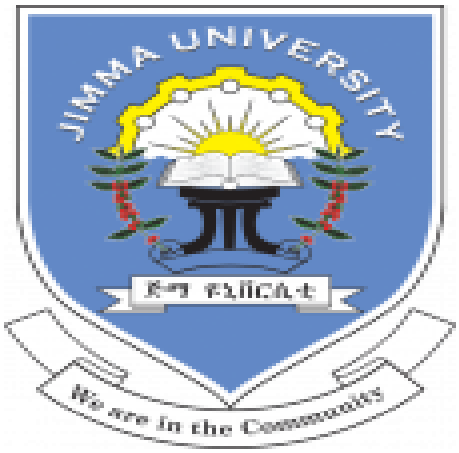

Jimma University College of Natural Sciences

Department of Biology

Coffee shade tree selection and management by smallholder coffee farmers in Goma district, Jimma zone, Southwestern Ethiopia

By: Mohammed Kemal

Main advaisor: Kitesa Hundera (Prof.)

Co advaisor: Dereje Denu (PhD)

A Thesis Submitted to the Department of Biology,College of Natural Sciences, Jimma University, in partial fulfillment for the requirement of Degree of Master of Science in Biology

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This thesis is approved by examining boards

Main advaisor: Kitesa Hundera (Prof.) Signature----------date----------

Co advaisor: Dereje Denu (PhD) Signature----------date----------

Internal Exminer:Mr.Desalegn Raga Signature----------date----------

Chairman---------- Signature----------date----------

External Exminer---------- Signature----------date----------

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DECLARATION

This is to certify that the thesis prepared by Mohammed Kemal entitled “Coffee shade tree selection and management by small holders coffee producers in Gomma district Jimma zone South west Ethiopia” and submitted in fulfillment of the requirements for the degree of Master of Science in Biology complies with the regulations of the university and meets the accepted standards with respect to originality and quality**.**

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Abstract

This study was conducted in Gomma district, Jimma Zone,Oromia Regional State, Southwest Ethiopia with the objective of assessing coffee shade tree selection and management by smallholder coffee farmers. Semi-structured interviews were administered to 234 coffee farmers. From these sample interviewees, a total of 54 farmers were selected based on their experience in coffee production for further in-depth interview, and also 7 of them were taken from 54 key informants for preference ranking and 4 of them by direct matrix ranking. Descriptive statistical methods such as percentages and an ethno botanical method were used to analyze the data. The findings revealed that a total of 26 species categorized in 20 genera and belonging to 12 families, were identified as the most common tree species used as coffee shades in the study area. Among these the highest number of species identified (7) was recorded for Fabaceae. *Albizia schimperiana* Olive and *Croton macrostachyus* Del. the highest in distribution in the coffee farms reported. Of the 26 tree species studied, only 11 were found to be farmers' favorite shade trees. These favorite native trees were identified to be *A. schimperiana* (100%), *Acacia abyssinica* Hochst.ex Benth (95.9%), *Millettia ferruginea* (Hochst) Bak (94.4%), *Cordia africana* Lam (93.2), *Albizia gummifera* (J.F.Gmel.) CA.Sm. (92.7), *Albizia grandibracteata* Taub.(91.0%), *Entadaabyssinica* Steud.ex A.Rich.(83.8%), *C .macrostachyus* (44.9%), *Ficus ovata* Vahl (2.6%). In addition to 24 native trees two exotic trees *Sesbania sesban* (L.) Merr.Var.nubica Chiov. (8.1%) and *Grevillea robusta* R.Br were also reported. By preference ranking and direct matrix ranking *A. schimperiana* Oliv, *A. abyssinica* Hochst.ex Benth and *M. ferruginea* (Hochst) Bak stood first, second and third, respectively. Farmers pointed out various challenges confronting their coffee small-holder plantations. One of the major challenges they are facing is the die-back of most of coffee shades specially that of *A. schimperiana.* Other threats include economic benefits as a timber tree, as well as use for fuel wood and for other local utilities. Based on this the researcher recommended the need for creating the nursery sites that mainly focused on planting the native tree species that are found out to be under threat.

Key words: shade tree, *Coffeaarabica*, direct matrix ranking, leguminous trees, preference ranking

1. INTRODUCTION

1.1. Background of the Study

Ethiopia is known as the origin of Arabica coffee (*Coffea arabica*L.), which is endemic to the highlands in the Southwest of the country. Coffee production is associated with other plant species which serve as shade trees. Since, shade is more essential to *Coffea arabica*. This nature of coffee has contributed for the survival of most remnant forests in Ethiopia as result of semi-forest coffee system (Dereje Denu, *et al*., 2016).

Since coffee is cultivated underneath the forest canopy and coffee yield was highly correlated with the number and size of the branches of coffee shade trees Debela Adugna, *et al.*, (2011). In the management systems, farmers deliberately select certain species of trees as coffee shade tree and remove others which they believe have adverse impacts on the growth and productivity of the coffee shrub. It is reported as coffee growth is affected by high light intensity, high temperature and low soil moisture (Nigussie Ashenafi *et al.,* 2014).

Shade trees are used to decreases stress of coffee (*Coffea spp.)* by improving adverse climatic conditions even though they compete to each other for resources (Beer *et al*., 1998). Adequate shade also improves soil fertility by way of returning large amounts of leaf litter to the underneath soil and retains soil moisture. In addition, most common coffee shade trees are also acknowledged for their good capacity in soil biological properties enhancing formation of symbiotic associations with certain soil bacteria, rhizobia Grossman *et al*., (2006) and arbuscular mycorrhizal fungi Wubet *et al*., (2003), which play a pivotal role in improvement of soil fertility and boost yields of associated crops by enhancing nitrogen fixation.

Nowadays, shaded coffee production system has received an enormous amount of attention from conservation organizations since it promotes biodiversity conservation while enhancing income generation from the sale of both timber and non-timber forest products as well as involving in carbon sequestration. Even though the area is the birth place of coffee and the related local knowledge of the farmers believed to be high; but, documented information on the benefit of some shade tree species for coffee plant is scanty.

It is therefore important to understand farmers' perception of the role of shade trees in coffee fields, in an area that has not received deserving attention in research agendas. This study is believed to add up to identify trees used for coffee production and in documenting local knowledge of the people regarding shade plants of coffee in the area. This study has been initiated to identify the most important native coffee shade tree species for coffee production from farmers' point of view and to document farmers' traditional knowledge on selection and management of various coffee shade trees in the area.

1.2 Statement of the problem

The livelihood of the communities living in rural kebeles of Goma district depends, in various ways, on the products and services provided by a diversity of trees in their coffee garden. There has been increasing encroachment on the shade trees and the forest reserve due to this high demand the coffee shade tree is threatened to unsustainable harvesting of these tree products. Furthermore, there was no research has been conducted in the District on the issues before. This is the main reason to investigate on the issue in the District.This research explored knowledge regarding selection and management practices of coffee shade trees by small holder coffee producers in Goma district. In doing so, the study attempted to answer the following research questions:-

Research Questions

How did farmers manage shade trees in their coffee plantation system in this area?

What type of shade tree species occurred along with coffee and how abundant are these species?

What are the criteria for selection of better coffee shade trees?

Are there challenges faced by the local farmers regarding their practice of managing shade trees in their coffee plantation?

What should be done to overcome those challenges?

1.3. Objectives

1.3.1 General Objective

To assess Coffee shade tree selection and management by smallholder coffee farmers in Goma district, Jimma zone, Oromia Regional State, Southwestern Ethiopia

1.3.2. Specific objective

- To assess farmer's traditional knowledge for the selection and management of good coffee shade trees in Goma district
- To identify the most important and favored shade tree species in the study area.
- To assess the biological attributes of this coffee shade trees
- .To assess other uses of shade trees other than shade provision for the coffee under the canopy

1.4. Significance of the study

This study may generate useful information on coffee shade tree selection and management system by small holder coffee producers. It may help to identify farmers' preferences on coffee shade tree selection in traditional way and to compare their preferences with the shade trees found in their coffee farm. The study may also serve as a point of reference for anyone who might wish to conduct further research on a similar or the same topic.

2. LITERATURE REVIEW

2.1 Farmers' Indigenous Knowledge in Coffee Production

Ethnobotany tries to get a holistic understanding of local knowledge on plants and their practical uses through the traditional knowledge of a local culture and people. Ethnobotany includes all the studies focus on the situation between plants and endemic people (Cotton, 1996). Ethnobotany also defined as the subjects that deals the study of interaction between humans and plants (Martin, 1995). Farmers' perception on role of coffee shade trees for coffee production is vital to bring sustainable economy that is useful for all of us .An indigenous knowledge is crucial for conservation of resources and sustainable development (Thomas, 1995).

2.2 .Functions of Using Shade Trees in Coffee Cultivation

2.2.1 Soil Organic Matter and Soil Fauna Improvement

Soil organic matter contents may increase with time under agroforestry system of coffee and cacao (Beer *et al*., 1998).*Coffea arabica* and *Coffea robusta* like a deep rich soil (Haarer, 1963). Cover crop leaf litter increase the available food supply for microorganisms resulting in increased biological activity (Kuit *et al*, .2004).

2.2.2. Biological Nitrogen Fixation

Roots of leguminous shade trees are useful for fixation of atmospheric nitrogen for coffee trees (Beer *et al*., 1998). Most common coffee shade trees have an ability to create symbiotic relationships with certain soil bacteria such as rhizobia (Grossman *et al*., 2006) and also with arbuscular mycorrhizal fungi (Wubet *et al*., 2003) all of which have crucial role for increasing quality and quantity of yields. An arbuscular mycorrhizal fungi penetrates the cortical cells of the roots of a vascular plant.Shade trees have an ability of producing large leaf litters and also different resides which are important sources of organic matters than nitrogen fixation especially when the farm isfertilized (Beer, 1998).

2.2.3. Nutrient Cycling Enhancement

Each species of shade trees are different in their biomass productivity, so that nutrient cycling is directly proportional to shade tree types (Palm, 1995). Roots of shade trees canabsorb leached

nutrients from deeper site which roots of coffee tree can't taking up, these nutrients returned to topsoil by leaf drop decomposition from shade trees which coffee trees roots can absorb it (Kuit *et al*, 2004). Nitrogen cycling is more efficient in shaded plantation because less nitrogen is lost through leaching (Babbar and Zak, 1994, 1995).

2.2.4. Reduce Soil Erosion

Leaf litters which are produced by shade trees are not only the sources of organic matters for coffee trees but also function to lessen soil erosion (Beer *et al*., 1998). A bare soil loses its richness and character. Rain drops pound it and splash it about and take all the good nutrient salts dissolved in the drainage water downhill. The sun turns the soil into dusts kill living things that found in the soil those important for decomposing organic matters (Haarer, 1963).

Erosion is more sever in an unshaded than shaded coffee farm (Wiersum, 1984) However, erosion can be minimized by mulching the soil without shade (Willey, 1975). Leaf litters and pruning residues are acts as mulch during rainy season and also dense canopy can prevents erosion than open canopy during strong rain (Beer *et al.,* 1998). Trees, however, can also adversely redistribute precipitation (Beer *et al.,* 1998). For example, during low-to moderate-intensity rainfall, coalescence and drip from the leaves of tall timber trees can loosen soil particle and increase soil surface erosion (Wiersum, 1984). Hence, a low crown with small leaves is preferable to reduce drip damage.

2.2.5. Reduce Environmental Contamination

Shade trees have the potential to reduce nitrate contamination of ground water in areas of intensive coffee management (Willy, 1975). Coffee trees also balance atmospheric air by producing oxygen. Each hectare of coffee produces 86lb of oxygen per day, which is about half the production of the same area in rain forest (Kuit *et al*, 2004).Fluctuation of coffee and cacao prices, **i**ts high inputs prices for cultivation and environmental problems in unshaded coffee/cacao farm increased the interest for using shade trees (Beer *et al*., 1998).

2.2.6. Light Availability

Photosynthetic rates of coffee are at a maximum at intermediate shade levels in many of the climatic conditions found in the tropics (Nutman, 1937a; 1937b). The upper branches of coffee

trees can be shade for the lower branches of the same tree and can be shade for the next coffee trees near to it (Willey, 1975).

2.2.7. Temperature, Wind Speed and Humidity Regulation

Shade trees are useful to protect too cold winds from coffee and also shade trees can prevents strong winds from coffee trees. Reduced heat-load of the coffee plants during the day time and reduced heat losses at night by buffering effects of shade trees helps coffee plants to regulate microclimate effects and to exists at wider climatic range (Beer *et al*., 1998).

2.2.8.Crop Phenology, Yields and Quality

Coffee tree can only take up nutrients in a soluble form and lack of water caused by extended dry periods have a negative influence on the quality of coffee (Kuit *et al*,.2004; Muschler 2001) has verified the main benefits obtained from shading in terms of improved coffee attributes compared to unshaded ones.Cannell (1975) suggested that close spacing of coffee bushes results in mutual shading that may inhibit floral initiation at existing nodes on coffee branches. Using artificial shade treatments, (Montoya *et al*., 1961) found significant increase in the number of nodes per coffee branches and flower buds per node as sunlight levels increased.

Cannell (1975) stated that the most important component of yield is the number of nodes formed. Number of nodes formed and the number of fruit set at each node can both be affected by light levels, shading on good sites can reduce coffee yields even when all other growth factors are favorable (Beer *et al*., 1998). Lagemann and Heuveldop, (1983) reported that higher shade density had a negative effects on coffee yield. The yields from unshaded coffee farm diminished from year to year or inconsistent probably because of widely varying site conditions and management (Beer *et al*., 1998).

