IMPACTS OF LAND USE TYPES ON SELECTED SOIL PHYSICO-CHEMICAL PROPERTIES AT YAYU DISTRICT, ILU ABA BORA ZONE, SOUTHWESTERN ETHIOPIA

MSc. THESIS

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Impacts of Land Use Types on Selected Soil Physico-chemical Properties at Yayu District, Ilu Aba Bora Zone, Southwestern EthiopiaMSc Thesis

Submitted to the Department of Natural Resource Management, Jimma University College of Agriculture and Veterinary Medicine, in partial fulfillment of requirements for the Degree of Masters of Science in Soil Science

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MSc THESIS APPROVAL SHEET

We, the undersigned, member of the Board of Examiners of the final open defense by **Solomon Abebe Kenea** have read and evaluated his/her thesis entitled **"Impact of Land Use Types on Selected Soil Physico-chemical Properties at Yayu District, Southwestern Ethiopia "** and examined the candidate. This is therefore to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree Master of Science in **Natural Resource Management (Soil Science).**

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DEDICATION

This work is dedicated to my wife, RahelTemesgen and my son Kakuu Solomon.

STATEMENTS OF THE AUTHOR

I undersigned, declare that this thesis entitled "*Impacts of Land Use Types on Selected Soil Physico-chemical Properties at Yayu District, Ilu Aba Bora Zone, Southwestern Ethiopia*" is my original work and has not been presented or summated for any degree in any other university and that all sources of materialused in this thesis have been accordingly cited and acknowledged. The thesis is deposed at the Jimma University library to make available to borrowers under the rules of the Library. Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgment of the source is made. Request for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the dean of the School of Graduate Studies when his or her judgment on the proposed use of the material is in the interest of scholarship. In all other instances, however, permission must be obtained from the Author.

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BIOGRAPHICAL SKETCH

The author, Solomon was born from his father Mr. AbebaKenea and his mother ShumaniGobana on August 25, 1987 G.C, in Guie Genet Abbokebele of Haru district, WestWollega zone, Oromia, Ethiopia. He has started and attended his schooling at Guie Genet Abbo primary school in 1995 G.C, and then continued secondary and preparatory schools at BiftuGimbi and Gimbi Comprehensive schools respectively from 2003-2007 G.C. In seek of his BSc degree; he joined Wondo Genet college of Forestry and Natural Resources, Hawassa University at 2007 G.C. He graduated on July 11, 2010, Bachelor of Science degree in Soil Resources and Watershed Management. In October 2010, he hired in Water, Mines and Energy offices of the Haru District of West Wollegga, where he had been working as Head of Water Resources Engineering section until September, 2016 when he enrolled in the Jimma University College of Agriculture and Veterinary Medicine to upgrade his educational level to Masters of Natural Resources Management (specialization in Soil Science). Now, he is presenting his Thesis work in partial fulfillment of the requirements for the Degree of Master of Science in Natural Resources Management (specialization in Soil Science).

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LIST OF ABBREVIATIONS

Bd	Bulk Density
C.V	Coefficient of Variation
CSA	Central Statistical Agency
CSAASS	Central Statistical Agency, Agricultural Sample Survey
DA	Development Agency
ECCCFF	Environment, Climate Change and Coffee Forest Forum
ERSS	Ethiopia Rural Socioeconomic Survey
Ex. Ca	Exchangeable Calcium
Ex. K	Exchangeable Potassium
Ex. Mg	Exchangeable Magnesium
Ex. Na	Exchangeable Sodium
GLM	General Linear Model
GPS	Global Positioning System
Kg	Kilogram
LSD	Least Significant Difference
m.a.s.l	meter above sea level
NRM	Natural Resources Management
NutriHAF	Diversifying Agriculture for Balanced Nutrition Through Vegetables in Multistory Cropping Systems
PA	Peasant Association
PBS	Percent of Base Saturation
PTN	Percent of Total Nitrogen
SAS	Statistical Analysis System
SEM	Standard Mean of Error
SESA	Strategic Environmental and Social Assessment
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SPSS	Statistical Package of Social Science
YDOARD	Yayu District office of Agricultural and Rural Development

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ABSTRACT

*The present study was initiated with aim of investigating the importance of homegarden agroforestry on improving soil properties with specific objective of evaluating selected physico-chemical properties under homegarden agroforestry and to compare with adjacent land use at Yayu district, Southwestern Ethiopia. Representative soil samples were taken from homegarden agroforestry with different age classes; new (Nh), established (Eh) and old homegarden (Oh), and from adjacent land of open cultivated land (Ocl), semiforest (Sf) and natural forest (Nf). Samples were collected in each site of soil sampling in Zigzag method from plot of 20mX20m at each soil depth of 0-30cm and 30-60cm by three replications, totally of thirty six composite soil samples were collected for analysis. Soil data was subjected to analysis of variance using the GLM procedure of the SAS version 9.3 and LSD test were used to compare treatment means at 0.05. The result showed significant difference in soil parameters analyzed.Considering the topsoil, the highest soil pH(6.06), available P(23.17ppm) and exchangeable K(6.53cmol(+)Kg^{-1})was obtained inold homegarden agroforestry, whereas the lowest (5.40), (5.81ppm) and (1.45 cmol(+)Kg^{-1})was in open cultivated land, in respectively. Regards to subsoil, the highest soil pH(6.18) available P (8.97ppm) and exchangeable (K 2.01 cmol(+)Kg^{-1}) in homegarden agroforestry, whereas 5.63, (2.34ppm) and (0.51 cmol(+)Kg^{-1}) respectively.Available p and exchangeable k was highly significantly associated with soil pH value at r=0.78** and 0.73** in topsoil, r=0.71**and r=0.87** in subsoil at $p<0.05$, in respectively. This soils property improvement in the soils of homegardens may perhaps due to house refuses bones and ash, animals manures, contribute of crop residues and litterfall to form SOM; as SOM mineralization form inorganic matter, and humification and buffering capacity of SOM; as it optimizes soil basic cations. Hence it can be concluded that, the soils in the homegarden agroforestry posses the improving trend in soils properties as compared to the adjacent land uses soils. Therefore the homegarden agroforestry practices that has been started and ongoing by the smallholder farmers for ancient time in Yayu district should be considered by NutriHAF and Government to scaling up the practices. Further, detail investigation on soils and plant nutrient analysis is important to clarify the impact of homegarden agroforestry on soil.*

Keywords: Homegarden Agroforestry, Soil Physico-Chemical Properties, Soil improvement.

1. INTRODUCTION

Homegarden agroforestry is considered as one of the sustainable farming systems. It is a land use system involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably livestock within the compounds of individuals houses, the whole tree – crops animal unit being intensively managed by family labour(Das and Das, 2005; Galhena *et al.*, 2013).Janaki and Evan (2005) defined the homegarden agroforestry as intimate, combinations of a variety of different woody trees and crops in homestead gardens; livestock may or may not be present. Etissa *et al.* (2016) defined homegarden agroforestry as "tree homegarden, mixed garden, household garden and compound farm.

Historically, the practices of the homegarden have been started in the fishing communities in Southeast Asia around 13000 B.C (Ong, 2014). Hence, homegardens practices are the ancient agricultural practice after shifting cultivation (Galhena *et al.*, 2013) and today it is widespread all over the world. Ethiopia is one of the ancient homegarden practices from tropical countries and has started the practice before about 5000 to 7000 years ago (Abebe, 2005). Many researchers evidenced that, the homegarden agroforestry of tropical country is mixed cropping systems that encompasses *Coffea arabica* L., *Enset ventricosum*, vegetables, fruits, plantation crops, spices, and herbs, ornamental and medicinal plants as well as livestock or the home of animals on the same land unit (Abebe, 2005; Glover *et al.*, 2013).

Therefore, the homegarden agroforestry considered as, repositories of genetic diversity, aside from providing environmental comfort, locations of family aggregation, food security and the other uses (Bargali, 2015). In fact of provides food; helps in reducing hunger and malnutrition and improving the livelihoods and provides social and cultural values thereby (Galhena *et al.*, 2013; Mekonen *et al.*, 2015).Therefore, it is an alternative sustainable farming system which is the surest way to dismount the today's conflict between food productions (Vieira *et al*. 2016).

Not only have those directed benefit, indirectly homegarden agroforestryis prominent solution to improve the soil fertility (Pinho *et al*, 2012; Ong, 2014; Kassa, 2016; Nimbolkar *et* *al*., 2016; Kumar and Tiwari, 2017). Moreover, roles of the homegardens agroforestry in the natural environments, or biodiversities conservation are illustrated by the different researchers (Kehlenbeck and Maass, 2004; Galhena *et al.*, 2013; Bekele, 2014; Demissew *et al.*, 2017).

In Ethiopia, indigenous knowledge has been shown to be of paramount importance for sustainable natural resource management practices including soil and water conservation in Konso (Tesfaye, 2003), irrigation practices in Tigray (Habtu and Yoshinobu, 2006), and stone bund in North Showa (Alemayehu*et al.,* 2006), forest around church in northern Ethiopia (Moges*et al.*,2013), also in fact, the practice of homegarden agroforestry become known in Ethiopia (Agize*et al.*, 2013; Kassa, 2016; Demissew*et al.*,2017).

This homegarden agroforestry establishment depends on the establishment of family of house establishment, whereas the purposesare toproduce the food, to generate income, fence, andboundary, as well as to reduces or alleviate severe scarcity of forest products in this study area (Gole, 2003; Etissa*et al.*, 2016; Yimer, 2017).However, very little is known about these homegardenpractices with regard to soil ecosystems; therefore thebenefitsor the constraints to natural resources is hidden. This is due to the extent and level of soil properties in relation to homegarden agroforestry with the adjacent land usewere not assessed, identified and quantified. However, the importance of homegarden agroforestry for soil environment was justifiedby different authors in various different areas(Pinho *et al.*, 2012; Vieira *et al.,* 2016), moreover, there is no concrete evidence regards to soils how and why these practice is maintained for a longer time of periodsin study area, Southwestern Ethiopia.

However, when comparing the conditions of the soils under original cover with soil from which it was removed or where a crop was planted, the resulting modifications / restoration or damage, especially with regard to soil fertility are generally visible, with greater or lesser evidence. Therefore, studiesof the soils' physical and chemical properties and variability are paramount importantto understand the changes and allow a rational intervention to ensure production on a sustainable basis, utilization, scaling up, corrections and site specific management practices of soil resources(Chimdessa, 2016).Hence, there is a need to know extent of soil properties under homegarden agroforestry system as compared with adjacent land uses; open cultivated land, semiforest and natural forest in Yayu district. To contribute to the research gap, this study was designed with the following general and specific objectives.

General objective

- To investigate the importance of homegarden agroforestry on improving the soil properties in Yayu district, Southwestern Ethiopia.

Specific objectives

- Toevaluate the selected soil physico-chemical properties oftopsoil and subsoil layer of soils under homegarden agroforestry and the adjacent other land use types.
- To evaluate the impact of homegarden agroforestry on soil properties compared to other land uses.

2. LITERATURE REVIEW

2.1. Overview of History and Evolution of Homegarden Agroforestry Practices

2.1.1. The concept of homegarden agroforestry and land use change

International concern is to find alternative farming systems that are ecologically and economically sustainable as well as culturally acceptable to local communities; whereas sustainable farming systems include traditional agroforestry systems (Molla and Kewessa, 2015, Alemu *et al.*, 2017). There are several types of traditional agroforestry practices in Ethiopia. Some of them are: homegarden agroforestry, coffee shade tree systems, and scattered trees on the farm land, woodlots, farm boundary practices, and trees on grazing lands (Gaba *et al.*, 2015; Kassa, 2016).

Homegarden agroforestry is a small-scale, supplementary food production system by and for household members by resembling the natural, multilayered ecosystem (Pinho*et al.* 2012). It is characterized by being near the residence, composed of a high diversity of plants, small, and important source subsistence foods and cash needs, diversify income communities (Ong, 2014).

