Importance of *Ficus thonningii* Blume in Soil Fertility Improvement and Animal Nutrition in Gondar Zuria, Ethiopia

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ABSTRACT

In response to the existing environmental problems in Ethiopia, *Ficus thonningii* is becoming an important component of the farming system in Gondar and Gojjam. Information regarding establishment and socioeconomic importance of this species was collected from Gondar Zuria district by interviewing 45 household heads within three villages. Based on the socio-economic survey indicated that most of the sample households have understood its importance for environmental protection and dry season animal fodder and planted 4 - 100 trees. About 84.4% of them indicated that they have recognized its benefits and planted it in their landholdings in the homesteads, along farm boundaries and in pasture lots. Soil samples were also collected under the canopy of the tree and in the open land from four points from the base of trees at 0-10cm and 10-20cm soil depth. We found 1623.5 and 877 kg N ha^{-1} respectively under and outside the tree canopy in 0-10 cm soil layer. Similarly 945.5 and 847 kg P ha^{-1}, and 24700 and 16800 kg C ha^{-1} respectively, were found under and outside the tree canopy, however there are no significant differences between the mean values of the under canopy and the open pasture soils. The amounts of exchangeable cations of soils under *F.thonningii* were also higher than in the open both in the 0-10cm and in 10-20cm depth, for all cations except Mg and Al. For Mg and Al lower contents were registered at one crown radius distance away from the base of trees and higher contents in the open pasture than under tree canopy. In both depths, the pH of soils under the canopy showed lower values than soils in the open pasture. The average soil pH is 6.99 under the canopy and 7.08 outside canopy in the 0-10 cm. It increases to 7.06 under canopy and 7.12 outside canopy in the 10-20 cm soil depths. The CEC of the soils was greater than 40 $mmol_c$/100g and generally, soils under canopy had higher CEC than the outside canopy soils. The species has no adverse effects on the soil physical and chemical properties. This study suggests that *F. thonningii* can widely be used for soil fertility maintenance and fodder production by planting it in association with crops and pasture in agroforestry systems.

Key words: *Ethiopia, Soil properties, Environmental degradation, Agroforestry, Ficus thonningii, Fodder*

ZUSAMMENFASSUNG

Als Antwort auf bestehende Umweltprobleme in Äthiopien, wird *Ficus thonningii* vermehrt als eine wichtige Pflanze in der Landwirtschaft in Gondar und Gojjam eingesetzt. Um Informationen über den Anbau und die sozioökonomische Bedeutung der Baumart in Gondar Zuria zu erhalten wurden 45 Haushalte in drei Dörfern befragt. Die Bevölkerung wertet die Baumart für den Boden- und Umweltschutz und als eine Futterquelle während der Trockenzeit hoch. Pro Haushalt wurden bis zu 100 Bäume für diese Zwecke gepflanzt. Mittels bodenchemischer Analysen sollte auch die Bedeutung der Baumart für die Feldfrüchte und eine mögliche Integration in Agroforestry erhoben werden. Dazu wurden 40 Bodenproben unter und außerhalb der Baumkronen von 5 Bäumen in zwei Bodentiefen an 4 Transsektpunkten analysiert. Die Proben wurden auf Hauptnährstoffe analysiert. Im Vergleich der Kohlenstoff-, Stickstoff- und Phosphorgehalte unter den Baumkronen und in der offenen Hutweide außerhalb, wurden für 0-10cm Tiefe 1623.5 und 877 kg N ha-1 unter bzw. außerhalb gefunden. Ähnliche Effekte konnten auch für P mit 945.5 and 847 kg P ha-1, und für C mit 24700 und 16800 kg C ha-1 festgestellt werden. Es wurde auch pH und KAK ermittelt um die Wirkung der Baumkronen auf die chemischen Verhältnisse im Boden zu quantifizieren. In 0-10cm Tiefe war der mittlere pH-Wert 6.99 unter den Kronen und 7.08 außerhalb. Er steigt in 10-20cm Tiefe auf 7.06 unter der Krone und auf 7.12 außerhalb an. Die KAK der Böden war größer als 40 mmolc/100g und Böden unter der Baumkrone hatten grundsätzlich höhere KAK als in der freien Weide. Die Baumart hatte keine negativen Wirkungen auf bodenphysikalische und -chemische Eigenschaften. Diese Studie bestätigt, dass *F. thonningii* weithin für die Erhaltung der Bodenfruchtbarkeit und für die Futterproduktion verwendet werden kann und gemeinsam mit Feldfrüchten oder auf Weideland in Agroforestrysystemen angepflanzt werden kann.

Schlagwörter: *Äthiopien, Boden eingenschaften, Degradatien, Agroforestry, Ficus thonningii, Vieh futter*

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LIST OF ABBREVIATIONS

ARCS	Amhara region conservation strategy
CEC	Cation exchange capacity
CEDEP	Consultants for economic development and environmental protection
CGIAR	Consulting group for international agricultural research
CSA	Central statistics agency
EFAP	Ethiopian forestry action program
EHRS	Ethiopian highlands reclamation study
FAO	Food and agriculture organization
FAOSTAT	Food and agriculture organization statistics
GZDOARD	Gondar Zuria district office of agriculture and rural development
HDRA	Henry Doubleday research association
ILCA	International livestock center for Africa
ILDP	Integrated livestock development project
MNRDEP	Ministry of natural resources and environmental protection
SRCP	Soil conservation research project
TLU	Tropical livestock unit
USAID	United Nations agency for international development

1 INTRODUCTION

1.1 Background and justification

Based on the estimate by MOFED (2007), Ethiopian population has been 75.1 million by the mid of June 2006 with a growth rate of 2.62%. Out of this population, over 84 percent live in rural areas and depend on natural resources for economic development, food security and other necessities. More than 80% of the labour force of the country is engaged in agriculture (Dejene, 2003). The rural economy is subsistence type and relays on the production of food crops and husbandry of animals. The highlands constitute high animal and human population.

The agricultural and economic growth in the country is constrained by the deterioration of the natural resource base. Agricultural productivity particularly in the highlands is affected by low level of soil fertility (EFAP, 1994). Dairy production and herd-of-take are also low mainly due to the shortage and low quality of feed (EFAP, 1994). Population of the Amhara region is growing at a rate, which is not comparable with development of the forest resources. The gap between demand and supply of forest products is increasingly widening. The agricultural lands are also shrinking due to abandonment because of low fertility that has resulted from soil erosion and inappropriate farming practice.

Thus, the requirement to feed the high population in the country caused more land to be under crop production and livestock production. Monocropping and ploughing up and down slope being usual practices. This exploitative farming practice has resulted in the degradation and depletion of the vegetative cover, mainly forests. The growing demand for household energy and construction has fueled the process of forest devastation in the country. Soil erosion affected nearly half of the agricultural land and resulted in a loss of 1.5 to 2 billion tons annually (FAO, 1984). There is a strong dependency on crop residues and animal dung for household energy, which otherwise could increase soil fertility if these were added to crop and pasture lands. Thus, lower crop yields and animal productivity prevailed in the country (Benin et.al, 2003).

According to EFAP (1994) during 1990 alone, reduced soil depth by erosion resulted in loss in grain production estimated at 57,000 tones and in a loss of soil depth of 3.5mm and 120,000 tones in 8mm. This loss caused an abandonment of between 1000 and 2500 km^2 cropland. The forgone production in livestock due to this loss was between 35000 and 78000 TLU. Despite depletion of the feed resource base, improved forage and feed crops production were not integrated into the farming systems at the level it was required. It is important to quickly screen and identify suitable grass, legume crops and multi-purpose tree species and to develop strategies for integrating them into the farming systems (USAID, 2000). According to this report, research and extension programs need to identify and take into account nutritional shortcomings in planning their strategic objectives.

