TEFF YIELD, SELECTED SOIL CHEMICAL PROPERTY AND ORGANIC CARBON STOCK IN *Acacia seyal (DEL)* PARKLAND AGROFORESTRY IN GUBALAFTO DISTRICT, NORTHERN ETHIOPIA

M.Sc. THESIS

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NOVEMBER, 2019

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A THESIS SUBMITTED TO THE DEPARTEMENT OF AGROFORESTRY,

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HAWASSA, ETHIOPIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE

DEGREE OF MASTER OF SCIENCE IN

(CLIMATE SMART AGRICULTURE AND LAND SCAPE ASSESSMENT)

NOVEMBER, 2019

APPROVAL SHEET- I

The research entitled as **“**Teff Yield, Selected Soil Chemical Property and Organic Carbon Stock in *Acacia Seyal* (Del) Parkland Agroforestry in Gubalafto District, Northern Ethiopia” has been approved by the Department of Agroforestry for partial fulfillment of the Degree of Master of Science in Climate Smart Agriculture and Land Scape Assessment Program. In addition, it is a record of original research carried out by *Nega Ashagrie Semaw ID*. No. *MSc/Ro16/10*, under my supervision, and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received during the courses of this investigation have been duly acknowledged.

______________________	______________________	______________________
Name of major advisor	Signature	Date

APPROVAL SHEET-II

As members of the Board of Examiners of the final Master's degree open defense, we certify that, we have read and evaluated the thesis prepared by *Nega Ashagrie Semaw* under the title "Teff Yield, Selected Soil Chemical Property and Organic Carbon Stock in *Acacia Seyal* (Del) Parkland Agroforestry in Gubalafto District, Northern Ethiopia". As a result, we recommend that it has been accepted as fulfilling the thesis requirement for the degree of Master of Science in agroforestry with Specialization Climate Smart Agriculture Landscape Assessment.

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Thank You All!

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DECLARATION

I, Nega Ashagrie Semaw, hereby declare that this thesis ***"****Teff Yield, Selected Soil Chemical Property and Organic Carbon Stock in Acacia Seyal (Del) Parkland Agroforestry in Gubalafto District, Northern Ethiopia"* is the result of my own original work and has not already been, and is not currently being submitted to any other educational institutions for achieving any academic degree awards.

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Name Signature Date

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ABREVITIONS AND ACRONOYMS

AGBC**:** Above ground biomass carbon stock

ANOVA: Analysis of Variance

Av K: Available potassium

Av. P: Available Phosphorus

BD: Bulk Density

BGBC: Below ground biomass carbon stock

CSA: Central Statistical Agency

CV: coefficient of variation

DBH: Diameter at Breast Height

LSD: Least Significant Difference

masl: Meter above sea lebel

MoA: Ministry of agriculture

NPK: Nitrogen, potassium, Phosphorus

SOC: Soil Organic Carbon

SOM: Soil Organic Matter

SSA: Sub Saharan Africa

TN: Total Nitrogen

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ABSTRACT

Agroforestry is viable option to alleviate the land degradation and loss of soil fertility from the agricultural fields. In Gojer Watershed Gubalafto District of Amhara region, Acacia seyal trees are deliberately left and managed, which naturally grow inside farmlands to fulfill wood requirements and generate extra income. Since, the effects of this tree on crop productivity and carbon stock have not been scientifically quantified; this study has been carried out with the aim of investigating teff yield, assessing soil nutrients and carbon stock of Acacia seyal based agroforestry system. Three transect lines were established along the gradient with 300 meters apart and 40m×50m is the area of string plot were systematically laid at the interval of 200 meters apart for the inventory of Acacia seyal. Total forty eight composite soil sample were collected at six tree base from (2, 2-4, 4-6 and 12) meters and two soil depths (0-20 and 20-40 cm) were taken for analysis of soil fertility parameters. Grain yields was collected (1 m × 1 m sub plot) just adjacent to soil sample plot following the same procedures as soil sampling. The results shown that, Acacia seyal farmland contribute 20.848±7.115 Mg carbon ha^{-1}. Soil organic carbon, soil pH, available phosphorous and potassium were not influenced significantly at ($p>0.05$) under Acacia seyal canopy than open field. Whereas total nitrogen, available and Teff yield were significantly ($P<0.05$) influenced. This could be due to, root uptake of nutrient from deeper soil profiles, modification of microclimate and soil temperature under tree canopy than open field. As a result, Adoption of Acacia seyal parkland agroforestry practices can be potential activity in yield improvement and climate change mitigation.

***Keywords**: adaptation, crop productivity, open field, soil nutrient, under canopy.*

1. INTRODUCTION

1.1. Background and justification

Nowadays, human population is increasing at alarming rate. Recent projections suggest that, global population will grow from a current 7 billion to more than 9 billion in 2050; and 60 percent estimated rise in global farming yield will be needed by 2050 (Kaczan *et al.*, 2013). Consequently, to ensure adequate food supplies will require faster increment in agriculture output than observed over the past decade. In Sub-Saharan Africa (SSA), crop output has been increasing largely due to expansion of farm extent rather than by improving productivity gains.

Ethiopia is among the most populous country in SSA and many studies shown that agriculture is the basis of the Ethiopian economy; which accounting for 46% of its Gross Domestic Product (GDP) and 90% of its export earnings and employ 85% country labor force (Yonas Mebratu *et al.*, 2016). According to Ethiopia Agricultural Growth Program (2010) Report No: AB5416 increasing in agricultural output in Ethiopia has largely driven by expanding the area of cultivated land rather than by productivity gains. Various research outputs indicated that, this expansion in the cultivated land characterized by continuous exploitation of natural resources by the communities via population pressure, continuous cropping, over grazing, limiting organic matter inputs aggravate the decline in soil fertility and low productivity (Mulegata Habte and Sheferaw Boke, 2017).

Soil fertility depletion is the most fundamental cause for low production, which explained through high bulk density, reduced organic matter content and lack of soil nutrients that leads to food insecurity, low incomes and poverty. As a result, Average cereal yields in the SSA region have remained below 1 tone ha^{-1} for the past 50 years, as compared to average yields of 2.5 tone ha^{-1} in South Asia and 4.5 tone ha^{-1} in East Asia (Kaczan *et al.*, 2013). In Ethiopia, even if teff is one among the major cereals and occupies about 27% of the grain crop area of land, that is more than any other major cereals; the yield is not increasing above the national average grain yield of 1.2 t ha^{-1} (Yonas Mebratu *et al.*, 2016).

Agroforestry can be considered as a viable option to alleviate the degradation and loss of soil fertility from the agricultural fields and provides a unique opportunity to combine the twin objectives of climate change adaptation and mitigation (Young, 1997). In SSA agroforestry practices encompass many traditional agroforestry systems such as home gardens, boundary tree planting, live hedges, rangeland trees, woodlot, and parkland are some of the best known a successful traditional agroforestry practices (Liniger, 2009).

Studies conducted on parkland provide evidence that; trees have proven to be applicable as means of both climate change mitigation, due to increased carbon sequestration, and adaptation, this is due to the creation of more favorable microclimates on agricultural fields (Ernstberger, 2016). A global survey has shown that over 43% of agricultural lands have more than 10% tree cover (Zomer *et al.*, 2016), and biomass carbon stock in agricultural lands have also been shown to range between 3–18 t C ha^{-1}, that has greater potential for emission/ sequestration and climate regulation (Agevi e*t al.*, 2017).

On the other hand, studies conducted on sorghum grain yields under the *Cordia africana* tree canopy increased by 14% than those grown on farmlands without trees in Burkina Faso (Boffa, 2000). In addition, under *Faidherbia albida* sorghum yields were increased by 36% in Ethiopia (Poschen, 1986). In contrast, previous studies on *Balanites aegyptiaca* with sorghum yield in Tigray region, and on *Cordia Africana* and *Croton macrostachyus* with maize yield in Eastern Oromia have shown, highest yield was recorded at far tree trunk than near tree trunk (Hailemariam Kassa *et al.* 2010 and Muktar Mohammed *et al.* 2018). This may be because of competition for light, water, nutrient and allelopathic effect of trees on the crop (Ralhan *et al.*, 1992; Akyeampong *et al.*, 1995b).

Scattered *Acacia seyal* trees are common features across the agricultural lands in Gubalafto district North Wollo, Ethiopia. Traditionally, farmers deliberately retained *Acacia seyal* tree on their farmlands and it exists in association with teff and other agricultural crops. This implies that the tree has been useful for creating favorable microclimates and improving soil fertility that enhancing crop productivity and carbon stock status in the farming system. Accordingly scientifically quantifying biomass carbon of *Acacia seyal* and soil carbon as well as the effect of this tree on soil fertility improvement and crop performance around the tree canopy becomes crucial to manage the overall system properly, enhance its productivity and uplift the benefits of the local community.