Homegarden agroforestry has been differently defined by various authors. Kumar (2015) defined homegarden agroforestry as homegarden represent intimate, multistory combinations of various perennial and annual crops, sometimes in association with domestic animals, around the homestead which serves as a permanent or temporary. Janaki and Evan (2005), homegarden are intimate, multistory combinations of a variety of different woody trees and crops in homestead gardens; livestock may or may not be present. Similarly, Das and Das (2005) defined the homegarden as 'land use system involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably livestock within the compounds of individual houses, the whole tree-crop animal unit being intensively managed by family labor'.

Glover *et al.* (2013) study reported that many traditional homegarden agroforestry in several tropical countries are formed from fruit-producing trees. Etissa *et al.*, 2016, mentioned homegarden as; tree homegarden, village forest gardens, mixed garden, household garden, and compound farm. Hence, homegarden agroforestry is dynamic ecologically based natural resources management system through integration of trees on farms that diversifies agricultural landscapes and sustains production for increased social, economic, and environmental benefits (Tajebe and Gelan, 2018).

Land use defined as the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (Abad *et al*., 2014). Land use is the purpose of human activity on the land. Unlike land cover, land use may not always be visible and may not be inferable from land cover. For example, a unit of land designated for use as cropland may appear identical or not identical in land cover in an adjacent unit of protected forestland or, if recently harvested, may appear not to be a forest land cover at all.

2.1.2. Evolution of homegarden agroforestry practices in tropical country

The practice of homegardening was associated with fishing communities in the tropics due to the fertile soils along rivers and coasts that favored cultivation. Homegardening practice is an ancient agricultural practice after shifting cultivation (Galhena *et al*., 2013) and today it is widespread all over the world. Ong (2014) reviewed the report of Wiersum (2006), that homegardening practices have been started in Southeast Asia around 13000 B.C.

Kumar (2015) reported that, the homegarden agroforestry system is one of the most prevalent types of land use systems suitable for high rainfall areas in tropical conditions. Abebe (2005) who reviewed the works of Westphal (1975) and Okigbo (1990), described that, Ethiopia is one of the ancient homegardening practices from tropical countries and have started the practice of home gardening systems before about 5000 to 7000 years ago, especially in the southwestern part of Ethiopia, at altitude lay between 1500 – 2300 m.a.s.l., which is categorized as the highlands of Africa.

Study of Abebe (2005) evidenced the southwestern part of Ethiopia has the high potential of homegarden agroforestry with perennial crop zones, for instance, *Coffea arabica* L. grow in an intimate association with other crops, trees, and livestock in homegarden agrofo restry systems. Therefore, the main structural arrangements in most homegarden in Ethiopia are primarily either coffee *Coffeaarabica*L.or *Enset ventricosum* or both mixed with trees and shrubs, fruit trees or planted in different ways and purpose (Abebe, 2005); as it produces natural multilayered forest consisting of diversified agricultural crops and multipurpose trees. Generally, homegarden agroforestry of tropical country is a mixed cropping system that encompasses vegetables, fruits, plantation crops, spices, and herbs, ornamental and medicinal plants as well as livestock or the home of animals (Etissa*et al.*, 2016).

Hence Yayu biosphere reserve is one of the southwestern parts of Ethiopia and lies at altitude between 1139-2589 m.a.s.l., it is included in ancient home gardening practices (Gole *et al.*, 2009; Etissa *et al.*, 2016; Kassa, 2016; Yimer, 2017). Similarly, study by Gole (2003) pointed out that the multistoried crops of the Yayu area consists different tree crops: perennials, semiperennials and annual crop species, 6-10 different plant species.

2.2.Importance of Homegarden Agroforestry in Biodiversity Conservation

Besides of providing food, generating income and social value, due to homegarden agroforestry is formed from integrated trees, it has the potentials to protect soil erosion, protects natural resources degradation and improve soil fertility, control erosion and conserve biodiversity (Mattsson*et al.*, 2013;Powell*et al.*, 2013; Emiru, 2014; Bhargava, 2017). Homegarden agroforestry are known to bring about changes in floral and faunal composition and other components of the ecosystem, including soil environment, environmental modifications and soil buffering (Karyono, 1990; Abebe, 2005; Kassa, 2016; Yadda, 2007).

Report of Molla and Kewessa(2015) generalized that, homegarden agroforestry plays five major roles in conserving biodiversity:(1) provides habitat for species that can tolerate a certain level of disturbance; (2) helps to preserve germ-plasma of sensitive species; (3) helps to reduce the rates of conversion of natural habitat by providing a more productive, sustainable alternative to traditional agricultural systems that may involve clearing natural habitats; (4) provides connectivity by creating corridors between habitat remnants which may support the integrity of these remnants and the conservation of area-sensitive floral and faunal species; and (5) helps to conserve biological diversity by providing other ecosystem services.

2.3.Land Use and Land Use Change

Land use is generally designated through zoning or regulation and is one of the most obvious effects of human habitation on the planet (Chemeda *et al*. 2017). Land use types develop or vanish depending on the soil properties, the climate, the socio-political factors and the interest of the society or the landowner, which is often influenced by the social, ecological, and economic values attained from the land use (Duguma *et al*, 2010). Though all these factors are important in general, soil properties are critical determinant for the existence of a given land use type (Erkossa and Ayele, 2003; Chemeda *et al*, 2017).

The dynamics of land uses in the tropical regions are great global concern due to its direct impacts on one of the major biodiversity or ecosystems of the world, the tropical rainforest (Lemenih *et al*., 2004). Recently, due to population growth, forest lands are degraded and converted to agricultural lands (Abad *et al*., 2014). In countries like Ethiopia, where the forestland area dropped below 3% of the land cover and the human population is growing sharply almost doubling every 26.3 years, land use is under question i.e. the frequent and continuous utilization of the available land has continued. This resulted in severe land degradation in highlands of Ethiopia (Duguma *et al*., 2010).

With the increment of human and livestock population, temporary intensification of arable farms and grazing areas has begun to influence the soil properties in turn, as the expansion is based on the conversion of the existing forestlands, which are rich in organic matter and other important soil nutrients.

Land use changes from natural ecosystems into managed ecosystems resulted impact on soil properties (Abad *et al*., 2014). For instances, the changing of land uses from natural forests to farmland results reduction in soil nutrients (Chemeda *et al.,* 2017). Various studies have been conducted to assess the effect of land use changes on soil properties in Ethiopia (e.g. Lemenih *et al.,* 2004; Lemma *et al.,* 2006; Yimer *et al*., 2007, 2008).

2.4.Impacts of land useschange on soil properties

Homegarden agroforestry improve soil conditions and thereby promoting understory crop productivity, especially on degraded sites, fodder and firewood, high biodiversity, low use of external inputs, soil conservation potential, nutritional security, ecological benefits, socio-cultural as well as mitigation of the impact of climate change(Mohan, 2004; Ong, 2014; Vieira*et al,* 2016) .

In terms of the component of homegarden agroforestry, sequentially the situation of the maximum growth of the different woods, fruit, spices, vegetables and herbaceous occur at a different time (Abebe, 2005). In this case, the woody perennials usually increase the yields of subsequent crops and pastures by improving the soil conditions and as well as simultaneously associations sharing of space and resources such as light, nutrients, and water occurs (Glover *et al.,* 2013).

Homegardens are considered as an alternative to preserve and/or restore the fertility and productivity of degraded soils (Vieira *et al.*, 2016). Surface and subsurface soil characteristics tend to change depending on the land use system and vegetation cover (Abera and Wolde-Meskel, 2013). Pinho*et al* (2012) depicted that the litterfall, dead part of the plant body and the waste materials of animals, and human occupation in the homegarden improve the soil nutrient. Nutrient cycling is another ecological benefit of homegardens, the abundance of plant litter and animal wastes and continuous recycling of soil organic matter contributes to a highly efficient nutrient cycling system (Teuling *et al.,* 2010).

Similarly, Bhatt (2013) reported that agricultural practices combined with trees and livestock accelerate the capacitate of enhancing the accumulation of soil nutrients by providing continuous supplies of organic matter, and increases soil microorganisms in which the nutrient cycle is preserved.. For instance, the litter fall to the ground is occurring turn by turn and left on the surface, and it added to the soil part through decomposition. Miheretu and Yimer (2017) reported that farmers plant trees on a plot of land to minimizing soil loss, enhancing soil fertility and improving the productivity of impoverished lands to attain food security.

The study of Nimbolkar *et al.* (2016) in Hessaraghatta lake post of India, reported that, multi - cropping systems is a solution to reduce the impacts of floods, landslides and droughts and improves the soil properties by increasing infiltration capacity, decrease bulk density and increase soil porosity, decreases soil acidity, protect soil from erosion, adds nutrient and increase productivity of soil.

Kehlenbeck and Maass (2004) reported that the forest like vegetation structure of homegardens (Fig.1) contributes significantly to the sustainability of this production system, due to this structure can protect the soil from erosion. Kumar and Nair (2004), besides the multi-tiered homegarden litter layer, its canopy and root architecture act as the multi-layer defense mechanism against the impact of the falling raindrops resulting in low rates of soil erosion.

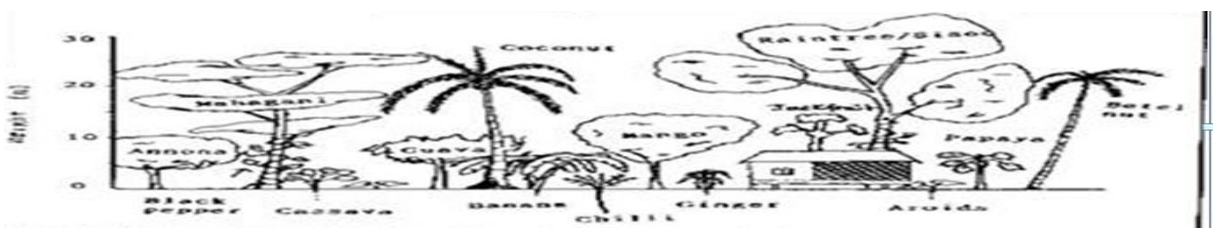

Figure 5: The schematic model structure and composition of the homegarden Agroforestry in the homestead (Sources: Rahim and Islam, 1998).

2.3.1. Soil physical properties as affected by land use types

Literfall, the dead body of different plants from lower leaf of trees/ crops, house refuse, animal manure and compost are known to improve soil physical properties (Yadda, 2007). Land use and soil depth are, therefore, extremely important factors for determining soil physical properties, mostly soil structures (Abad *et al.*2014). The adaptability to cultivation, the soil's water and air supplying capacity to plants and the level of biological activity (Chemeda *et al.,* 2017). Vieira*et al.* (2015) reported that, soil properties vary within different soil depth due to the instrument used to plow, plant root mechanisms and human occupation. The diversity of plants associated with other organisms contributes to the formation and maintenance of soil structure, retention of moisture and nutrient levels and promotes the recycling of nutrients.

Soil texture affects the infiltration and retention of water, soil aeration, absorption of nutrients, microbial activities, and tillage and irrigation practices. Clay soils have the ability to hold water than the sand and silt. Chemeda *et al.* (2017) reviewed Lilienfein *et al.* (2000) that, soil texture is also an indicator of the type of soil parent materials within the profile and intensity of soil material weathering.

Texture is an inherent soil property that not influenced in a short period of time by land use (Chemeda*et al*, 2017). On other land, the study of Abad *et al*.(2014) in Iran, reported that, land use changes from forest to agriculture resulted in significant decreases in silt contents(67 to 52%), aggregate stability(1.58 to 0.68mm), with this change, bulk density(1.21 to 1.58), and sand content(11 to 58%) increased significantly but, no significant change in the clay among studied land use types.

Similarly, the study of Kiflu and Beyene (2013) in southwest Ethiopia identified that, the soil texture of soils in the grassland was clay loam, whereas soil texture in enset and maize land was loam and remained the same and author suggested that, the difference wasdue to accelerate weathering as a result of disturbance during continuous cultivation soilstructure.In contrasting, study of Abad *et al*. (2014) in Iran, reported that, soil texture responded to following the change of land use. In the authors' study, land use changes from forest to agriculture land resulted in significant variation in silt contents (67 to 52%) and sand content (11 to 58%) increased respectively, but, no significant change in the clay among studied land use types.

