82***
18HAG088	***6.08***	***1.71***	***2.95***	***14.02***		***0.86***
18HAG089	***6.01***	***1.72***	***2.97***	***11.19***		***0.68***
18HAG090	***6***	***2.85***	***4.91***	***18.13***		***1.08***
18HAG091	***6.28***	***1.71***	***2.95***	***7.03***		***1.05***
18HAG092	***6.55***	***1.77***	***3.05***	***8.41***		***1.09***
18HAG093	***7.75***	***1.71***	***2.95***	***12.51***		***0.98***
18HAG094	***6.44***	***2.32***	***4***	***6.02***		***1.04***
18HAG095	***6.4***	***1.24***	***2.14***	***8.63***		***0.87***
18HAG096	***6.39***	***1.35***	***2.33***	***9.22***	***184.8***	***1.27***
18HAG097	***5.38***	***2.2***	***3.79***	***11.92***		***1.41***
18HAG098	***6.13***	***1.97***	***3.4***	***13.46***		***1.31***

Appendixtable5-baselineandpostSLMamountofSOCstintCha^{-1}from samples collected from Grassland (calculated)

No of samples	tC per Ha at Baseline	tC per Ha at PostSLM	Land-usetype
SampleNo1	44.91	46.18	Grassland
SampleNo 2	47.58	45.63	Grassland
SampleNo3	59.62	62.1	Grassland
SampleNo4	48.17	48.17	Grassland
SampleNo5	60.36	99.76	Grassland
SampleNo6	41.2	60.69	Grassland
SampleNo7	47.58	45.63	Grassland
SampleNo8	52.06	48.82	Grassland

SampleNo9	68.63	57.24	Grassland
SampleNo10	67.56	73.19	Grassland
SampleNo11	49.33	56.9	Grassland
SampleNo12	34.44	61.68	Grassland
SampleNo13	32.14	51.6	Grassland
SampleNo14	47.64	75.68	Grassland
SampleNo15	80.44	54.68	Grassland
SampleNo16	61.46	64.22	Grassland
SampleNo17	61.5	61.56	Grassland
Mean	51.45	59.63118	

AppendixTable6baselineandpostSLMcalculatedamountofSOCstintC ha^{-1} from samples collected from Farmland

SampleNo1	tC_ha_Baseline	Tc_ha_Project	LanduseType
SampleNo2	36.06	37.18	Farmland
SampleNo3	44.91	46.18	Farmland
SampleNo4	46.93	46.62	Farmland
SampleNo5	51.06	52.21	Farmland
SampleNo6	50.23	52.25	Farmland
SampleNo7	25.07	37.63	Farmland
SampleNo8	28.70	28.29	Farmland
SampleNo9	29.45	26.98	Farmland
SampleNo10	37.60	37.22	Farmland
SampleNo11	46.23	45.31	Farmland
SampleNo12	41.30	39.16	Farmland
SampleNo13	68.50	52.25	Farmland
SampleNo14	38.04	31.54	Farmland
SampleNo15	50.49	52.64	Farmland
SampleNo16	24.57	22.93	Farmland
SampleNo17	40.26	40.02	Farmland
SampleNo18	62.41	55.54	Farmland
SampleNo19	46.08	46.78	Farmland
SampleNo20	49.63	45.08	Farmland
SampleNo21	48.63	29.95	Farmland
SampleNo22	40.55	35.89	Farmland
SampleNo23	44.16	56.81	Farmland
SampleNo24	35.56	44.96	Farmland

SampleNo25	55.81	56.30	Farmland
SampleNo26	53.56	56.76	Farmland
SampleNo27	27.31	36.98	Farmland
SampleNo28	31.99	30.26	Farmland
SampleNo29	78.20	110.08	Farmland
SampleNo30	56.56	59.53	Farmland
SampleNo31	54.93	45.93	Farmland
SampleNo32	31.35	34.02	Farmland
SampleNo33	64.21	72.19	Farmland
SampleNo34	53.45	96.76	Farmland
SampleNo35	52.59	72.62	Farmland
SampleNo36	48.38	45.80	Farmland
SampleNo37	67.79	82.18	Farmland
SampleNo38	64.94	49.85	Farmland
SampleNo39	38.15	73.84	Farmland
SampleNo40	47.90	87.26	Farmland
SampleNo41	51.03	47.03	Farmland
SampleNo42	67.17	104.53	Farmland
SampleNo43	61.06	65.94	Farmland
SampleNo44	64.71	39.17	Farmland
SampleNo45	61.10	49.78	Farmland
SampleNo46	66.42	58.05	Farmland
SampleNo47	56.47	67.03	Farmland
SampleNo48	41.23	47.27	Farmland
SampleNo49	44.66	22.69	Farmland
SampleNo50	30.31	51.98	Farmland
SampleNo51	31.10	36.86	Farmland
SampleNo52	64.08	38.81	Farmland
SampleNo53	41.90	33.91	Farmland
SampleNo54	80.39	69.76	Farmland
SampleNo55	28.96	18.17	Farmland
SampleNo56	37.68	27.16	Farmland
SampleNo57	71.08	66.40	Farmland
SampleNo58	43.62	49.00	Farmland
SampleNo59	48.47	43.24	Farmland
SampleNo60	50.90	51.73	Farmland
SampleNo61	20.45	27.88	Farmland
SampleNo62	19.68	29.41	Farmland
SampleNo63	16.32	23.39	Farmland
SampleNo64	33.60	35.91	Farmland