Coffee yields decreases at lower elevations because of higher temperature and decreases at higher elevation because of lower temperature so shade stabilizes microclimate extremes and also shade contribution is higher on sites with soil limitations (Beer *et al*., 1998). The relative yield advantage of unshaded coffee may be limited by frequently replanted and pruned plantations since unshaded coffee bushes have a shorter life expectation than shaded bushes (Wrigley, 1988).

2.2.9. Pests and Diseases control

Cercospora coffeicola, a fungus disease which can completely defoliate coffee plants is greater in unshaded plantation (Nataraj and Subramanian, 1975),possibly due to the higher susceptibility of water stressed or nutrient deficient plants (Wrigley, 1988). The coffee berry borer (Hypothene mus hampei) is reported to be favored by dense shade (Wrigly, 1988). *Colletorichum kahawae* is fungal plant pathogen that causes Coffee Berry Disease on Arabic coffee crops. Coffee berry disease causes dark necrosis in spots and causes the green berries of the coffee to drop prematurely. High humidity, relatively warm temperatures and high altitude are ideal for disease formation. (*https://en.m.Wikipedia.org > Wiki >Collet...*)

"Tip die –back" **(***Rhizoctonia spp)* which is die-back of tips and branches of coffee is caused by dense shade and humid conditions (Haarer, 1963)."Hot and cold" disease which is young tips and twigs and leaves turns black and shrivel caused by extremes of temperature. Especially cold night temperature can be protected by shade that protect cold winds (Haarer, 1963)."Die-back"caused by warm temperature and intense light that makes tree to overbear or bumper crop that cause the leaves shrivel and fall because of competition between leaves and fruit for carbohydrate, then the branches begins to die-back this can be avoided by shade trees (Haarer, 1963).

"Star flower" unshaded coffee trees leaves become wilt because of long dry seasons, yet they seemed to recover and show no damage and, Arabian coffee (a plant) it leads to one of the two things:- The tree initiates too many flower buds and overbears at a time when, on account of wilting the leaves have been unable to manufacture enough carbohydrate to sustain the crop and Due to a similar causes and insufficient carbohydrates the buds turn in to "star flower" which are immature malformed flowers. The buds swells, they open their scales and the petals appear to be atrophied.

Only the calyx remains with stiff swollen miniature green flower parts. The sexual parts are also abnormal, so fruit is produced. The tree is saved from greater harm thereby, but the crop is lost (Haarer, 1963).

2.2.10. Weeds Control

A coffee shade tree reduces the development of weed species that compete for nutrients with coffee trees. After removing shade trees and thinning coffee plants, weed biomass increased

almost tenfold to greater 12 Mg ha^{-1}(dry weight), with a higher incidence of the more light-demanding aggressive graminaceous weeds (Goldberg and Kigel, 1986).

2.2.11 Buffer Zone Agroforestry and Conservation of Biodiversity

The native *Coffea arabica* in highlands of Jimma hosts the highest genetic diversity of coffee on Earth, and that is recognized globally for its broader biodiversity value (Mittermeier *et al*., 2004). The four coffee managements: are wild coffee, semi-forest coffee, garden coffee and coffee plantation. (Demel Teketay, 1999). Shade trees species protects the environments and maintains biodiversity (Dirriba Muleta *et al*., 2011). More species of coffee shade trees increases biodiversity because different tree species attract different insects, birds and other organisms (Kuit *et al*, .2004). Shaded coffee and shaded cacao have great contribution for conservation of biodiversity which is internationally focused now on it (Perfecto *et al*., 1996) and creating favorable conditions for migrating birds (Wille, 1994). When native species are used as shade trees in a buffer zone, a larger gene pool of these species can be maintained than would be possible in the protected area alone (Beer *et al*.,1998).

The role of coffee growing areas in providing ecosystem services is important not only because of the area covered but also because coffee farms are frequently close to priority areas for biodiversity conservation **(**Moguel and Toledo, 1999). Diverse and abundant tree cover in association with coffee contributes to biodiversity conservation (Philopott *et al*., 2008), carbon sequestration **(**Albrecht and Kandji, 2003) are some of benefits of trees within coffee plantation

2.2.12. Fruits, Timber and Fuel-Wood Production

Coffee shade trees have an additional value for farmers'. The fuel wood obtained from coffee pruning and renewal is also an important resources for many families (Beer *et al.*, 1998).Trees within coffee plantations may also diversify the product mix and in the case of timber represent a saleable commodity: particularly important when coffee prices are low *(*Beer *et al*.,1998).

2.3. Some Selected Coffee Shade Trees and Their Biological Attributes to Coffee (*Coffea arabica* L.)Production

2.3.1. *Albizia schimperiana* Oliv

This native tree species were more selected than all other coffee shade trees in Goma district because by farmers because of its smaller and thinner leaves and by its umbrella like crown

which balance light rays and also, its leaf litters can quickly decomposed and increases soil fertility. This species has a symbiotic relationships with certain soil bacteria, this bacteria form nodules on the roots and fix atmospheric nitrogen .Some of this nitrogen is utilized by the growing plants but some can also be used by other plants growing nearby. The tree is planted in agroforestry system as a shade tree and for soil conservation and improvement .The wood is fairly strong and not resistant to termites. It is identified by its large pods and called large-podded *Albizia* .It is a deciduous tree with a flattened or rounded, often umbrella-shaped crown that allows moderate light interception, usually growing up to 30m tall but occasionally to 35m.It can exists at 900m-2600m.It is a dominant species in the upper canopy in the southern Sudan and Ethiopia. It has slow growth rate (http://WWW.prota.org).

2.3.2. *Acacia abyssinica* Hochst.ex Benth

Its' good flat crown makes its shade for animals, humans and suitable for birds to build their nets on it, its ability to grow fast, can fix atmospheric nitrogen, provide shade that improves microsite and also its different part dead roots, bark, branches can form necromass (dead things of its parts like pod branches..) which increase soil fertility .It has an advance-retreat types of growth strategy which means grow fast when condition is favorable like good when the condition became harsh like long dry season. So it can restore a xeric environments. Nitrogen is important to make organic molecules like protein and other that used for seed germination, for growth, flowering and for seed formation (Legesse Negash, 2016).

2.4.3 .*Cordia africana Lam*

It is one of economically socially and ecologically important endemic trees of Ethiopia. Can be found in 550-2600m a.s.l. It is deciduous tree .it sheds its leaves heavily usually during the dry season. During dry season it can conserve water by minimizing water consumption, closing stomata and shedding its leaves. Its leaf litters decomposed to soil and increase soil nutrients. Its branching feature and broad leaves are suitable for coffee plant for shading (Legesse Negash, 2016).

2.3.4 *Mellita ferruginaea* (Hochst) Baker

M. ferruginea has desirable biological characteristics and economic benefits (Tadesse Hailu *et.al*, 2000). *M. ferruginea* is a native leguminous trees which can fix nitrogen. This suggests that the

species has been useful for improving soil fertility and productivity of the traditional farming systems (Tadesse Hailu *et al*., 2000). The C to N ratio under *M. ferruginea* trees is lower than that in the open this shows of nitrogen availability under this tree (Tadesse Hailu *et al*., 2000.). The level of soil P, organic C, exchangeable base-forming cations and cation exchange capacity is high under trees of *M. ferruginea* (Tadesse Hailu *et al*., 2000).

Phosphorus deficiency creates violet color on leaves and stems which reduces leaf size and decreases rate of leaf expansion and reduced leaf surface area (Brady, 1990; Marschner1995). It is an effective nutrient pump. This means that it selectively absorbs essential nutrients elements (B, Zn, Cu, Mn, Co, Mb) through its roots and releases these via its leaflets when these are shed .It can grow in nitrogen deficient soil because of its ability of fixing atmospheric nitrogen (Legesse Negash,2016).

2.3.5. *Albizia gummiferria* (J.F.Gmel.) C.A.Sm

A.gummiferria is a nitrogen fixing and can be used for soil stabilization. Its leaves form a good mulch and it is a good shade tree. It can grow rapidly. The roots develop nitrogen-fixing nodule containing *Bradyrhizobium* bacteria. And also live in association with *arbuscular mycorrhizae*. It has good lopping and copping ability when young. It is sensitive to frost. It is a good shade tree. Its leaves and twigs has low P and K contents as result increases soil fertility. Because of its obliquely rhombic leaflets, but differs in having stipules at the base of pinnae and stamens united at the base in a much shorter tube.

2.3.6. *Croton macrostachyus* Hochst.ex Del

C. macrostachyus is a deciduous and medium sized tree that has many function: such as growing in degraded areas, ability to withstand drought, having fast growth, production abundant litter that important for agroforestry and its suitability for attracting avian frugivorous (Kibebew Wakjira and Legesse Negash, 2013). Is a broad-leaved, deciduous tree with a spreading but rounded, open crown, it stabilize and enriches the soil and provides protection. Its seed can germinate without pre-sowing treatment and can germinate within 30-60 days (tropical.theferns.info > viewtropical > id.)

2.3.7. *Albizia grandibracteata* Taub

A.grandibracteata is a nitrogen fixing tree .It can improve soil fertility it differs from *A. gummifera* inhaving fewer leaflets per pinna and broad bracts and stipules. It is a nitrogen fixing tree.

2.3.8 .*Entada abyssinica* Steud.ex A.Rich

E. abyssinica small tree of woodland and wooded grassland, widespread in Africa .In Ethiopia it is found in dry moist and wetkolla and Weynadega agroclimatic zones in almost all regions,1300-2050 a.s.l. Its functions are firewood, medicine, shade and nitrogen fixation (uses.plantnet-project.org > Entada-abyssi).

2.3.9. *Sesbania sesban* (L.) Merr.Var.nubica Chiov

S. sesban is one of the exotic.multipurpose fodder trees introduced in the Ethiopian highlands for livestock feed and soil conservation (Oosting *et al*., 2011).*S. sesban* has a capacity to control soil erosion and maintain soil fertility as result it is useful in traditional farming (Tulu Degefu *et al*., 2011). *S. sesban* is a temporary shade which can fix nitrogen and has deep rooting systems (Desaeger and Rao, 2001).

It is a fast growing nitrogen-fixing leguminous tree species which has the capacity of rapid decomposition when incorporated into soil serving as a green manure (Patra *etal*., 2006). It has many function such as weed control, medicinal fodder and soil improvement (Zerihun Nigussie and Getachew Alemayo, 2013).

2.3.10.Impacts of *Grevillea robusta* R.Br.on Coffee Plant and on Environment

G. robusta common name is Silk oak (Austerialian silky oak). The crown is conical and symmetrical with major branches spaced at intervals of about 1m and projecting upwards at an

angle of 45^{o}. It is semi-deciduous in its natural range, being shortly leafless before flowering .The seeds of *G. robusta* dispersed by winds (Smith, 1998). It is an effective colonizer and has economic impact, social impact, environmental impacts and biodiversity impacts: alters trophic level, damages ecosystem service ,ecosystem change, modification of successional patterns, negatively impacts human health, reduce native biodiversity , has high reproductive potential, highly adaptable to different environment, long lived, tolerate or benefits from cultivation, pressure fire etc (Gilman and Watson, 1993).

Proteoid roots sections of the secondary roots which develop as dense cylindrical clusters of rootlets develop in conditions of low phosphorous availability and are thought to increase the plants ability to take up nutrients (Skene *et al.,* 1996). *G. robusta* does not form symbiotic associations with soil rhizobacteria or mycorrhizal fungi (Skene *et al*., 1996). *G. robusta* produces an allopathic substance which inhibits the establishment of all species (www.botany.hawaii.edu > gre-rob). This allelopathic substance negatively affects biodiversity by restricting the growth of other plants including other individuals of *G. robusta* Smith (1998). *G. robusta* leaf litters and its fruit litter (Gilman and Watson, 1993), its leaves produces an allelopathic chemicals that prevents the developments and establishment of native species (ISSG, 2015), also pointed it can change the patterns of nutrient cycling.

3. METHODOLOGY

3.1. Description of the Study Area

Goma district is found in Jimma zone,Oromia region, in southwest Ethiopia. The district is bordered by Mana district to the Southeast, Seka-chokorsa in the South, Gera district in the west and Gumay district in the north. It extends between 7^o 48'-7^o 53' N latitude and 36^o 33'-36^o 36' E longitude. It is located at distance of 390km from the capital Addis Ababa and 45km far from Jimma town to the west. Its altitudinal range is 1387m a.s.l-2870m a.s.l. Some areas of the district have altitudinal ranging from 2229m - 2870m.The total area of the district is 93,655 (ha) or 936.55 km^2. According to central statistics agency reports of 2014 the total population of the district was 263,434, of whom 134,340 were men and 129,094 women. Ethnically majority of the people are Oromo (79.1%), Amhara (7.3%), Dawro (4.2%), Silte (2.6%) and Keficho (2.0%), the remaining all other ethnic groups made up 4.77% of the population. The majority of the inhabitants are Muslim. It has 36 Farmers association and 5 urban centers (Chego, Gembe, Limu-shay, Beshasha and Choche towns). Totally, this disstrict contains 41 farmers association and urban centers.

Climate

Agroecologically, Goma district is classified as 88% Weynadega (Wet-midland), 8% Dega (High land) and 4% Kola (Low-land). It has an annual rainfall of 1700mm to 2000 mm and also its annual temperature ranges the lowest 7^oC-12^oC and the highest 25^oC -30^oC. One of the coffee biodiversity center (Gene bank) is found in Goma district in site called Choche. (Source: Goma district communication office).

3.2. Methods

3.2.1. Reconnaissance Survey and Selection of Study Site

Reconnaissance surveys to the study site were conducted from September 25 to October 10, 2018. Based on three different altitudes lower, medium and higher altitudinal areas nine kebels were selected from 36 total farmers association. From each altitude three farmers association were selected.