Soil structure variation attributed due to differences in land management practice and land use history and it is the mass of a unit volume of dry soil, as well as its measurement (Moges and Holden, 2008), is required for the determination of compactness, as a measure of soil structure, for calculating soil pore space and as an indicator of aeration status and water contents. The changes in the soil physical properties under the tree cover can be attributed to the impacts of plants' root, litterfall and the increase in SOM content of the soil (Yeshaneh, 2015). Bulk density also provides information on the environment available to soil microorganisms. Soils having low and high bulk density exhibits favorable and poor physical conditions, respectively. Therefore, bulk densities of soil horizons are inversely related to the amount of pore space and SOM (Bhattacharyya *et al.*, 2004).

The factors that influences soil pore space such as the manner of cultivation, the instrument used for plowing, the time period of fallowing and etc will affect the bulk density (Ong, 2014). For instance, intensive cultivation increases bulk densities resulting in a reduction of total porosity, by confirming this statement, the results from a study by Adugna*et al.*(2015) showed that soil amendments through animal wastes reduce bulk density and compaction, increases pore spaces and infiltration capacity, which ultimately reduce runoff and soil erosion. Similarly Tefera *et al.*(2003) review reported that the grazing of leftover residues on cropland after harvesting cause soil compaction due to heavy and continuous trampling by livestock.

2.3.2. Soil chemical properties as affected by land use types

The chemical reactions that occur in the soil affect processes leading to soil development and soil fertility build up (Yeshaneh, 2015). Minerals inherited from the soil parent materials over time release chemical elements that undergo various changes and transformations within the soil. Soil reaction is the degree of soil acidity or alkalinity, which is caused by particular chem ical, mineralogical and/or biological environment. Soil acidification is a process by which soil pH decreases over time due to natural (high rainfall and leaching of nutrient such as basic cations), human occupation (fertilizer inputs), parent materials, and weathering of soils(Sanga, 2013; Wagh and Sayyed, 2013).

Unlike the other land use, somehow, soil acidity in the soil under tree cover (e.g. homegarden)reduced due to different inputs is supplied to the soil (Pinho*et al*, 2012; Vieira*et al*. 2016). According to study of Kiflu and Beyene (2013) in Ethiopia, the soil pH value obtained in homegarden (6.73, 5.9) was significantly different from park land (4.90, 4.63) and woodlot (4.63, 4.5) in surface and subsurface respectively. Also poorly managed cultivation; inappropriate use of ammonium based fertilizers and accelerated erosions that implied the degradation of soil quality. In another hand, soil depth can affect the soil pH due to the presence of soil organic carbons, as well as long duration of forest on specific land due to decrease soil pH due to prolonged uptakes of basic cations by tree roots (Moges*et al*., 2013).

Study of Moges*et al* (2013) in Sidama Zone, South Ethiopia, the soil organic carbon and total nitrogen in protected forest were 4.18% and 0.26%, whereas that of in farmland was 1.98% and 0.14%, respectively, but, soil pH-value was increased from forest land (5.97) to farmland (6.15). Abad *et al*. (2014) reported that land use changes from forest to agriculture resulted in significant decreases in N, P, K and organic matter significantly, but, no significant change in CEC among studied land use types.

Yimer*et al*. (2007) had been compared croplands, forestlands and grazing lands and they found that the content of SOC and TN decreased in croplands when compared to forestlands as tree/crop residues, root biomass and litterfall are important.The study of Kiflu and Beyene(2013) in Ethiopia, extrapolated that, nitrogen content in homegarden was significantly ($p<0.05$) different from the other land use type; for instance, they obtained the TN% in homegarden land, parkland and woodlot, 0.16, 0.14 and 0.13%intopsoil, 0.14, 0.12 and 0.11% in subsurface of homegarden land, park land and woodlot,in respectively.

In addition, organic fertilizers such as livestock manure, ash, and leaf litter applied to soil simultaneously through homegardening practices to soil environment; especially the perennial fruit tree-based production system has been found successful to improve the soil characteristics (Chitakira and Torquebiau,2010; Megersa, 2011; Nimbolkar*et al.* 2016). Nitrogen (N) is the forth plant nutrient taken up by plants in greatest quantity next to carbon, oxygen, and hydrogen, but it is one of the most deficient elements in sub-Saharan Africa, especially in the tropics for crop production. Continuously and intensively cultivated and highly weathered is lower in nitrogen content (Chemeda *et al.*, 2002).

CEC is an important parameter of soil because it gives an indication of the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assessing their fertility and environmental behavior. Land use and soil depth are the factors that affect CEC of soils; for instance, according to a study conducted by Emiru and Gebrekidan (2013) in western Ethiopia, conversion of natural forest land into grazing and cultivated lands caused losses of CEC in the magnitude of 38 to50%, respectively, in the surface (0-30 cm) soils.

According a to study of Kassa *et al* (2017) in Nile basin, Ethiopia, in topsoil, cation exchange capacity and the exchangeable base cation of homegardens agroforestry are significantly different fromthe open cropland ($P < 0.05$). However, the authors obtained the same CEC and exchangeable base cations regarding samples of area under coverage of vegetation.

Vieira *et al.* (2016) explained the relation between the basic cation with the SOM and soil reaction.Soil parent materials contain potassium (K) mainly in feldspars and micas. As these minerals weather, and the K ions released become either exchangeable or exist as adsorbed or as soluble in the solution. Conversion of forest land into cropland can increase losses of potassium (k) which could be attributed to run-off and crop residue clearing. Gong *et al.* (2005)also indicated that harvest could take high K values from the soil and hence results in lowering K levels in agriculture fields. Potassium is the third most important essential element next to N and P that limit plant productivity (Brady, 2002). Its behavior in the soil is influenced primarily by soil cation exchange properties and mineral weathering rather than by microbiological processes.

Exchangeable Na alters soil physical and chemical properties mainly by inducing swelling and dispersion of clay and organic particles resulting in restricting water permeability and air movement and crust formation and nutritional disorders (decrease solubility and availability of calcium (Ca) and magnesium (Mg) ions (Chemeda *et al.*, 2017).Moreover, it also adversely affects the population, composition, and activity of beneficial soil microorganisms directly through its toxic effects and indirectly by adversely affecting soil physical and as well as chemical properties.

3. MATERIALS AND METHODS

3.1. Description of the Study Area

3.1.1 Location

The research was conducted in Yayu district, which is situated in Ilu Abba Bora Zone of the Oromia National Regional State, Southwestern Ethiopia (*Fig. 2*). The geographical location of the area is between 08° 10’ 00” N to 08° 30’ 00 ” N latitude and 35° 00’ 00 ” E to 35° 40’ 00 ” E longitude. The altitude ranges from 1, 139 to 2, 300 m.a.s.l, which is the location of potent ial Ethiopian forest (Gole *et al.*, 2008; Etissa *et al.*, 2016) and it share the boundary with the Hurumu district in the south, the Doreni district in west, Chora district in the north and Jimma zone in the east. The district was purposely selected due to the fact that it consist more homegarden agroforestry (Etissa *et al*., 2017, Duguma, 2017).

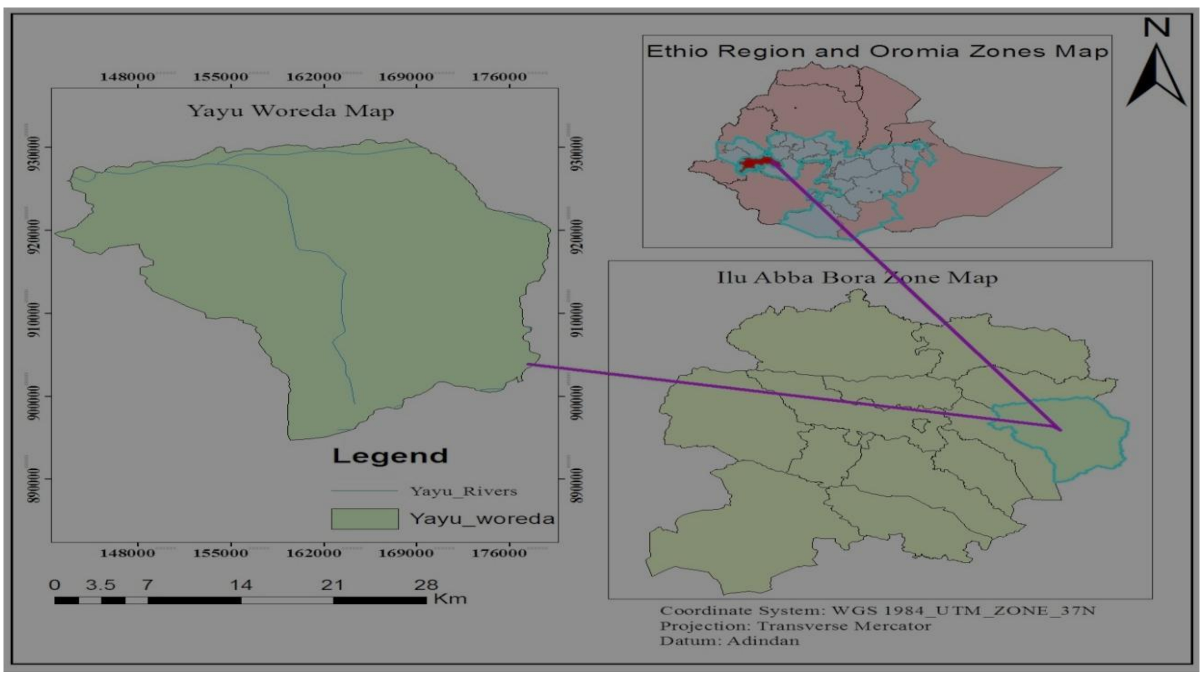

Figure 2: The map of the Yayu district, January, 2018.

3.1.2. Population of the study area

Table 1: Population of Yayu District

Total population			Rural population			Urban population			Households		
Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
35,135	34,668	69,803	29,121	28,484	57,605	6,014	6,184	12,198	9,974	1,820	11,794

Source: Extracted from CSA, (2017).

3.1.3. Climate

There is some variation in temperature throughout the year, with the hottest months from February to April (29°C) and the coldest months during July to September (12°C).The mean annual temperature is about 20°C. The mean annual rainfall is 2100 mm per year with high variation from year to year, ranging from about 1400–3000 mm per year as reported by CSA(2017).

3.1.4. Vegetation cover

The study area is rich in coffee (Coffea arabica) genetic diversity, home of coffee arabica genetic reserve and many crops (Gole, 2002; Gole, 2003 and Gole et al., 2008). The area is under forest management practices with clear gradation of human intervention: forest garden, semiforest with coffee arabica production system, and a protected forest with wild coffee arabica population and riverine vegetation. Some of the major trees are: Ambaltaa (Entada abysinicca) oobdaa (Ficusvasta), kosoo (hagenia abysinica), laaftoo (acacia sieberiana), Eebicha (vernonia amygdalina), hoomii(prunus Africana), sootalloo (militia ferruginia), mukarbaa(albizia gummifera), Qayii(celtis Africana), Arbu (ficus sur), Gatama(oleacapensis welwitschii) and Bosoqa(sapium elliptical) (Duguma, 20017; Yimer, 2017).

3.1.5. Hydrology

The study area is an important catchment of the Nile basin, with comparatively higher forest covers than any other area in Ethiopia (Gole, 2003) whereas around 80% of the water flow in the Nile comes from the highlands of Ethiopia. Selassie and Ayanna (2013) reported that the highlands of Ethiopia, with altitude 1500 meters above sea level (m.a.s.l), are the dominant sources of water. Many rivers like Geba, Dogi, Saki, and Sese, which discharge into Baro River (Gole *et al.*, 2009) originate, or drain this forest and others within the region, and flow into the Nile River. Being a high rainfall area (over 2000 mm/year), the contribution of water from the Ethiopian areas is quite high. Hence, sustainable management through a biosphere reserve approach can contribute significantly to the local and regional hydrology.

3.1.6. Soilsof the study area

The soils of the study area are classified as *Orthic Acrisols (Nitisols)* and acidic in reaction, whereas the area is under the humid sub-regions(Tefera *et al*., 2003; Takala, 2018; Teshale, 2018). These soils are deep andhave high potential for agricultural uses on which subsistent farmers of the study area dependson grow a variety of crops and graze livestock.