SampleNo65	32.09	38.59	Farmland
SampleNo66	21.05	33.52	Farmland
SampleNo67	18.79	21.58	Farmland
SampleNo68	31.06	34.29	Farmland
SampleNo69	84.40	62.04	Farmland
SampleNo70	59.71	51.61	Farmland
SampleNo71	38.02	31.54	Farmland

AppendixTable7soilanalysislaboratoryresultandcoordinatesofeach sample point at Baseline

FieldNo	Depth (cm)	Coordinates		O.C
		X	Y	
SampleNo1	0-15	298146	1191783	1.914
SampleNo2	0-15	287984	1189611	1.768
SampleNo3	0-18	287984	1187511	2.114
SampleNo4	0-25	288297	1185596	2.724
SampleNo5	0-20	289757	1183000	2.009
SampleNo6	0-17	288950	1182028	1.279
SampleNo7	0-16	291500	1178499	2.774
SampleNo8	0-30	288228	1180046	1.872
SampleNo9	0-30	287414	1176940	2.959
SampleNo 10	0-35	290999	1174999	2.152
SampleNo11	0-20	292503	1173510	2.349
SampleNo12	0-25	289556	1175516	1.731
SampleNo13	0-20	289742	1174132	1.763
SampleNo14	0-30	290620	1173821	2.57
SampleNo15	0-30	290393	1172293	2.241
SampleNo16	0-25	289031	1176980	3.742
SampleNo17	0-30	288506	1193023	1.761
SampleNo18	0-30	290000	1192003	3.07
SampleNo19	0-30	289005	1192026	3.413
SampleNo20	0-30	288007	1192006	2.254
SampleNo21	0-20	287949	1190953	1.752
SampleNo22	0-20	288969	1190970	2.942
SampleNo23	0-25	290041	1190809	1.996
SampleNo24	0-25	291029	1191005	4.74
SampleNo25	0-25	287510	1190037	2.382
SampleNo 26	0-25	288500	1190000	2.4
SampleNo27	0-25	289500	1190010	1.694

SampleNo28	0-25	290508	1190020	3.618
SampleNo29	0-25	287997	1189047	2.542
SampleNo30	0-30	288480	1188986	2.663
SampleNo31	0-25	289510	1189040	2.963
SampleNo32	0-25	288418	1187904	2.147
SampleNo33	0-25	287529	1187954	3.038
SampleNo34	0-25	287018	1187018	2.103
SampleNo35	0-25	288107	1187014	2.078
SampleNo36	0-20	289133	1186982	2.09
SampleNo37	0-30	289561?	1185935	1.92
SampleNo38	0-30	287518	1186009	1.4
SampleNo39	0-20	287014	1185005	2.052
SampleNo40	0-30	289502	1185010	2.076
SampleNo41	0-30	290512	1185016	2.484
SampleNo42	0-30	290507	1184002	2.08
SampleNo43	0-25	288496	1183029	1.019
SampleNo44	0-25	289501	1182999	2.027
SampleNo45	0-25	289503	1181909	3.596
SampleNo46	0-25	288507	1181939	1.311
SampleNo47	0-25	290487	1183000	2.023
SampleNo48	0-30	290972	1183000	1.678
SampleNo49	0-25	291987	1181967	2.299
SampleNo50	0-30	290988	1181993	2.308
SampleNo51	0-25	288024	1180993	1.244
SampleNo52	0-25	289012	1180997	2.835
SampleNo53	0-30	290010	1180983	1.91
SampleNo54	0-30	290025	1180001	2.277
SampleNo55	0-30	288981	1180012	2.994
SampleNo56	0-25	288944	1179970	1.435
SampleNo57	0-25	290983	1181141	2.265
SampleNo58	0-30	292008	1181000	2.267
SampleNo59	0-30	293002	1181017	2.419
SampleNo60	0-30	292972	1179995	1.339
SampleNo61	0-30	291984	1179994	2.648
SampleNo62	0-30	290983	1179998	2.423
SampleNo63	0-30	287530	1179006	1.585
SampleNo64	0-25	288510	1179006	2.671
SampleNo65	0-30	289533	1178880	2.247
SampleNo66	0-25	290498	1178893	1.514
SampleNo67	0-25	291003	1178009	2.525
SampleNo68	0-30	289991	1177994	4.826
SampleNo69	0-25	288934	1177989	3.746
SampleNo70	0-30	287909	1177994	2.718