The nine sampled farmers association are:

1. From lower altitudinal areas (1387m a.s.l. - 1500m a.s.l) Choche-lemi, Bulado-choche and Gabene abo farmers association were selected.
2. From middle altitudinal areas (1500m .a.s.l - 1800m a.s.l) Yachi-urache, Dedo-urache, Kilole-kirkir farmers association were selected.
3. From higher altitudinal areas (1800m a.s.l - 2200m a.s.l) and above are Omo-guride, Omo-beko and Ganji-dalecho farmers association were selected.

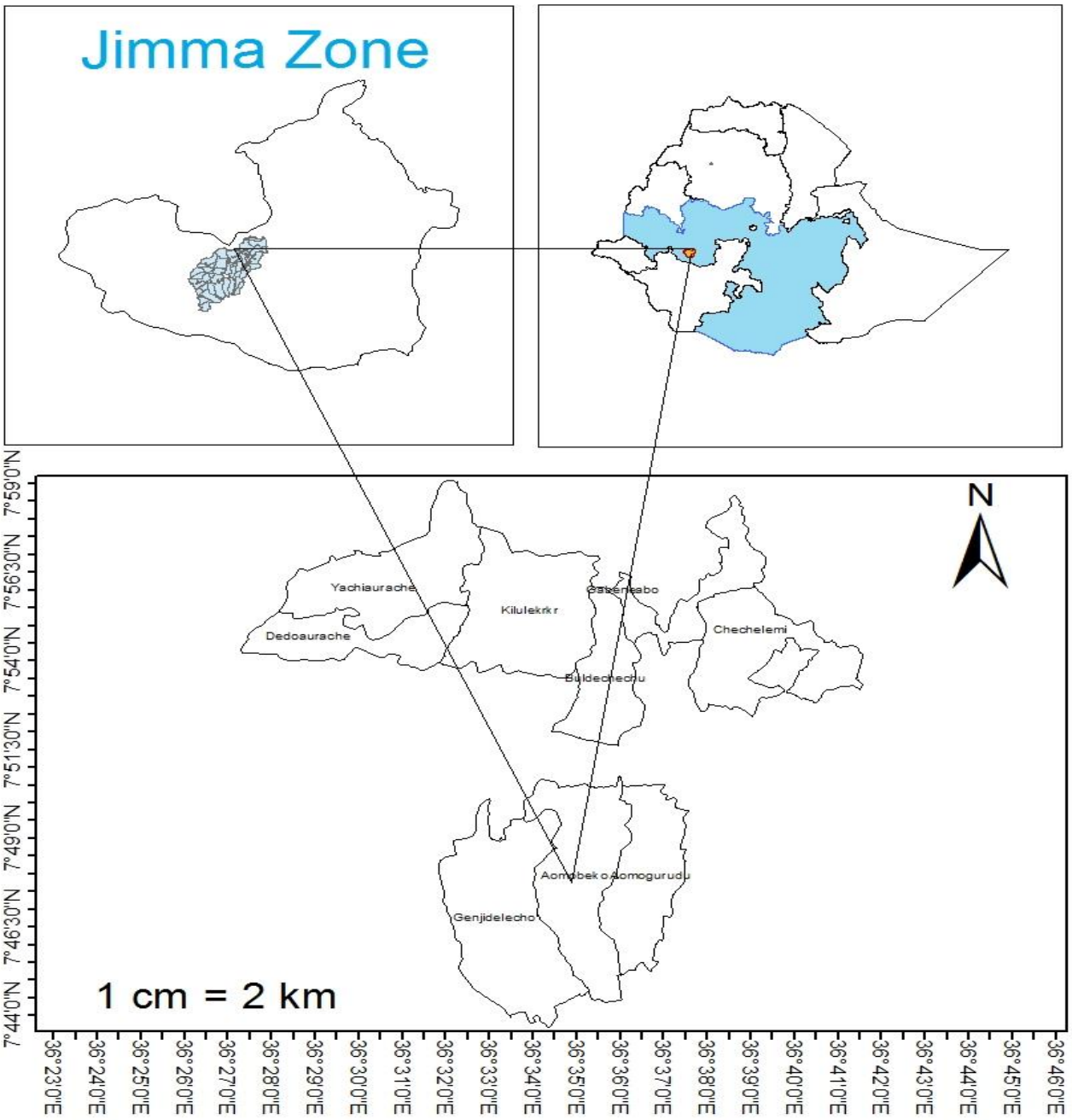


Figure 1. Map of Ethiopia showing the study area.The green area is Goma district

3.2.2. Sample size and sampling techniques

A total of 234 respondents were selected for the study, of which54 key informants selected by purposive sampling method and 180 by simple random sampling. From these informants 192 are Male and 42 female, all in the age of greater than 20 were selected from sampled sites. The 54 key informants were identified based on long experience in coffee production, This was done by selecting 6 key informants purposively from each farmers association based on recommendation made by elders, farmers association administrative staffs and also by developmental workers from each farmers association. The choice of key informants was based as stated by Martin (1995).

To identify the general knowledge about shade tree selection and management for coffee plant production,180 individuals were selected randomly from the nine farmers association equally (which was 20 informants from each farmers association).This was done by tossing a coin and using him/her as an informant whenever head of the coin was up and if he/she had coffee farms and had willing to interviewed based on the suggestion of Martin (1995) From the key informants seven individuals were selected based on their knowledge for preference ranking and direct matrix ranking.

3.2.3. Methods of data collection

Data were collected by the technique of semi- structured interviews (prepared and administered by Afan Oromo) from January 3, 2019 to March 30, 2019 from farmers about their indigenous knowledge towards the benefits of shade trees for *Coffea arabica* L. production. This was done mainly at their home or on their coffee garden or road and guided field walk method was used in most of the possible cases.

Figure 2. Photos that shows data collecting methods in the study area (Photo by Mohammed Temam Jan. 10, 2019)

3.2.4. Plant data collection

At the end of the interview, coffee shade trees named by the informants were searched for collection. Their fruits (seeds) and leaves with some branches were collected with the help of some volunteer farmers from their villages. Lastly, the samples were pressed and dried for scientific identification.

3.2.5. Specimen Identification

The specimen were identified by using Flora of Ethiopia and Eritrea, comparing with the existing sample specimens in the Herbarium and consulting expert in the field of plant taxonomy. The final confirmation was done in JU herbarium for all 26 coffee shade trees collected.

3.3. Data Analysis

For this study descriptive statistical methods such as percentage and an ethnobotanical methods of analysis like preference ranking to assess the degree of selected coffee shade trees following Martin (1995) and direct matrix ranking to compare multipurpose coffee shade trees following Cotton (1996) were used to analyze and summarize the data on types of coffee shade trees, the benefit to coffee plant, their additional values and also the most threatened coffee shade trees were analyzed through descriptive statistics.

4. RESULTS

4.1. Demographic Characteristics of Farmers and Basic Coffee Farms Data

4.1.1. Sex and Age of Farmers

For this study a total of 234 coffee producing farmers were selected from Goma district. From these 192 (82.1%) were male and 42 (17.9%) were female. The age of the respondents ranges between 20 to 80 years (Figure 3).

Age group	No of Respondent	Percent
21-30	27	11.54
31-40	57	24.36
41-50	38	16.24
51-60	55	23.5
61-70	23	9.83
71-80	34	14.53
Total	234	100

Table 1. Age ranges of farmers interviewed for the study in Goma district Jimma Zone.

4.1.2. Educational Levels of Farmers

The farmers educational levels: illiterate farmers were 88 (37.6%), basic education levels were 39 (16.7%), grade 1-4 were 42 (17.9%), grade 5-8 were 57 (24, 4%), grade 9-12 were 8 (3.4%). Even if 37.6% of farmers were not attended modern education they have a plenty of local knowledge regarding coffee production system.

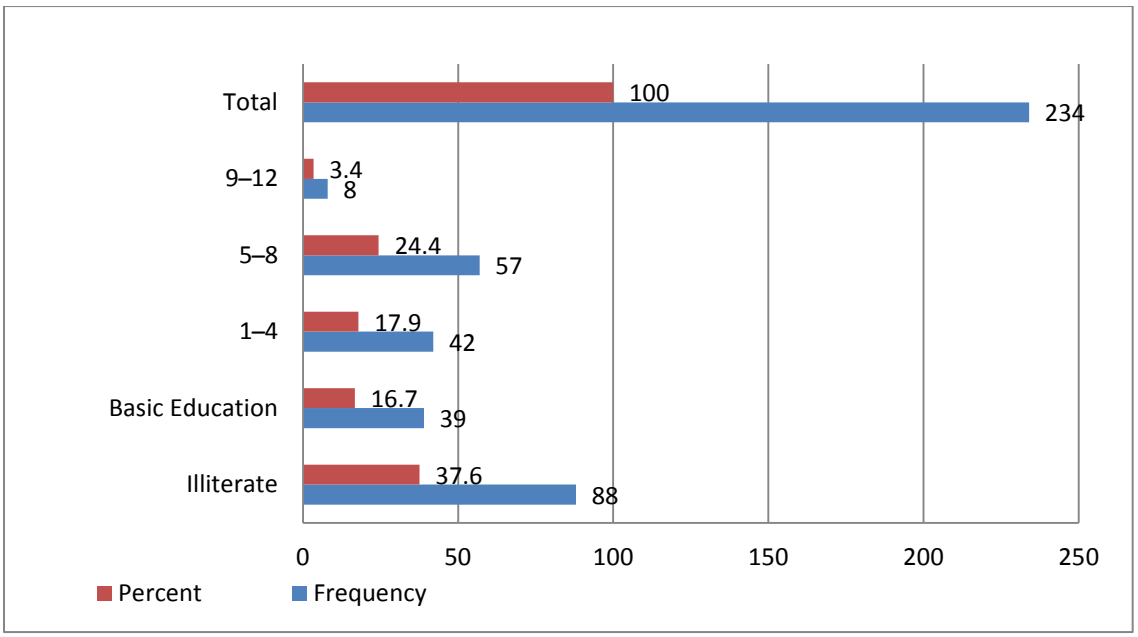


Figure 3. Educational levels of farmers interviewed for the study (Y-axis) and frequency of interviewed (X-axis) in Goma district Jimma Zone.

4.1.3 Age of Coffee Trees and Size of Coffee Farms

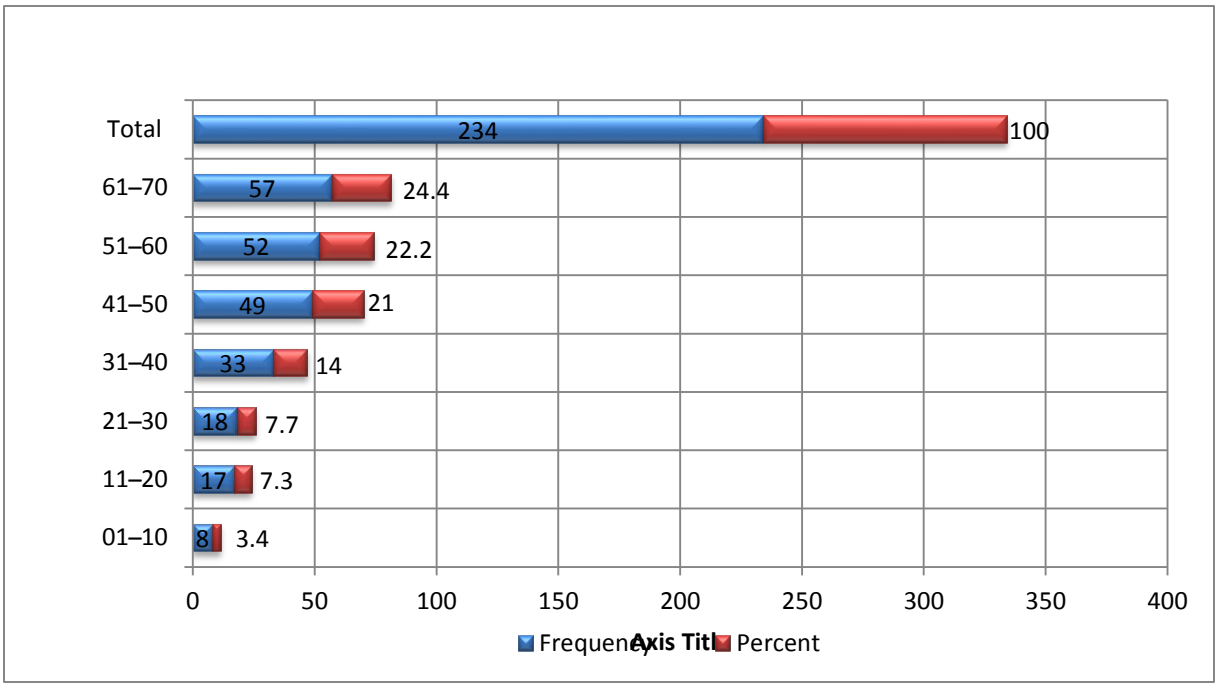


Figure4. Age range of farmers' coffee trees studied in Goma district Jimma Zone.vertical axis shows age of coffee tree and horizontal axis shows number of respondants.

As displayed in the above (Figure 4) the majority of farmers (226, or96.6%) have coffee trees ages which are above 10 years.

The majority of farmers which were 143 (61.1 %) of them owned less than two hectares of coffee farms. 71 (30.3 %) of farmers owned 2-3 hectares and 20 of them owned 4-5 hectares of coffee farms.

4.2. Coffee Shade Trees Identified in the Study Area

A total of 26 species (Table 2) belonging to 20 genera and 12 families were identified and recorded from the study area.