Competitions for land between crops and livestock, crops and forests and forests and livestock are very serious. In the mean time, forests are disappearing at alarming rates from the landscape. Due to shortage of land for agricultural production, inaccessible and fragile areas including steep slopes and wet lands have been brought under cultivation. This further aggravated the "environment-poverty trap" (Pearce et al., 1990). Shortly, the state of Ethiopian environment is very precarious, and calls for urgent response to combat land degradation problems through research and continued public dialogue. The size of available grazing land is also shrinking in many of the farming systems due to high livestock pressure and absence of appropriate land use policy. These grazing lands are overstocked and the land is overgrazed and degraded. Their productivity is too low and cannot support the growth of high biomass and nutritious feed for the livestock.

Generally, rural household's possibilities to increase crop productivity are highly dependent on the land availability and land user's capacity. Increasing productivity by increasing the land under cultivation is constrained by shortage of land while increasing by use of inputs in the form of seed, fertilizer and other technologies like composting or application of dung, which in turn depend on the financial capacity of the landholder for purchasing better seeds and/or breeds. In the same way, productivity of livestock needs improving the quality grazing and using high quality livestock breeds. The possible solution to this complicated problem is implementing an integrated land management practice that optimizes most of the needs of the land users at the same time rehabilitating the land, i.e. agroforestry.

If appropriately implemented, agroforestry has the potential to solve the problems of decline in crop productivity through control of erosion and maintenance of soil fertility. Trees in agroforestry have a direct impact upon other system components through positive and negative biophysical interactions with soil (Nair, 1984; Young, 1989), crops (Chirwa et al., 2006), water (Nair, 1993) and livestock. They have an indirect effect as substitutes for purchased inputs or through individual and collective decisions on the allocation of land, labor, capital or other resources among different system components at farm level and landscape levels (Franzel et al., 2001).

To involve a particular tree/shrub as component of farming system in agroforestry development packages, it is very important to understand the characteristics of each individual tree/ or shrub. *F. thonningii* is a species which has been least considered in agroforestry development practices in most parts of the country although its propagation methods are easier for farmers. And yet, there is no sufficient information on the impact of this species on soil properties underneath and outside its canopy.

Therefore the objectives of this study are:

1. To assess the knowledge of the local people in the communities about the values of *F. thonningii*
2. To identify the constraints and problems that confront farmers in tapping the full potential of *F. thonningii* and to identify the conditions and local practices that favour the practice of agroforestry systems associated with the species in question.
3. To evaluate soil biophysical and chemical properties under and around the canopy of *F. thonningii* to find indications for its influence on soil fertility and agricultural productivity
4. To investigate the foliage nutritive value by determining the content of major mineral nutrients in the leaves (e.g. N, P, K, Ca and Na) of *F. thonningii* as quality indicators for use in livestock feed and productivity.

1.2 Limitations of the study

Only three villages were used to represent the district. It is unlikely to have all the characteristics of one district with three villages' survey to fully address all the variations in attitude and opinion of the farmers in the district. Since the time was also peak season it was not possible to undertake focus group discussions and a former focus group assessment made by ILDP is used to cross check the findings from this individual household survey. This study has shortcomings to undertake further biophysical study on farm lands due to lack of isolated trees with open distance twice crown radius on farm lands since trees around homesteads were grown in association with other trees and shrubs. The study time is only limited to the wettest season of the country and no comparisons were made regarding the effects of *F. thonningii* on soil moisture status beneath its crown.

2. LITERATURE REVIEW

2.1 Deforestation in Ethiopia

Ethiopia's forest has been said to account 42 million hectares, covering about 35 percent of the country's total area in 1900s and 16% in the beginning of 1950s. However, due to inappropriate land use and population growth followed by massive removal of forests from all types landscapes for commercial logging, agriculture and fuelwood (CEDP, 1999) the forests declined both in area and quality. The country stood fourth in using as large as 93,029000 m^3 wood for fuelwood next to Brazil 136,637000 m^3, China 191,044000m^3 and India 30383900 m^3 (FAOSTAT, 2004). The country is also the third biggest charcoal producer (3,221000 tons) next to Brazil (12,896000 tons) and Nigeria (3,421000 tons). According to the report by FAO (2002), the total forest area stood at only 4.593 million hectares in 2000. Out of this, the natural forests constitute 4,377000 ha and plantations 216,000 ha. The change in area cover for the natural forest during 1990-2000 was -9% and 1% for plantations. The net change in forest area during these periods has been -8%. Thus, the original forest cover has been dwindled down to 4% within 100 years time. The rate of deforestation in the country has been reported to be in the range of 160,000 to 200,000 ha/yr (EFAP, 1994).

2.2 Overgrazing

Nationally, livestock population is the largest in Africa (78 million cattle, 11.5 million sheep, 9.6 million goats, 3.9 million equines, 0.25 million camels and 25.8 million poultry), however, it is characterized by low productivity. About 27.9 percent of Ethiopia's livestock is found in Amhara region (Hawando, 1999 and USAID, 2000).

Figure 2.1: Livestock and overgrazing

Free grazing is a major problem in the country in general and in the region in particular (Fig.2.1). In the country livestock are kept free to graze in all land use types regardless of their suitability, feed availability and whatever side-effects are produced. Animals graze or browse in the field all the day until dusk. They are kept on crop residues after harvest, in grass lands, in communal forestlands, in rangelands and riverine forests, destroying the vegetation cover by overgrazing, browsing and trampling. They also compact the soils of these land use units thereby causing less infiltration of water into the soil, thus increasing the reaction runoff water to cause erosion. The amount of nitrogen, phosphorus and potassium in the livestock manure produced annually in Ethiopia has been estimated to be 1.4 million tons in terms of N, P_2O5 and K_2O (Hawando, 1995).

2.3 Inappropriate farming practices

Farmers in the highlands lost their tradition of rotational cropping systems due to shortage of land for cultivation. They used to grow one type of crop year after year. There is no integration of perennials with annual crops. Due to lack of suitable lands for agriculture, steep and rugged terrains are also brought under cultivation. Ploughing fields up and down slope is also another problem in these highlands, Both physical and biological soil conservation measures are not well adopted and practiced by the farmers to the level required.

2.4 Consequences of environmental degradation in Ethiopia

2.4.1 Soil erosion

The Ethiopian highland reclamation studies (EHRS) revealed that the highlands which cover 44% of the country's total land area are seriously threatened by physical and biological degradation. About 27 million ha, approximately 50% of the highlands are found in Amhara region. The Amhara region is known for its rugged topography, high relief and steepness which have resulted into many agro-ecologic zones, of which 56.22% are cultivated. Amongst them 24% are moderately to intensively cultivated land on slopes between 25%-50% and 20% moderately and intensively cultivated land on slopes greater than 50%. And 50 % of the highlands in the region experienced severe soil erosion (FAO, 1986). The region accounts 58% (42% of the loss from Gondar, Wollo, Gojjam, Shewa and Waghmra) of the nation's total soil loss (ARCS, 1997).

Soil erosion is a factor of land cover and erosive factors. The land cover (land use type) beside others determines the erodibility of soils by erosive forces. The region is mountainous with soils rendering to erosive factors when exposed to water and wind. A soil conservation research projects (EPA, 2003, and Hurni, 1988 cited in Berhe, 2004) has estimated an average soil loss of 42 t/ha/yr on cultivated lands and a maximum of 300-400 t/ha/yr on highly erodible and intensively cultivated cereal fields (NCS, 1992, cited in Hawando, 1995). An estimate three decades ago shows that about half of arable lands in the highlands have been eroded from moderate to serious levels (Constable, 1985). The yield decline, food insecurity, increased susceptibility to drought, and household economic decline are partly linked to the ongoing severe degradation.

2.4.2 Nutrient depletion

Nutrient depletion takes a variety of forms. Nutrients are lost through harvested products in the form of grain and crop residue (often called nutrient mining) and runoff erosion jeopardizing the productivity of agricultural lands. The study carried out by Stoorvogel and Smaling, 1990 (cited in Smaling et al., 1997) shows that among the 38 countries under the study, Ethiopia's nutrient depletion was observed to be the highest. The amounts for the major nutrients were equivalent to 40 kg N /ha/yr, 6.6 kg P /ha/yr and 33.2 kg K /ha/yr. Onsite depletion of nutrients (NPK) has been estimated to cost reduction of 5-11% GDP (Drechsel and Gyiele, 2001).