1.2. Statement of the Problems

In the Amhara region manly in west and east Gojam, north Shewa and north Wollo, farmers maintain different shrubs and tree species on their croplands for a long time. According to Northern Wollo Zone Administrative information, Gubalafto district farmers are known to deliberately leave and manage naturally regenerated seedlings on farm boundaries, marginal areas, and inside farmlands to fulfill their wood requirements and to generate extra income. Trees integrated with farming systems may increase crop productivity and sustainability, because trees are able to maintain soil fertility, through litter fall and root decomposition (Nair, 1984). Even if there are a number of researches finding in many parts of the country that ensuring parkland agroforestry sustain agricultural productivity and minimizing environmental degradation, there is no any scientific investigation so far whether the tree is enhancing crop productivity or improving organic carbon stock in present study area. Hence, this study was conducted to generate some basic information regarding the contribution and effects of *Acacia seyal* tree to enhance crop productivity, improving organic carbon stock as well as NPK at different distances of standing tree. As a result, this study help to convince land users, policy makers and promote the significant role of trees integration in farming system to enhance the overall productivity of the system in general and crop productivity in particular.

1.3. Objectives

1.3.1 General Objective

The general objective of this study was to investigate organic carbon stock, selected soil chemical property and teff yield difference with distance from standing *Acacia seyal* tree at Gojer Watershed Gubalafto District of Northern Ethiopia.

1.3.2 Specific Objectives

1. To estimate biomass and soil organic carbon stock of *Acacia seyal* tree grown in Teff field.
2. To determine soil organic carbon content and NPK concentrations from under the canopy of *Acacia seyal* tree and at open field.
3. To assess teff yield under the canopy of *Acacia seyal* tree and at open field.

1.4 Hypothesis

The following hypotheses were set:-

1. There is variation in soil organic carbon and nutrients (NPK) concentrations under *Acacia seyal* tree canopy and at open area away from the tree.
2. There is variation in teff yield of at a different distance under canopy of standing *Acacia seyal* tree and open area.

1.5 Significance of the Study

This study generated scientific information about the role of scattered *Acacia seyal* trees on teff yield; and filling the information gap on *Acacia seyal* trees biomass and soil carbon stocks potential that mitigate climate change of the farm land and play great role in yield improvement for adaptation mechanism.

As a result, this study points out the importance of *Acacia seyal* trees for climate change mitigation and adaptation. Besides this, it convinces and gives important information for policy makers who may formulate policies by providing valuable documents, evidence and relevant information. It also benefits both governments as well as the community by producing additional income sources from adaptation program of climate change through carbon trade. Therefore, it promotes or motivates farmers for integrating trees into their agriculture.

2. LITERATURE REVIEW

2.1. Concept of Agroforestry

Agroforestry is one of the best low-cost alternatives that could be applied by the poor rural population to fulfill their wood requirements and to generate extra income. Agroforestry in this context is defined as "a dynamic and ecologically based natural resource management system through which perennial trees and shrubs are integrated with farmland and rangeland either in some form of spatial arrangement or temporal sequence to diversify and sustain production and for increasing social economic and environmental benefits for land users at all levels" (ICRAF, 2000).

There are numerous types of traditional agroforestry systems in Ethiopia. For instance, Enset-coffee based agroforestry systems of Sidama zone (Mesele Negash, 2002; Zebene Asefaw, 2003), and dispersed trees on-farms in Gununo Watershed Wolayitta Zone (Aklilu Bajigo *et al.*, 2015), are some of the known successful traditional agroforestry practices in Ethiopia. Trees are planted in agricultural or silvopastoral systems to provide fodder, shade, windbreak, medicines, or to meet household energy needs. The tree also has potential to rehabilitate land from further degradation over addition of litter fall that is main source of organic matter besides the tree root turnover It is also important for diversification of income through the selling of fruits, fuel wood and/or timber and other non-wood tree products like spices, honey, gum and incense.

2.2. Concept of Parkland Agroforestry

Many researchers argue that, parkland agroforestry practices are growing individual trees and shrubs in wide spaces in croplands and most often characterized by the dominance of one or few species. For instance, Melese Worku (2017), stated that, Trees would be grown in a scattered form over a crop field, usually between 1-20 trees per hectare to minimize the impact on the companion crop. similarly Nair (1993), stated that, scattered trees on cropland is one practices of a large number of tropical agroforestry systems and practices which consists of growing agricultural crops under scattered or dispersed or systematically planted trees on farm. Pervious study shows, these parkland trees are selectively left or regenerated by farmers because of the variety of functions such as food, medicine, temperature amelioration, privation of soil erosion (Asako T, 2007).

Parkland trees may provide mulch when their leaves, fruits, branches drop and decompose. This results in the rise of organic material and recycling of nutrients from deep zones of the soil and leguminous trees fix nitrogen that can benefit food crops (Sanchez, 1995). Integrating agricultural crops with growing a number of tree species such as; *Faidherbia albida, Cordia Africana, Croton macrostachyus (Lam), Acacia albida, Milletia ferrugenia* and *Albizia gumifera* on farmlands is very well practiced in different parts of Ethiopia (Jiregna Gindaba *et al.*, 2005; Abebe Yadessa *et al.*, 2009; Gizachew Zeleke *et al.*, 2015; Desalegn Mamoand and Zebene Asfaw, 2017 and Muktar Mohammed *et al.*, 2018).

2.3. Roles of parkland trees to soil fertility

As we all know, crop yield is based largely on soils. The ability of a soil to support crop production determined by the entire spectrum of its soil fertility attributes. According to Muchena (2008), the decline in soil fertility is becoming one of the major challenges for establishing sustainable agriculture. Therefore, agriculture productivity per unit of land is declining through time and food production could not keep pace with population growth.

Different research findings stated that; nutrient deficiency, particularly of nitrogen (N), phosphorus (P), and potassium (K) are considered a limiting factor for plant growth. For instance, Elhag and Abaker (2018) indicated that; the concentrations of total NPK and water holding capacity significantly depended on soil organic carbon (SOC) concentrations and correlated with SOC at different depths.

Study findings by (Tadesse Hailu *et al.* 2000 and AbebeYadessa *et al.* 2009) indicated that total nitrogen is higher under the canopy *Millettia ferruginea and Cordia africana* when compared to the open field respectively. Which is in line with Desalegn Mamo and Zebene Asfaw (2017), finding under *Croton macrostachyus*. Other similar trends were found by (Jiregna Gindaba *et al. (*2005); and Enideg Diress (2008) under *Cordia africana* and *Croton macrostacyus* and *Ficus thonningii* respectively. Whereas according to Hailemariam Kassa *et al.* (2010) the available nitrogen had no significant difference in the three zones (0-4 m,4-6 m and 6-8 m) from the base to the outside of the canopy on *Balanite aegyptica* at Humera district of Tigiray region.

Research in the semi-arid areas of the Tsavo West National Park, Kenya, shown substantially higher phosphorus under canopies of *Acacia Senegal* (L.willd), *Balanites aegyptiaca* and *Adansonia digitata (L.baobab)* **(**Young, 1989). According to the study report of Jirenga Gindaba (2005); Desalegn Mamo and Zebene Asfaw (2017), *Croton macrostachyus* has a higher contribution of phosphorus on the surface soil than *Cordia africana*. In contrast to this, Enideg Diress (2008), reported no change in available phosphorus concentration at different distances of standing *Ficus thonningii*(Blume –fig.) in Gonder zuria, Ethiopia. Whereas the soils outside the canopy of *Acacia toritilis* have higher concentration of available P than the soil under the canopy of the two trees in Kenya (Kahi *et al.*, 2009).

At the Humera district of the Tigray region a study undertaken on *Balanite aegyptica*, indicated that the concentration of potassium in the soil was higher under the canopy than far from the canopy (Hailemariam Kassa *et al*., 2010). Similarly, Desalegn Mamo and Zebene Asfaw (2017) discover that, concentrations of potassium exhibited a decreasing trend with increasing distance from tree trunk in Gemechis district, West Hararghe.

2.4. Effects of parkland trees on soil bulk density and organic carbon

Bulk density (BD) is an indicator of soil compaction. An increase in bulk density of the soil results in reduced porosity, aeration, root growth and infiltration that increase runoff and erosion. Bulk density is inversely related to soil porosity and organic matter content of the soil (Brady and Weil, 2002). Soil bulk density was lower under the canopy of the trees than outside the canopy of the trees. This higher soil bulk density recorded in subsurface soil than surface soil and open field than under canopy might be due to declining of soil organic matter, less root turnover or concentration of tree roots both with distance and depth besides soil outside the canopy of the tree dried out more being exposed to direct solar radiation. This accelerates decomposition and shrinking of organic matter making the soil more compact and higher soil bulk density in the open (Aweto and Dikinya, 2003). Bulk density is calculated as the dry weight of soil divided by its volume and typically expressed in g/cm^3.

Research conducted shown that, Soil bulk density was significantly lower under the canopy of *Ficus vasta, Croton macrostachyus, Cordia Africana* trees than outside the canopy of the trees (Gizachew Zeleke *et al.,* 2015; Desalegn Mamoand and Zebene Asfaw, 2017; Muktar Mohammed *et al.,* 2018) in Hawassa Zuria District, West Hararghe and Eastern Oromia respectively. Whereas Enideg Diress (2008) reported that, no significant difference in bulk density between outside the canopy of *Ficus thonningii* as compared to the canopy zone in north Ethiopia.

Soil organic carbon (SOC) content is directly related to the amount of organic matter contained in soil and SOC is often how organic matter is measured in soils. Soil organic matter is composed of soil microbes including bacteria and fungi, decaying material from once-living organisms such as plant and animal tissues. The ability of agriculture lands to store or sequester carbon depends on several factors; including climate, soil type, type of crop or vegetation cover and management practices (Pathak, 2012).