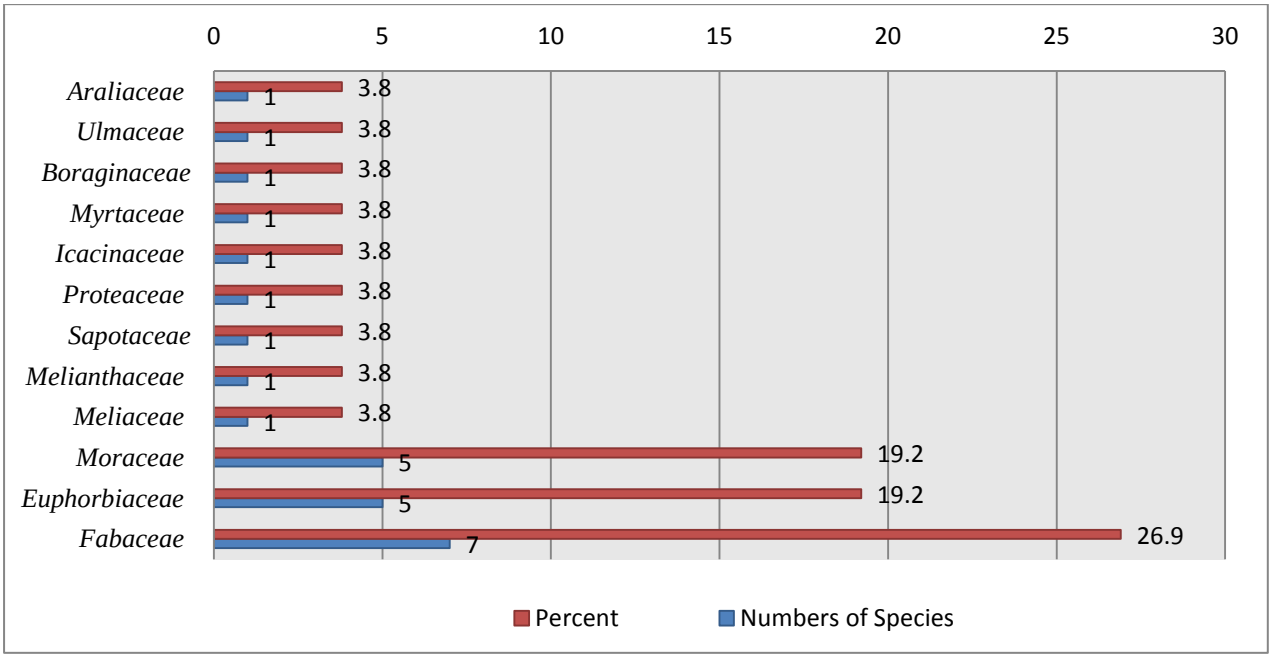


Figure 5. Number of species, percentage and the corresponding families of shade tree species studied in Goma district Jimma Zone.

In regards of family distribution Fabaceae stood first with comprising 7 (26.9%) species and followed by Euphorbiaceae and Moraceae each contains 5 (19.2%) species. The remaining families contain one species per family. The majority of coffee shade trees of the study area are Fabaceae, Euphorbiaceae and Moraceae.

Table 2 Coffee shade trees found in the study area

Local name (Afan Oromo)	Botanical Name	Family Name	Frequency	Percent
Ambabesa- adi	*Albizia schimperiana* Oliv.	Fabaceae	228	97.7
Makanisa	*Croton macrotachyus* A.Rich	Euphorbiaceae	214	91.5
Wadesa	*Cordia africana* Lam.	Boraginaceae	196	83.7
Lafto	*Acacia abyssinica* Hochst.ex Benth.	Fabaceae	182	77.8
Askira	*Millittia ferruginea*(Hochst) Bak.	Fabaceae	178	76.1
Ambabesa-muke	*Albizia gummifera*(J.F.Gmel.)CA.Sm.	Fabaceae	106	45.9
Ambabesa- arba	*Albizia grandibracteata* Taub.	Fabaceae	98	41.9
Bosoka	*Sapium ellipticum* (Krauss) Pax	Euphorbiaceae	92	39.3
Qiltu	*Ficus ovata* Forssk	Moraceae	76	24.5
Anunu	*Spathoda companulata P.Beauv*	Bignoniaceae	57	24.3
Denbi	*Ficus thonningii* Blume**.**	Moraceae	52	22.2
Ambelta	*Entada abyssinica* Steud.exA.Rich.	Fabaceae	47	20
Qe'o	*Celtis africana* Burm.f	Ulmaceae	42	17.9
Akuku	*Flacourtia indica (Brm.f) merr*	Flacourtiaceae	38	16.2
Grevilla	*Gravillea robusta* R.Br.	Proteaceae	32	13.7
Lolchisa	*Bersama abyssinica* Fresen.	Melianthaceae	30	12.8
Badesa	*Syzygium guineense* (Willd.) DC.	Myrtaceae	16	6.8
Qilinto	*Ficus lutea* Vahl.	Moraceae	16	6.8
Wango	*Macaranga capensis (*BailL.) Sim	Euphorbiaceae	14	6.0
Qolati	*Mimusops kummel* A.DC.	Sapotaceae	12	5.1
Wendebiyo	*Apodytes dimidiata* E.Mey.ex Arn.	Icacinaceae	9	3.8
Kariyo	*Polyscias fulva* (Hiem) Harms	Araliaceae	7	3.0
Omo	*Prunus Africana (Hook.f) kalkam*	Rosaceae	7	3.00
Sesbaniya	*Sesbania sesban* (L.) Merr. Var. nubicaChiov.	Fabaceae	6	2.60

Balansofi	*Ficus exasperate* Vahl	Moraceae	6	2.6
Arbu	*Ficus sycomorus* L..	Moraceae	4	1.7

In the study area 26 species of coffee shade trees were identified by farmers in different frequencies with the highest rates of *A. schimperiana* 228 (97.4%). The second most frequent coffee shade tree was *C. macrostachyus* according to the informant. The least frequent coffee shade tree was *F. sycomorus* L. by 4 (1.7%). In the study area also an exotic coffee shade trees identified. According to the informant,*G.robusta* planted by13.7% of farmers and *S.sesban* planted by2.6% of farmers on their coffee farms.

4.3 .Characteristics Used for Selection of Coffee Shade Trees By farmers

Wider canopy of trees, their smaller leaves, less dense and trees with deciduous leaves character were favored by all informants. 226 (96.6%) of respondents favored trees with umbrellas like canopy and223 (95.3%) of farmers favored shade trees with their leaf litters easily decomposed. Trees those have additional value other than shading were considered by 60.7% of informants. Trees take 7-8 years to be shade for coffee plants. Trees that are long lived also seen as criteria to selects shade trees which were cited by 96 (41%) of farmers. Some trees have fair height above coffee trees. This characteristics of trees were favored by 83 (35.5%) of informants.

Spines or thorns can trouble and causes infection particularly during harvesting of coffee cherries. These features of coffee shade trees were disliked by 41 (17.5%) of farmers. Trees like *F.ovata* extends their larger roots on ground which avoids growth of coffee roots. To minimize this kind of problems 23 (9.8%) of informants were favored trees with deeper roots (Table 3).

Table 3. Characteristics of trees used for coffee shade tree selection.

No	Characteristics of trees	Frequency	Percent
1	Wider tree canopy area, smaller leaves, less dense and deciduous leaves	234	100
2	Crown shape (With umbrella shaped crown)	226	96.6
3	Easily decomposable leaf litters	223	95.3
4	Tress with additional purposes	142	60.7
5	Long-lived trees	96	41
6	Tree size (fair height)	83	35.5
7	Easily reproducible	82	35
8	Free from spine (thorn)	41	17.5
9	Having deeper roots	23	9.8

4.4. Benefits of Coffee Shade Trees for Coffee Plants

All informants (100%) cited shade trees improve soil moisture and enhance soil fertilityfor coffee plants. Majority of farmers about 97.0% were responded that shade tree regulates light penetration and increases the life span of coffee trees.Shade trees decreases flood speedswhich washes fertile soil from the surface. In relation to this benefits 220 (94.0%) of informants cited that shade tree reduces soil erosion. 218 (93.2%) of respondents said that it helps to increase coffee seed quality (taste and mass), and helps to bear seeds year to years. The interviewed farmers 214 (91.5%) pointed that shade trees reduces weeds and grasses from coffee farms 13 (5.6%) of farmers were showed that the function of leaf litters for the occurrence of earth worms which its action contribute for soil fertility (Table 4).

Table 4. Benefits of Coffee Shade Trees for Coffee Production

No	Benefits of shade tree for coffee trees	Frequency	Percent
1	Soil moistures improvements and soil fertility enhancement	234	100
2	Regulate light penetration	227	97.0
3	It increase coffee trees longevity	226	96.6
4	Reduce soil erosion	220	94.0
5	It increases coffee yields as well as enhancements of coffee qualities	218	93.2
6	It reduces weeds and grasses	214	91.5
7	Its leaf litters are suitable for earth worm occurrences	13	5.6

4.5 .Farmers Favored Eleven Coffee Shade Trees

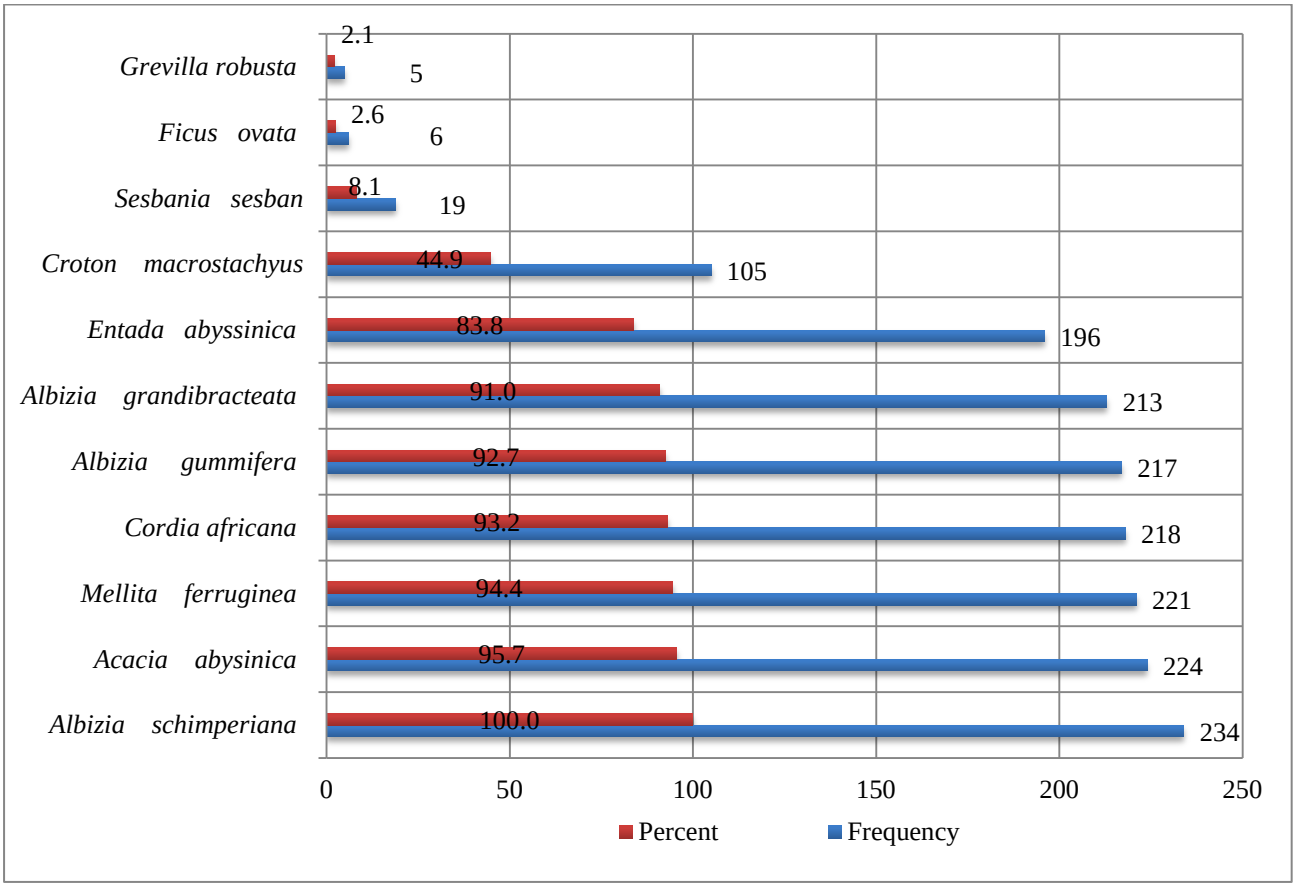


Figure 6. Coffee shade trees favored by Farmers studied in Goma district Jimma Zone.

Based on their indigenous knowledge farmers favored 11 shade trees that benefittheir coffee plants. Nine of them were native to Ethiopia. All farmers favored *A. schimperiana*. 224 (95.7 %), farmers favored *A. abyssinica. M. ferruginea* favored by 221 (94.4%), and *C. africana* by 218 (93.2%), *A. gummifera* were also favored by 217 (92.7%) of farmers (Figure 9).