SampleNo 71	0-30	286958	1178004	2.565
SampleNo72	0-30	290998	1177008	2.084
SampleNo73	0-30	290998	1177008	2.478
SampleNo74	0-30	289005	1177017	2.441
SampleNo75	0-30	287010	1177007	2.504
SampleNo76	0-30	291995	1178990	2.46
SampleNo77	0-30	292994	1179009	1.532
SampleNo78	0-25	293626	1178035	2.241
SampleNo79	0-15	292501	1177991	1.762
SampleNo80	0-25	291431	1177995	2.401
SampleNo81	0-25	292068	1176621	1.341
SampleNo82	0-25	293081	1176781	1.62
SampleNo83	0-25	293999	1176001	2.543
SampleNo84	0-20	290588	1175951	3.186
SampleNo85	0-25	289329	1175784	3.174
SampleNo86	0-20	288477	1175726	2.138
SampleNo87	0-25	287325	1175622	2.662
SampleNo88	0-30	291008	1175005	1.379
SampleNo89	0-30	290005	1175009	1.259
SampleNo90	0-30	289005	1175009	2.026
SampleNo91	0-30	288002	1175003	2.323
SampleNo92	0-30	288513	1173989	1.558
SampleNo93	0-25	289501	1173002	2.634
SampleNo94	0-30	290518	1172990	2.293
SampleNo95	0-20	291502	1173010	3.951
SampleNo96	0-30	292510	1173007	1.247
SampleNo97	0-30	293006	1175008	1.144
SampleNo98	0-30	292000	1175000	1.2
SampleNo99	0-25	290034	1173992	2.847
SampleNo100	0-30	291593	1174004	1.6
SampleNo101	0-30	292540	1174020	1.472
SampleNo102	0-25	293403	1174008	1.074
SampleNo103	0-30	294415	1174005	1.148
SampleNo104	0-30	292510	1176008	1.08
SampleNo105	0-25	293485	1176008	1.223
SampleNo106	0-25	294488	1175992	2.993
SampleNo107	0-30	293993	1175003	2.279
SampleNo108	0-30	293006	1175008	2.527

Appendix:Table8Coordinatepoint,slopeclassandLanduse/landcoverofsamplepoints where soil sample were collected-

CODE	ELEVATIO N(Mt)	UTM-N	UTM-E	SLOPE CLASS	LAND COVER	LANDUSE
SampleNo1	2516	1193023	288506	7	CF	AR
SampleNo2	2429	1192003	290000	7	GO	GEL
SampleNo3	2473	1192026	289005	7	GO,WO	GEL
SampleNo4	2485	1192006	288007	7	CF	AR
SampleNo5	2372	1190953	287949	7	CF	AR
SampleNo6	2274	1190970	288969	7	CF	AR
SampleNo7	2278	1190809	290041	8	CF	AR
SampleNo8	2334	1191005	291029	9		GEL
SampleNo9	2386	1190037	287510	6	CF	AR
SampleNo10	2312	1190000	288500	6	CF	AR
SampleNo11	2280	1190010	289500	5	CF	AR
SampleNo12	2268	1190020	290508	5	WL	GR
SampleNo13	2095	1189047	287497	6	WL	GEL
SampleNo14	2234	1188986	288480	6	GO	GEL
SampleNo15	2245	1189040	289510	6	GO	GEL
SampleNo16	2222	1187904	28818	6	CF	AR
SampleNo17	2274	1187954	287529	7	GO	GEL
SampleNo18	2219	1187010	287018	5	CF	AR
SampleNo19	2213	1187014	288107	6	CF	AR
SampleNo20	2178	1186982	289133	7	CF	AR
SampleNo21	2151	1165995	289561	5	CF	AR
SampleNo22	2143	1186009	287518	5	CF	AR
SampleNo23	2127	1185005	287014	5	CF	AR
SampleNo24	2127	1185010	289502	5	CF	AR
SampleNo25	2121	1185016	290512	5	GO,WO	GEL
SampleNo26	2029	1184002	290507	5	CF	AR
SampleNo27	2051	1183029	288496	4	CF	GEL
SampleNo28	2070	1182999	289501	4	CF	AR
SampleNo29	2043	1181909	289503	4	CF	AR
SampleNo30	2053	1181939	288507	7	CF	AR
SampleNo31	2082	1183000	290487	6	CF	AR
SampleNo32	2065	1183000	290972	2	CF	AR
SampleNo33	2080	1182968	291985	5	CF	AR
SampleNo34	2072	1181967	291987	7	CF	AR
SampleNo35	2069	1181993	290988	5	CF	AR
SampleNo36	2048	1180993	288024	5	CF	AR
SampleNo37	1984	1180997	289012	4	GO	GEL