Different scholars indicated that; the overall mean values soil organic carbon content was higher under canopy than an open area. Fore instance Study conducted by Muktar Mohammed *et al.* (2018), of SOC content among all radial distances at ($p<.0001$ and between soil depths at ($p <.0001$) for both *Croton macrostachyus* and *Cordia Africana* species have shown a significant difference. Similar trends have been stated by (Gizachew Zeleke *et al.,* 2015; Desalegn Mamoand and Zebene Asfaw, 2017) organic carbon content was significantly higher at ($P<0.05$) under canopy zone of *Ficus vasta* (Forssk) *and Croton macrostachyus* than open area. This variation of organic carbon was quite logical as accumulation of the litter falls and dead roots from the tree may result in higher contents of organic carbon under the tree canopy. The animal excretion including birds might also contribute to enhancing soil organic carbon concentration as well as SOC stock. On another side Study by Hailemariam Kassa *et al*. (2010) in Humera district northern Ethiopia on *Balanites aegyptica* indicated that organic carbon of the four sites was not significantly different among the three zones (0-4m, 4-6m and 6-8m) from the base of tree.

2.5. Soil pH

Soil pH is an activity (concentration) of hydrogen ions in the soil solutions. The degree of acidity or alkalinity of a soil measured by soil pH and it is indicated by a pH scale of 0 - 14. According to (Brady and Weil, 2002) suitable soil pH value for agricultural purposes is between 5.5-7.5 pH values. pH influences nutrient absorption and plant growth through its effects on nutrient solubility and availability (Brady and Weil, 2002). *Hagienia abyssinica, Cordia africana and*

Croton macrostachyus trees among different canopy positions in central Ethiopia and western Oromia of Ethiopia (Kindu *et al.* 2009; Muktar Mohammed *et al.* 2018) did not significantly influence soil pH. Moreover, soil pH under the canopy has similar trends to that of outside the canopy of *Balanite aegyptiaca* tree at Limat site (Hailemariam *et al.,* 2010).

2.6. Biomass and soil carbon stock of Parkland Agroforestry Trees

Above ground biomass carbon stock is associated with stand density/number of individuals per hectare. Basic structural parameters such as size, height and diameter at breast height (1.3m) have a significant positive relationship with aboveground carbon stock (Weifeng W,Xiangdong *et al*.; 2011). Fast growing tree species, for instance, *Eucalyptus camaldulensis* (Dehn) have high efficiency of carbon sequestration than native species (Gil L, Tadesse Hailu *et al.,* 2010).

A global survey has shown that over 43 % of agricultural lands have more than 10% tree cover (Zomer *et al.,* 2016); and biomass carbon stocks in agricultural lands have also been shown to range between 3 – 18 t C ha^{-1} (Agevi *et al.*, 2017). A study conducted in Kou and Cassou (2018) in south-central Burkina Faso, among the preferred woody species the highest quantity of carbon was stored by *Vitellaria paradoxa (C.F.Gaertn)* (1,460.6 ±271.0 kg C ha^{-1} to 2,798.1±521.0 kg C ha^{-1}) and the lowest by *Grewia bicolor (L.)* (1.6±1.3 kg C ha^{-1}). Similarly, in Gununo Watershed Wolayitta Zone southern Ethiopia, parkland agroforestry has 0.57 ± 0.13 Mg AGBC per hectare (Aklilu Bajigo *et al.,* 2015).

SOC stock for tropical agricultural land has been reported to be 80–103 Mg C ha^{-1} (Lal 2004). On the other hand the mean of SOC stock of for cultivated land of East and West Africa 18.5–52.5 Mg C ha^{-1} (Brown *et al.*, 2012); and in scattered trees on the farm area ranged between 2.28 and 40.5 Mg C ha^{-1} in Tigray region Northern Ethiopia (Yikunoamlak Gebrewahid *etal.* 2018).

2.7. Effects of parkland trees on crop yield

Different findings have shown, trees in parkland have both positive and negative effect on crop productivity. For instance, experiment conducted by Kiros Hadgu *et al.,* (2009) In the highland of Tigray, northern Ethiopia found that higher barley yields were found at 1m distance from the tree (1396 kg ha^{-1}) compared to yields at 25 m (992 kg ha^{-1}) and 50m (940 kg ha^{-1}) on scattered *Faidherbia albida.* Similar trends have been reported by (Dechasa Jiru 1989; Saka *et al.,* 1994; EARO 2000), in Debre Zeit, Malawi and Alemaya; that shown, wheat and maize yields increased by over 50% under *Faidherbia albida* (Delile) canopy (within 1.4 m radius) compared to those further away from the base of the tree respectively.

In contrast, other study on *Balanites aegyptiaca* with sorghum yield in Tigray region Hailemariam Kassa *et al.* (2010), have shown, no significant difference in sorghum yield at difference distances from the tree trunk. And in Eastern Oromia (Muktar Mohammed *et al.,* 2018), found the highest maize yield (1.51 ton ha^{-1}) at 15m from tree trunk, and lowest (1.05 & 1.12 ton ha^{-1}) mean values at 0.5m from tree trunk of *Cordia Africana* (Lam.) and *Coroton macrostachyus* (Hochst. Ex Del) trees respectively. In Kenya, another finding has shown that; the grain yield of maize in Kenya Elton Ndlovu (2012), was significantly reduced by 64.8% at 1m from the trees compared to those harvested at 3.25 m away from the *Cordia africana* tree. This may be attributed to the shading effect by trees on the crop and some fast-growing trees such as eucalyptus reduce crop yields because of competition for light, water, nutrient and allelopathic effect of trees on the crop (Ralhan *et al.,* 1992; Akyeampong *et al.,* 1995b).

2.8. Teff productivity in Ethiopia

According to the Central Statistical Agency (2008) the majority of farmers in Ethiopia are smallholder farms, producing mostly for own consumption and generating only a small-marketed surplus. As Central Statistic Authority (2008) report, Teff (Eragrostis tef) is one among the major cereals of Ethiopia and occupies about 2.7 million hectares (27% of the grain crop area) of land which is more than any other major cereals cited in (Yonas Mebratu *et al.,* 2016). Regardless of its high area coverage, adaptation to different environmental conditions and requirement as a staple food in Ethiopia, the yield of tef grain is not increasing above the national average grain yield of 1.2 t ha^1 cited in (Yonas Mebratu et*al*., 2016). Teff predominantly cultivated on sandy-loam to black clay soils gives better grain yield and possesses higher nutrient content especially protein when grown on Vertisols rather than Andosols. Its grain is mainly used for making enjera, spongy flatbread, the main national dish in Ethiopia. Tef is also valued for its fine straw, which is used for animal feed as well as mixed with mud for building purposes cited in (Yonas Mebratu *et al* 2016).

2.9. Description and Ecology of *Acacia seyal* trees

According to Azene Bekele (2007), *Acacia seyal* belongs to the family Fabceae and sub family Mimosoideae subfamily and it has a common name such as Wachu in Amharic, Tseada-chea in Tigrigna, Waqo-dimo in Oromigna and white galled acacia and white whistling torn in English. Acacia trees are very drought resistant, commonly found on clay soils in areas with a mean annual rainfall of 250-1000 mm (Thorstensson, 2009). But as Azene Bekele (2007), In Ethiopia, it also found seasonally flooded in and black-cotton soil, in river valleys and wooded grass land of dry and moist weyna dega agro climatic zone in Gojam, Shewa, Arsi , Wollo, Tigray, Sidama, Harerge and Ilubabor region,1200-2100 m.a.s.l.

Besides the use of fuel wood for cooking and heating of houses, biomass is also used for the construction of houses and fences amongst other things. In addition, many researchers like Thorstensson (2009) stated *Acacia seyal* tree spices tapped for gum Arabic, a resin used in food, beverages as well as for industrial purposes, as an extra source of income. Among farmers in semiarid Sudan it's a known fact that the Acacia trees that grow and regenerate naturally on their lands help improve soil fertility and crop yield and in another side the removal of vegetation, in turn, makes the land susceptible to erosion and the need for even more land rises as nutrients are lost (Thorstensson,2009).

3. MATERIALS AND METHODS

3.1. Description of the Study Site

3.1.1. Geographical location of the Study Area

This study was conducted in Gubalafto woreda Aykel webi kebelle Gojer watershed. According to the Gubalafto woreda agriculture office, (2016) Gubalafto woreda is one of the 15 rural administrative districts in the Northern Wollo zone of Amhara reginal state. The wereda is found at 521 km North of Addis Ababa. A chain of mountains, hills and valleys ranging from 1379 – 3809 masl characterizes the topography of the woreda.

The study area is located within the range of 11^{0}34'54" N and 12^{0}58'59" N latitude and 39°6'9"E and 39°45'58"E longitude. It shares a common border to the south with south wollo zone, to the west with Delanta and Wadla woredas, to the north with Meket, to the south east with Harbu and to the north Gidan Woreda.