As can be shown from the above table *F. ovata:* 6 (2.6 %) and *G. robusta:* 5 (2.1 %) were relatively the least favored shade trees. From the top five shade trees four of them were legumes species. The majority of farmers' preffered coffee shade trees were belongs to Fabaceae family

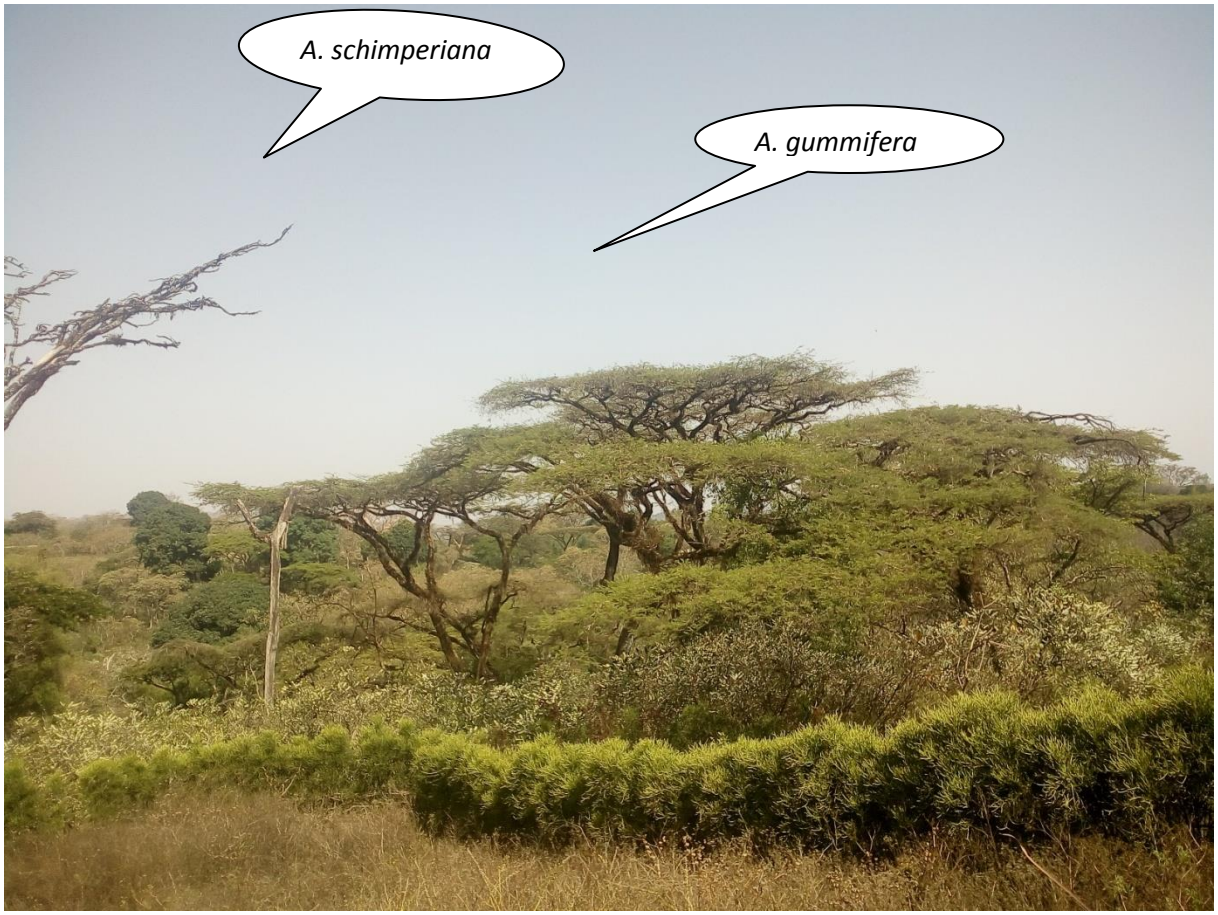


Figure 7. *A. schimperiana* and *A.gummifera* coffee shade trees from Deo-Yureche farmers association in Goma district Jimma Zone (Photo by Mohammed Kemal Mar.8,2019).

4.6. Characteristics of Favored Coffee Shade Trees by Farmers

From 26 tree species identified in the study area farmers preferred only eleven of them. They are different in characteristics. As can be shown in Table 6, from these species 9 (81.8%) of them are tall, 1 (9.1%) medium, 1 (9.1%) is short in height. With respect to their leaf size 7 (%) are small and 4(%) are large. In their crown shape 8 (%) of them are wide, 1 (9.1%) is medium, 1 (9.1%) is small and 1 (9.1%) is also pyramidal. Regarding deciduousness except 1 (9.1%) all are deciduous. In their growth form all of them are trees, from this 10 (90.9%) of them are permanent trees and 1 (9.1%) is temporary tree.

Table 5. Characteristics of eleven favored coffee shade trees identified in the study area.

Botanical Name	Height	Leaf size	Crown size	Litter decom.	Deciduousness	Growth form	Permanent/temporary
A. schimperiana	Tall	Small	Wide	Fast	Yes	Tree	Perm.
A. abysinica	Tall	Small	Wide	Fast	Yes	Tree	Perm.
M. ferruginea	Tall	Small	Wide	Fast	Yes	Tree	Perm.
C. Africana	Tall	Large	Wide	Medium	Yes	Tree	Perm.
A. gummifera	Tall	Small	Wide	Fast	Yes	Tree	Perm.
A. grandibracteata	Tall	Small	Wide	Fast	Yes	Tree	Perm.
E. abyssinica	Medium	Small	Medium	Fast	Yes	Tree	Perm.
C. macrostachyus	Tall	Large	Wide	Fast	Yes	Tree	Perm.
S. sesban	Short	Small	Small	Fast	Yes	Tree	Temporary
F. ovate	Tall	Large	Wide	Medium	Yes	Tree	Perm.
G. robusta	Tall	Large-fern like	Pyramidal	Slow	No	Tree	Perm.

4.7. Strong Side and Weak Side of Eleven Selected Coffee Shade Trees

The interviewed farmers have indicated the strong side for each coffee shade tree. The coffee shade trees strong characteristic were the smallness and thinness of their leaves, wider crown, deciduousness, coffee bean quality, decomposability of leaf litters and additional value. All farmers selected *A. schimperiana* at first order above all shade trees, then *A. abyssinica* selected by 224 (95.7%) respondents. *M. ferriginea* selectedby 221 (94.4%) respondents. *A. gummifera* selected by 217 (92.7%) farmers, *A. grandibracteata* selected by 213 (91%) farmers. *Entada abyssinica* was selected by 196 (83.8%) farmers by their smaller and thinner leaves, deciduousness and good coffee yields in mass and taste under its shade. *C. africana*favored by

218 (93.2%) of farmers for its timber and for quality berries under its canopies. *G. robusta* favored only for its timber by 5 (2.1%) of farmers.

C. macrostachyus favoredby 105 (44.9%), farmers for its fast growth rate and for its ability to convert rangeland to fertile land. *F. ovata* favored only by 6 (2.6%) farmers for its long-living and for its source of food for many living things such as cattle, birds and wild animals. No matter how *S. sesban* is very small in height it favored by farmers for its fast growth rate in new coffee farms and being fodder for cattle by 19 (8.1%) farmers.

(A) 

(B) 

Figure 8. C. macrostachyus trees (left) and S. sesban (right) in new created coffee farm which has been grazing land for many years from Omo guride farmers asociation Goma district Jimma Zone(Photo by Mohammed Kemal Mar.20,2019).

The interviewee also pointed the main limitation of each coffee shade trees they favored: *A. schimperiana*'s seedling can be slashed with weeds because of its slow growth rate .*A. abyssinia's* sensitivity to winds were cited by 166 (70.9%) farmers (Figure 12) and also its flat-topped crown makes individual coffee trees less branched and taller were cited by 58 (24.8%) of farmers.

M. ferruginea: 218 (93.2%), *A. gummifera 217* (92.7%), *A. grandibracteata* 213 (91.0%), *E. abyssinica* 196 (83.8%) were cited for their less horizontal branches when compared to *A. schimperiana* as limitation.

C. africana 218 (93.2%)and *F.ovata* 6 (2.6%)thick litters not easily decay when compared with *Albiziaspecies* and *M. ferruginea*.

C. macrostachyus (105%) *and G. robusta* 5(2.1%) their leaves can wrapped up around branches of coffee plants which reduces flowering, ripening of fruits and also suitable for growth of epiphytes on branches of coffee trees.

S. sesban 19 (8.1%) its short longevity to function as shade and its short size.

4.8. Preference Ranking

Since there are different plant species that serve as coffee shade in the area, local people show preference of one over the other. Preference ranking, of seven tree species that were reported for shade coffee, was conducted after selecting seven key informants. The informants were asked to compare and put the given shade plants hierarchically based on their preference as overall quality for coffee production and to give the highest number (7) for the shade plant which they thought most important as a shade and the lowest number (1) for the least preferred shade plant and the value is summarized (Table 6).

Table 6. Preference ranking of some dominant coffee shade plants by 7 key informants

Key informant	*Millittia ferruginea*	*Albizia schimperiana*	*Grevilla robusta*	*Acacia abyssinica*	*Cordia africana*	*Croton macrostachyus*	*Ficus ovata*
I_1	6	7	1	5	4	3	2
I_2	3	7	6	5	2	4	1
I_3	5	7	2	4	6	3	1
I_4	5	6	4	7	3	1	2
I_5	6	7	1	5	4	2	3
I_6	6	7	1	5	4	3	2
I_7	5	6	3	7	4	2	1
Total	36	47	18	38	27	18	12
Rank	3^{rd}	1^{st}	5^{th}	2^{nd}	4^{th}	5^{th}	7^{th}

As indicated in the Table 7 preference ranking for seven tree species used as shade coffee shown that *A. schimperiana* ranked first. The second, third and fourth most preferable shade plants for coffee plants are *A. abyssinica, M. ferruginea*and*C. africana* respectively, while the least preferable species compared to other six species is *F. ovate* according to informants.

4.9. Direct Matrix Ranking

In addition to the value of the tree species for shade; it was found that almost all of the species have different values for the quality of coffee production as well as ecological purposes. Some of the advantages identified for these species by local people were soil fertility, soil moisture, yield, taste of the coffee bean, life span of the tree and wild animals' refuge .To assess the relative importance and to check the knowledge of the community on shade plants direct matrix ranking was preformed.Six commonly reported tree species and seven benefit-categories were involved in direct matrix ranking with four key informants. Respondents evaluate their relative importance of the trees for the environment based on seven criteria (5 = best; 4 = Very good; 3 = good; 2 = less used; 1 = least used and 0 = no value). The values for use reports across the selected species were summed up and ranked in the Table 7.

.

Table 7. Direct matrix ranking of six plant species by four informants based on seven use criteria(5= best; 4 =Very good; 3 = good; 2 = less used**;** 1 = least used and 0 = no value)

Benefit-categories	Shade Plants																	
	A. schimperiana				*A. gummifera*				*C. africana*				*M. ferruginea*				*A. ab*	
	Informants (I_{1-4})				I				I				I				I	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	
Soil moisture	5	5	5	5	5	5	5	5	5	5	3	4	5	5	5	5	5	
Yields	5	5	5	5	4	5	4	5	4	5	4	5	5	4	4	5	5	
Taste	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	
Soil fertility	5	5	5	5	5	5	4	5	5	5	4	5	5	5	5	5	5	
Coffee Shade	5	5	5	5	3	5	5	5	3	4	4	4	4	4	4	4	5	
Wild animals	5	5	5	5	4	4	4	5	5	5	5	5	5	5	5	5	4	
Plant life span	5	5	5	5	4	5	5	4	5	5	5	5	5	5	5	5	5	
Ind. Total	35	35	35	35	30	34	32	34	32	34	30	33	34	33	33	34	34	
Grand total	140				130				129				134				135	
Rank	1st				4th				5rd				3th				2nd	

As it can be shown in Table 7 the direct matrix ranking revealed that *A. schimperiana*ranked first and hence it is the most preferred plant by coffee farmers. *A. abyssinica* ranked second, *M. ferruginea ranked as thirdA. gummifera*obtained fourth place, *C. africana* placed on fifth place and *F. ovata* got the last sixth place. So, the top ranked species are highly favored species by farmers not only as a shade but also for the health of the environment. *C. africana* and *F. ovata* are trees with wider leaves so they can reduce light transmission to coffee plants because of this feature they stood the last rank.

4.10. Disliked Trees for Coffee Shade by Farmers

Farmers were mentioned coffee shade trees those not liked by them because of their negative impacts on coffee production .These trees reduces light penetration, reduces soil moisture, and they creates suitable conditions for growth of epiphytes. They reported *Sapium ellipticum* in the first order by 223 (95.3%) and *Macaranga capensis* by 34 (14.5%) in the last order from eleven tree species. Seven of them are evergreen, three of them are deciduous and none of them are with small and thin leave.

Figure 9. *Sapium ellipticum,* the most disliked tree from Omo Beko farmers association in Goma district Jimma Zone (Photo by Mohammed Kemal, Apr.18, 2019).

Table 8. Characteristics of disliked trees for coffee shade studied in Goma district Jimma Zone.

Botanical Name	Deciduous-ness	Leaf size	Height	Crown size	Leaf litter decomposition	Frequency	Percent
Sapium ellipticum	No	Medium	Tall	Medium	Slow	223	95.3
Celtis Africana	Yes	Medium	Tall	Medium	Slow	215	91.9
Spathoda companulata	No	Large	Tall	Medium	Slow	212	90.6
Ficus thonningii	No	Medium	Tall	Medium	Slow	212	90.6
Bridelia micrantha	No	Medium	Medium	Less	Slow	211	90.2
Grevilea robusta	No	Large-fern like	Tall	Pyramidal	Slow	103	40.0
Ficus ovate	Yes	Large	Tall	Wide	Medium	86	36.8
Ficus lutea	Yes	Large	Tall	Wide	Medium	52	22.2
Croton macrostachyus	Yes	Large	Tall	Wide	Fast	48	20.5
Syzygium guineense	No	Medium	Tall	Medium	Slow	40	17.1
Macaranga capensis	No	Large	Tall	Medium	Medium	34	14.5

4.10.1. The Major Negative Effects of Disliked Shade Trees

Farmers can easily determine the disliked coffee shade trees by the amounts of harvested coffee cherries from underneath of each species of coffee shades.The interviewed farmers stated the main problems of each trees.Majority of disliked trees were evergreen and with a dense leaves that not allow adequate light penetration, and also those greatly decreases soil moisture were: *Sapium ellipticum* (95.3%), *Spathoda companulata* (96.6%), *Celtis africana* (91.9%), *F. thonnigii* (90.6%), *Bridelia micrantha* (90.2%), *G. robusta* (40%), *Syzgium guineense* (17.1%) and *Macranga capensis* (14.5%).