A report by FAO (1984) indicated a removal of 7.8 million tons of soil per year by erosion from 780000 km^2 of land in the country. This removal of soils has resulted in the loss of 15.6 million tons organic matter, 2.16 million tons nitrogen and 5.85 million tons of phosphorus from 7.8 million hectare of cultivated, rangelands and grazing lands. On the other hand, grazing and consumption of crop residue by livestock cause a loss of over three million tons of N, P and K (NCS, 1992 and FAO, 1984 cited in Hawando, 1995). Considerable amounts of nutrients are also lost through use of dung and crop residue as fuel by the poor people, who also collect manure from common grazing lands for their household consumption and for markets leading to severe nutrient depletion in the grazing areas.

2.4.3 Shortage of forest products

Nowadays, the region is facing acute wood shortages that originate from the deforestation activities prevailed in the last centuries. As the population grows where the majority is engaged in agriculture, the question of shortage of land becomes so obvious and competition among the different landuses becomes more and more evident. In Ethiopia (Soussan, 1988), fuelwood accounts for more than 75% of the energy used and cost of acquiring it is increasing due to limited supplies. It's collection is also physically hard and time consuming work and arduous burden for woman who typically are also responsible for collecting water, caring for children, doing agricultural work and handling a myriads of other tasks that make up the day of a third world woman (CEDEP, 1999). The demand-supply gap for fuelwood alone on sustainable basis during 1999 has been 71% (equivalent to -10560217 m^3) and it has been estimated to grow to 27.9 million m^3 by the year 2020. Additional studies in the energy sector by the World Bank (1984) and Cesen (1986) reported that 99% of the energy used in Ethiopian homes comes from biomass sources that include dung, crop residues, and woody biomass. The amount of biomass fuel used for household consumption has been estimated to be 94.7% (Wolde-Giorgis, 2001).

2.4.4 Shortage of animal feed

Though Ethiopia is a country of large animal population, the benefits from these animals are constrained by shortage and lack of nutritious feed resulting from the depletion of nutrients from the pasture and /or rangelands. Crop residue is the second most important source of feed putting higher pressure on farmlands. The study by World Bank (1984) and Cesen (1986) estimated that out of the 22.5 million tons of cattle manure annually produced, 38% used as a fuel. Out of the 21.2 million tons of crop residues produced annually, 24% used as a fuel. The remaining 76% of crop residue is left on the ground and/ or consumed by livestock depending on the type of crop and its palatability.

Figure 2.2: Crop residue on sale

2.5 Harnessing environmental degradation

In response to the existing problems in Ethiopia, mechanical soil and water conservation and afforestation schemes were undertaken. It was reported that about 998,000 ha of farmlands and 208,000 ha of hillsides were terraced, 15,500 km check dams were constructed on gullies, 296,000 ha of land were afforested on denuded areas, 310,000 ha closed for regeneration of vegetation, etc (EFAP, 1994). In these activities, the contributions of integrating biological/agronomic measures with mechanical conservation measures were not given much attention.

These separate practices of afforestation and mechanical soil conservation were not successful because of the socioeconomic problems especially land scarcity and property ownership rights leading to fear and lack of acceptance on the side of land users. The method of environmental rehabilitation that time did not realize the existing problems and therefore, the farmers destructed the conservation measures after construction. For successful adoption and sustainability reasons, the measures should base on a system of integrating the various interests and maximizing both ecological aspects of the system and socioeconomic benefits for the land user. This can be gained through agroforestry system which is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, either on the form of spatial arrangement or temporal sequence Lundgren and Raintree, 1983 (cited by Nair, 1984).

2.6 Agroforestry and its contributions in forest restoration and crop productivity

However, Ethiopia possesses a diversity of tree and shrub species, the contribution of these species to the country's agriculture was not at the level required. Some of the contributions of trees in agroforestry to the agro-ecosystems and the land user can be described in the followings.

2.6.1 Maintenance of soil fertility

A fertile land is a necessity for producing food and raw materials for household consumption and markets. In most crop and pasturelands, the nutrient flow and transfer are mostly manipulated in an unsustainable way by human interference resulting in nutrient imbalance in both land use systems.

Trees contribute to fertility maintenance of the soils by nutrient additions from litter, nutrient uptake from the subsoil and atmospheric input into the soil. Agroforestry systems improve soil fertility in various ways. The system usually combines more than one species and the trees are intensively managed for the products (timber and non-timber) in which some of the pruning during management and litter fall are returned into the soil. Trees also increase the organic matter through the turnover of decaying fine roots, which is an important source of nutrients.

According to research by Kho et al. (2001), in N'Dounga, Niger, *Faidherbia albida* improved soil physical and chemical properties through improving microclimate of the system and increasing nutrient availability. In this study, the soil away from the base of the trees at 0-15 cm depth had 49 kg N ha^{-1} and 34 kg P ha^{-1}while under the tree it increased to 155 kg N ha^{-1} and 44 kg P ha^{-1}. The effect is 2.16 for N and 0.29 times greater for soil phosphorus. Hence, the productivity of millet was increased by 26% due to N input and 13% due to P additions resulting from the intercropping with *F.albida*.

Similar study by Sierra et al., (2002) and Chirwa et al. (2006) showed better nutrients under *Gliricidia sepium* than in the open grass with a C: N ratio as little as 11 and total N input 176±35 kg/ha/yr and total C input 191±03 Mg/ha/yr.

In a research carried out to understand the contribution of trees to soil fertility by studying the under canopy soil of the isolated *Cordia africana* (Del.) and *Croton macrostachys* (Lam.) trees investigated promising results. The available P under these trees canopies in the 0-15 cm soil depth was 34-50% higher than the corresponding soil away from canopies while the N content of the soil in this depth was 22-26% higher than the corresponding soils away from tree canopies. The available soil N content in the 15-30 cm soil depth was improved by 12-17%.Trees of both species increased underneath exchangeable K in the 0-15 cm and 15-30 cm soil depth by 18-46% compared with the corresponding controls (Gindaba et.al, 2005). Similar studies also found that leguminous trees or shrubs of genera *Sesbania, Tephrosia, Crotalaria, Gliricidia, and Cajanus* which have the capacity to fix atmospheric nitrogen added between 100 and 200 kg N/ ha/y in the sub humid tropical regions of East and Southern Africa (Place et al.,2002 cited in Rao et al., 2007).

The litter from *F. thonningii* was reported to undergo slow decomposition due to its high and more sclerophyllous input of leaves (rigid and thick cuticle) Haile et al. (2001). This property of leaves is mainly in response to the growth conditions and this may be the trees are growing in dry areas in addition to the natural content of the leaves. However, no studies were made to investigate the lateral and vertical influences of this species on soil nutrients. And yet, there are no clues regarding whether *F. thonningii* should be used or not in agroforestry development for fertility maintenance.

Trees also protect the soil from erosion, and reduce the rate of organic matter decomposition (Young, 1989). They also capture mineral nutrients from deeper soil layers through physical and chemical weathering and recycle to the topsoil. Tree and shrub root also reduce top soil acidity through retrieving leached cations (Huxley, 1999). This helps the associated crops to benefit from the integration with trees.

Trees in agroforestry systems can play a significant role in the adaptation of the crop plants to climate change including changes in the microclimate, protection through permanent cover/shelter, efficient use of water and climatic resources (solar radiation), reducing carbon emissions and increasing sequestration (Rao et al., 2007). Trees on farms bring about favourable changes in the microclimatic conditions by influencing radiation flux, air temperature, wind speed, saturation deficit of understorey crops all of which will have a significant impact on modifying the rate and duration of photosynthesis and subsequent plant growth, transpiration, and water use efficiency (Monteith et al., 1991 and Chirwa et al., 2006). They may also improve soil biological activity and nitrogen mineralization through their shade, protection from erosion, nitrogen fixation and improve soil fertility through the decomposition of biomass from tree root systems. These benefit can be exemplified by shade trees protecting heat sensitive crops like coffee, cacao, ginger, and cardamom from temperatures, wind breaks and shelter belts to slow down the wind speed to reduce evaporation and physical damage to crops, mulches to reduce soil temperature and various crop tree mixes to reduce erosion and maximize resource use efficiency (Rao et al., 2007).