3.1.7. Main land use types

Yayu Coffee Forest Biosphere Reserve that has been registered by UNESCO in 2010 and is under the management of UNESCO, which focuses on conserving biodiversity, therefore, the study area, has three different the management zones (Gole, 2003). These are (1) Core zone (protected forest area), (2) Buffer zone (semi-protected) and (3) Transitional zone (the area where the human interference is taking place).

The transition zone area is where the resident life and human inference are taking place; whereas, the area is covered by a small-scale mosaic of different land use types and intensities; cereal crop or agricultural land with and without scattering trees, homegarden agroforestry, which composed from perennials, semi-perennials and annual crops, grazing land and fallows.

Adjacent to this transitional zone, semiforest lands (Buffer zone) are covered by less dense forest because of human interference is partially allowed to weed and collect the coffee bean without impacting the forest trees. Next to this semi forests, and covering alongside of rivers, natural forest lands (Core zone) are occupied by dense forest with wild *coffea arabica* and different spices (Gole, 2003, Gole *et al*, 2009; Etissa *et al.*, 2016).

Table 2: Description of land use types in YayuDistrict

Land use types	Natural forest	Semiforest coffee	Plantation coffee	Crop field	Wetland	Grazing	Settlement and home-gardens	Total area
Area (ha)	47,774.75	22, 804.33	402.75	8, 885.1	302.75	1,732.5	2,717.85	84, 620.03
Percent (%)	56.46	26.95	0.48	10.50	0.36	2.05	3.21	100

Source: Extracted from YDOARD (2017)

3.1.8. Farming systems

There are four main farming systems in the study area; 1) Annuals crop land, 2) Homegarden agroforestry, 3) Plantation coffee and 4) Semiforest coffee systems. Open cultivated land is dominated by annual crops / mostly monocropping systems/ cereal crops such as maize (*Zea mays*) teff (*Eragrostis tef*), barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*) and sorg hum (*Sorghum bicolor*)(Etissa *et al.*,2016). Homegarden agroforestry land is dominated by complex farming that consists of annual crops, semiperennials crop, perennials, tree/crop and different livestock (Yimer, 2017). Beside these, there are many trees in the homegardens (Etissa *et al.*, 2016*)*.

3.1. Research Design and Methodologies

3.1.1. Site selection, soil sampling and preparation

3.1.1.1. Site selection

The field work was started with the reconnaissance survey in the study area to obtain the basic information needed for field work. During a reconnaissance field survey started from December 2017, the biophysical observation was carried out to have the general view of the environmental variations in land use types, history of cultivation; cropping systems and soil use. The procedures for selection of study site were started on 1st January 2018 with the assistance of Horticultural Crop expert, Rural Development expert, Natural Resources Management expert from sector of YDOARD and local farmers in the study area. To achieve the selection of study site, three kebeles; Bondao – Megela, Gechi, and Wabo those within the same climate, environment, similar topography and soil uses, were purposively selected from Yayu district, depending on their potential of homegarden agroforestry.

In the procedureof selecting the specific site, two-sampling stage was used to select the specific sampling sites. On 1St stage, homegarden with different age classes was purposively selected and delineated from Bondao-Magela, Wabo and Gechikebeles by using the method described in Pinho *et al.* (2012).Then the total of 42 homegarden agroforestry systems were identified by total counting in three kebeles, whereas 17 were new homegardens (0-10 years-old), 14 were established homegardens (15–35-years old), and 11 old homegardens (more than 40-years old). In the 2ndstage, by using the simple random sampling method, 3 homegarden were selected for soil sampling in each homegarden age category (i.e. 3 new, 3 established and 3 old homegarden) for convenience of replication of the sample, whereas total 9 homegarden were selected for soil sampling.

For each homegarden selected for soil sampling, samples were also taken from each adjacent open cultivated land, semiforest and natural forest, for a total of 9 samples. Generally, the representative soil sampling site, duration of establishment, category of the age (in year) classes of homegarden agroforestry and other land use systems at in the study area are described as follows:

Open cultivated land (*Ocl*): Land adjacent to homegardens and settlement where mono crop (cereal crops) is cultivated, and this farm system, were started on this agricultural land before 1997 G.C and continued up to 2017. Most of the transitional zone in the study areas is covered by this land use type, whereas it is around 87% of the study area. The bulk of the residues of those crops was used as a fuel for cooking by the rural and nearest town dwellers, livestock feed while the remaining are burnt on cropland (*Appendix-II Figure 1*).

New homegarden (*Nh*): Homegarden plot where the seedlings of different fruit trees are established earlier from the years of 2007 G.C. With and under that crop/seedling, there are different shade-tolerant crops: cereal crops, climbers, vegetables, coffee seedling, root tubers, and spices (Appendix-II Figure 2). Cut and carry is common in order to protect livestock impact on early vegetation.

Established homegarden (*Eh*): The land consisted of different fruit trees, climbing trees, and seedling of legume trees that has been planted starting from1982G.C. Under these crops /trees, there are different shade-tolerant crops: climber's crops, vegetables, coffee and coffee seedling and different spices (*Appendix-II Figure 3*). Cut and carry for animal feeding are common, but, not at all.

Old homegarden (*Oh*): The land consisted different old fruit trees, coffee, different big shade trees and in or under those crops/trees different spices and vegetables, livestock and others (wild trees, legumes tree and animals, and mammals), while the formation/ establishment of homegarden was before the year of 1977 G.C (*Appendix-II Figure 4*).

Semiforest (*Sf*): Forest land where some nondestructive uses are allowed (Buffer zone). Picking the ripe fruits of coffee, and honey production can be practiced with care and frequent monitoring(Gole, 2003; Etissa *et al.*, 2016). Farmers enter the semiforest only for weeding and collection of coffee beans (*Appendix-II Figure 5*).

Natural forest (*Nf*): Land covered by undisturbed natural forest which encompasses native *Coffeaarabica (Core zone*) (Gole, 2003; Etissa *et al.*, 2016). The area is protected by government and community, while the residents enter only for the collection of coffee beans (*Appendix-II Figure 6*).

3.1.1.2. Soil sample collection and preparation

Soil samples were collected after crops harvested and were started in mid-January, 2018. GPS and clinometers were used in the geographical location and slope measurement of the soil sampling sites. The main factors such as depth, sampling intensity per unit area of the site sampled, and the sampling design was usually considered when developing soil sampling protocols to monitor change in major soil property parameters.

Soil samples in the homegarden were taken outside the periphery of the periodically swept and weeded bare earth ‘‘yard’’ that surrounds the dwelling, with a 20m X 20 m plot marked out in a location with greater density of trees as method described by Madalchoand Tefera(2016). In each homegarden plot (*Nh, Eh and Oh*) marked for soil sample, fifteen soil subsamples were taken by Zigzag method according to the method used by Yeshaneh (2015) and mixed to obtain one composite sample and separately at the different depths of 0–30cm, and 30–60cm according to the method used by Sharma *et al.* (2014) for investigation of the soil physico-chemical properties in the rooting depths of fruit trees/ perennial crops.

Then after, similar procedures in soil sampling in homegarden were made in the adjacent three land use types; open cultivated land(*Ocl*), semiforest (Sf) and natural forest(Nf), nine(9) composite soil samples were taken. Accordingly a total of thirty six composite soil samples (6 land uses X 2 soil depths X 3 replication) were collected. Separated soil samples from each plot of soil samples were taken with a core sample from each soil depth for determination of soil bulk density following the Bashour and Sayegh (2007).

To minimize error factors, representative soil sample was kept free from contamination, leaves, litters, dead plants, furrow, manures, wet spots and compost pits during collection of soil samples. Finally, soil samples were prepared, properly labeled, and packed in plastic bag, and then transported to the laboratory for analysis. Then, a soil sample was air dried, crushed, mixed well and passed through a 2mm-sized sieve for the analysis of soil properties in Jimma University College of Agriculture and Veterinary Medicine Laboratory of Soil Science.

3.2. Soil analysis

Except for the determination of bulk density(Bd)which transported to soil laboratory processing immediately on January 18, 2018, the selected soil physico–chemical properties; soil texture(sand, silt and clay fraction), soil pH, soil organic carbon(SOC), total nitrogen (TN%), available phosphorus(Av.p), cation exchangeable capacity(CEC), basic cations (Ca, Mg, K, Na) and percent of base saturation(PBS) wereanalyzedinFebruary, 2018.

Bulk density was determined from undisturbed soil samples by the core method after drying a defined volume of soil in an oven at 105 °C for 24 hours (Black, 1965). For bulk density calculation, the mass of each empty core (a), and the mass of each core with its dry soil (b) were used, as the standard formula described in Dadey*et al*., (1992).

Bulk density (g/cm3) = (weight of oven dry soil in gm (b-a))/(volume of core in cm3)………………..…1

For soil texture, initially the soil sample was pretreated with H_2O_2 (30%) to remove any organic material and sodium hexametaphosphate to disperse clay. The density of the soil suspension was determined by a Bouyoucoshydrometer method (Day, 1965) to read in grams of solids per liter after the sand settles out and again after the silt settles. A correction was made for the density and temperature of soil-water suspension. Percentage of particle size classes were identified according to the USDA textural triangle (USDA, 1987).

Soil pH (H_2O) was measured by using a pH meter in a 1:2.5 soil: water ratio (Van Reeuwijk., 1992). Soil organic carbon (SOC) was estimated by the Walkley-Black wet oxidation method and converted to soil organic matter (SOM) by multiplying the percent organic carbon content by a factor of 1.724, assuming that organic matter is composed of 58% carbon (Walkley and Black, 1934). Total nitrogen was determined by the micro Kjeldahl digestion, distillation and titration method as described in Sahlemedhin and Taye(2000). Available phosphorous was determined using the standard extraction method for PH< 7 Bray II method (Bray, 1945).

An amount of Ex.Ca^{2+} and Mg^{2+} in the leachate was analyzed by atomic absorption spectrophotometer at a wavelength of 422.7and 285.2nm respectively. The Ex.K^+ and Na^+were analyzed by flame photometer method with a wavelength of 768 and 598nm respectively (Houba *et al.,* 1989).Cation exchange capacity (CEC) was determined at a soil pH level of 7 after displacement by using 1N ammonium acetate method in which it was estimated titrimeterically by distillation of ammonium that was displaced by sodium (Chapman, 1965). Percent of base saturation (PBS) was calculated by dividing the sum of the base forming cations (Ca, Mg, Na, and K) by the cation exchange capacity (CEC) of the soil and multiplying by 100 as the standard formula described in Fageria*et al.* (2011).

*PBS% = [(Ca2++ Mg2++ Na++K+)/CEC] *100 ……………………..………………..……………2*

3.3. Statistical analysis

The soil physical and chemical propertydata were subjected to analysis of variance using the general linear model (GLM) procedure of the statistical analysis system of version 9.3(SAS Institute, 2011). The least significance difference (LSD) test was used to separate significantly differing treatment means after main effects at the probability significance level of 5%. Moreover, simple correlation analysis was executed with the help of persons' correlation coefficient to decide the magnitudes and directions of relationships between selected soil physico-chemical property parameters at 1%and 5% levels.

4. RESULTS AND DISCUSION

4.1. Soil Physical Properties

4.1.1. Soil particles size distribution

In 0-30cm of soil depth, among studied land uses, the natural forest consist the highest clay fraction (38.67%) whereas the open cultivated land (20.67%) was the lowest (*Table 3*). More or less the clay content in 0-30cm homegardens exhibited the positive trend in the clay content as mean value in land use studied was Ocl < Nh < Eh <Oh ≤ Sf≤ Nf in clay fraction(*Table 3*). The presence of high clay fraction in 0-30cm in homegarden agroforestry next to semiforest and natural forest may be due to the presence of various trees and shrub canopy, litter and root protection of the surface soil from translocation and soil erosion.

In another way, highest clay content in natural forest showed the complete alteration of weatherable minerals into secondary clays and oxides (Buol*et al.*, 2003). Statistically, clay content of surface of new and established homegarden was significantly ($p<0.05$) greater than soil of open cultivated land, whereas old homegarden was similar with semiforest.