SampleNo38	2027	1180993	289012	4	CF	AR
SampleNo39	1988	1180001	290025	4	CF	AR
SampleNo40	2012	1180012	288981	4	GO	GEL
SampleNo41	2017	1179970	287944	4	CF	AR
SampleNo42	1801	1181141	290983	6	CF	AR
SampleNo43	2062	1181000	292008	4	CF	AR
SampleNo44	1945	1181017	293002	4	CF	AR
SampleNo45	1920	1179995	292972	4	CF	AR
SampleNo46	2058	1179994	291989	5	CF	AR
SampleNo47	2048	1179998	290983	5	CF	AR
SampleNo48	2065	1179006	287530	7	CF	AR
SampleNo49	2036	1179000	288510	5	CF	AR
SampleNo50	2024	1178880	289533	4	GR	GEL
SampleNo51	2022	1178893	290498	6	CF	AR
SampleNo52	2015	1178009	291003	4	CF	AR
SampleNo53	2015	1177994	289991	3	GO	AR
SampleNo54	2016	1177989	288934	5	GO	GEL
SampleNo55	2054	1177994	287909	4	CF	AR
SampleNo56	2088	1178004	286958	6	CF	AR
SampleNo57	1766	1177008	290998	5	CF	AR
SampleNo58	2020	1177008	290998	5	CF	AR
SampleNo59	2050	1177017	289005	6	CF	AR
SampleNo60	2056	1177005	288004	6	CF	AR
SampleNo61	2052	1177007	287010	6	CF	AR
SampleNo62	1986	1178990	291995	6	CF	AR
SampleNo63	1927	1179009	292994	6	GO	GEL
SampleNo64	1875	1178035	293626	5	CF	AR
SampleNo65	1884	1177991	292501	8	CF	AR
SampleNo66	2012	1177995	291431	5	CF	AR
SampleNo67	1881	1176621	292068	6	CF	AR
SampleNo68	1842	1176781	293081	5	CF	AR
SampleNo69	1845	1176001	293999	6	CF	AR
SampleNo70	1911	1175951	290588	9		GEL
SampleNo71	1977	1115784	289329	7		GEL
SampleNo72	2012	1175726	288477	5	CF	AR
SampleNo73	2007	1175622	287325	5	CF	AR
SampleNo74	1832	1175005	291008	5	CF	AR
SampleNo75	1851	1175009	290005	6	CF	AR
SampleNo76	2001	1175009	289005	5	CF	AR
SampleNo77	2002	1175003	288002	5	CF	AR
SampleNo78	1956	1173989	288513	5	CF	AR
SampleNo79	1984	1173002	289501	5	CF	AR
SampleNo80	1984	1172990	290518	5	CF	AR

SampleNo81	1916	1173010	291502	6	GO	GEL
SampleNo82	1826	1173007	292510	6	CF	AR
SampleNo83	1810	1175008	293006	5	CF	AR
SampleNo84	1825	1175000	292000	5	CF	AR
SampleNo85	1913	1173992	290034	8	GO	GEL
SampleNo86	1846	1174004	291593	6	CF	AR
SampleNo87	1774	1174020	292540	5	CF	AR
SampleNo88	1765	1174008	293403	5	CF	AR
SampleNo89	1760	1174005	294415	5	CF	AR
SampleNo90	1840	1176008	292510	5	CF	AR
SampleNo91	1830	1176008	293485	5	CF	AR
SampleNo92	1825	1175992	294488	5	CF	AR
SampleNo93	1793	1175003	293993	5	CF	AR

AppendixTable9:-Relativedistributionofland-usetypesinthestudyarea

Land-usetype	SamplesizebyAEZ		Area(Ha)	areacoverage (%)
	Mid-highland	Highland		
Cultivated land	69	9	78	74
Grazingland	14	6	20	19
Shrub land	7	0	7	7
total	90	15	105	100