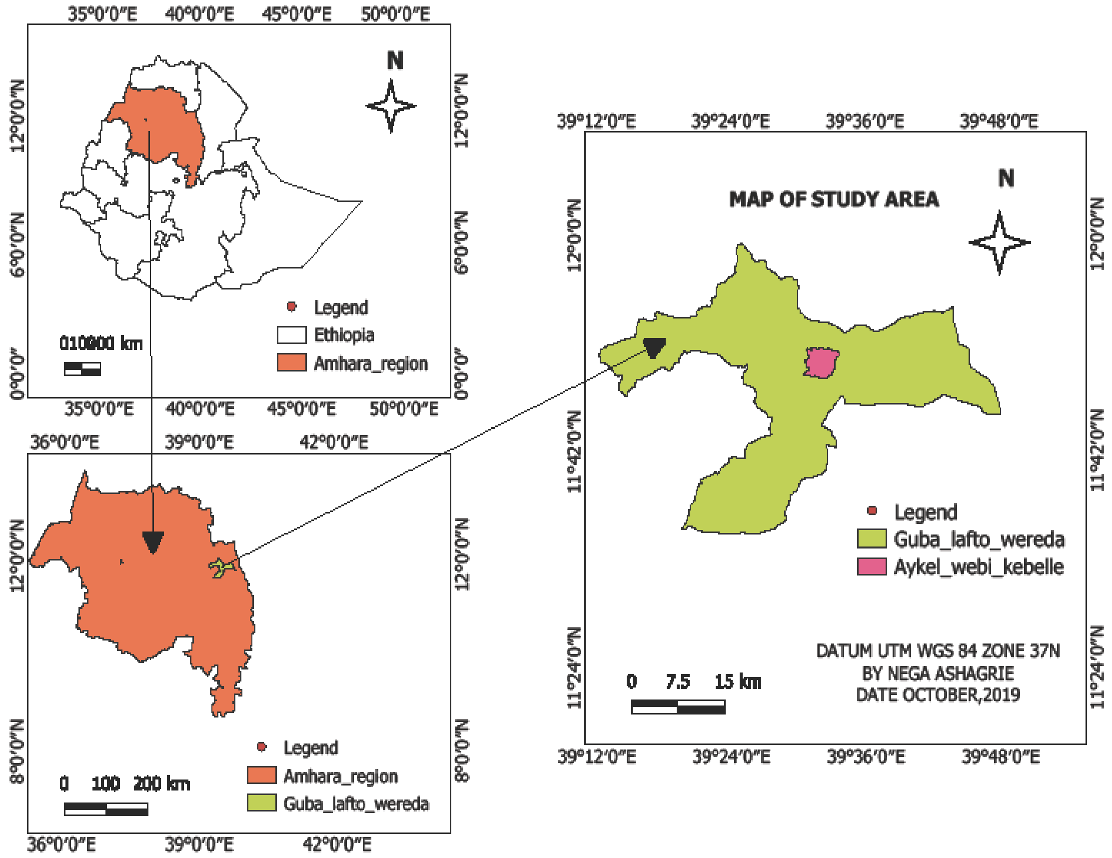

Figure 1: Location map of the study area

3.1.2. Climate

The agro-climatic classification of Gubalafto district is characterizes 42.8% Dega, 38.25 % Weynadega and 18.9% kola (Gubalafto woreda Agricultural office 2016). The mean annual rainfall of the woreda is 800-1050mm. Rainfall is bimodal, i.e. the main rain fall season (Maher) is from June to August and short rains fall season (Belg) occurs February/March. The rainfall type is erratic with high intensity in a short period of time.

The average temperature of the study area is 7.5 - 22 degree cielcious. April to May is the hottest/warmest months whereas a low temperature occurs from October to January (Guba Lafto woreda office of agriculture, 2016).

3.1.3. Soils

The soil textural class of the area belongs to 14.66% sandy, 21.76% silt and 63.67% clay. Lithic Leptosols and Vertisols are the most dominant soil types cover in the area, while Cambisols and Lithosol were also observed in the area. (Ali Mohammed, 2010). The soil pH is nearly in neutral to slightly alkaline range.

3.1.4. Land covers and Vegetation

Gubalafto woreda covers a total of 114, 079 hectares with land use pattern of (34.1%), agricultural land, grazing land (17.9%), forest (27.1%), water bodies (6%), rocky land (5%) and others (9.9%) respectively (Dereje Mengistie and Desale Kidane , 2016).

The main woody species found in Guba Lafto woreda are *Eucalyptus camaldules*, *Eucalyptus globullus* (dominant), *Cupressus lustanica*, *Oleaa africana*, *Hagenia abyssinica*, *Juniperus procera* and different types of Acacia species with small coverage (Guba Lafto woreda office of agriculture, 2016).

3.1.5. Population

The human population of Gubalafto woreda is 168,406 people. From this (52%) are male and the rest (48%) are female. From the total population size of the district, Aykel webi kebelle alone accounts about 3,310 (2150 male and 1160 female). (Central Statistic Agency, 2007). According to Gubalafto district agricultural office information, the average family size of the people is five per household and the average land-holding size for a farmer has been estimated to be 0.78 hectares. The majority of populations are active labor age. Since, over 90% of the people live in rural areas are engaged in rain fed crop production and animal husbandry. Population growth leads to deforestation, conversion of pastureland to croplands, overstocking and further degradation of the remaining vegetation of the district.

3.1.6. Socio-economic Condition and Livelihoods

The economy of the study area depends on traditional, rain fed crop production, irrigation and animal husbandry. Mixed crop-livestock farming is the dominant system of production. According to the report of the districts' agricultural office (2016), 92% agriculture, trade 2%, handcrafts 5%, and the other 2% are important mainly for income generation purposes.

3.2. Methods

3.2.1. Experimental design and sampling techniques

A reconnaissance survey was conducted in the third and fourth week of October 2018 in order to obtain an impression of the site condition and to determine the sampling methods and design to be used. During this period, an initial discussion took place with Zone, Woreda, and Kebele leaders and with the farmers owning *Acacia seyal* trees and cultivate crops to obtain their agreement or permission to carry out the research and overall information on the study site. A systematic sampling method was used to collect the data. In order to assess and count population distribution *Acacia seyal* trees, transect and quadrants based methods were used. Whereas soil and crop yield data collection was done by Tree-Transect methods.

3.2.2. Methods of Data collection

3.2.2.1. Tree data collection

To collect *Acacia seyal* trees samples, three transect lines, were established along the gradient with 300 meters apart from each other and 40m*50m string plots /quadrants were systematically laid at the interval of 200 meters distances on each transect adopting the method used by Nikiema (2005). The first transect line and sample plot were systematically selected. To avoid the border effect, the sample collection started after 50 meters distance from the border. In each sample plot/quadrant all *Acacia seyal* DBH (diameter at breast height (1.3 m) which have ≥ 5 cm and greater than and equal to 2 meters height of each tree was measured by caliper and hypsometer respectively. The crown radiuses of the trees were measured by using meter tape. There were replicate within 200 meters interval between them and three transect lines.

Table 1: height, crown radius, DBH, age of *Acacia seyal* trees and crop history of the study area.

Replication	Height(m)	crown radius(m)	DBH(cm)	Estimatedage (year)	Crop history (5yr)
Tree 1	10	4.25	29	9.0	T,T,T,T,S
Tree 2	8	3.75	27	9.0	T,T,T,S,T
Tree 3	11	4.00	30	10.0	T,T,T,T,T
Tree 4	11	4.50	27	10.0	T,T,V,T,T
Tree 5	12	4.50	31	8.00	T,T,T,T,T
Tree 6	12	3.80	28	10.0	T,T,V,T,T
Mean±st.dev	10.67±1.51	4.1±0.32	28.67±1.63	9.14±0.81	

Where: T= teff, S= sorghum, V= vetch, DBH= diameter at breast height.

3.2.2.2. Soil sample data collection

Acacia seyal trees were purposely selected in the farm having similar topography, cropping history, management practice and trees with approximately the same size and age used for study purposes. Six selected trees were considered as replication and the area covered by the canopy divided in to four radial distances. The transects were laid at four distances from *Acacia seyal* tree designated as zones(D) were, 0 - 2 m (D_1) under canopy, 2 m - 4 m (D_2) middle of canopy, 4 m - 6 m (D_3) edge of canopy and 12 meter (D_4) away from tree trunk used as control.

Soil data was collected with depth difference by using auger and core sampler at three different distances from standing *Acacia seyal* tree. The core sampler has a 7cm diameter and 20 cm height. From four compass directions (North, South, East and West) four composite soil samples were taken from surface (0 – 20 cm and sub-surface soils (20 – 40 cm) to make one representative sample for each distances from tree trunk. The composite soil sample was careful mixed and quarter approach was used to get about a kg of soil. Soil processing and analysis took place at Wondo Genet College of Forestry and Natural Resource Soil Laboratory. 48 composite soil samples from (six trees, four distances and two soil depths) were analysed.