The lowest clay content in soils of open cultivated land probably due to the reducing degree of the weathering, as silt fraction defaulted lowest in the open cultivated landdue to exposed to erosion. According to the study of Albert and Modenhauer (1981), finer soil fractions (clay) are more subjected to losses by erosion. Similarly, the statement is confirmed by Beshir*et al.*(2015) who reported that the lowest clay content at cultivating land in Southwest Ethiopia. Contrasting of the present study, the study of Moges *et al. (*2013) reported that the higher clay fraction was obtained at soils under farmland than other land use types, they suggested that, the case of cultivation of soil promotes further weathering processes as it shears and pulverizes the soil and changes the moisture and temperature regimes.

In 30-60cm of soil depth, soil clay content was not showed any significant ($p<0.05$) variation in studied homegardens and land use.Topsoil clay content was positively and highly significantly associated with the CEC ($r = 0.71^{**}$) and Ca($r = 0.89^{**}$), whereas it was negatively and significantly correlated with the sand fraction ($r = -0.79^{**}$) as described inthe tablebelow(*Table 6*).Texturally, in 0-30cm of soil depth, except that of in soils of open cultivated land which is sandy clay loam for all land use studied was clay loam (CL). In 30 – 60cm, soil texture ofthe open cultivated land, new and established homegarden were sandy clay loam, while the texture of the soil under the old homegarden, semiforest, and the natural forest was loamy as shown (*Table 3*). This difference in soil textures could be due to the influence of age of vegetation on soil properties. As Zinke (2015) reviewed Jenny (1941), the function of time determines the magnitude of soil properties as it is one of the soil forming factors.

4.1.2. Soil bulk density

The result revealed that bulk density values were very highly significantly ($p<0.05$) showed variations in land use at different soil depths (*Appendix - I Table 1*) as shown in table (*Table 3*). Regard to topsoil, highest bulk density was recorded in open cultivated land (1.29gcm^{-3}), while the lowest was obtained in old homegarden (0.94gcm^{-3}) and semiforest (0.90gcm^{-3}). The highest bulk density recorded in soils of open cultivated land may be attributed to the compaction resulted from the continuous tillage of cropland, free grazing after harvesting on cropland and leaching of poor dense soil particles by erosion during rainy season as removal of crop residues was adopted in the study area.

In other hand, the lowest soil bulk densities obtained in aged homegarden agroforestry and semiforest probably due to the change in soil physical properties resulted from association of different trees/ crops systems, as a result, those trees/crops increase the soil porosity. This statement is in agreement with the study of Ahmed *et al. (*2012) in Sudan and Haile (2012) in South Ethiopia.Statistically, even the soil bulk density in new and established homegarden was significantly ($p<0.05$) showed similar with that of natural forest (*Appendix-I Table 1*). Generally, this result indicated that soil of new to old homegarden agroforestry showed the descending rate of soil compaction compared to the soils in open cultivated land, due to addition of soil organic matter in vegetative cover accompanied with increasing age.

Regard to subsoil, the highest soil bulk density was obtained in an open cultivated land (1.32gcm^{-3}) and new homegarden (1.26gcm^{-3}), whereas the lowest was obtained in old homegarden (1.06gcm^{-3}) and semiforest (1.00gcm^{-3}) as shown in table (*Table 3*). The highest bulk density obtained in the subsoil of open cultivated land may be due to tilling during the wet season. This result is confirmed by the report of Clogger (2014).

On the other hand, low bulk density resulted in soils of old homegarden next to in soils of semiforest attributed to the more litter of trees, crops and the weed decomposition and mixed with soil and form organic matter, as result, soil particles loosely attached to each other. Soil organic matter contentincreases the volume of soil without affecting its weight.This statement is constituted in Bhattacharyya *et al.* (2004), who reported that bulk densities of soil horizons are inversely related to the amount of pore space and SOM, because OM makes soils loose, porous, or well aggregated and thereby lowers bulk densities. Similarly, this is a result that is similar to finding of Amanuel*et al*. (2018) and they reported that the lower bulk density in the soils under forest and higher bulk density in soils under cultivated land were attributed to the differences in soil organic matter and less disturbances under forest land use than in the cultivated land.

Additionally the loosely and fine soil particles removed by erosion from the surfaces of open lands could be anchored by a plant's root; as increases the soil pore. This study agrees with the study of Bargali (2015) who stated that soil bulk density under canopy trees/ vegetation varied from soil in open areas due to root biomass and cover mechanism as they play an important part in the maintenance of the soil fertility.

Table 3: Sand, silt and clay fraction,and soil texture and bulk density oftopsoil and subsoilunder new, established and old homegarden agroforestry, open cultivated land, semiforest and natural forest.

SP	*Ocl*	Nh	Eh	Oh	Sf	Nf	LSD	CV	P
				Soil depth(0-30cm)					
Sand %	52.33 ± 3.18^{a}	43.67 ± 2.96^{b}	38.33 ± 1.20^{c}	26.33 ± 0.33^{d}	32.67 ± 2.85^{cd}	35.00 ± 4.16^{c}	7.44	10.75	0.0002
Silt %	23.67 ± 1.20^{d}	30.33 ± 0.88^{bc}	31.67 ± 1.45^{b}	41.33 ± 0.88^{a}	31.67 ± 2.60^{b}	26.33 ± 1.76^{cd}	5.13	9.15	0.0003
Clay%	20.67 ± 0.88^{e}	25.00 ± 1.15^{d}	30.00 ± 0.58^{c}	32.33 ± 0.67^{bc}	35.67 ± 1.86^{ba}	38.67 ± 2.67^{a}	4.04	7.30	0.0001
STC	SL	CL	CL	CL	CL	CL			
BD	1.29 ± 0.01^{a}	1.20 ± 0.01^{ab}	1.13 ± 0.01^{b}	$(0.94\pm0.03)^{c}$	0.90±0.03c	1.19 ± 0.08^{ab}	0.11	5.65	0.0001
				Soil depth(30-60cm)					
Sand %	51.00 ± 0.58^{a}	48.67 ± 0.88^{ab}	43.67 ± 0.33^{ab}	41.67 ± 0.33^{ab}	41.67 ± 10.35^{ab}	36.67 ± 2.19^{b}	14.24	17.83	0.3300
Silt %	21.33 ± 0.88^{c}	21.67 ± 0.33^{c}	25.67 ± 0.67^{b}	28.67 ± 1.20^{a}	25.00 ± 1.35^{b}	23.67 ± 0.67^{cb}	2.78	6.28	0.0014
Clay%	31.33±2.19	26.33±0.88	28.33±2.19	31.33±0.67	33.33±9.41	39.67±1.86	13.78	23.88	0.4119
STC	SCL	SCL	SCL	L	L	L			
BD	1.32 ± 0.01^{a}	1.26 ± 0.01^{a}	1.12 ± 0.01^{bc}	1.06 ± 0.06^{c}	1.00 ± 0.04^{c}	$1.22a\pm0.06^{b}$	0.13	6.04	0.0015

Ocl = open cultivated land, NH = new homegarden, Eh = Established homegarden, Oh = old homegarden, Sf = semiforest NF = natural forest, CL = clay loam, SL = sandy loam, SCL=sandy clay loam, L=loam;LSD=Least significance difference; CV=coefficient of variation.
**Mean value ± SEM with the same letter within the same row and depth are not significantly different from each other at $p < 0.05$*

4.2. Soil Chemical Properties

4.2.1. Soil reaction (soil pH)

In 0-30cm of soil depth,soilpH in the soils of old homegarden showed the greatest($p<0.05$) difference from all studied land use (*Appendix-I Table1*), whereas that of established homegarden was statistically similar tothat of semiforest as shown in table (*Table 4*). The highest and the lowest soil pH-values were recorded in old homegarden (6.06) and open cultivated cropland (5.40) respectively. This highest soil pH value could be due to basic cations (e.g. Ca^{2+}) inputs to soils in the form of bones and ashes, and to a lesser extent, buffering by organic matterandthe ameliorating effect of the high accumulation of organic matter. This statement is in agreement with the study of Madalcho and Tefera (2016). The presence of lower soil pH value in open cultivated cropland could be related to the decrease in base forming cations (Ca^{2+}, K^{+}, Mg^{2+} and Na^{+}) through a continuous nutrient cation uptake by plants during repeated cultivation and leaching and soil erosion loss, as stated by Kidanemariam*et al*.(2012) and Kassa*et al*. (2017).

In 30-60cm, soil pH value in the soils of established and old homegarden showed greatest significant ($p<0.05$) difference, while that of in new homegarden was statistically similar with open cultivated land, semiforest and natural forest(*Table 4*).The existence of high subsoil pH in forest like homegardens may be related to the availability of high exchangeable bases cation (because of the organic matter decomposition and weathered parent material by the tree, shrub and mycorrhizal fungi function in the subsoil). This finding is in accordance with the findings of Sharma *et al*.(2014).The lowest soil pH value in open cultivated land probably associated with high rainfall in the study area which washes out soluble basic cations from the deep soils; as a results reduction in CEC. This statement is in agreement with study of Wagh and Sayyed(2013).

Generally, while comparing the soil pH-value in the topsoil and subsoil of open cultivated land, all soil pH-values in soils of homegarden weregreatest at $p<0.05$.This increasing of soil pH- value in homegardensindicated that the trends of reducing the level of the soil active acidity due to the formation of basic cations in contribution of litterfall and residues to the soils. This is constituted in the study of Pinho *et al.* (2012).

This soil acidity may be attributed to the acidic nature of the parent materials and somehow extensive weathering of the soils and leaching, and the mostly due to the removal of basic cations from the surface. This is in agreement with the study of Negassa, (2001) and Sanga (2013). The soil pH values in for the present study were less than the soil pH value reported by Yeshaneh(2015) in South Wello Zone, North Ethiopia.

4.2.2. Soil organic carbonand percent of total nitrogen

In 0-30cm, organic carbon in the old homegarden showed greatest and significantly ($p<0.05$) varyfrom the open cultivated land, new homegarden and established homegarden, but statistically similar to that of the semiforest and natural forest as shown in the table below (*Table 4*). The highest soil organic carbon was measured in the soils of old homegarden(5.00%), semiforest (4.73%) and natural forest(4.91%), while the lowest was obtained in an open cultivated land(1.70%). The occurrence of higher topsoil organic carbon in old homegarden agroforestry probablydue addition of the litter fall from trees and shrubs, animal manures to the surface soil(Fernandes and Nair, 1986; Gobena *et al*., 2013; Amanuel*et al*, 2018).

The lowest SOC% in soils of open cultivated land probably due to the effect of continuous tillage practices that aggravates organic carbon oxidation and the removal of crop residue from cereal cropland removed year to year, which thereby perpetually remove the nutrients from the soil. The removal of the crop remains for cooking and animal feed almost leaves no biomass to be returned to the soil(Aberaand Belachew, 2011). This result is in agreement with study of Haileslassie*et al*. (2005) andAmanuel*et al.*(2018).

Furthermore, in 30-60cm of soil depth, the homegardens showed significantly ($p<0.05$) greater mean value of SOC (1.70-2.69%) than that in the open cultivated land(1.36%), but less than the highest mean value of subsoil SOC in both forests(2.92-2.98%). This highest SOC % obtained in soils of old homegarden, semiforest and natural forestmay perhaps due todead fine trees and shrub roots and the mycorrhizal fungi contribution of organic matter in the subsoil. This result is in line of Kassa*et al.*(2017).

Regard to topsoil, as per SOC rating developed by Shiferaw (2012), the present study revealed that, SOC% of the soils of established(3.79%) and old homegarden(5%) was situated in very high(≥2.90%), the same to that of SOC% range in semiforest(4.73%) and natural forest(4.91%), but, high(1.74-2.90%) and medium(1.16-1.74%) for new homegarden (2.43%) and open cultivated land(1.70%) respectively.

This result indicated that the reduction of SOC% with reduction of root biomass along the soil profile, as low in annuals crop roots deny in short depth and perennials, trees or crops have long roots, thereby their residues in soils after a long duration of time in case of aged homegardens and forest types. This study is confirmed by a study of Yadda(2007) in southern Ethiopia, who concluded the SOC % decreased with increasing soil depth. Similarly, the study of Pabst *al et* (2013) reported that the content of organic carbon is higher at the surface of the soil, because of much of the organic input is localized on and close to the soil surface.