In a study which was carried out to determine whether agroforestry (sivopasturalism) might be introduced more successfully into xeric (450mm annual rainfall) or mesic environments (750mm annual rainfall) in semiarid Kenya, an investigation was made on mature trees of isolated *Acacia tortilis* and *Adansonia digitata* in a moderately mesic savanna. The results showed reduction of solar radiation by 45-65% and soil temperature by 5-12°C under both tree species (Belsky et al., 1993). In similar study carried out by (Vandenbeldt and Williams 1992 cited by Rao et al., 2007) a decrease of temperature (5-10°C) was observed under *Faidherbia albida* tree canopies as compared to open areas influenced by the effect of tree shades.

Additional study carried out in Northern Lake Kivu region, Rwanda to observe tree shade and coffee interactions (Boffa et al., 2007), shade trees (with crown diameter of 7-21 m) consisting of 70% of *F. thonningii*, *Persia americana* and Papaw in association with other shade trees on coffee plantation induced high productivities of coffee berries. In this research the volume and yield was significantly higher in the shade than in the open land. There was higher positive correlation between the crown size and the yield with higher yields under large crown trees which might probably be associated with the nutrient accumulation underneath older tree crowns and microclimate changes. Increasing crop productivity of 30%-200% higher under *F. albida* canopies than in open fields were also found (Rhoades, 1995). *Sesbania sesban* has also increased crop productivity in fallow systems (Phiri et al., 2003). Increased herbaceous-layer productivity associated with the lower soil temperatures and greater soil fertility was investigated under canopy of *A. tortilis and A. digitata* trees in a semi-arid savanna in Tsavo National Park, Kenya (Belsky et al., 1989).

2.6.2 Carbon sequestration

Currently, energy and the use rate of fossil fuels and forest resources are the world's hot environmental issues (Unruh et al., 1993). The requirement for higher energy has led to severe world deforestation and Ethiopia became one of those countries which have lost their forest resource within 100 years time. Thus, use of fossil fuels and deforestation increased atmospheric CO_2 concentration leading to spatiotemporal climate changes in the world and Ethiopia is one region where climatic changes may be evidenced through recurrent droughts. The global CO_2 emission associated with deforestation of 17 million ha/yr is 1.6 Pg[1]/y (Rao et al., 2007 and Unruh et al., 1993).

The problem of deforestation stems from the fact of shrinking land resources for agricultural and pasture use, due to loss of fertility and of overutilization. Inconsequence to the ever-increasing demand for food, most suitable lands have already been brought to crop and livestock production and land is now a scarce resource to be put under reforestation to harvest atmospheric carbon. Systems that reduce conflicts between interests for crop, pasture and forests and/or environment should be maintained through practices with positive cumulative effects. Crops and pasture occupy the largest and most suitable areas leading to shortages for reforestation. Hence, integrating trees with crops and or pasture will help to sequester carbon dioxide and would be a priority.

The role played by trees and shrubs in agroforestry systems is by acting as a sink for atmospheric carbon dioxide. Trees in the system productively sequester carbon from the atmosphere and keep up carbon pools in live biomass through conservation of existing carbon pools (Rao et al., 2007 and Unruh et al., 1993). An indirect effect may be through the offsetting of immediate greenhouse gas emissions. In addition to offsetting emissions, trees in agroforestry may have also significant contributions to substitute the use of fossil fuel by biofuel and bioenergy (Montagnini and Nair, 2004 and Unruh, 1993). Carbon

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[1] **Pg = petagram (10^{15} grams) which is equivalent to 1 x 10^{9} metric tons (1 metric ton=10^{6}grams or 1000 kilograms)**

stocks for smallholder agroforestry systems in the tropics indicated C sequestration rates ranging from 1.5-3.5 Mg/ha/y of C (Watson et al. 2000 cited by Montagnini and Nair, 2004).

2.6.3 Source of animal fodder

Livestock contributes to the livelihoods of 60-70% of the Ethiopian population. In addition to its contributions as source of food, income and employment, draught power, manure and transport, livestock also serve as a productive asset that allows households to be self-sufficient. It may also be a guarantee against crop production failure and as symbol of status for some households to advance to relative wealth by the standards of contemporary Ethiopia (Taddesse et al. 2002).

However, animal productivity is limited by poor nutrition and growth rates resulting from the low protein and high fiber content of many of the native grasses and crop residues. This condition put the focus on leguminous trees and shrubs, by being nitrogen-fixers and thus having high protein contents. Thus, they could be vital fodder plants for the improvement of productivity and should be introduced into the farming system (CGIAR, 2002 and Nair, 1985). The feeding of *Calliandra calothyrsus* increased the milk productivity and thus household income in Kenya (CGIAR, 2002).

The feeding value of low quality agricultural residues and tropical grasses can be greatly improved by mixing foliage from leguminous trees and shrubs , which can be grown integrated directly to pastures, in fences and in the so called "protein banks". In mixed farming areas, the tree-strata concept significantly raises the overall photosynthetic capacity of the agricultural system by enlarging the leaf-area index and favouring nutrient enrichment and recycling. In some cases, pure stands of forage shrubs and trees can be the best option to intensify animal production replacing traditional low performing grass-based systems (Leng, 1997).

There are many species and varieties available for farm use with a wide range of ecological adaptation. However, no single species delivers all stated benefits, and there is no single species suited to the entire range of conditions. Therefore, we must be realistic in our goals when selecting forage trees for farming systems. Choice of species will depend on the specific requirements of the farming system in which they are to be grown.

A comparative assessment carried out on *F.thonningii* and *Mangifera indica* in Nigeria by feeding rabbit with an initial weight of 700g for 42 days Jokthan et al. (2003) has shown promising results. In this study, the total weight gain after the feeding was 320g in *F. thonningii and 120*g in *M. indica* leaves. The intake of *F. thonningii* leaves was reported significantly (P>0.01) higher than that of *M. indica* leaves. *F. thonningii* has dry matter content of 54.32% (40.61% in Tegbe et al., 2006) crude protein18.50% (18.51% in Tegbe et al. 2006), crude fibre16.22% (19.41% in Tegbe et al., 2006), nitrogen free extract 42.44%, ether extract 5.54% (5.57% in Tegbe et al., 2006) and ash 17.34% (10.87% in Tegbe et al., 2006) showing some variations in the results obtained by the two studies. Accordingly, rabbit fed *F. thonningii* leaves had significantly (P>0.01) higher average daily weight gain and feed/gain efficiency and both of these species have feeding value as fodder for rabbits making survival possible to them during critical periods in the dry seasons. In these studies important mineral nutrients components in animal feed, like sodium, calcium and phosphorus were not investigated.

2.6.4 Medicinal uses of *F. thonningii*

The fruit of *F.thonningii* is edible and can be used in alcohol production (Watt and Breyer, 1962 cited by Ndukwe et al., 2007). The leaves are commonly used as food by local people (Danthu et al., 2002). According to the study carried out in South and Eastern Africa (Watt and Breyer, 1962), *F. thonningii* can be used in therapeutic preparations. It contains carbohydrates, flavornoids, tannins, glycosides, saponins and alkaloids. These metabolites present in various parts of the tree are known to have varied pharmacological actions in man and animals. The stem bark is used to treat colds, sore throat, diarrhea, wounds and to stimulate lactation; the latex is used for traditional medicines, leaves to treat malaria and yellow fever (Danthu et al., 2002). It has other sacred ceremonial purposes. The powdered bark is used on wounds and a decoction of the bark is used for cough and throat infections in West Africa (Watt and Breyer, 1962 cited by Ndukwe et al., 2007). In Tanzania the bark is used as an influenza remedy and the stem bark and root bark for stimulating lactation. The bark is also used in Tanzania and Belgian Congo (The Democratic Republic of the Congo) for making bark-cloth (Brenan and Greenway, 1949 cited by Ndukwe et al., 2007).