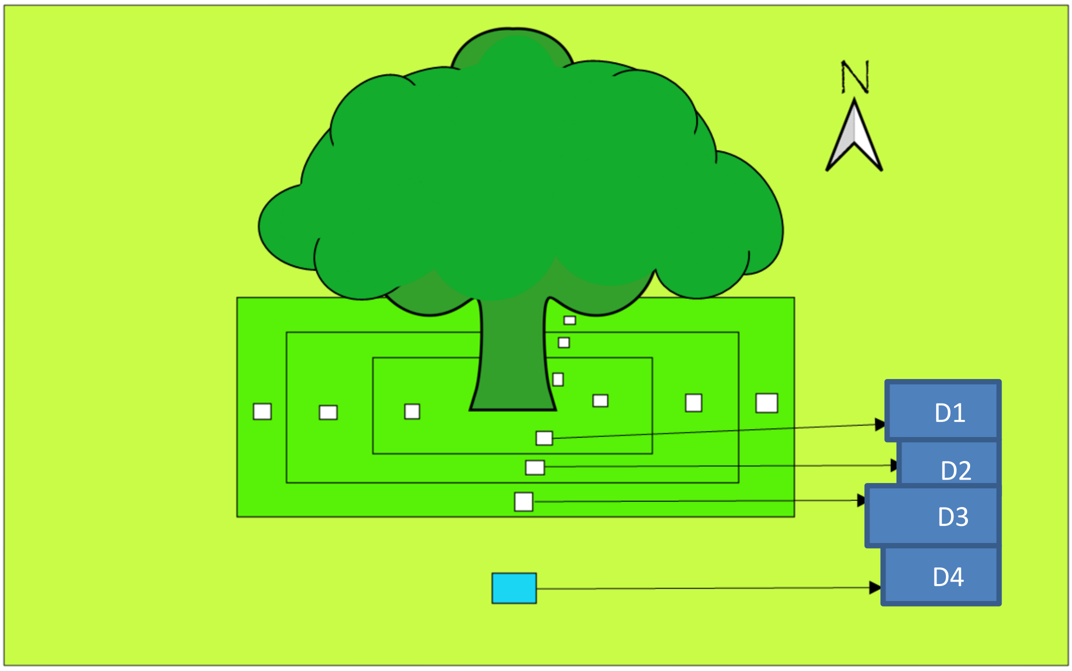

Figure 2*:* Design for soil and yield data collection technics at farm field of Gojer watershed.

3.2.2.3. Teff yield data collection

Teff yield was collected (1 m × 1 m sub plot) just adjacent to soil sample plot following the same procedures as soil sampling. Threshing of teff was done manually, cleaned, exposed to sun light for three consecutive days and weighed the grain yield in grams. Based on this, the grain yield was estimated by kg per hectare.

3.3. Method of Data Analysis

3.3.1. Soil laboratory analysis

Soil samples were analyzed at the soil laboratory of Wondo Gent College of Forestry and Natural Resources. Soil pH was determined by using pH meter in a 1:2.5 (%) soil: water suspension. Total nitrogen (TN) was determined by the Kjeldahl method (Bremner and Mulvaney, 1982).

Available soil phosphorus was determined by the Olsen method (Olsen *et al.*, 1954). Available potassium was determined by the Neutral Ammonium acetate extraction method (Merwin and Peech, 1951). The extract potassium (K) was estimated by flame-photometer.

Soil organic carbon (SOC) was determined by the Walkley-Black (1934) procedure (a wet combustion of organic matter with a mixture of potassium dichromate and sulfuric acid and residual potassium dichromate titrated against ferrous sulfate) (Jackson, 1958; Reeuwijk, 2002). SOC stock (Mg ha^{-1}) was calculated as the product of carbon content (%), bulk density (g/cm^3), and layer thickness (cm) (Pearson *et al.*, 2005).

SOC stock = BD * Depth Soil * %OC *100---Equation (1)

Where: SOC is Soil Organic carbon stock (Mg/ha), BD is bulk density (g/cm3), Depth (cm), percentage of OC is soil organic carbon content or carbon fraction.

The SOC stock values for the two layers (0–20 cm and 20–40 cm) were summed to give the SOC stock for the entire 0–40 cm layer.

For soil bulk density, fresh soil samples extracted by cores were bagged in a plastic bag, sealed and labeled. The samples were transported to a laboratory for oven dry and the oven dry weight was measured after drying for 48 hours at constant temperature of 105^0C (Blake, 1965). Finally, soil pore space was calculated from measured bulk density values using the following equation:

BD (gm/cm^3) = (oven dry weight of the soil) / (volume of the core) ………..*Equation (2)*

The volume of the core = $\pi r^2 h$……………………………….……..……………*Equation (3)*

Where: r = radius of the core sampler which is 3.5 cm, π =3.14, h =height=20 cm

3.3.2. Above ground biomass carbon stocks

To estimate the aboveground biomass of carbon stocks (AGBC) of the *Acacia syeal* trees in farm field, three allometric equations were evaluated; that was Kuyah *et al*. (2012a), Chave *et al*., (2014), and Abreham Berta *et al.* (2018). However, the equation by Kuyah *et al.* (2012a) was selected for this study to estimate aboveground biomass. Because the highest R^2 (0.97) and lowest error of prediction values, used breast height diameter > 2.5 cm. Besides this, equation were developed for trees grown in parkland agroforestry systems in western Kenya. Furthermore, studies on parkland agroforestry in the Northern Ethiopia use this allometric equation having similar environmental conditions as those study area.

The equation is as follows

$AGB = 0.0905*DBH^{2.4718}$; $R^2 = 0.97$, ……………………… Equation (4)

Where: AGB is above ground biomass, kg/tree, DBH is diameter at breast height (1.3 m).

According to (Mac Dicken 1997; Brown 2002), the tree biomass stock density was converted to carbon stock densities by using Equation 5.

AGBC =AGB *0.5------------------------- Equation (7)

Where: AGB is above ground biomass, kg/tree, AGBC is above ground biomass carbon, kg/tree.

3.3.3. Belowground carbon stock estimation

The below ground biomass carbon stocks were analyzed based on equation (6) developed by Kuyah et al. (2012b). This equation was selected for its easiness to apply, less time consuming, and is non-destructive.

BGBC Stock = $0.490*AGBC^{0.923}$; --------------------------Equation (8)

Where, AGBC = Above ground biomass carbon (Mg/ha), BGBC is Carbon in below ground biomass carbon

Total biomass C stock is defined as the sum of the total aboveground and belowground biomass C stock associated with the tree.

The carbon stock density of a study area was calculated by summing the carbon stock densities of the individual carbon pools following Equation (7) (Pearson *et al.* 2005).

Carbon stock density of the study area: AGBC + BGBC + SOC-----------------------Equation (9)

Where: C density is Carbon stock density for all pools (Mg/ha), AGBC is Carbon in above ground tree biomass (Mg/ha), BGBC is Carbon in below ground biomass (Mg/ha) and SOC is Soil Organic carbon (MG/ha).

3.4. Statistical Analyses

Data collected from field inventory was organized and recorded in Microsoft Excel 2016 data sheet. The required Statistical analyses were performed using SPSS (version 16). The grain yield data were subjected to one-way ANOVA (distance) while soil organic carbon, NPK and biomass carbon stock were tested by two-way ANOVA (distance and depth) using General Linear Model (GLM) procedures. Mean comparison of treatment was performed by Tukey's high significance difference (HSD*) at a 5% probability level.

4. RESULTS AND DISCUSSTION

4.1. Biomass Carbon Stocks

The analyzed overall mean of biomass carbon stocks shown 0.884 ± 0.445 Mg C ha^{-1} (Table 2). This indicate that *Acacia seyal* parkland agroforestry contribute to emission sequestration and climate change regulation.

Table 2: Mean BCS of trees in Mg ha^{-1} in Gubalafto distrect of Northern Ethiopia.

Parameter	Height (m)	DBH (cm)	Nº tree ha^{-1}	Mg ha^{-1}	
				AGBC ±std.	BGBC ±std.
BC Stock	7.5±1.07	19.4±1.102	35±2	0.587±0.302	0.297±0.1430

Where: BCS =Biomass Carbon Stock, DBH =Mean diameter at breast height, N ha^{-1}= number of trees per hectare, AGBC= Mean above ground biomass carbon stock, BGBC= Mean below ground biomass carbon stock, std. = standard deviation,

The study conducted in Gununo Watershed Wolayitta Zone of southern Ethiopia, parkland agroforestry showed 0.57 ± 0.13 Mg ha^{-1} biomass carbon stock (Aklilu Bajigo *et al.;* 2015). Whereas average global survey in agricultural lands biomass carbon stocks has been shown to range between 3–18 t C ha^{-1} (Agevi *et al.*, 2017); that has greater potential for emission sequestration and climate regulation than the present study. Furthermore studies conducted by Kou and Cassou (2018), in south-central Burkina Faso, among the preferred woody species, indicated the highest quantity of stored carbon *Vitellaria paradoxa* (1,460.6 ±271.0 kg C ha^{-1} to 2,798.1±521.0 kg C ha^{-1}) and the lowest by *Grewia bicolor* (1.6±1.3 kg C ha^{-1}). However, biomass carbon stock values were lower than reported for scattered trees on the farm area ranged between 3.89 - 17.97 Mg C ha^{-1} and 7-28 Mg C ha^{-1} in Northern Ethiopia and Sub-Saharan

Africa respectively (Yikunoamlak Gebrewahid *etal.*, 2018; Unruh *et al.*, 1993). Those variations could be due to influences of local people and altitudinal gradient differences of the study area where many and bigger trees with maximum DBH were more frequent at upper altitudes due to the favorable conditions for tree growth in higher altitudes (Rahayu *et al.*, 2005).

4.2. Soil bulk density in *Acacia seyal* teff field

There was no significance difference (P > 0.05) in bulk density among mean value in the four distances from a tree trunk.