The topsoil TN% was highest in established (0.43%) and old homegarden (0.43%), while the lowest was in open cultivated land (0.15) as shown in the table below(*Table 4*). TN% in new homegarden was statistically similar with semiforest, but higher than in soils of natural forest land. The subsoil TN% was obtained the highest (0.26%) in old homegarden and lowest (0.12) in open cultivated land. This result revealed that the TN% in homegarden significantly($p<0.05$) increment with age of homegardens, for instance TN% in new, established and old homegarden was 0.15%, 0.21% and 0.26% respectively.

This higher TN% recorded in established and old homegarden probably due to the presence of legume plants / crops, or grains such as waleensuu (E. bruci), militia, acacia, *Leucaena*, *Calli andra* spp. *Gliricidia septum, Cassia spectabilis,* Waddeessa (*Cordia Africana*), soybean, pea, peanut and pigeon pea in homegardens and their availability of nutrients to the soil and N fixation characteristics in addition to human occupation to soils in homegardens. Haile (2012) study in southern Ethiopia, reported that those legumes crops are enriched with higher nitrogen, phosphorous (P), and potassium (K) content especially; *E. bruci.*

Gliessman(2001) reported that SOM has a close relationship with the soil N content and it influences the levels of this nutrient in the soil by up to 80%. Similarly, the study of Sinclair and Vadez(2012) reported that grain legumes have the ability to enhance the levels of nitrogen in cropping systems. Lower TN% obtained in open cultivated land may associatedwithremoval of crop residues after harvest and burning of soils, which is optimizingthe removal of nitrogen with crop biomass and the vulnerability of nitrogen to atmosphere respectively(Madalcho and Tefera, 2016).

This result also clearly indicated that the time of establishing of vegetation cover also affected the soil nutrient (Mbwiga, 2016).Comparatively, even the TN% in new homegarden exceeds the TN%in the soils of open cultivated land 50%.This increment in TN% in soils of homegardens probably due to legume plants such as sabenia and E.bruci purposively planted and conserved in the homegardens. This statement is confirmed by Bezabih*etal*. (2016) whose depicted that leguminous crops contributes important role in soil fertility.Total nitrogen was positively and significantly associated with soil organic carbon at topsoil (*r=0.52***) and subsoil (*r= 0.83**).* This result is in agreement with study of Kiflu and Beyene (2013) in southwest Ethiopia.

According to rating of soil nitrogen developed by Debele(1980), the present study revealed that, study area posses range of the medium (0.12-0.25%), to high (>0.25%) TN% in the study area (*Appendix- I Table 2 and Appendix- I Table 5*). Similar to this result, range of TN% has beenreported by Yadda (2007) and Megersa, (2011) in soil of areas generalized as nitisols soils.

4.2.3. Available phosphorous

Topsoil available phosphorous was highest in old homegarden (23.17ppm) and lowest in natural forest (2.69ppm) as shown in table below(*Table 4*). Available phosphorous in homegardensshowed greatest significance ($p<0.05$) from open cultivated land, semiforest and natural forest. This great difference may attribute to human occupation; as the addition of inputs in homegardens; compost, house refuse, livestock manure as they have an effect on phosphorous mineralization (from organic to inorganic, which is available to crop up taking), to form crop available phosphorous (PO4). This result is aligned withthe study of Selassie and Ayanna(2013); Yadav *et al.* (2016), who's depicted that the addition of organic imputes directly change the content of soil phosphorous. Organic matter maintenance is an important factor in controlling the phosphorus availability (USDA, 2001; Amberber *et al.*, 2014).

Even, the available phosphorous in new homegarden was 53% greater than that of in open cultivated land, thus suggesting that there is a rapid increase in this nutrient in the first few years following the initial occupation of the dwelling and establishment of the homegarden agroforestry. The available phosphorous in 30-60cm of soil depth also situated the condition of available Phosphorous in topsoil, whereas the highest in soils of old homegarden (8.97ppm) and the lowest in soils of natural forest (2.23ppm). Available phosphorous in 30-60cm of soil depth in new homegarden, established homegarden and in semiforestwas statistically similar at $p<0.05$.

As per rate of soil available phosphorous developed by Olsen *et al.(*1954), the present study revealed that, the available phosphorous in the topsoil of the new homegarden (12.37 ppm), es tablished homegarden(14.98ppm) and old homegarden (23.17ppm) was rated in the rate of high (>10ppm),whilesoils in natural forest (2.69ppm) was in low(<5ppm), that in the semiforest (5.01ppm) and open space (5.81ppm) received the range of medium (5-10ppm)(*Appendix - I Table 2 and Appendix-I Table 5*).

In view of this result high rate of available in soils of homegarden probably associates with human occupation and animal manure. According to Woods (2003), available phosphorous is a key indicator of anthropogenic effects on soils, as it is found in many of the materials related to human occupation and also shows great stability in the soil. In other hand, the maintaining availability of phosphorus in homegardens attributed to the presence of legumes plants (sasbenia, Acecia, walensuu and etc) and crop such as soybean, pea, peanut and pigeon pea in aged homegardens. According to study of Gajaseni and Gajaseni(1999) cited by Mohri*et al*.(2018), in Thailand, greater levels of available phosphorous was obtained inside homegardens in comparison to areas outside the homegardens of the study area. In addition to this, Sinclair and Vadez(2012) reported that, legumes plants or crops increased phosphorus recovery from the soils.

Available phosphorous was positively and highly significantly associated with silt ($r = 0.80^{**}$), soil pH($r = 78^{**}$), and TN ($r = 0.79^{**}$), whereas it was negatively and significantly correlated with sand ($r = -0.39^{*}$) fraction (*Table 6*).The study of Vieira *et al. (*2016) in Eastern Amazon, Brazil revealed that the available phosphorous in 7 years old and 35 years old homegarden was showed the greatest difference from other land use and this variation was reported due to higher soil pH value was recorded under homegarden of thirty-five years (less acidic soil) than ten years old (more acidic soil). This clearly indicated that the time of establishment of homegarden also affected the soil nutrient accumulation (Imiolemen *et al.*2012;Mbwiga, 2016).

Table 4: Soil pH, SOC, TN and Av.P of topsoil and subsoil in new, established and old homegarden, open cultivated land, semiforest and natural forest.

SP	Ocl	Nh	Eh	Oh	Sf	Nf	LSD	CV	P
				Soil depth(0-30cm)					
Soil pH	$5.40{\pm}0.04^{d}$	$5.56{\pm}0.08^{cd}$	$5.80{\pm}0.09^{b}$	$6.06{\pm}0.07^{a}$	$5.64{\pm}0.06^{bc}$	$5.57{\pm}0.06^{cd}$	0.22	2.09	0.0007
SOC (%)	$1.70{\pm}0.15^{d}$	$2.43{\pm}0.14^{c}$	$3.79{\pm}0.12^{b}$	$5.00{\pm}0.35^{a}$	$4.73{\pm}0.25^{a}$	$4.91{\pm}0.05^{a}$	0.67	9.79	0.0001
TN (%)	$0.15{\pm}0.01^{d}$	$0.30{\pm}0.08^{b}$	$0.43{\pm}0.02^{a}$	$0.43{\pm}0.01^{a}$	$0.32{\pm}0.01^{b}$	$0.23{\pm}0.01^{c}$	0.03	5.30	0.0001
Av.P (ppm)	$5.81{\pm}0.27^{d}$	$12.37{\pm}0.42^{c}$	$14.981.07^{b}$	$23.17{\pm}0.99^{a}$	$5.01{\pm}1.09^{de}$	$2.69{\pm}0.15^{e}$	2.60	13.37	0.0001
				Soil depth(30-60cm)					
Soil pH	$5.63{\pm}0.05^{b}$	$5.73{\pm}0.01^{b}$	$6.02{\pm}0.95^{a}$	$6.18{\pm}0.08^{a}$	$5.71{\pm}0.11^{b}$	$5.63{\pm}0.06^{b}$	0.23	2.20	0.0014
SOC (%)	$1.36{\pm}0.09^{e}$	$1.70{\pm}0.09^{d}$	$2.15{\pm}0.04^{c}$	$2.69{\pm}0.05^{b}$	$2.98{\pm}0.08^{a}$	$2.92{\pm}0.06^{a}$	0.16	3.84	0.0001
TN (%)	$0.12{\pm}0.01^{e}$	$0.15{\pm}0.02^{d}$	$0.21{\pm}0.01^{c}$	$0.26{\pm}0.01^{a}$	$0.25{\pm}0.01^{ab}$	$0.25{\pm}0.01^{ab}$	0.02	5.69	0.0001
Av.P (ppm)	$2.34{\pm}0.23^{c}$	$3.01{\pm}0.07^{bc}$	$3.56{\pm}0.16^{b}$	$8.97{\pm}0.82^{a}$	$4.04{\pm}0.48^{b}$	$2.23{\pm}0.03^{c}$	1.04	14.19	0.0001

Ocl = open cultivated land,Nh = new homegarden, Eh = Established homegarden, Oh = old homegarden, Sf = semiforest,Nf = natural forestLSD=Least significance difference; CV=coefficient of variation.
**Mean value ± SEM with the same letter within the same row and depth are not significantly different from each other at $p < 0.05$*

4.2.4. Exchangeable base cations, CEC and percent of base saturation(PBS)

In 0-30cm of soildepth, CEC was highest in established homegarden (31.20cmol (+) Kg^{-1}), and old homegarden (31.27cmol (+) Kg^{-1}), while the lowest was in open cultivated land (22.85cmol (+) Kg^{-1}) at $p<0.05$ as shown in table below (*Table 5*). Cation exchange capacity in new homegarden was statistically similar with that of semiforest and natural forest at$p<0.05$.

Similar to that of CEC, exchangeable Ca in 0-30cm was highest in established(13.43cmol(+)Kg^{-1}), old homegarden (14.04cmol(+)Kg^{-1}), semiforest(14.16cmol(+)Kg^{-1}) and natural forest(14.53cmol(+)Kg^{-1}) while the lowest was in open cultivated land (7.43cmol(+)Kg^{-1}) at $p<0.05$. The higher CEC and Ca in homegardens may probably associate with the humification and buffering capacity of soil organic matter in soil system(EPA, 2009). Pinho *et al.(*2012) reported that, SOM produced by the homegardens have a buffering effect on soil pH due to several processes, which include the increase in CEC and the size of the exchange complex from humification of SOM additions, the formation of complexes with Al^{3+}, and the release of ionic forms of Ca and Mg in the soil solution, thus reducing the activity of H^+.

Topsoil in new homegarden was statistically similar with that of in semiforest and natural forest at $p<0.05$. This immediate improvement in soils of early homegarden could be due to house refuse and industrial fertilizer used for annuals crops during early seedling in new homegarden. In 30-60cm of soil depth CEC and Ca content, there was not showed any significant ($p<0.05$) variation among all land use studied for present study (*Table 5*).

Topsoil CEC was positively and highly significantly associated with silt fraction ($r = 0.55^{**}$) and SOM($r=0.73^{**}$), whereas it was negatively and highly significantly correlated with sand fraction ($r = -0.75^{**}$) as shown in table(*Table 6*).This statement is in report of Madalcho and Tefera (2016), who's depicted that the higher SOM, the higher CEC and basic cations,due to homegarden are highest in SOM similar to semiforest and natural forest, they are appreciable in CEC and basic cation optimizing than other land use. Similarly the report of Abay and

Sheleme(2012) identified that the higher basic cations results high CEC in soil, and higher sand fraction lowers CEC content.

As per rating of soils CEC developed by Berhanu (2011);Tabi *et al.(*2013) the present result revealed that, topsoil CEC obtained in new (28.03cmol(+) kg^{-1}), established (31.20cmol(+) kg^{-1}) and old homegarden agroforestry (31.27cmol(+) kg^{-1}) was constituted in high levels(25-40cmol(+) kg^{-1}), the same to CEC levels in semiforest and natural forest. This indicated that the extent of immediate soil nutrient restoration under homegarden, or contribution homegarden to soil environment.