In similar studies, antimicrobial screening of the crude petroleum spirit and methanol extracts showed activity against *Klebsiella pneumoniae, Staphylococcus aureus, Escherichia coli, Providencia stauti* and *Bacillus subtilis (*Ndukwe et al., 2007*)*. The methanol extracts of the root, leaves and the stem bark are highly favoured in this regard and have proved to be more efficacious as is seen in this *in* vitro studies. These results agree with the claims by the ethno medicinal practitioners that the plant parts can be used in the treatment of colds, sore throats, diarrhea and wounds. From the result of the antimicrobial screening the crude petroleum spirit and methanol extracts of the leaves of the plant are active on *S.aureus* and *P.stauti* respectively. It is only the crude methanol extract of the stem bark that was active on *E.coli.* The crude petroleum spirit extract of the root was not active on any of the organisms tested the crude methanol extract of the root was active on *K. pneumo niae, S. aureus, P. stauti and B. subtilis.*

2.7 Agroforestry development in the country

Traditional agroforestry is not a new practice for Ethiopia. It is an age-old agricultural practice evolved with the domestication of plants and animals in the past, however, it is very much restricted to homesteads and some parklands in North and Central highlands of the country. Wood produced from the formerly established agroforests is mainly sold to the nearby towns to generate income for the family. Despite its importance, the farmers are not curious enough to replant the trees they cut. Presently, the large majority of farmlands are crop dominated and devoid of trees and or shrubs. In order to reduce the impacts of these interwoven environmental and socio-economic problems associated with deforestation, the Amhara region includes different agroforestry practices in the annual plans and follows the achievements. The plan focuses on diversification and intensification of farming systems through the integration of indigenous and exotic tree and shrub species such as *Sesbania sesban, Leucaena leucocephala, Grevillea robusta, Cordia africana, Croton macrostachyus, Moringa oleifera, Moringa stenopetala, Prunus perisca, Mangifera indica, Millettia ferrugenia, Persia americana, Psidium guajava* etc. Currently, ILDP through the support of Austrian development co-operation (ADC), is aggressively including *F. thonningii* in the farming system to improve livestock production and reduce the impact of dry season animal feed shortages in North Gondar Province.

2.8 Tree selection for agroforestry

Trees for agroforestry may be selected based on a variety of evaluation criteria. The capacity and ability of the tree to regenerate when grazed or harvested, the feeding behavior of animals when confronted with tree foliage/forages and the voluntary intake of tree foliage under different environmental conditions are important to evaluate the species to involve it based on its values for fodder. The potential to become weeds, the ease of seedling establishment, the growth pattern of tree/ shrub in relation to crops or pasture, the required soil properties like pH characteristics, nutrient status, the nutritive value of the foliage, the change with harvesting, grazing or cultivation (Leng, 1997) are among the most important considerations. The trees′ ability to establish under the existing environmental conditions (fast growing species usually selected over the slower ones), absence of parasitism and severe competition, environmental services and the need for its products are among the most important considerations to be seen during tree selection for any purpose (Young,1984). Regarding the qualities, tree for industrial wood production may be evaluated based on its height, diameter, taper, branch dimensions, forking and wood density while a tree for animal fodder evaluated based on its fodder yield and quality.

While designing agroforestry in areas where land is a limiting resource, it is very important to select trees, which provide more than one purpose (multipurpose). Multipurpose trees/or shrubs are woody perennials (trees, shrubs, woody wines, palms, bamboos) which provide more than one significant contribution to the production and/or service functions of the land use systems they occupy (Huxley, 1984).

Trees in agroforestry systems will increase productivity by minimizing competitions with the associated crops through using underutilized water and nutrients pumping from deeper soil horizons and off-season rainfall (Ong, 2000) and releasing nutrients via litter fall and decaying roots. For example, *Calliandra calothyrsus* is a multipurpose, nitrogen fixing, deep-rooted tree that can grow on degraded sites. It produces abundant litter with rapid decay (Young, 1989). On the other hand, a species introduced without study (*Prosopis juliflora*) may lead to deleterious effects on the existing biodiversity and ecosystem productivity. It may compete with other life support species for space and nutrient, harbor disease and insect, may have destructive effect on the endemic local ecosystem (HDRA, 2005).

2.9 *Ficus thonningii* in agroforestry

Belonging to the Moraceae family, *F. thonningii* is one of the 750 species in the pan tropical genus *Ficus*. It is pollinated by obligate mutualism wasps called *Alfonsiella longiscapa, and Elisabethilla suckenberg* which hosts a nematode called *Schistonchus africanus (*Berg and Wiebes, 1992 cited by Vovlas et al., 1998*)*.

It grows in areas with altitudes ranging from 1000-2500 m a.s.l. in mixed evergreen and deciduous open woodland and mesophyllic deciduous open woodland in association with *Ficus salicifolia* and *Ficus sycomorus.*It is well distributed in areas with precipitation between 500 and 800 mm (Eckman and Hines, 1993). It is widely distributed in upland forests, open grasslands, rivers and rocky areas. It is found in the savannahs. *F. thonningii* occurs on a variety of soils but prefers light, drier and well drained soils with neutral to acid reaction. It is propagated by cutting and seed dispersal by birds and animals. It is used as a live fence with the intention of using the leaves as mulch or green manure, and also for producing shade or fodder. It has the ability to store water and conserve soil *(*Ndukwe et al., 2007).

Although biodiversity in agro-systems is one of the cornerstones of sustainability, little is known about the colonizing organisms of the species introduced into the system (Mapongmetsem, 2002). *F. thonningii,* among the other Moraceae and Rubiaceae, is considered to be epiphytic to other trees and shrubs The base and lower trunk parts are the main niches for *F. thonningii* establishment. It has been reported as a hemiepiphytic plant that disperses more horizontally with its 1cm diameter fruit and restricted to the first branches of the host plant (Nieder et al., 2001)

Based on technology specifications and species characteristics with relevance to agroforestry, *F. thonningii* can be grown in alley cropping due to its less compact (less thick crowns) in the same way as *Albizia gummifera, Celtis africana, and Terminalia brownii* (Oduol and Akunda, 1987). It can be grown dispersed on cropland, rangeland, or improved pastures, in mixed cropping, boundaries, as soil conservation measure and as live fences to provide shade creating conducive microclimatic conditions for the undergrowth. However, there are no studies conducted on its influence on the physical and chemical soil properties under its canopy.

3. SOCIOECONOMIC SURVEY

3.1 MATERIALS AND METHODS

Setting priorities among tree species for use in development, involves an integration of researchers and farmers perspectives for choosing those species that will give the greatest benefits. The process requires both socioeconomic and biophysical expertise and begins with an assessment of users' views that is "resource-poor farmers" needs (Franzel et al., 2001). Based on this fact, this research methodology contains two components, the socioeconomic survey and the biophysical data collection. Thus, the study results and discussion chapters possess two parts.

3.1.1 The study area

This study was carried out in Gondar Zuria district, Tsion, Das Dinzaz, Degola and Bahriginb, villages in the Amhara Region of Ethiopia during July-September 2007. The district is located at $37^0$24'24E-$37^0$45'43E and $12^0$7'23N-$12^0$39'24N and its total area is 1286.76 km^2. Being part of the Semien Gondar Zone, Gondar Zuria district is bordered on the south by the Debub Gondar Zone, on the southwest by Lake Tana, to the west by Dembiya, to the north by Lay Armachiho, to the northeast by Wegera, and to the southeast by Belessa. Towns and cities in Gondar Zuria district include Degoma, Emfraz, Maksegnit and Teda. The city and district of Gondar surround this district in the northern part (CSA, 2005).

The district has an estimated total population of 264,920 (of whom 130,796 were males and 134,124 were females). About 10.24% of its population is urban dweller, which is less than the Zone average of 14.1%. The rural area constitutes 40,551 households. With an estimated area of 1,286.76 square kilometers, Gondar Zuria has an estimated population density of 205.9 people per square kilometer as compared to the Zone average of 60.23 (CSA, 2005).