Farmers also mentioned the main problems of *F.ovata* (36.8%) and *F. lutea* (22.2%) which are their thick leaf litter prevents infiltration of water to soil. 166 (70.9%) of informants indicated the complex side effects of *Sapium ellipticum* trees. *Sapium ellipticum* leaves eaten by worms from April to June when there is a prolonged dry season happened. Baboons (*Papio.anubis*) feeds on these worms. During these process of food chain, baboons (*Papioanubis*), breaks many coffee tree branches to picks worms from the surface of coffee trees which were dropped from the upper branches of *Sapium ellipticum*trees *C. macrostachyus* by 48 (20.5%) because of its softy and broad leaved, *G. robusta* 103 (44.0%) because of its incised leaf margin, their leaves wrapped up around branches of coffee plants which reduces flowering, ripening of fruits and also suitable for growth of epiphytes on branches of coffee trees.

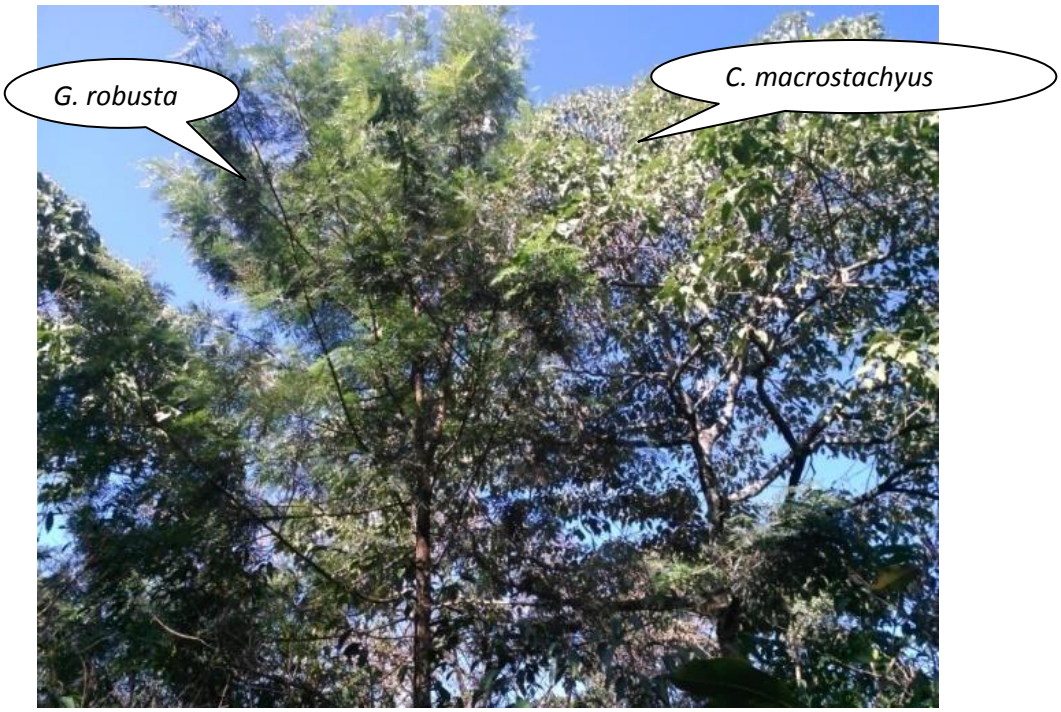


Figure 10.G. robusta and C. macrostachyus side to side in the coffee farm. The *G. robusta tree* inhibit both *Coffee* plants and *C. macrostachys* trees existence by its invasive behavior from Omo-Guride in Goma district Jimma Zone (Photo by Mohammed Kemal, Feb.21, 2019)

(A) 

(B) 

Figure 11. *C. macrostachyus* (left) and *G. robusta* (right) their leaf litters wrapped up on branches of coffee trees from. Bulado Choche in Goma district Jimma Zone (Photo by Mohammed Kemal, Jan.27, 2019)

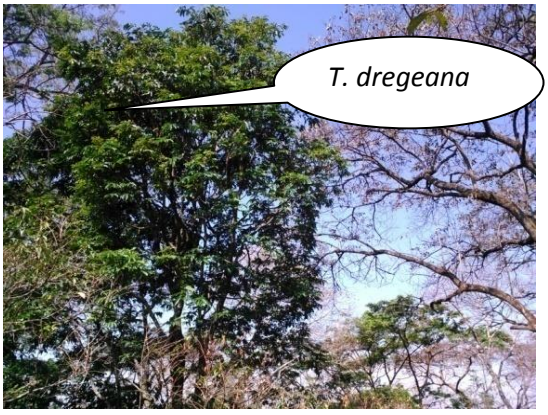
(A) 
(B) 

Figure 12. Disliked shade tree.Huge and tick leaf litters shed from T. dregeana tree(A) and phots of T.dregeana (B) from Omo-Guride farmers association in Goma district Jimma Zone (Photo by Mohammed Kemal Jan.28/2019).

4.10.2. Current Managements of Disliked Coffee Shade Trees and Their Functions

All of the informants were mentioned they were cutting the disliked shade trees time to time. In the farms of coffee plants different tree species are found. Some of them are preferred for shading than others.The most disliked trees for shading have other purposes for coffee plants and

for environments 135 (57.7%) of farmers explained these disliked trees prevents coffee trees from storm, heavy rains and helps to minimize the impacts of prolonged dry season. 81 (34.6%) of informants have pointed out its contribution in increasing air humidity.18 (7.7%) of informants were not responded for current management of disliked coffee shade trees.

4.11. An Exotic Coffee Shade Trees and Their Sources

From the coffee shade trees found in their coffee farms 175 (74.8%) of farmers knew an exotic trees species and 59 (25.2%) of respondents not knew any exotic tree species which are functioning as coffee shade.Two major exotic coffee shade trees were named by the informants those knew an exotic trees.56 (23.9%) of respondents named *G. robusta* and *S.sesban* as an exotic trees, 65 (27.8%) of respondents named only *S. sesban* and 54 (23.1%) of respondents named only *G. robusta* as an exotic tree species. In the study area the two mentioned exotic trees were highly distributed to farmers for planting.district agricultural office and individual farmers were the sources of these seedling which were mentioned by 175 (74.8%) of informants.

Table 9 Data of tree seedling distributed to farmers and to different organization by Goma district agricultural and natural resource office in six years (2011-2016).

Botanical name	Year						
	2011	2012	2013	2014	2015	2016	Total
A.schimperiana	675,000	563,400	467,100	567,200	679,200	600,000	3,551,900
C.africana	1,793,600	2,120,000	1,979,000	2,110,000	2,630,000	4,110,000	14,742,600
Cupressus lusitanica Mill.	1,252,300	2,119,000	2,223,000	2,320,000	2,350,000	2,850,000	13,114,300
G.robusta	765,000	976,500	897,560	1,110,000	1,210,000	300,000	5,259,060
S.sesban	2,390,000	3,430,000	2,130,000	2,440,000	2,577,000	6,330,000	19,297,000
Total	6,875,900	9,208,900	7,696,660	8,547,200	9,446,200	14,190,000	55,964,860

Depending on the above table the researcher has certified that one of the sources of exotic tree seedling were government body itself that supports the responses of respondents. As shown from the data of tree seedlings distributed for the previous six years out of 5 tree species 3 (60%) of them *G. robusta,S. sesban*, and *Cupressus lustanica* Mill. were exotic tree species and 2 (40%) of them were native trees (*A. schimperiana* and *C. africana*). as it can be seen in (Figure 17) more care were given for exotic seedlings than native trees in the nursery site.

4.12. Additonal Functions of the Coffee Shade Trees

Many coffee shade trees in the coffee farm were retained their mainly for shading purposes, however some trees can be planted for additional purposes like for timber and fodder. Farmers of the study area were cited the additional values of coffee shade trees.

Additional function of coffee shade trees for construction, timber and fuel wood

C. macrostachyus: its flower to make honey were cited by 159 (65.4%), also for fuel wood and house construction cited by 217 (92.7%) informants, *S. sasban* function as fodder were cited by 6 (2.6%) informants, *G. robusta* for timber were mentioned by 32 (13.7%), *Mimusops kummel* for house construction were cited by 21 (9.0%). *C. africana* for timber were cited by 234 (100%). *A. abyssinica* and *Celtis africana* for charcoal were cited by 234 (100%).

F. exasperate function for dish cleaning by its leaves were cited by 12 (5.1%). *S. ellipticum* for fodder and house construction were cited by 186 (79.5%). *F. ovata* and *F. lutea* its seeds function as fodder for wild animals and cow/ox and also for house construction were cited by 173 (73.9%). informants.

Additional function as traditional medicine

C. macrostachyus: to heal ringworms by painting with young leaves the area 4 (1.7%).to heal gonorrhea by taking powder of white parts of the bark with tea 2 (0.9%), to stop accidental bleeding from the skin by dropping liquid of young leaf on it 3 (1.3%), to heal malaria by firing its branches and inhaling its smock through nose 98 (41.9%), to heal swelled cow/ox by inserting compressed young leaves to nose by 3 (1.3%) farmers.

Spathoda companulata: to heal breast problem of cows and diarrhea of cow/ox by giving powder of its barks with porridge 78 (33.3%), to heal glandular swelling in human taking powders of its barks with tea 6 (2.6%).

E. abyssinica: drinking boiled leaves to heal diarrhea 2 (0.9%).

4.13. Consequences/Challenges on Unshaded Coffee Plants

The interviewees cited consequences comes on unshaded coffee plants from the points of their indigenous knowledge All of an interviewed farmers were mentioned prolonged full sun causes death of the whole coffee trees. Weeds and grasses shaded by coffee trees as result they become dominant in the community. In relation to this 221 (94.4%) of them cited in unshaded coffee farms weeds and grasses attacks coffee trees. According to 213 (91.0%) of respondents coffee trees in full sun bears large amounts of coffee cherries which results to die-back. 221 (90.2%) of respondents cited coffee trees in unshaded farms more attacked by coffee berry disease than shaded farms. According to 87 (37.2%) of farmers coffee trees in full sun light become mature before shaded coffee trees.

Table 10. Consequences of un-shaded coffee plants

No	Consequences/Challenges	Frequency	Percent
1	Death of coffee trees.	234	100
2	More attacked by weeds and grasses.	221	94.4
3	Berry overbearing which causes die-back.	213	91.0
4	More frequent attacks by coffee berry disease. compared to coffee tree grown under native shade species	211	90.2
5	Early ripening. compared to shaded farms	87	37.2

Figure 13. Unshaded coffee trees attacked by graasses and intense sun light from Bulado Choche famers association in Goma district Jimma Zone (Photo by Mohammed Kemal, Mar.19, 2019).

A

B

Figure 14. A two-year-old coffee seedlings.Shaded seedling (A) and Unshaded seedling (B) studied in Goma district Jimma Zone (Photo by Mohammed Kemal, Mar.30, 2019).

4.14. Side Effects of Un shaded Coffee Farms on Human and Wild Life

Majority of farmers about 221 (94.4%) indicated that they losses additional income gained from trees in the coffee and it requires more management than unshaded coffee farms. 215 (91.9%) of informants cited coffee shade trees are sources of food and place of living for wildlife, if there is no food for wild life they become more attacks our cattle and cereals, which increases human-wild life conflicts. According to 4 (1.7%) of informants they were defenseless to ultraviolet light during harvest of coffee cherry in full sun coffee farms.

4.15. Threats to Coffee Shade Trees

Most coffee shade trees are sources of fodder for animals. During this food chain animals can affects plants, or can creates suitable condition for the next consumers. As result plants become in threats. The interviewees revealed two coffee shade trees: *A. schimperiana* and *C. africana* .According to 223 (95.3%) of informants *A. scimperiana* is under threats because of its slow growth rate of its seedling, feeding of *Colobus guereza* Ruppell. along with ants and worms on its stem. *C. africana* mentioned by 51 (21.8%) of farmers as the second threatened coffee shade tree species because of its excessive exploitation of its stems for timber.