Topsoil Mg was highest in established homegarden(2.31cmol(+)Kg^{-1}) and natural forest(2.21cmol(+)Kg^{-1}), while the lowest was in open cultivated land (1.57 cmol(+)Kg^{-1}) and new homegardens (1.67cmol (+) Kg^{-1}). New, old homegarden and semiforest was statistically ($p<0.05$) similarwith open cultivated land in Mg content for present study (*Table 5*).In 30-60cm of soil depth, the highest Mg was obtained in semiforest (1.91cmol (+)Kg^{-1}) and natural forest (2.09cmol (+) Kg^{-1}), while the lowest was aligned in open cultivated land (1.20cmol (+) Kg^{-1}). This result revealed that Mg content in homegardens at different age classes was showed increment separately from open cultivated land and goes toward the soil of semiforest and natural forest.In line of soil Mgrating developed by Brindha and Elango (2014); Pam and Brian (2007) the soil Mg in soils of homegardens and different land use studied was medium (1.39-2.15cmol (+) Kg^{-1})(*Appendix–I Table 4 and Appendix – I Table 5*).

In 0-30cm, exchangeable K was highest in old homegarden (6.53), while the lowest was in semiforest (0.95 cmol(+)Kg^{-1}) and natural forest(0.63). The exchangeable k in homegarden showed greatest ($p<0.05$)increment starting from new homegarden to old homegarden. Like the available phosphorous (*Table 5*) in present study showed greatest difference in soils of homegardens, the K levels in homegarden exhibited the greatest increases over time.

Even, the level of exchangeable k levels in soilsof new homegarden showed about 44%, 63% and 73% greater than that of k levels in soils of adjacent open cultivated land, semiforest and natural forest respectively. This suggesting that there is a rapid increase in this nutrient in the first few years following initial occupation of the dwelling and establishment of the homegarden.Subsoil exchangeable K was highest in established homegarden (1.27cmol (+)Kg^{-1}) next to old homegarden (2.01cmol(+)Kg^{-1}) which showed greatest ($p<0.05$) mean values, while the remaining land use studied was lowest mean values(*Table 5*).

This highest k in homegardens may be attributed to the house refuses (Kiflu and Beyene, 2013), manure of livestock or feces of different wild animals (Vieira*et al*, 2016) and birds dwell for seeking their food and release their feces in homegardens (Gole, 2003), as feces are rich in N, P and K, and a high P supply can cause great impacts on ecosystems. Topsoil K was positively and highly significantly associated with silt fraction (*r = 0.81***), soil pH(r=*0.73***),TN %(r=*0.66***) and Av.P(*r=0.90***) as aligned in table below (*Table 6*). Contribution of residue to formation of SOM is also important case for exchangeable K in soils. These statements are in constitutedwith the study of Vieira *et al.(*2016) and Kaihura*et al*.(2001).

The low exchangeable K obtained in forest probably due to the long duration of forest on the specific land. This study result is in agreement with Moges*et al.* (2013) and (Zinke, 1992) whose the report indicated that basic cations are impacted due to prolonged duration of forest presence in specific area.Similarly, the report of Abera and Wolde-Meskel(2013) depicted his study that, the soil nutrients are not affected and management disturbance denies lower due to very limited cultivation in the natural and semi natural ecosystems.

Highest exchangeable Na in 0-30cm of soil depth was obtained in new (0.30), established homegarden (0.30cmol (+) Kg^{-1}) and natural forest (0.30cmol (+) Kg^{-1}), whereas the lowest was obtained in open cultivated land (0.09cmol (+) Kg^{-1}). However, the homegarden soil in content of exchangeable Na was statistically similar; somehow this result accompanied that with increasing the age of homegardens, there was reduction in exchangeable Na content. This study result is in constituted with Moges*et al.* (2013).Regards to content of exchangeable Na content in 30-60cm, there was no significant variation among all land use type used for present study ($p<0.05$) as shown in appendix table (*Appendix-I Table 1*).

Highest PBS at surface layer of soil was obtained in old homegarden (73.23%), whereas the lowest was obtained in semiforest (55.14%) as described in table below (*Table 5*). Soils of established and old homegarden showed the greatest significant different ($p<0.05$) from other land use types; open cultivated land, semiforest and natural forest. The higher the PBS in 0-30cm of soilmay probably attribute due to the return extent of litters or crops residues to the soils through SOM formation and decomposition. This result is in agreement with the study of Alemu (2015) in southeast Ethiopia. Subsurface PBS content at studied land use was not showed significance ($p<0.05$) variation for present study.

Table 5: CEC, Ex.Ca, Mg, K, Na and PBS of topsoil and subsoil in new, established and old homegarden agroforestry, open cultivated land, semiforest and natural forest.

SP	Ocl	Nh	Eh	Oh	Sf	Nf	LSD	CV	P
				Soil depth(0-30cm)					
CEC	22.85±0.33^{c}	28.03±0.21^{b}	31.20±1.01^{a}	31.27±1.03^{a}	29.66±1.42^{ab}	29.98±0.66^{ab}	2.94	5.60	0.0007
Ex.Ca	7.43±0.31^{c}	10.59±0.41^{b}	13.43±0.54^{a}	14.04±0.22^{a}	14.16±0.54^{a}	14.53±0.54^{a}	1.22	5.43	0.0001
Ex.Mg	1.57±0.13^{b}	1.67±0.08^{b}	2.31±0.10^{a}	2.05±0.01^{ab}	1.84±0.31^{ab}	2.21±0.07^{a}	0.51	14.51	0.0480
Ex.K	1.45±0.11^{bc}	2.30±0.13^{b}	2.53±0.19^{b}	6.53±0.81^{a}	0.95±0.19^{c}	0.63±0.03^{c}	1.16	26.65	0.0001
Ex.Na	0.09±0.02^{c}	0.30±0.01^{a}	0.30±0.01^{a}	0.29±0.01^{ab}	0.24±0.04^{b}	0.30±0.01^{a}	0.05	11.15	0.0001
PBS	59.88±2.69^{cd}	61.74±1.93^{bc}	65.04±1.68^{b}	73.23±1.09^{a}	55.14±0.93^{d}	58.93±0.73^{cd}	5.10	4.50	0.0002
				Soil depth(30-60cm)					
CEC	28.37±0.63	30.32±0.66	30.68±0.24	31.18±0.89	27.83±4.45	28.18±1.63	6.61	12.35	0.7805
Ex.Ca	13.34±0.10^{b}	13.89±0.09^{b}	13.84±0.38^{b}	15.26±0.59^{a}	14.19±0.79^{ab}	14.45±0.39^{ab}	1.33	5.17	0.1119
Ex.Mg	1.20±0.02^{c}	1.35±0.03^{bc}	1.29±0.11b^{c}	1.69±0.10^{ab}	1.91±0.32^{a}	2.09±0.13^{a}	0.48	16.64	0.0096
Ex.K	0.51±0.06^{c}	0.79±0.03^{c}	1.27±0.11^{b}	2.01±0.37^{a}	0.71±0.03^{c}	0.62±0.09^{c}	0.43	23.73	0.0001
Ex.Na	0.32±0.00^{ab}	0.33±0.00^{ab}	0.33±0.01^{ab}	0.35±0.01^{a}	0.28±0.04^{b}	0.32±0.02^{ab}	0.06	10.56	0.2835
PBS	54.82±1.53^{ab}	53.99±1.27^{b}	53.89±1.04^{b}	61.96±2.72^{a}	55.61±3.72^{ab}	56.95±1.48^{ab}	7.73	7.07	0.2097

Ocl = open cultivated land,Nh = new homegarden, Eh = Established homegarden, Oh = old homegarden, Sf = semiforest Nf = natural forest.LSD=Least significance difference; CV=coefficient of variation.
**Mean value ±SEMwith the same letter within the same row and soil depth are not significantly different from each other at $p < 0.05$*

Table 6: Pearson's correlation matrix for selected soil physicochemical parameters of soils open cultivated land(Ocl),new(Nh), established (Eh) and old (Oh) homegarden agroforestry, semiforest, natural forest.

	Bd	Sand	Silt	Clay	pH	SOC	TN	Av.P	CEC	Ca	Mg	K	Na	PBS
							Topsoil (0-30cm)							
Bd	1													
Sand	0.65**	1												
Silt	-0.64**	-0.77**	1											
Clay	-0.46*	-0.79**	0.28^{ns}	1										
pH	-0.61**	-0.68**	0.80**	0.33 ^{ns}	1									
SOC	-0.69**	-0.82**	0.49*	0.88**	0.59**	1								
TN	-0.60**	-0.66**	0.82**	0.31^{ns}	0.81**	0.52**	1							
Av.P	-0.35^{ns}	-0.39*	0.80**	-0.14^{ns}	0.78**	0.14^{ns}	0.79**	1						
CEC	-0.52**	-0.75**	0.55**	0.71**	0.65**	0.77**	0.73**	0.36 ^{ns}	1					
Ca	-0.60**	-0.83**	0.49*	0.89**	0.58**	0.93**	0.60**	0.16 ^{ns}	0.87**	1				
Mg	-0.19 ^{ns}	-0.36^{ns}	0.13^{ns}	0.57**	0.46*	0.58**	0.42*	0.13 ^{ns}	0.75**	0.65**	1			
K	-0.37^{ns}	-0.45*	0.81**	-0.08^{ns}	0.73**	0.25 ^{ns}	0.66**	0.90**	0.37 ^{ns}	0.17^{ns}	0.10^{ns}	1		
Na	-0.34^{ns}	-0.59**	0.42^{ns}	0.58**	0.53**	0.60**	0.65**	0.36^{ns}	0.88**	0.77**	0.64**	0.26^{ns}	1	
PBS	-0.17^{ns}	-0.32^{ns}	0.62**	-0.10^{ns}	0.71**	0.21 ^{ns}	0.62**	0.86**	0.35^{ns}	0.18 ^{ns}	0.29 ^{ns}	0.88**	0.35 ^{ns}	1.
							Subsoil (30-60cm)							
Bd	1													
sand	0.39^{ns}	1												
Silt	-0.77^{ns}	-0.49*	1											
Clay	-0.12^{ns}	-0.86**	0.18^{ns}	1										
pH	-0.44*	-0.30^{ns}	0.79**	-0.03^{ns}	1									
SOC	-0.70**	-0.61**	0.59**	0.42*	0.19^{ns}	1								
TN	-0.65**	-0.50*	0.60**	0.18^{ns}	0.39*	0.83**	1							
Av.P	-0.56**	-0.06^{ns}	0.75**	-0.12^{ns}	0.71**	0.36^{ns}	0.46*	1						
CEC	-0.08^{ns}	-0.52**	0.36^{ns}	0.35^{ns}	0.44*	-0.04^{ns}	0.11^{ns}	0.12^{ns}	1					
Ca	-0.35^{ns}	-0.66**	0.58**	0.45*	0.58**	0.53**	0.53**	0.42*	0.59**					
Mg	-0.39*	-0.80**	0.41*	0.70**	0.06^{ns}	0.78**	0.55**	0.04^{ns}	0.29^{ns}	0.69**	1			
K	-0.43*	-0.13^{ns}	0.77**	-0.14^{ns}	0.87**	0.26^{ns}	0.47*	0.81**	0.34^{ns}	0.59**	0.04^{ns}	1		
Na	0.13^{ns}	-0.42*	0.34^{ns}	0.29^{ns}	0.60**	-0.16^{ns}	0.00^{ns}	0.25^{ns}	0.87**	0.64**	0.16^{ns}	0.49*	1	
PBS	-0.16^{ns}	-0.17^{ns}	0.42*	0.12^{ns}	0.53**	0.37^{ns}	0.32^{ns}	0.59**	-0.16^{ns}	0.53**	0.23^{ns}	0.59**	0.23^{ns}	1

***significant at P<0.01 level; * significant at P <0.5 level; ns = non significance<0.5 level; SOM = soil organic matter; Total N = total nitrogen; Av.P = available phosphorous; CEC = cation exchange capacity; Ca =calcium; Mg=Magnesium; K= potassium; Na = sodium; PBS = percent of base saturation.*

5. SUMMARY AND CONCLUSION

The present study results clearly indicated the significant variation among the soil properties in soils of studied homegarden agroforestry at different age classes and adjacent land use in the study area.Regard to soil physical properties, in 0-30cm of soil depth, bulk density, sand, silt and clay fraction was significantly ($p<0.05$) showed variation, but in 30-60cm of soil depth, except the bulk density and silt fraction, there was no significant variation obtained in sand and clay fraction for studied land use($p<0.05$).