Agro ecology

Gondar Zuria district (Woreda) is located at 1107-3022 m a.s.l, and falls in to three agro-ecological zones. The two agro-ecology zones, Weynadega (1500-2300 m a.s.l) and Dega (2300-3200 m a.s.l.) constitute the largest area coverage as compared to the Kolla that falls in the range of 500-1500 m a.s.l In the district, temperature ranges between 14-20°C with the mean annual temperature of 17.9°C. Rainfall ranges between 1030-1223 mm with mean the annual of 1100 mm. Crops cover 56.5% the area, pasture 14.7%, forests and shrubs 10%, settlements 5.3% and the rest 13.5% is a miscellaneous land (GZOARD, 2007). The soils of the district are Litic Luvisols (49%), Humic Nitosols (10%), Haplic Luvisols (12%), Eutric Vertisols (16%) and Chromic Luvisols (13%) (FAO, 2004).

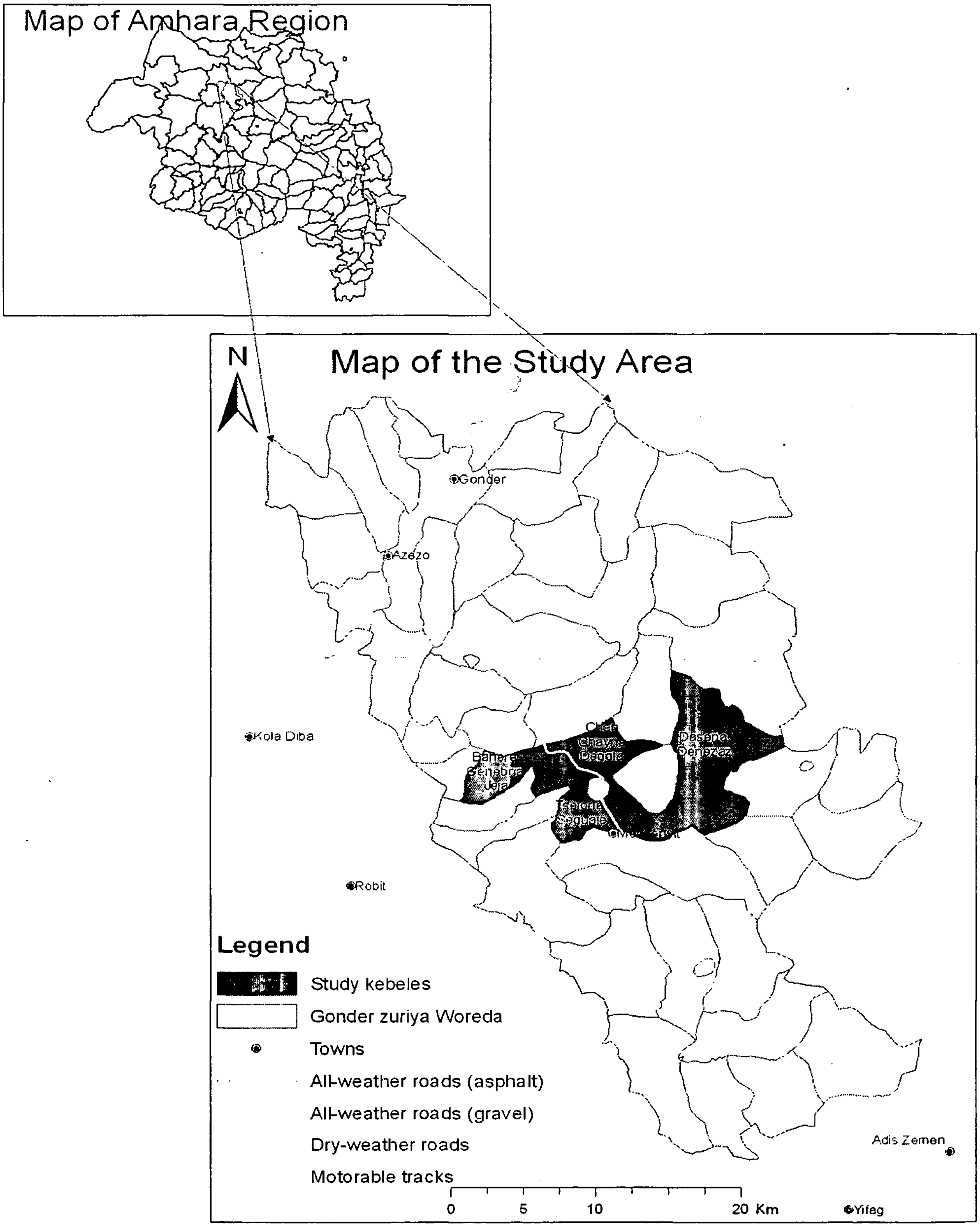

Figure 3.1 Map of the study area

3.1.2 Data collection and analysis

Reconnaissance survey was conducted to observe agricultural practices on farms. This visit gave an insight on the agroforestry systems and the traditional practices involving the use of *Ficus thonningii* as farming component. Additional information was collected informally by asking some farmers on management, propagation, side effects and constraints of using this species in association with crops and pastures/animals.

Following a reconnaissance survey of the district, 3 villages (Tsion, Das Dinzaz and Degola) were selected by consulting the deputy office head of the district. From each village 15 households were selected based on their experience and the abundance of *F. thonningii* in the agricultural landscape. The households surveyed were selected randomly from the long list of the farmers who has planted *F. thonningii* with the help of the extension workers (development agents). Out of the 45 households, thirty-nine households were those who have planted the species and six who have not planted. The household heads are the major decision makers and have influence in both production and management of the local plant and animal resources in the area. Six of the households visited were female headed. The number of households that were selected was to provide sufficient information about the socio-economic characteristics of the people and their awareness of the local situations and the management of *F. thonningii* in the area. Cross-sectional method was used, whereby data were collected only at one point in time from selected sample villages and respondents to represent the population of these villages (Kajembe, 1994).

The questionnaire used to collect the data from the individual households was designed to gather the type of information needed and to address the specific objectives of the study. The questionnaire included, identification of variables on demographic characteristics of the household, identification of land uses, economic activities, status of their holdings in relation to productivity and erosion as well as tree planting practices in the local communities. The questionnaire contained open and closed-ended questions. Open-ended questions served the purpose of disclosing the system of knowledge and structuring of ideas central to respondent's own view of the researched problem. While in closed or forced questions, yes or no answers had to be given (See appendix A).

Apart from the above methods to collect primary data, secondary data were collected from relevant organizations such as the district office of agriculture and rural development and the regional bureau of agriculture and rural development. Besides information from similar research works was collected. These Secondary data were used to supplement, and in some cases to compare with the primary data collected from the field.

Primary data collected from the respondents were according to the requirements of the Statistical Package for the Social Scientist (SPSS). The data were then analyzed and presented in tables and graphs. Chi-square tests were used at a significance level of 0.05 for all the analysis.

3.2 RESULTS

3.2.1. Socioeconomic situation of the study area

The minimum family size of the study area is 2 whereas, the maximum is 13 and the average family size is 6.7. The size of landholding varies between 0.25 and 3 ha with the average holding 1.89ha. There is significant positive correlation (p=0.01) between family size and farm size. About 64.4% of the households claimed shortage of farmland, 53.3% recognized the decrease in the fertility of their holding and 97.8% of them recognized the existence of soil erosion in their farmlands. According to this survey, the existing land tenure system has seems to have a minor influence on tree planting. Only 31.11% of the respondents claimed the negative influences of the existing land tenure towards tree planting. However; these respondents themselves have planted *F. thonningii* on their plots. With respect to the system of planting, 84.6% of the farmers would like to plant it in home gardens, and 42% to plant it on boundaries and 2.2% in pasturelands. Their source of the planting material is dominantly from private plots (93.33%) by either exchange or buying and the rest being from communal pasture or from churches compounds(see appendix B).

3.2.2 Crop productivity

The trees form a dense root net up to greater than 1m (Fig. 3.2) from their trunk which may reduce the area for crop growing. Crop productivity in the vicinity of *F. thonningii* was observed to be decreased as recognized by 20% the farmers. On the other hand an increase in productivity resulting from organic matter additions was justified by 62.22% of the farmers and the rest were indifferent about the effects it might have caused. In a maize field, we observed that the crops near the trees were growing better and green as compared to the crops away from the trees which showed stunted growth and yellowish color.