Table 3: Soil bulk density at different soil depth and distances from *Acacia seyal* tree trunk.

Distances (m) from *Acacia seyal*	BD in (gm. Cm^{-3}) at different Soil depth (cm)		
	0-20 cm	20-40 cm	0-40 cm
D_1	$0.615^a \pm 0.092$	$0.687^b \pm 0.05$	1.38+0.138
D_2	$0.625^a \pm 0.076$	$0.697^b \pm 0.07$	1.35+0.97
D_3	$0.632^a \pm 0.041$	$0.701^b \pm 0.02$	1.33+0.08
D_4	$0.665^a \pm 0.057$	$0.718^b \pm 0.06$	1.43+0.07
Mean	0.634±0.0675	0.701±0.05	1.37+0.09

Where: Columns with the same letter superscript are not significantly different at $p < 0.05$, BD = bulk density (gm. per cm^3).

The finding of this study is supported by Enideg Diress (2008), reported that no significant difference in bulk density between outside the canopy of *Ficus thonningii* as compared to the under canopy zone in northren Ethiopia. Whereas other researches conducted in different part of the countries show that, soil bulk density is significantly lower under the canopy of *Ficus vasta, Croton macrostachyus, Cordia Africana* trees than outside the canopy of the trees (Gizachew

Zeleke *et al.*, 2015; Desalegn Mamoand and Zebene Asfaw, 2017; Muktar Mohammed *et al.*, 2018) in Hawassa Zuria District, West Hararghe and Eastern Oromia respectively.

4.3. Organic carbon content and carbon stock of *Acacia seyal* farm field

The mean values of soil organic carbon percent had shown a significant difference in surface soil than subsurface soil depths but no significant difference in distance. The higher soil organic carbon percent recorded in surface soil than sub surface soil (Table 4). This might be due to declining of soil organic matter less root turnover of tree roots with both distances and depth. Besides this, soil outside canopy of the tree dried out more being exposed to direct solar radiation. Accelerated decomposition and shrinking of organic matter making the soil more compact and higher soil bulk density and lower soil organic carbon percent in the open field than under canopy (Aweto and Dikinya, 2003).

Studies in soil organic carbon content by (Tilahun Fromssa 2011; Gizachew Zeleke *et al.*, 2015; Desalegn Mamo and Zebene Asfaw 2017 and Muktar Mohammed *et al.* 2018), at different tree species shown that, significance differences under canopy than far away from canopy and in surface than the subsurface soil. Whereas Study conducted by Hailemariam Kassa *et al*. (2010) in Humera district northern Ethiopia on *Balanites aegyptica* indicated that organic carbon percent of the four sites was not significantly different among the three zones (0-4m, 4-6m and 6-8m) from the base of tree. Because of low litter fall and the existed organic matter might have readily decomposed due to high temperature (Dolan *et al*., 2006; Jantalia *et al.*, 2007; Thomas *et al.*, 2007). Besides this, non-significant difference of organic carbon supports the assumption regarding the rapid mineralization of OC in the semiarid environment in Ethiopia (Tesfy Teklay, 2004).

Table 4: SOC % and SOC stock in Mg ha^{-1} in tree trunk and soil depth from standing tree.

Distances (D) meter from tree	A parameter with in different of Soil depth (cm)					
	SOC (%)		Mean %SOC	SOC Stock in (Mg C ha^{-1})		Mean SOC stock
	0-20 cm	20-40 cm	0-40 cm	0-20 cm	20-40 cm	0-40 cm
D_1	0.93^a±0.15	0.76^b±0.13	1.43± 0.62	9.64^a±4.25	9.48^b±3.65	19.12±7.9
D_2	0.92^a±0.36	0.72^b±0.28	1.69 ±0.46	12.33^a±4.48	10.17^b±4.24	22.5±8.72
D_3	0.78^a±0.11	0.66^b±0.19	1.43± 0.26	9.63^a±1.70	9.05^b±2.59	18.68±4.29
D_4	0.74^a±0.20	0.63^b±0.19	1.37 ±0.36	9.51^a±2.70	8.94^b±2.66	18.44±5.36
Mean	0.84±0.22	0.69±0.19	1.47 ±0.43	10.28±3.46	9.41±3.21	19.69±6.67

Where: Columns with the same letter superscript are not significantly different at $p < 0.05$, SOC % = Soil organic carbon (percent) and SOC stock= soil organic carbon stock in (Mg Carbon per hectare.

The mean of SOC stocks for the 0-40 cm layer around scattered *Acacia seyal* trees in the farm of the study area was 19.96 ± 6.67 Mg C ha^{-1}. Whereas 9.51 ± 2.70 - 12.33 ± 4.48 Mg C ha^{-1} for the surface layer and 8.94 ± 2.66 - 10.17 ± 4.24 Mg carbon ha^{-1} for sub- surface layers. This shows; soil under *Acacia seyal* canopy had greater value of SOC stocks than an open field and the surface soil than sub surface soil. This may due to the accumulation of litter fall and fine root decay under canopy than outside the canopy and surface soil than subsurface soil.

Current result was within the ranges of those reported for cultivated land of East and West Africa 18.5‐52.5 Mg C ha^{-1} (Brown *et al.*, 2012); and scattered trees on the farm area ranged between 2.28 and 40.5 Mg C ha^{-1} in Tigray region Northern Ethiopia (Yikunoamlak Gebrewahid *et al.*, 2018). Besides this SOC stock for rain fed, crop production of semi-arid areas in Northern Ethiopia stores 16.1 Mg C ha^{-1} (Aweke Gelaw *et al*., 2014).

4.4. Effects of *Acacia seyal* tree on soil Nitrogen, phosphorus, and potassium

Soils at different distances from standing *Acacia syeal* tree have different N, PK values (Table 5). Relatively, soil nutrients (N, PK) concentration under the tree canopy higher than the soil in the open fields but decreasing values as the distances increased from the tree trunks.

Total nitrogen concentration at under canopy scattered *Acacia seyal* is significantly different as compared to at edge and away from canopy. This probably due to the accumulation of organic matter through litter fall addition and deep rooted nature of a tree can take up or tapped N nutrients from deepest soil profile and non-volatilized under canopy than open area. Besides this the residential organic waste addition from animals and birds could also be responsible for the higher total nitrogen observed under the tree canopies (Pandey and Sharma, 2005; Kahi *et al.*, 2009). Similar trends have been reported for other species across Ethiopia. For example Tilahun Fromssa, (2011) for *Acacia tortilis and Acacia seyal*; Muktar Mohammed *et al.,* (2018) for *Cordia africana* and *Croton macrostachyus;* Enideg Diress, (2008) *Ficus thonningii*, *Balanites aegyptica*; Desalegn Mamo and Zebene Asfaw, (2017) *Cordia africana* and *Croton macrostacyus.*

Contrast finding was reported on *Balanite aegyptica* tree, which has no significant effect on total nitrogen at three zones (0-4 m,4-6 m and 6-8 m) from the base to the outside of the canopy (Hailemariam Kassa *et al*., 2010).

Available phosphorus under *Acacia seyal* tree canopy has not significantly affected as compared to the soil at open field shown from (Table 5). The present finding supported by (Hailemariam Kassa *et al.,* 2010 and Tilahun Fromssa, 2011) under scattered *Balanite aegyptica, Acacia tortilis and Acacia seyal* tree species in Humera district of Tigiray region and Arsi Neglle, western Oromia.

In contrast to this finding, studies by (Zebene Asfaw 2003; Jirenga Gindaba 2005; Desalegn Mamo and Zebene Asfaw 2017); soil available phosphorus under the canopy of *Cordia africana* and *Croton macrostachyus* tree were significantly higher as compared to the soil beyond the canopy.

Table 5: Effects of *Acacia seyal* on Nitrogen, phosphorus, and potassium

	Mean + std. deviation of NPK		
Distance (m)	Total N %	Available P kg ha^{-1}	Available K kg ha^{-1}
D_1	0.0813^{b}±0.015	87.678^{a}±63.65	875.0^{a}±104.6
D_2	0.125^{a}±0.007	49.22a±46.82	801.2^{a}±91.30
D_3	0.0797^{b}±0.007	43.56^{a}±57.95	681.75a±288.7
D_4	0.0775^{b}±0.01	68.61^{a}±74.45	757.0^{a}±171.6
Mean	0.0910 ±.022	62.271±60.06	62.271±60.06

Where: Columns with the same letter superscript are not significantly different at $p < 0.05$.

The concentration of available potassium did not shown significant difference at different tree trunk. This finding inline with the finding of (Enideg Diress, 2008; Tilahun Fromssa, 2011; Desalegn Mamo and Zebene Asfaw 2017). The authors have shown that; available potassium was not significant difference under *Ficus thonningii*, *Acacia seyal*, *Cordia africana and Croton macrostacyus* in Northern, Westren and eastern Parts of Ethiopia respectively. The reason behind the high concentration of available potassium under canopy might be due to high organic matter accumulation and decomposition release in the soil (Brady and Weil, 2002).

4.5 Soil pH

The soil pH under *Acacia seyal* at a different distance from the tree trunk has not varied significantly (Figure 2). This finding ranging from 7.02 - 7.16 pH value which is nearly neutral to slightly alkaline ratings and the result of soil pH value was suitable for agricultural purposes (Brady and Weil, 2002).