Except soil bulk density in the topsoil and subsoil of new homegarden which was similar to the soils of open cultivated land, the bulk density in the topsoil and subsoil of established and old homegarden was similar to that of in soils of semiforest and natural forest. Silt fraction in old homegarden at 0-30cm and 30-60cm significantly ($p<0.05$) showedthe greatest mean value among studied land uses, whereas new and established homegarden was statistically similar to that of semiforest.

Clay fraction in 0-30cm was significantlyincreasedin homegardens starting from new homegarden separately from the open cultivated land and move toward to that of the mean value of clay in soils of semiforest and natural forest. However, there was no significant ($p<0.05$) variation showed in clay and sand fraction in the subsoil.

Considering the chemical properties, in 0-30cm of soil depth , soil pH-value, SOC, TN, available phosphorous, CEC, basic cations and PBS was significantly ($p<0.05$) showed variation. However, in 30-60cm of soil depth, there was no significant ($P<0.05$) variation obtained in the CEC, Ca, Na and PBS, but the remaining studied soil chemical properties showed variation for studied land use($p<0.05$).

The mean values of soil pH-value, available phosphorous (P) andexchangeable potassium (K) in topsoil (0 – 30cm) and subsoil (30 – 60cm) of old homegarden showed highly significantly ($p<0.05$) greatest mean value among the soils of land use analyzed. In general, the soils trend in soils of new to old homegarden agroforestry progressively modified and positively improved in essential soil nutrient, especially in available P and exchangeable K contents. Available p and exchangeable k was highly significantlyand positively associated with soil pH at $r=0.78^{**}$ and r= 0.73^{**}in topsoil, $r=0.71^{**}$ and r=0.87^{**} in the subsoil at $p<0.05$in respectively.

These soil properties improvement happens in the soils of homegarden agroforestry may perh aps due to house refuse; bones and ash, animals' maniures, contribute of crop residues and litt erfalls to form SOM; as mineralization form inorganic matter, and humification and buffering capacityof soil organic matter. According to this study, it can be concluded that the soils of the homegardens agroforestry are improved than the other land use typesin the study area.

Therefore, it is very important to strengthen and scaling up the homegarden agroforestry, which has been started and now ongoing by small holder farmers in Yayu district, as it is a one of the way of sustaining the agriculture production and restore the soil ecosystem services at around the homestead, in particularly, the heavy rainfall areas of the southwestern Ethiopia and probably in the other similar areas. Additional efforts ought to be taken so as to maintain the soil fertility in open cultivated cropland, especially the nitrogen and available phosphorous. Further studies are needed to assess the soil nutrients in the homegardens in order to long run the practices.

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7. APPENDICES

7.1. Appendix -I Tables

Appendix-I Table 1 : Mean square (MS) estimates for analysis of variance of soil physicochemical properties under six land uses (homegarden of different age and others land use types) in Yayu District.

Soil properties	Soil depth					
	0-30cm			*30-60cm*		
	MS	F	P	MS	F	P
Bd(gcm^{-3})	0.07	17.94	0.0001	0.05	9.47	0.0015
Sand (%)	246.72	14.75	0.0002	81.29	1.33	0.3300
Silt (%)	110.10	13.82	0.0003	22.53	9.66	0.0014
Clay (%)	134.32	27.29	0.0001	63.92	1.11	0.4119
pH(H_2O)	0.16	11.57	0.0007	0.16	9.59	0.0014
SOC%	5.87	43.42	0.0001	1.36	174.21	0.0001
TN %	0.04	141.14	0.0001	0.01	52.09	0.0001
Av.P(ppm)	178.26	87.56	0.0001	19.08	58.51	0.0001
CEC (cmol(+) kg-1)	30.01	11.50	0.0007	6.40	0.48	0.7805
Ca(cmol(+) kg-1)	23.61	52.40	0.0001	1.29	2.40	0.1119
Mg(cmol(+) kg-1)	0.27	3.88	0.0480	0.40	5.70	0.0096
K (cmol(+) kg-1)	13.96	34.15	0.0001	0.97	17.71	0.0001
Na(cmol(+) kg-1)	0.02	26.01	0.0001	0.00	1.46	0.2835
PBS	157.44	14.95	0.0002	27.76	1.76	0.2097

, **, * = significant at p < 0.05, at p < 0.01 and p< 0.001 respectively; ns = not significant at 5% alpha level; Bd= bulk density; SOC= soil organic carbon; SOM = soil organic matter; TN (%) = percent of total nitrogen; Av. P = Available phosphorus; CEC = cation exchange capacity; Ca =calcium; Mg=Magnesium; K= potassium; Na = sodium; PBS = percent of base saturation*

Appendix-I Table 2: Rating the mean value of soil SOC, SOM, TN and Av.P

SOC	Total Nitrogen (%)	Av. P (ppm)	Rating
>2.90	-	-	Very high
1.74-2.90	> 0.25	> 10	High
1.16-1.74	0.12-0.25	5-10	Medium
0.6-1.16	0.01-0.12	< 5	Low
<0.6	< 0.01	-	Very low
Shiferaw(2012)	Olsen *et al.(*1954)		

Appendix-I Table 3: Rating the mean value of soil pH

pH (H_2O)	Rating	Sources
< 4.5	Extremely acid	soil pH for 1:2.5 soils to water ratio suspension (Foth and Ellis, 1997)
4.5-5.0	Very Strongly acid	
5.1-5.5	strongly acid	
5.6-6.0	moderately acid	
6.1-6.5	Slightly acidic	
6.6-7.3	Neutral	
7.4-7.8	Slightly alkaline	
7.9-8.4	Moderately alkaline	
> 8.5	Strongly alkaline	

Appendix-I Table 4: Rating the mean of soil CEC and basic cationin(cmol (+) kg-1) and PBS

CEC	Ex. Ca	Ex.Mg	Ex.K	Ex.Na	PBS	Rating
> 40	>30	>8	>2	>2	80	Very high
25-40	10-30	3-8	0.7-2	0.7-2	60-80	High
15-25	5-10	1-3	0.3-0.7	0.3-0.7	40-60	Medium
5-15	2-5	0.3-1	0.2-0.3	0.1-0.3	20-40	Low
< 5	<2	0-0.3	0-0.2	0-0.1	0-30	Very low
Berhanu (2011);Tabi*et al.(*2013)	Brindha and Elango (2014); Pam and Brian (2007)					

SOM = soil organic matter; Total N = total nitrogen; CEC = cation exchange capacity; Av.P = available phosphorous; Ex. Ca = exchangeable calcium; Ex. Mg= exchangeable magnesium; Ex. K= exchangeable potassium; Ex. Na = exchangeable sodium; PBS = percent of base saturation

Appendix-I Table 5: Soil texture and selected soil chemical properties levels in homegarden agroforestry and different land use atYayu, Southwestern Ethiopia

Soil parameters	Ocl	Nh	Eh	Oh	Sf	Nf
			Soil depth(0-30cm)			
STC	SL	SCL	CL	CL	CL	CL
Soil pH-value	Stro A	Mod A	Mod A	Sli A	Mod A	Mod A
SOC (%)	M	H	V.H	V.H	V.H	V.H
TN (%)	M	H	H	H	H	M
Av.P (ppm)	M	H	H	H	M	L
CEC(cmol(+) kg-1)	M	H	H	H	H	H
Ex.Ca(cmol(+) kg-1)	H	H	H	H	H	H
Ex.Mg(cmol(+) kg-1)	M	M	M	M	M	M
Ex.K(cmol(+) kg-1)	H	V.H	V.H	V.H	H	M
Ex.Na(cmol(+) kg-1)	V.L	L	L	L	L	L
PBS	M	H	H	H	M	M
			Soil depth(30-60cm)			
STC	SCL	SCL	SCL	Loam	Loam	Loam
Soil pH	Mod A	Mod A	Sli A	Sli A	Mod A	Mod A
SOC (%)	M	M	H	H	V.H	V.H
TN (%)	M	M	M	H	H	H
Av.P (ppm)	L	L	L	M	L	L
CEC(cmol(+) kg-1)	H	H	H	H	H	H
Ex.Ca(cmol(+) kg-1)	H	H	H	H	H	H
Ex.Mg(cmol(+) kg-1)	M	M	M	M	M	M
Ex.K(cmol(+) kg-1)	M	H	H	V.H	H	M
Ex.Na(cmol(+) kg-1)	M	M	M	M	L	M
PBS	M	M	M	H	M	M

(*Sources: STC(USDA, 1987), soil pH (*Foth and Ellis, 1997*), SOC%(Shiferaw, 2012),SOM% and TN% (Debele, 1980),Av.P(Olsen et al., 1954), CEC(Berhanu, 2011;Tabiet al., 2013), Ca,Mg, K, Na and PBS%(Brindha and Elango,2014;Pam and Brian, 2007))*

STC = soil texture class; SL=sandy loam, CL= clay loam; SCL = sandy clay loam; Ocl=open cultivated land; NH=new homegarden; EH= established homegarden; OH= old homegarden; SF= semi forest; NF= natural forest; SOM = soil organic matter; TN = total nitrogen; CEC = cation exchange capacity; AvP = available phosphorous; Ex. Ca = exchangeable calcium; Ex. Mg= exchangeable magnesium; Ex. K= exchangeable potassium; Ex. Na = exchangeable sodium; PBS = percent of base saturation; Stro A=strongly acid; Sli A=slightly acid; Mod A= moderately acid; V.L=very low; L=low; M=medium; H=high; V.H=very high.

7.2. Appendix – II: Figures

Open space or Cereal crop land (Transitional zone of Yayo Biosphere Reserve)

Appendix II Figure 1: Original and Image processed photos of open cultivated land, January 2018.

Appendix II Figure 2: Original and Image processed photos of new homegarden agroforestry, January 2018

Established homegarden agroforestry (Transition zone of the Yayo Biosphere Reserve)

Appendix II Figure 3: Original and Image processed photo of established homegarden agroforestry, January 2018

Old homegarden agroforestry (Transitional zone of Yayo Biosphere Reserve)

Appendix II Figure 4: Original and Image processed photos of old homegarden agroforestry, January 2018

Semiforest land (Buffer zone area of Yayo Biosphere Reserve)

Appendix II Figure 5: Original and Image processed photo of semiforest land, January 2018

Natural forest (Core zone area of Yayo Biosphere Reserve)

Appendix II Figure 6: Original and Image processed photo of natural forest land, January 2018

Appendix II Figure7: Original and Image processed photos of laboratory soil analysis, January 2018

7.3. Appendix – III: Questionnaire

Checklist for discussion

1. Location

   State _____ Zone ______ District______ Kebele _____specific site _________________

   Latitude _____________ Longitude ____________ Altitude ___________ m.a.s.l

   Total area of the study site (ha) _________or (Km^2) _______Name of supervisor _____

2. Climate and topography of the study area

   Mean annual rainfall (mm): highest __________ lowest__________________

   Mean daily temperature: highest ____________ lowest_________________

   Mean annual temperature: highest ____________lowest_________________

   Elevation (m. a. s. L): highest _______________ lowest ________________

3. Topography a/ flat plain, 0-1% b/ almost flat plain; long, smooth c/ slopes 2-3% d/gently sloping plain; long, smooth slopes 4-8% e/ other (specify) ____ slope (%) _

4. The history of land before establishment of homegarden agroforestry? a/ Forest land b/ Cropland c/ Grazing land d/ Settlement and other (specify)

5. Year of the establishment (current age) of the homegarden plot and other land use types? a/ 2007-2017 (0-10 years old) b/1982- 2002(15-35 years -old) c/ established before 1997 (≥ 40 years)

6. What are the common crop (trees) species and others in the homegarden? And how it introduced in?a/ *coffeaarabica* b/ *Ensetventricosum* c/ both *coffeaarabica* and Ensetventricosum d/ legume crop or trees e/ allopathic tree f/ others (specify) ____

7. Structure of the homegarden? a/ perennials b/ semi perennials c/ annual crops

8. Fertilizers used in homegardens? a/ house refuse b/ animal manure c/ industrial fertilizers d/ other e/ none

9. Systems of livestock feeding?

   a/ Control grazing b/ cut and carry c/partially cut and carry d/ open grazing