3.2.3 Livestock production and feed availability

In the study area, the main sources of feed for the livestock are free grazing on communal pasture, crop residues and browse from trees and shrubs. Only 48.89% of the farmers perceived the problem of shortages. Shortages occur from April to June with peak often occurring during the months of April and May and less frequently occur in March, July and August. About 68% of the respondents use hay in addition to the above sources. The large majority (84.44%) of the respondents uses *F. thonningii* for animal fodder. Feeding intensity varies depending up on the availability of the resource and the type of animals they own. However, the survey result shows that 91.11% feed to cattle, 46.67% to equines and 71.11% feed to it sheep and goats in addition to cattle. About 88.64% of the respondents recognized the loss of many browse species in their locality, which contributes to the problem of animal supplementary feed.

Feeding *F. thonningii* has shown an increase in milk productivity as indicated by 53.33% of the interviewed persons, 40% rated it indifferently while absence of changes in milk production was indicated by 6.67%. Of the 45 respondents, 46.67% had observation of increase in biomass of livestock and improved physical appearance of animals. From the total respondents 86.67% prepare leaves in the mornings so that leaves can wilt all the day and feed them in the evenings while 73.3% feed also fresh leaves to their livestock. About 77.3% of the respondents confirmed the absence of problems related to the feeding of *F. thonningii* to livestock while 20.45 % indicate presence of some problems associated with feeding fresh leaves mainly because the process of ingestion by cattle is impaired. Only 6.82% have been using the species for medicinal purpose for their animals especially after delivery for cows. About 65.91% of the respondents said that the species is being used at the presently possible level. Availability of pasture in the past, beliefs (31.82% confirmed the presence of irrational beliefs, which made people afraid of planting e.g. image of being poor, it pulls the devil, death), lack of sufficient planting material and knowhow are the most important problems for the limited use of the species.

The existence of fuel shortage was reported by 51.11% of the respondents and 86.67% use *F. thonningii* as a source of fuel for their household energy consumption.

3.2.4 Management

In the study area, farmers started to plant *F. thonningii* in their homegardens for shade and wind break since 1986 villagization when they settled in their new environment. The management practice for regulating its impact on the crops underneath and in preparation of animal feed is pollarding/pruning (93.33%). They may cut side branches (pruning) or cut all the branches and the leader (pollarding) to feed their animals during high feed shortage dry periods and/or to prepare for planting season and also to restrict expansion of the tree canopy towards crop land during the cropping season.

3.3 DISCUSSION

3.3.1 Socioeconomic condition

Local people have knowledge about the existing conditions of their environment through experience and traditional experimentations. They know what assistance they need. Missing to understand the local knowledge leads to false generalizations and waste of time and property. Therefore, studying the social and economic situations of an area is important in any development action.

Farmers in the study area depend on the products they reap from a combined activity of agroforestry components. The average family size is 6.7 with the landholding as small as 1.89 ha to support the family and there is a strong correlation between family size and landholding. They depend still on it for their survival even though the fertility of their farm is declining through time and the products thereof are reduced. The land tenure system had a minor influence on tree planting and all the respondents have planted trees including *F. thonningii* on their limited size of farms to produce fuelwood, construction wood and animal fodder for their livestock. Farmers prefer to plant the trees around homes because of better protection against animal damage. The source of planting material for *F. thonningii* mainly comes from private sources either through exchange for fuel or buying.

3.3.2 Crop productivity

Productivity of crops near the tree has increased as most of the farmers experienced, due its addition organic matter. An exception was observed around trees less than one meter from the base of the tree with the interwoven roots on the surface of the soil (Fig. 3.2). In our observation of home gardens, the growth performance of maize stalks near the tree has been better than farther away from the tree. The crops near the trees are green and become yellowish as one goes farther from the trees. This suggests the potential of *F. thonningii* to increase crop productivity (Fig. 3.3). The tree can be used in association with crops and/or pasture considering spatial arrangements that can prevent negative outcomes. The trees can be planted in the boundaries of farms and/ or scattered over the farm. The observation of the field showed better crop growth near the trees. Out planting of the species in pastures is just a start up and needs motivation and resource mobilization.

Figure 3.2:Roots of *F.thonningii*

Figure 3.3: Maize (green) near and (grayish yellow) far from tree

3.3.3 Livestock production and feed availability

Livestock production is important in the faming system of the region and in the district. The need for draught power, source of food and income has made the mixed farming of animals with other agricultural activities inevitable. However, animal husbandry is largely constrained by feed quality and availability due to an imbalance between animal population and pasture size and productivity. The availability of browse to animals, especially in the dry seasons is essential when grass and herbaceous legume forages are scarce. However, the trees and shrubs of feed importance are lost from the landscape due to deforestation activities and the following species are considered to be in danger of extinction, namely *Olea africana, Zizyphus mucronata, Capparis tomentosa, Ficus vasta, Ficus sycomorus, Rhus glutinosa, Premna schimperi, Grewia ferrugenia, Dodonea viscosa, Carissa edulis, Cordia africana, Gardenia volkensii, Stereospermum kunthianum, Piliostigma thonningii, Erythrina brucei, Bersama abyssinica, Acacia albida, Enthada abyssinica, Dombeya torrida, Ficus sur, Ekebergia capensis, Euclea racemosa, Strychnos innocua,* and the like. *F. thonningii* remains green most of the year and provides supplementary protein, vitamins and minerals that are lacking in grassland pastures in the dry season (Tegbe et al., 2006).

F. thonningii is used as fodder (Danthu et al., 2002, Sabiti et al., 1992, and Gautier, 1996) to supplement the dry season feed resources. Its leaves are palatable to animals (Houérou et al., 1983). According to the study by (Azene, 2006), it is the second dominantly used fodder species next to *Cordia africana* by Gondar Zuria district farmers. According to this study in Tsion village, 87.9 % of the farmers use *F. thonningii* as fodder (Azene, 2006). It has high fodder value based on the evaluation for palatability and digestibility (Smith et al., 1992). The observation proved that the leaves of the tree are consumed by all types of animals in the district (Fig. 3.4). Surprisingly, animals eat also immature twigs regardless of availability of leaves with it. Due to its latex content, animals suffer from ingesting fresh leaves of this species and most of the farmers cut leaves in the mornings and leave it in the sun throughout the day to feed them after wilting. Another problem associated with feeding the species is the problem arising from a nematode called *Schistonchus africanus* hosted a wasp; *Elisabethiella stuckenbergi (*Vovlas et al., 1998*)*. This nematode probably causes sickness to animals after it is consumed with leaves and entering into the digestive system of the ruminants.

Figure 3.4: Fodder value of *F. thonningii*

3.3.4 Other contributions of *Ficus thonningii*

F.thonningii is used for local furniture and house utensils. It is also used in small constructions like animal shelter and for fuel wood (Danthu et al., 2002). In the study area, 86.6% of the farmers use *F. thonningii* wood for fuel (see Fig. 3.5). However, *F. thonningii* is among the trees and shrubs with less than 60% fixed carbon (FC[2]) or less than 7000 cal/g of wood used and is classified under the very low energy level group of tree species (Ogur and Ayaya, 1999).