The present finding confirmed the studies under taken by (Enideg Diress, 2008; Kindu Mekonnen *et al.*, 2009; Hailemariam Kassa *et al.*, and Camargo-Ricalde *et al.*, 2010). The authors are shown, soil pH under the canopy of *Ficus thonningii*, *Haginia abyssinica*, *Balanite aegyptica* and *Mimosa species* trees have not significantly affected as compared to the soil outside the canopy.

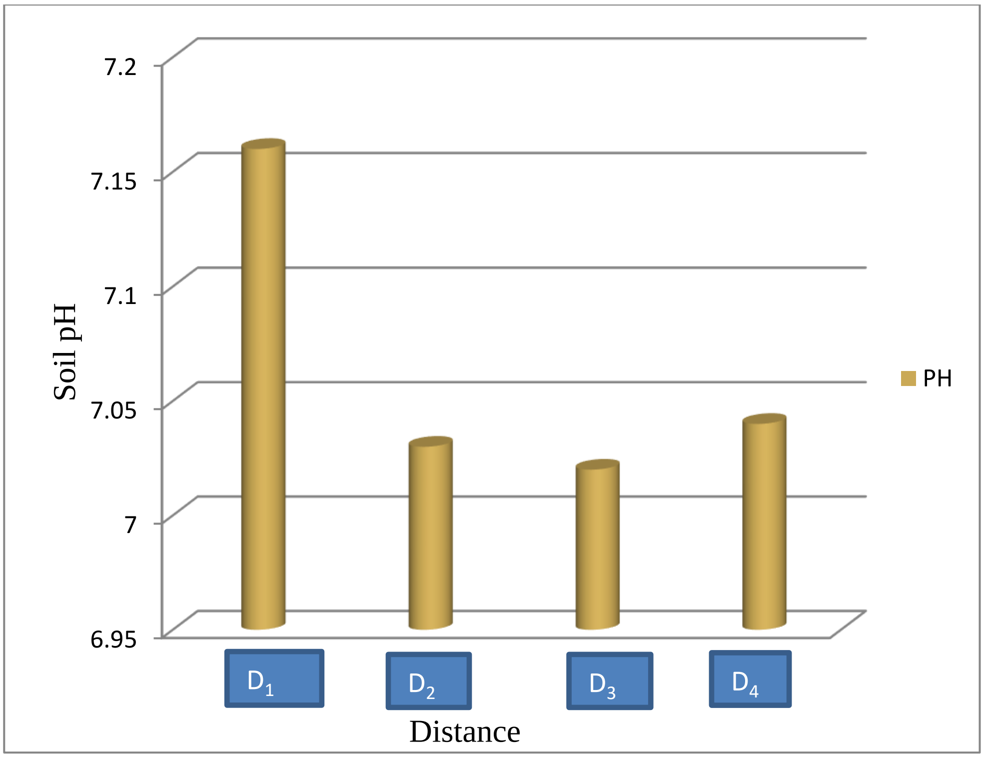

Figure 3: Effects of *Acacia seyal* on soil pH at different tree trunks.

In contrast, soil pH value has shown either significantly decreasing or increasing with horizontal distance from the tree trunk. For instance, studies by Desalegn Mamo and Zebene Asfaw (2017), soil pH under a canopy (6.65) significantly decreasing as compared to the soil outside the canopy (6.1) under *Croton macrostacyus* parkland farming system in western Harergie. Those variations might be due to attribute to higher litter deposition, decomposition and subsequent mineralization release cations to the soil system under canopy than open land.

Whereas Hailemariam Kassa *et al*. (2010) shown soil pH value was significantly increasing beyond canopy (8.22) than under canopy (7.96) in scattered *Balanites aegyptiaca* farmland at Goblel and Korbebite sites from Northern Ethiopia. This pH range reflects the nature of the calcium carbonate ($CaCO_3$) parent material of the soil at outside the canopy (Abebe Yadessa *et al.,* 2009).

4.6 Effect of *Acacia seyal* tree on teff yield

Acacia seyal has a significant ($P < 0.05$) effect on teff yield at under canopy than from at edge of the canopy and outside of the canopy; whereas, not significantly affected at different aspects (north, southeast, and west) from the tree base (Table 6). The reason of highest grain yield was found under the canopy of the tree trunk and lower amount of teff yield existed from outside of the canopy is due to nutrient fixation by *Acacia seyal* tree, modification of soil temperature and microclimate under tree canopy. Inline with the present study, research conducted in the highland of Tigray, significantly higher barley yields found at under canopy from the tree (1396 kg ha^{-1}) compared to yields at outside the canopy (940 kg ha^{-1}) on scattered *Faidherbia albida* (Kiros Hadgu *et al.,* 2009). Similar studies Shown that Maize yield increases more than 100% in Malawi (Saka *et al.,* 1994) and 76% in Ethiopia (Poschen, 1986) under canopy compared to open fields.

Table 6: Effects of *Acacia seyal* on teff yield in kg ha^{-1} at different distances from the tree base.

Distance from tree trunk	Parameter Teff yield in kg ha^{-1}
D1	$945.8^{b} \pm 189.9$
D2	$1125^{a} \pm 241.3$
D3	$960.4^{b} \pm 221.2$
D4	$810.4^{b} \pm 175.7$

Where: Values in rows with the same letter are not significantly different at $p < 0.05$ and row with different letter superscript are significantly different at ($p < 0.05$).

Contrast studies in the Tigray region by (Hailemariam Kassa *et al.,* 2010) under *Balanites aegyptiaca* with sorghum yield and Selamyihun Kidanu *et al.* (2004) under the canopy of *Eucalyptus globules (Lauabill)* with wheat yield reported that, no significantly different in yield. This probably due to reduced sun light reaching on soil and crop, intensity and the modified microclimate under trees might favor the development of fungal diseases, which may attack crops, and subsequently resulted in yield reduction.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This study highlighted the importance of scattered *Acacia seyal* trees in local people's strategies to sustain their livelihoods, through climate change adaptation and mitigation. Based on this study the following conclusions are forwarded:

There was no significance difference in soil bulk density and organic carbon among mean value in the four distances from *Acacia seyal* tree trunk. Whereas the mean values of soil bulk density and organic carbon percent shown a significant difference in surface and subsurface soil depths. When the total biomass C stocks were 0.884 ± 0.444 Mg C ha^{-1} whereas SOC stock values for the 0-40 cm layers were 19.96 ± 6.67 Mg C ha^{-1}. This suggests that the significant potential of these crop production systems and enhances to store carbon stocks. This could be an attractive opportunity for farmers to benefit economically from scattered trees on farmland if the carbon sequestered is sold to developed countries.

There were significance different values of total nitrogen under *Acacia seyal* canopy as compared to that of soil beyond the canopy. The higher total nitrogen and recorded at near distances from tree trunk than from far the tree trunk.

Available soil phosphorus, potassium and soil pH were statistically not significantly different in horizontal distances at *Acacia seyal* tree species. However, it has shown declining trend away from the tree base to the open control.

Acacia seyal had a beneficial effect on teff production by providing maximum yield under canopy than away from canopy due to suitable microclimate and nitrogen fixation.

5.2. Recommendations

- There was no diversity of multipurpose tree species in the study area; it is only *Acacia seyal,* so that the incorporation and planting of this type of tree need special attention.
- Since more crop yield, Nitrogen and potassium were under canopy than open field, more tree plantations are needed in for better crop yield and carbon storage of the area.
- The result of teff yield reported in this study was from under farmer's management, so that, further study is needed under controlled experiment in association with this tree.
- The study was done on selected soil chemical experimental intervention of soil. Therefore, further research should be conducted on physical and chemical property of soil, fine root and litter production, distribution of the tree, chemical compositions and decomposition of the tree.

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APPENDIX

Appendix 1: Soil NPK and pH analysis

Distance	N(ppm)	K kg/ha	P kg/ha	pH	depth
1	0.099	786.6256	55.676	7.61	0-20
1	0.088	830.8296	58.21285	7.19	0-20
1	0.07	1007.601	101.2271	7.1	0-20
1	0.07	831.5256	2.17765	7.08	0-20
1	0.064	1007.601	185.8187	7.1	0-20
1	0.097	785.997	122.9587	6.91	0-20
2	0.125	786.6256	10.12495	6.88	0-20
2	0.123	830.8296	65.80095	6.91	0-20
2	0.123	963.3969	14.4578	6.93	0-20
2	0.127	785.9296	1.4368	7.19	0-20
2	0.139	742.444	110.252	7.2	0-20
2	0.115	698.2399	93.27975	7.1	0-20
3	0.081	113.1256	6.1513	7.1	0-20
3	0.071	830.8296	56.0352	6.7	0-20
3	0.085	919.2153	26.7604	7.22	0-20
3	0.07	786.6256	15.1762	7.1	0-20
3	0.09	742.444	2.17765	6.94	0-20
3	0.081	698.2399	155.0846	7.04	0-20
4	0.073	609.8543	6.5105	6.94	0-20
4	0.076	654.0583	62.1865	7.02	0-20
4	0.091	1051.783	15.5354	7.21	0-20
4	0.081	830.8296	26.7604	7.06	0-20
4	0.085	609.1134	96.086	6.97	0-20
4	0.059	786.6256	204.6093	7.04	0-20