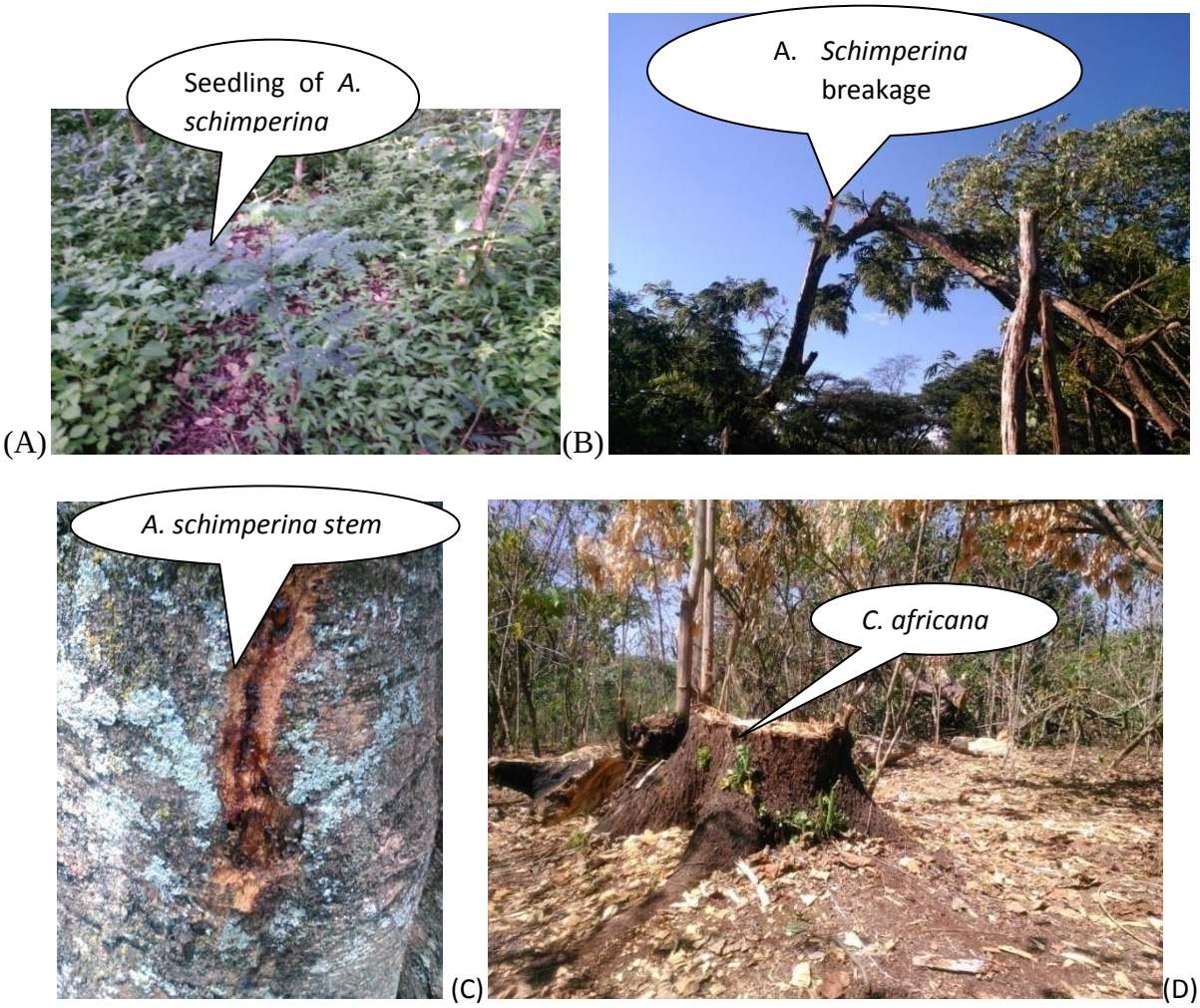


Figure 15. Threatened coffee shades A. schimperina (A,B,C) and C. africana (D).from Bulado choche farmers association in Goma district Jimma Zone (Photo by Mohammed Kemal, Mar.30, 2019).

4.2. DISCUSSION

The maximum figures for the respondents interviewed were male this may be articulated due to farming activities and external exposure for interview culturally linked with male and at the same time the associated knowledge of male is better than female in the area The interviewed farmers had long experiences in growing coffee plants under different coffee shade tree species. Their overall understanding of shade was very interesting and they took shade trees as pivotal precondition for coffee production systems. According to the present research findings, all farmers had coffee shade trees in their coffee farms. However, there were some areas of unshaded parts in the coffee farms. The majority of farmers' coffee trees age lies between ages of 10 to 70. The reason why 96.6% of coffee trees ages were above 10 years are probably the effects of coffee shade trees according to the present research finding. The finding agreed with the assessment of Techale Birhan *et al.,* (2014),

Goma district is branded in history by its production of coffee and dominated by old coffee shrubs with traditional coffee farms management. According to the finding majority of farmers owned less than of two hectares of coffee farms. Even if the district is known by its coffee production, the majority of the farmers participated in other jobs for additional income generation. Similarly Zerihun Nigussie (2012), described in his review, Ethiopia is an agricultural based country where the majority of the population engage in subsistence level crop and livestock production .All of the interviewees mentioned that additional jobs solves the fluctuation of coffee price they met for many years "Coffee price is too low" this is a regular statements by coffee farmers in the world (Kuit *et al*., 2004) which agreed with the informants.

Based on the interviewed farmers a total of 26 species of trees categorized in 20 genera and 12 families with the highest of Fabaceae family were identified. This finding is a good indicator for the presence of considerable diversity of plant species in the study area Similarly, Abomsa Bulcha, (2016) stated Fabaceae is the dominant coffee shade trees. The coffee farms of the area are categorized under semi-forest coffee farms. Similarly Kumsa Lemessa *et al*., (2016) reported coffee farms in Southwest Ethiopia as whole grown under dense shade of native trees often in distinct area surrounded in an open agricultural landscape .*A schimperiana* was the most frequent

and *Ficus sycomorus* was the least frequent probably because of smaller leaf size and wider leaf size respectively.

All of the farmers favored coffee shade trees characteristics were an intermediate shade conditions which happens by wider tree canopy, smaller and thinner leaves. This characteristics of trees are important for increasing coffee yields, coffee bean taste, and coffee bean mass in general to increase coffee trees age. Moderate shade levels increases photosynthetic rate for coffee trees (Beer *et al*., 1998). About 60.7% of farmers stated that additional uses of shade trees as criteria to select coffee shade trees as supported by analysis of Herzog, (1994) fruits, timber and firewood gained from shade trees solves income difficulties of small-scale coffee farmers.

Farmers were also favored long-lived trees and trees with its branches not easily detached from the main stems. Long lived trees increases coffee trees age It takes minimum 7 years to be shade for coffee trees.so long lived trees minimize this problem. *A. abyssinica* was nominated in the second rank by all informants, however it falls to ground easily by winds and harms many coffee trees around it. Selection of long lived trees by farmers were crucial understanding Beer, (1987), mentioned in its report shade trees breakage can damage coffee plants when falls to ground. Farmers also had good accepting about height of shade trees.

Too tall trees with large leaves increases the influence of rain (water dripping) which affects soil texture. Tree height is characteristics favored by farmers Albertin and Nair, (2004), too tall trees could exposes coffee plant to intense light radiation when there is extended dry season (Dirriba Muleta *et al*., 2011). Farmers were also favored easily reproducible trees. Being free from thorns also a characteristics chosen by informants because thorns in the ground prevents coffee beans picking. Deeper roots can holds trees up, absorbs nutrients from deepest site which coffee trees cannot reaches and also not compete with coffees roots for nutrients. Through leaf litter decomposition coffee trees obtain a mineral which its roots cannot absorb from deeper site (Kuit *et al*, 2004).

All of the interviewed farmers were specified that the benefits gained from coffee shade trees are increasing of soil nutrients, and soil moisture. Similarly in the review of Dirriba Muleta *etal*., (2011) soil fertility is increased by leaf litter decomposition. The majority of the interviewed farmers pointed coffee shade trees regulates light penetration and also increases lifespan of

coffee trees. The other benefits of coffee shade cited by majority of farmers were the reduction of soil erosion. Dirriba Muleta *et al.,* (2011) have mentioned that coffee plants under shade trees bears bigger and heavier coffee seeds and also higher coffee yields from shaded coffee farms.

The other benefits of shade trees mentioned by farmers were its ability to avert the growth of weeds and grasses Feyera Senbeta and Danisch (2006) and Schmitt *et al*., (2009) have also mentioned that slashing of weeds and emergent trees from coffee farms increases coffee yields. Native legume trees have great contribution for biological nitrogen fixation (Grossman *et al*., 2006). They are giant biological industries, (Legesse Negash, 2016). None of the interviewees cited the role of microorganisms for the soil fertility. However, some of them cited the role of earth worms for soil fertility based on their day to day observations of their soil. Similarly Kuit *et al*., (2004) cited the role of earthworms in increasing aggregate stability and improving infiltration by forming macropores.Coffee farmers' knowledge on soil biologicalcomponents categorized in to what farmers could easily observe and non-visible features of soils (Grossman, 2003). One example was farmers can observe frequently earth worms that related with soil fertility.

Majority of interviewed farmers were mentioned native trees such as *A. schimperiana, A. abyssinica, M. ferruginea, C. africana, A. gummifera, A. grandibracteata, E. abyssinica, and C. macrostachyus* in that order as best coffee shade tree species to have in their coffee farms and also very small percent of farmers have cited that *S. sesban*, *F. ovata* and *G. robusta* as favored coffee shade trees. From the mentioned coffee shade trees all farmer calls *A. schimperianas* as *"mother of coffee trees"* The majority of favored shade trees were leguminous plants, similarly leguminous plants favored by coffee producers across the world (Beer, 1987; Grossman, 2003; Albertin and Nair, 2004; Dirriba Muleta*et al*., 2011). Different tree species have different function for coffee trees. Farmers of the study area were totally favored 11 shade tree species. For shading purposes one tree species are more suitable than other trees (Kitessa Hundera *et al*, 2013). The farmers favored coffee shade trees also preferred in most areas like Yayu and Bonga district farmers which were *A. gummifera*, *A. abyssinica*, *M. ferruginea* and *C. africana* (Dirriba Muleta *etal*., 2011).

The majority of farmers favored coffee shade trees belongs to family of Fabaceae which were seven species in numbers .All of them were trees, with smaller and thinner leaves, have fast

growth rate, taller and deciduous leaves Except *S.sesban* all of them were permanent shade trees. Majority of the favored coffee shade trees were those can allow moderate light transmission through it, which can be managed easily such as shade branches .The most known practice in coffee management includes the reduction of the upper branches to facilitate the penetration of light towards the coffee trees (Labouisse *et al* 2008).

All farmers favored *A. schimperiana* in the first order, following *A. abyssinica, M. ferriginea, A. gummifera, A. grandibracteata,* as well as *E. abyssinica* by their smaller and thinner leaves which allows moderate light penetration, by their wider crown, and deciduousness, were their strong sides. Also coffee production under their canopy were good coffee yields, heavier bean mass and tasty coffee beans. By preference ranking and direct matrix ranking still *A. schimperiana, A. abyssinica* and *M. ferruginea* stood first, second and third respectively.

Because of the larger leaf size of *C. africana and F. ovata,* not allow light as the other species Abomsa Bulcha, (2016) they stood the last. This indigenous knowledge agreed with work of Beer *et al*., (1998), an intermediate shade level increases photosynthesis rate which increases coffee yields and quality in the tropics. *C. africana*'s strong side was for its economic timber sources and for its sources of good coffee beans in mass and tastiness .under its shade *G. robusta'* strong side was for its economic timber sources.

Functions of *C. africana* was also reported by Behailu Etana, (2010). *C. macrostachyus* strong side was fast growth rate its seedling and ability to convert rangeland to fertile coffee farms. Similarly the work of Kibebew Wakjira and Legesse Negash, (2013), stated that strong sideof *C. macrostachyus* essentiality for soil fertility, for water conservation and rapid growth in degraded land. *F. ovata* favored only by 6 (2.6%) farmers for its long-living and by its source of food for many living things such as cattle, birds and wild animals.*S. sesban* favored for its fast growth in newly established coffee farms and being fodder for cattle.The interviewees also pointed that the main limitations of each coffee shade trees they favored: *A. schimperiana* its slow growth rate of seedling as result cannot be distinguished from weeds so easily can be slashed with weeds. .*A. abyssinica* is sensitive to winds and its flat-topped crown makes individual coffee trees less branched and taller coffee plant in height. This may be because of competition for light between individual coffee trees as result branches and numbers of nods decreased which decreases coffee berry numbers per trees. *C. macrostachyus* because of its softy and broad leaved and *G. robusta*

trees because of its fern like leaf margin, their leaves wrapped up around branches of coffee plants which lessens flowering, ripening of fruits and also suitable for growth of epiphytes on branches of coffee trees as the main limitations.

Farmers also stated that the reason why they disliked coffee shade trees like *S.ellipticum, Celtis africana, Spathoda companulata, F. thonningii, Bridelia micrantha, G. robusta, Syzygium guineense* and *Macaranga capensis* were: they utilize excess water from the soil, their leaf litters take too long to be decomposed as result their leaf litters prevents rain water infiltrations especially when rain water is very low. Similarly Beer *et al*., (1998) reported shade trees reduce the stress of coffee trees by ameliorating adverse climatic conditions and nutritional imbalances, but they may also compete for growth resources.

S. ellipticum trees have dense leaves which are more eaten by worms during prolonged dry seasons by baboons (*Papio.anubis*).They breaks branches of coffee trees to feed on these worms. Dense leaves suitable for some pests like coffee berry borer (*Hypothenemus hampei*) which was also reported by (Wrigly, 1988).

Traditionally coffee in Ethiopia was grown under diverse, dense and largely native tree covers. However, recently in some areas farmers have started to use exotic trees such as *G. robusta* for the sake of timber production and *S. sesban* on their coffee farms. (23.9%) of them named *G. robusta* and *S. sesban*, (23.1%) of them only named *G. robusta* and (27.8%) of them only named *S. sesban* as an exotic trees. (25.1%) of farmers haven't knew any species of an exotic trees.

Farmers have also mentioned that an additional values of their coffee shade trees such as for honey production, for fuel-wood, for timber, house building materials, for charcoal, and fodder. The additional values solves coffee price fluctuations Beer *et al.,* (1998) *C. macrostachyus* leaves with its white part of the bark is used to heals malaria when inhaling the smokes formed from firing. Behailu Etana, (2010) was also reported *C. macrostachyus* as medicinal plants.

T. dregeana barks used to heal breast problem of cows and diarrhea from cows/oxen and also function to heal glandular swelling in human. This findings agrees with the work of Behailu Etana, (2010). *M. ferruginea*: its seed powder with butter used to heal dandruff and also seed powder kills ants, bedbug, and chigger flea (*Tunga penetrans* L.) were cited by 138 (59%) of farmers. This also agreed with the work of Tadesse Hailu *et al.,* (2000).

All of the interviewed farmers expressed the main challenges encounters the unshaded coffee plants were short life span of coffee trees because of erosion, intense light radiation, occurrences of frost and foggy on it.

The erosion reduces nutrients by washing from the soil; intense light radiation causes photo inhibition, and fogginess reduces temperature which inactivate photosynthetic enzymes. This finding agreed with Wrigley, (1988) and Kuit *et al*,.(2004) unshaded coffee bushes have a shorter life expectation than shaded bushes According to majority of farmer full sun grown coffee farms invaded by weeds, grasses and shrubs. The other challenges on unshaded coffee plant are berry overbearing which were reported by majority of farmers. Overbearing occurs as result of high light intensity. It decreases the next season yields and leads to die-back of coffee trees. Unshaded coffee farms also more attacked by disease like coffee berry disease when compared to shaded coffee trees. Also berry overbearing impacts supported by Haare, (1963), coffee is more severely attacked by disease if the trees are get worse by overbearing .The other disease that attacks coffee is *Cercospora coffeicola*, a fungus disease which can completely defoliate coffee plants is greater in unshaded plantation Nataraj and Subramanian, (1975), possibly due to the higher susceptibility of water stressed or nutrient deficient plants (Wrigley, 1988).Unshaded coffee farms creates problems on biodiversity and nature. This finding supported by reviews of Perfecto *et al.,* (1996) tree species found in traditional coffee plantation are important to conserve nature.

The majority of farmers stated that *A. schimperiana* as the most threatened coffee shade because of slow growth rate of its seedling which can be slashed along with weeds, as result its density reduced. Disturbance decreases species density and species richness Kumsa Lemessa *et al*., (2016), and feeding of its barks by *Colobus guereza* as well as attacks of trees' stems by ants and worms. Farmers also pointed solution for these problems: growing its seedlings side to side with *C. macrostachyus* and removing of nets of ants from the stems. Threats on *C. africana* include economic benefits as a timber tree, as well as use for fuel wood and for other local utilities. This also reported by IBC, (2012); Behailu Etana, (2010); and Dirriba Muleta *et al*., (2011). *C. africana* is threatened species because of its excessive exploitation of its stems for timber.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Farmers have an astonishing knowledge of shade trees and their contributions for coffee production and also for conservation of biodiversity which should be given more recognition as scientific knowledge had. All coffee farmers retained coffee shade trees in their coffee farms. The best coffee shade trees for *Coffee arabica* production are shade trees with smaller and thinner leaves that allow moderate light penetration to coffee trees, the one that their leaf litter rapidly convertible to fertile soil, the one with umbrella like crown shape and those shed their leaves during dry season. The survey identified farmers' favored native shade trees such as: *A. schimperiana, A. abyssinica, M. ferrginea, C. africana, A. gummifera, A. grandibracteata* and *C .macrostachyus*. The species densities of *A. schimperina* and *C. macrostachyus* were higher than other shade trees, probably because of highly favored and fast growth rate of them respectively. The majority of coffee plant ages were above age of ten; this was due to the presence of shade trees in the farms which prevent different environmental hazards.

The majority of farmers favored coffee shade trees were categorized under the family of Fabaceae which are legumes trees They can fix nitrogen from the atmosphere that are necessary to synthesis organic molecules that increases coffee taste, size of coffee beans and yields. Shade trees used to reduce erosion, improves soil moisture, regulate temperature, generally coffee shade trees increases life span of coffee trees, and have great role in environment and biodiversity conservation were benefits of coffee shade trees identified by the survey in the study area.In the study area *A. schimperiana, A. abyssinica,* and *M. ferruginea* were ranked in the first order in producing higher yields and reliable for coffee production. Coffee shade like *S. ellipticum, Spathoda companulata* and *Celtis africana* were the most disliked coffee shade trees since they reduce soil moisture and their dense leaves decreases light penetration to coffee shrubs.

5.2. Recommendations

The following recommendations were forwarded:

For better production of coffee, farmers' traditional knowledge about coffee production and biodiversity conservation should be conserved and combined with scientific knowledge. From all selected coffee shade trees by farmers nine of them were natives to Ethiopia under the family of Fabaceae, Boraginaceae and, Euphorbiaceae, so farmers and government should give more attention to these native trees to expand them and care for them as they are main precondition for coffee plant managements that increases coffee yields which benefits individual farmers and country as a whole. However the effects of these shade trees on raw and cup quality of coffee need further investigations.

Local people use trees for timber, charcoal, fuel wood and for other uses. Shade trees contribute for carbon dioxide sequestration. So farmers those owned shaded coffee farms should be paid better price to encourage them for retaining shade trees in the coffee farms.*A. schimperiana* is the best favored coffee shade trees. It is also the one in higher threat because of impacts of animal like *Colobus guereza* Ruppell, ants, worms, and its sensitivity to sharpen tools and slow growth rate of its seedlings which increases death of this tree. To solve or minimize the threats of *A. schimperiana* necessary research should be conducted and more attention should be given by all stakeholders for this mother of coffee trees. *E. abyssinica* were selected by 83.8% of farmers whereas it found only in 20% of farmers coffee farms, more seedlings should be prepared in nursery site and distributed to farmers by governments like other seedlings.

Local farmers were using exotic tree species like *G.robusta* as coffee shade tree and for timber production. Local government bodies should give awareness raising on the selection of appropriate and native shade trees than the exotic species plantation and creating nursery sites for native coffee shade tree species in the area are advisable.Farmers and government should give more attention to expand best compatible native trees for better shade and increase coffee production in the area and establishment of forest protected areas should be encouraged for conserving other tree species in the area

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APPENDICES

Appendix 1. Questionnaire for Coffee Farmers

The purpose of this questionnaire is to gather data on different coffee shade trees in Gomma district Jimma zone about selection and management practice of coffee shade tree by small holder coffee producers. It is conducted with the aim of obtaining information to the research as the partial fulfillment for Master of Science in Biology. To attain its objective you are kindly requested to give reliable information. The researcher assures that your response will be confidential and only to be used for the purpose of the study.

1. Sex: Male_____. Female_____.

2. Kebele_____ 3. Occupation _____

4. Age: _____.

5. Educational background: _____

6. Age of coffee trees _____.

7. Size of coffee farm_____ (in hectare).

8. It is known that you have an annual income from your coffee farm. In addition to this income do you have other sources of annual income for your family? Yes_____, No_____

8.1 If your answer for the question number 8 were "Yes" name the types of your income.

_____,_____,_____

8.2 What is the functions of additional incomes from other sources in addition to coffee production?

_____

9 In your coffee garden are there a coffee shade trees? Yes_____, No ____.

10 If your answer is "Yes" for question number 9, what are the names of coffee shade trees that are found in your coffee garden ?_____,_____

11. Every trees have their own features and characteristics. By what features and characteristics of it you choose coffee shade trees for your coffee garden? _____.

12. What are the benefits of coffee shade trees for your coffee plants?

_____,_____

13. Which tree species are more favored as coffee shade trees from all coffee shade tree species?

1 _____2_____3_____

14. For the above question number 13 what are the main strong sides and weak sides of each coffee shade trees?

14.1 Describe the main strong side for each selected coffee trees?

Tree species	Strong side of a tree

14.2 Describe the main weak side for each selected coffee shade trees

Tree species	Weak side of a tree

15. Name the coffee shade trees those have sever effects on coffee trees and coffee yields.

_____,_____,_____,_____,

16.1 In question "15" above you have mentioned coffee shade trees that are not preferred for coffee shade trees. Describe their major negative effects on coffee plants.

Species name	Their negative effects

16.2. What are their existing status (current management) of those not preferred coffee shade trees?

_____,_____,_____,_____

16.3 Even if they are not preferred trees to be as coffee shade trees, what are their current function for coffee trees and for environment._____, _____?

17. From coffee shade trees those found in the coffee farm do you know exotic tree species?

Yes _____ No_____.

17.1 If your answer is "Yes" name them._____, _____

17.2 What is the sources of exotic tree seedlings and their seeds for farmers? _____

18. What additional functions or purposes do you get .from coffee shade trees?

Species name	Importance	Plant part	Preparation(if it is for medicine)

19.1 What problems can encounters the unshaded coffee plants? _____

_____,_____,_____,_____

19.2 What side effects are comes from unshaded coffee farm other than affecting coffee production?_____,_____,_____,

20. Which coffee shade trees are in threatening condition? Why threatened? Is there a solution to protect them?

20.1 Why they are threatened?

Species name	Causes of their threats

20.2 What is a possible solution to protect them?

Species name	Solutions

Appendix 2.Questionnaire for coffee farmers (Version Afan Oromo)

Gaafannoo qotee bulaa buna omishanuuf dhiyaate

Kaayyoon gaafannoo kana aanaa Gomma keessatti muka qabbana Buna jedhamanii buna keessatti dhaabamanii jiranu gosa sanyii isaanii fi kan baayyinaan buna keessatti argamanu adda baafachuu fi hubannoo qonnaan bulaan muka qabbana bunaaf dhaabamanii jiran irratti qabu madaaluu dha.Kaayyoon qo'annoo kanaas barumsa baayolojiin digrii lammaaffaa hojjechuuf waan taeef gaaffiwwan dhiyaatan qalbiin erga dhaggeffattani booda odeeffannoo dhugaa tae akka naa kennitanu kabaja guddaan isiin gaafataa,odeffannoon keessanis kaayyoo qo'annoo kana qoofaaf kan oolu ta'uusaa isinii mirkaneessa.Gargaarsa keessaniif galatoomaa.

1. Saala ilaalchisee: Dhiira_____. Dhalaa_____2. Ganda_____3.Gosa hojii _____

4. Umurii: _____.

5. Haala barumsaa ilaalchisee: _____.

6. Bunnii keessan erga dhaabamee waggaa meeqa ta'eeraa? _____.

7. Bunni keessan hammamii facaasaan? _____.

8 Jireenya keessaniif galii bunarraa argattanu dabalataan burqaa galii kan biraa qabduu?

Eee_____Hin qabu_____

8.1 Gaffii 8ffaaf deebiin keessa "ee" yoo ta'e maal maalirraa argattuu?

_____,_____,_____

8.2 Buna malee galii dabalataa qabaachuun maaliif fayyadaa? _____

9. Buna keessan keessa mukti qabbana bunaa jiraa? Jira _____Hin jiru ____.

10. Gaffii 9^{ffaa} f deebiin keessan "jira" yoo ta'e maqaan tarreesaa.

_____, _____,_____

11. Muka qabbana bunaaf ta'u amala ykn sababa isaa kam irratti hundooftanii filattuun?

_____,_____,_____

12. Mukti qabbana bunaa buna keessa jiru bunaaf faayidaa maalii kennaa?

_____,_____

13. Mukti qabbana bunaaf caalaatti filatamaa dha jettanu eenyuu dha.

1 _____2_____3_____

14. Gaaffii "13ffaa"f ciminni (bareedummaan) fi hanqinni (rakkoon) gurguddoon jarri qabu hoo maali?

14.1 Ciminni gurguddoon muka qabbana bunaa filattani maalinni?

Gosa mukichaa	Cimina mukichaa

14.2 Hanqinni gurguddoon muka qabbana bunaa filattani maalinni?

Gosa mukichaa	Hanqina mukichaa

15. Gosti mukaa buna keessa dhaabamu hin qabu jettanu eenyuu dhaa sababa miidhaa bunarratti qabanuun._____, _____,

16.1 Gaaffii "15ffaaf"muka qabbana bunaaf hin filatamne tarreessitanmiidhaa gurguddoon isaan bunarraan gahanu maalinni?

Gosa mukaa	Rakkoo isaa yookiin miidhaa isaa

16.2 Yeroo ammaa mukeleen hin filatamne Kun haala maaliin qabamaa jiru? _____

_____

16.3 Mukeelen qabbana bunaaf hin filatamne kun bunaa fi naannoof yeroo ammaa faayidaan kennanu maalidha? _____.

17) Muka qabbana bunaa jedhamanii yeroo ammaa buna keessa jiranu muka sanyi biyya alaa kan ta'anaddaan baaftani beektuu? Eee_____Hin beeku_____.

17.1 Deebiin keessan "eee" yoo ta'e eenyuun fa'ii? _____,_____,

17.2) Qotee bulaan sanyi muka biyya alaa kana eessaa argataa jiraa? _____

18. Muka qabbana bunaaf buna keessa jiru oomisha bunaati malee dhimma maaliif itti fayyadamtuun?

Gosa mukaa	Faayidaa isaa	Gosa qaama isaa	Haala itti qophaa'u(yoo qorichummaa ta'e qofa)

19.1 Bunni muka qabbanaa hin qabne rakkoo maalitu isa qunnamaa?

_____,_____,_____

19.2 Bunni muka qabbanaa hin qabne rakkoo bunarraan ga'un ala rakkoo maali fida? _____

_____

20. Mukni qabbana bunaa sodaa baduu qabu eenyu? Sabanisaa hoo?Furmata qabaa akka hin badneef?

20.1 Sababni baduu danda'a jettaniif maalinni?

Gosa mukaa	Sababa soda

20.2 Furmaanni muka kana baduurraa hanbisanu hoo?

Gosa mukaa	Furmaata badurraa hanbisu

Appendix 3.Preference ranking of some dominant coffee shade plants by 7 key informants

	M. ferruginea	*A. schimperiana*	*G. robusta*	*A. Abyssinica*	*C. africana*	*C. macrostachyus*	*F. ovata*
I_1							
I_2							
I_3							
I_4							
I_5							
I_6							
I_7							
Total							
Rank							

Appendix 4.Direct Matrix Ranking by 4 key informants.

	A. schimperiana				*A. gummifera*				*C. Africana*				*M. ferruginea*				*A. abyssinica*				*F. ovata*			
Soil moisture	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Yields																								
Coffee shade																								
Wild animal																								
Plant lifespan																								
Ind.total																								
Grand total																								
Rank																								