Appendix 2: Soil organic carbon analysis

Distance	depth	dry weght of soil gm	volume of core cm3	Bulk dencity gm/cm3	%OC	depth cm	SOC MG/ha
1	1	576.3	769.3	0.749	0.59	20	8.84
1	1	554.3	769.3	0.721	0.54	20	7.78
1	1	503.4	769.3	0.654	1.15	20	15.05
1	1	491.6	769.3	0.639	0.73	20	9.33
1	1	467.8	769.3	0.608	1.12	20	13.62
1	1	477	769.3	0.62	0.26	20	3.22
				3.991	4.39		57.85
1	2	615.3	769.3	0.8	0.52	20	8.32
1	2	563.8	769.3	0.733	0.71	20	10.41
1	2	554.8	769.3	0.721	0.89	20	12.84
1	2	568.7	769.3	0.739	0.43	20	6.36
1	2	481.5	769.3	0.626	1.13	20	14.15
1	2	529.2	769.3	0.688	0.35	20	4.82
				4.307	4.03		56.88
2	1	467	769.3	0.607	1.47	20	17.85
2	1	518.5	769.3	0.674	0.79	20	10.65
2	1	451.5	769.3	0.587	0.69	20	8.1
2	1	522.2	769.3	0.679	0.98	20	13.3
2	1	392.2	769.3	0.51	0.7	20	7.14
2	1	548.1	769.3	0.712	1.19	20	16.96
				3.769	5.82		73.99
2	2	508.6	769.3	0.661	0.62	20	8.2
2	2	595.3	769.3	0.774	0.32	20	4.95
2	2	560	769.3	0.728	0.93	20	13.54
2	2	546.2	769.3	0.71	0.74	20	10.51
2	2	472.9	769.3	0.615	0.6	20	7.38
2	2	565.8	769.3	0.735	1.12	20	16.47
				4.223	4.33		61.05
3	1	515.9	769.3	0.671	0.86	20	11.53
3	1	539.4	769.3	0.701	0.65	20	9.12
3	1	346.5	769.3	0.45	0.89	20	8.02
3	1	460	769.3	0.598	0.62	20	7.41
3	1	488.1	769.3	0.634	0.84	20	10.66
3	1	538.3	769.3	0.7	0.79	20	11.06
				3.754	4.65		57.8
3	2	523.9	769.3	0.681	0.6	20	8.17

3	2	556.8	769.3	0.724	0.5	20	7.24
3	2	490.5	769.3	0.638	0.72	20	9.18
3	2	574.1	769.3	0.746	0.49	20	7.31
3	2	496	769.3	0.645	0.64	20	8.25
3	2	544.4	769.3	0.708	1	20	14.15
				4.141	3.95		54.31
4	1	554.3	769.3	0.721	0.62	20	8.93
4	1	460.3	769.3	0.598	0.51	20	6.1
4	1	445.7	769.3	0.579	0.62	20	7.18
4	1	508.2	769.3	0.661	0.73	20	9.64
4	1	518.1	769.3	0.673	0.95	20	12.8
4	1	468.4	769.3	0.609	1.02	20	12.42
				3.841	4.45		57.08
4	2	563.8	769.3	0.733	0.61	20	8.94
4	2	559.7	769.3	0.728	0.57	20	8.29
4	2	545.5	769.3	0.709	0.51	20	7.23
4	2	529.7	769.3	0.689	0.49	20	6.75
4	2	525	769.3	0.682	0.58	20	7.92
4	2	552.9	769.3	0.719	1.01	20	14.52
				4.259	3.77		53.65

Appendix 3: biomass carbon analysis

SU	tree no	DBH (Cm)	Hieght (m)	wood Density (gcm-3)	AGBS kg/tree	BEF	AGB kg/ha	AGB ton/ha	AGCS ton/ha	BGB ton/ha	BGCS ton/ha
SU1	1	29	10	0.497	358.0935	5	1790.47	1.79	0.84	0.47	0.22
	2	17	8	0.497	102.566	5	512.83	0.51	0.24	0.13	0.06
	3	24	7	0.497	229.9308	5	1149.65	1.15	0.54	0.30	0.14
	4	11	8	0.497	37.01885	5	185.09	0.19	0.09	0.05	0.02
	5	14	7	0.497	65.10411	5	325.52	0.33	0.15	0.08	0.04
	6	10	6	0.497	29.61575	5	148.08	0.15	0.07	0.04	0.02
	7	22	7	0.497	187.5574	5	937.79	0.94	0.44	0.24	0.11
				3.479	1009.886	35	5049.43	5.05	2.37	1.31	0.62
SU2	1	27	8	0.497	302.9321	5	1514.66	1.51	0.71	0.39	0.19
	2	23	9	0.497	208.1266	5	1040.63	1.04	0.49	0.27	0.13
	3	21	7	0.497	168.2047	5	841.02	0.84	0.40	0.22	0.10
	4	18	8	0.497	117.2507	5	586.25	0.59	0.28	0.15	0.07
	5	17	6	0.497	102.566	5	512.83	0.51	0.24	0.13	0.06
	6	27	8	0.497	302.9321	5	1514.66	1.51	0.71	0.39	0.19
				2.982	1202.012	30	6010.06	6.01	2.82	1.56	0.73
SU3	5	32	11	0.497	450.8985	5	2254.49	2.25	1.06	0.59	0.28
	2	21	9	0.497	168.2047	5	841.02	0.84	0.40	0.22	0.10
	3	15	7	0.497	76.51601	5	382.58	0.38	0.18	0.10	0.05
	4	11	5	0.497	37.01885	5	185.09	0.19	0.09	0.05	0.02
	5	20	6	0.497	150.0493	5	750.25	0.75	0.35	0.20	0.09
	6	16	7	0.497	88.9954	5	444.98	0.44	0.21	0.12	0.05
	7	19	6	0.497	133.07	5	665.3	0.67	0.31	0.17	0.08

					14		6				
				3.479	1104.754	35	5523.77	5.52	2.60	1.44	0.68
SU4	1	25	10	0.497	252.9882	5	1264.94	1.26	0.59	0.33	0.15
	2	17	7	0.497	102.566	5	512.83	0.51	0.24	0.13	0.06
	3	26	8	0.497	277.3162	5	1386.58	1.39	0.65	0.36	0.17
	4	24	7	0.497	229.9308	5	1149.65	1.15	0.54	0.30	0.14
	5	22	6	0.497	187.5574	5	937.79	0.94	0.44	0.24	0.11
	6	12	7	0.497	45.38225	5	226.91	0.23	0.11	0.06	0.03
				2.982	1095.741	30	5478.70	5.48	2.57	1.42	0.67
SU5	1	31	12	0.497	418.6011	5	2093.01	2.09	0.98	0.54	0.26
	2	32	8	0.497	450.8985	5	2254.49	2.25	1.06	0.59	0.28
	3	28	7	0.497	329.8524	5	1649.26	1.65	0.78	0.43	0.20
	4	15	6	0.497	76.51601	5	382.58	0.38	0.18	0.10	0.05
	5	16	7	0.497	88.9954	5	444.98	0.44	0.21	0.12	0.05
	6	8	8	0.497	17.56533	5	87.83	0.09	0.04	0.02	0.01
				2.982	1382.429	30	6912.14	6.91	3.25	1.80	0.84
SU6	1	28	12	0.497	329.8524	5	1649.26	1.65	0.78	0.43	0.20
	2	27	7	0.497	302.9321	5	1514.66	1.51	0.71	0.39	0.19
	3	17	6	0.497	102.566	5	512.83	0.51	0.24	0.13	0.06
	4	20	7	0.497	150.0493	5	750.25	0.75	0.35	0.20	0.09
	5	5	5	0.497	5.845363	5	29.23	0.03	0.01	0.01	0.00
	6	28	7	0.497	329.8524	5	1649.26	1.65	0.78	0.43	0.20
	7	20	6	0.497	150.0493	5	750.25	0.75	0.35	0.20	0.09
				3.479	1371.147	35	6855.73	5.21	3.22	1.78	0.84

Appendix 4: Teff yield in kg ha analysis by aspect

Aspect			
East	west	South	North
60	70	100	120
65	70	90	65
110	85	100	105
100	105	125	85
115	85	105	105
95	110	120	80
100	95	185	135
90	90	80	100
100	95	115	115
130	100	135	90
95	100	120	125
140	115	150	100
70	95	85	75
85	85	90	65
80	100	95	70
115	105	125	130
75	105	90	65
120	110	130	140
85	75	85	90
90	85	90	70
65	70	65	60
100	75	70	75
70	75	55	65
115	80	110	125

Appendix 5: crop yield at different distance from standing trees

Su	0.5 meter yield in g/m2	2.5 meter yield in g/m2	6 meter yield in g/m2	12 meter yield in g/m2
1	62.5	128.75	81.25	83.75
2	72	90	81.25	83.75
3	81.25	106.25	86.25	65
4	103.75	113.75	118.5	80
5	102.5	110	83.75	66.25
6	101.25	126.25	125	107.5

Figure 4: *Acacia seyal* trees inventory Process for ABC stock estimation (Nega Ashagrie, 2018).

Figure 5*:* Soil samples data collection Process for laboratory analysis (Nega Ashagrie ,2018).

Figure 6: Teff yield samples data collection Threshing and cleaning process