[2] **FC is the major part of charcoal composed of high molecular weight hydrocarbons left after heating with high decomposition temperatures, e.g. at 800°C**

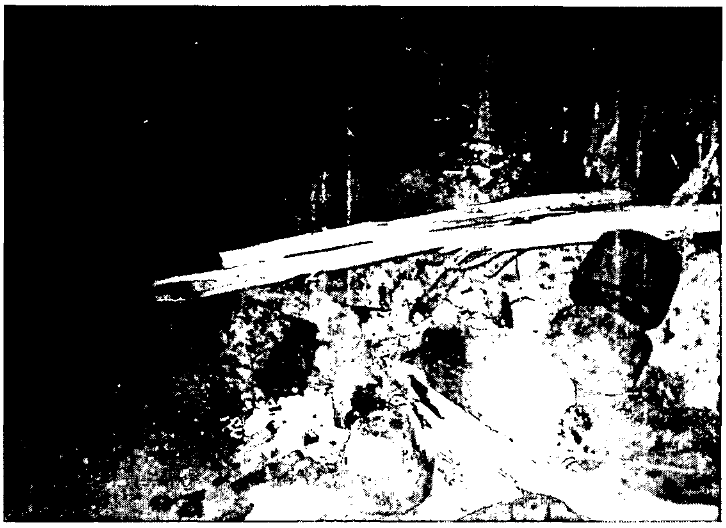

Figure 3.5: Use of *Ficus thonningii* as fuel (in traditional open stove)

The species can contribute to the protection of the environment in the following ways. Firstly, it directly protects from erosion by holding the soil through its interwoven and dense root system and this has been proved in our field study (See Fig. 3.6). It is used to strengthen structural conservation measures as well as a barrier to the erosive forces of runoff water. As a secondary effect the provision of additional feed for animals enables livestock managers to use this chance to stop free grazing by keeping the animals around homes, thus the risk of environmental degradation due to open field grazing and the destruction of conservation structures is reduced.

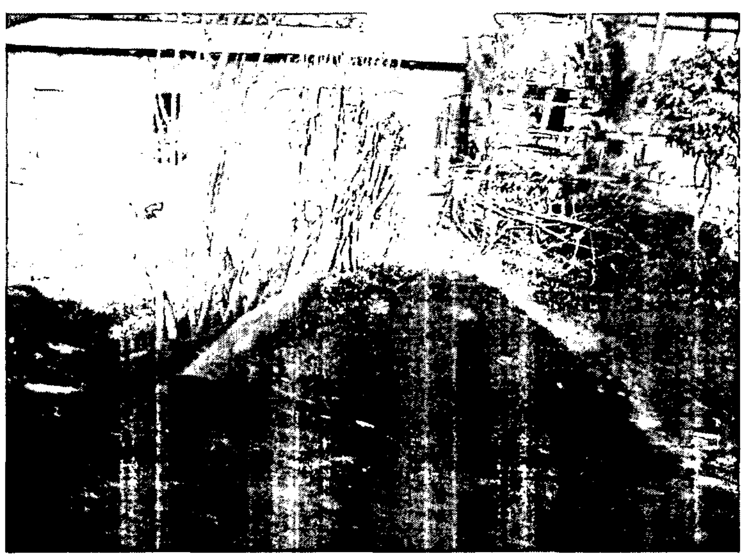

Figure 3.6: *F. thonningii* used as live-check dam for soil Protection

3.3.5 Management of *Ficus thonningii*

F. thonningii is an easy tree for propagation and management in the farms. It can be easily grown vegetatively from cuttings (Sabiti et al. 1992, and Gautier 1996) after the leaves are consumed by livestock. Cuttings can be apical or terminal 10-12 cm long, nodal 10-12 cm long, stem or pole cuttings 1m long and aerial root cuttings made by harvesting 10-12 cm long pieces (Danthu et al., 2002). In their study, stem cuttings performed best in all seasons. Aerial roots and fruits of the species are shown below in (see Fig. 3.7).

Figure 3.7: Aerial roots (left) and fruits (right) of *F. thonningii*

It needs protection against animals at the early stages of growth. Fertilization may improve its establishment. Survival count made in North Gondar by ILDP, 2005 shows 87% survival which is smaller than 94% reported by Sabiti et al.(1992). It tolerates pollarding and pruning. The tree can be used for shade demanding species like coffee in the absence of branch pruning. High foliar biomass is obtained by frequent pruning of *F. thonningii* trees.

Most of the respondents planted *F. thonningii* near their houses, while some planted on the boundaries of their yards to make care and management easier and to protect it earlier stages against animal browse and damage. For these reasons very few farmers planted it in the pasture. Farmers also planted *F. thonningii* as a barrier against erosion. They obtain planting material freely from their relatives, in exchange of other wood products or purchase it for a price of 2-3 Ethiopian Birr per one cutting. Mostly, the cuttings are planted after the leaves and twigs are consumed by livestock and wildlings are also transplanted (Hines and Eckman, 1993). From the field observation and measurement it was possible to find sizes ranging from 4-10cm in diameter and 1.5-2.46 m in height for newly planted cuttings. The size of the planting material often varies depending upon the availability of the required sizes. The time of planting starts in March with the most suitable period from May to June when the soil is not too wet. Protection is ensured by staking thorny bushes as a fence encircling the plant or by using *Euphorbia trucalli* (see Fig. 3.9) as a live fence. The cuttings planted will establish within 2-3 months and then young shoots start to emerge.

Figure 3.8: Size of *F. thonningii* for planting (one year old)

Figure 3.9: Protection against damage by livestock and /wind

4. BIOPHYSICAL DATA COLLECTION

4.1. MATERIALS AND METHODS

4.1.1 Soil sampling and analysis

Five *Ficus thonningii* trees were selected from a school in Bahriginb village and soil samples around the trees were taken to laboratory for analysis. The trees were growing independently i.e. they are isolated. All the five trees had nearly equal crown width. Around each tree, a transect was laid out North to east and South to west aspects, beginning at the tree base as a center. For each tree, four distances were identified across the transects in proportion to the crown size. Along each transect, soil samples were collected at four points arranged in proportion to the tree canopy size. Those are 1m (one meter from tree base, 0.5r (half the crown radius), 1r (equal to the crown radius) and 2r (twice the crown radius). The latter sample point is located in the open land at two canopy radii from the sample tree. At each sample point, a pit 40x40cm was dug out and a soil core at 0-10 cm and 10-20 cm depth was collected using a coring device of 7cm inner diameter and 5 cm height to know the nutrient level the soil underneath and outside tree canopy by analyzing it. A depth of 20 cm is selected because it is the depth to which the roots of most crop plants concentrate.

All soil samples were air dried at ambient temperature for the same duration. Following drying, the coarse materials, stones and roots were removed and weighed. The mineral soil samples were also homogenized and 200-250 g of soils was sieved by using a 2mm diameter mesh in the regional soil laboratory at Bahir Dar. Then 40 fine soil samples (each 105 g) were taken to the laboratory at Boku for chemical analysis. Soil pH was measured both in a suspension with deionized water and 0.01 M suspensions of $CaCl_2$ solutions. The soil samples were weighed and a subsample was oven dried at 105°C for 24 hours to determine the conversion factor from air-dry to oven dry at Boku University soil laboratory. Total nitrogen was then subsequently analyzed from air dried samples using a semi micro Kjeldahl Austrian standard procedure (ONORM 1082). Similarly, carbon was analyzed by using the Leco SC-144 dual range element analyzer. Phosphorus was also extracted in Aqua regia (ONORM 1085) and determined by simultaneous plasma emission spectroscopy ICP-AES Perkin Elmer Optima 3000 XL. Exchangeable element contents (K, Ca' Mg, Na, Mn and Al) were determined by extraction of air-dried samples with 0.1 M NH_4OAc.pH 7.0. Determination of exchangeable elements was carried out by simultaneous Atomic Emission spectroscopy ICP-AES Perkin Elmer Optima 3000 XL ICP-AES. The determinations were made after calibration with matrix adapted standard solutions. The cation exchange capacity and percent base saturation were calculated using standard methods.

Soil bulk density was calculated on oven dry basis (Rayment and Higginson, 1992 cit. in Wilson and Lemon, 2004). Gravimetric soil moisture % was determined and volumetric soil moisture % was then calculated from soil moisture loss and bulk density.

4.1.2 Plant sampling and chemical analysis

The leaves were taken from the middle of canopy of 10 trees of 20 years age air dried on shade and oven dried at 70°C for 24 hours and the total nitrogen content was determined in the laboratory using a semi micro Kjeldahl digestion using ONORM 1082. Oven dried leave samples were extracted in a mixture of HNO_3 and $HClO_4$, to determine the total P, K, Ca, Mg, Na, Fe, Mn, Al, and S a simultaneous Perkin Elmer, OPTIMA 3000 XL was used.

4.1.3 Calculation procedures and formulae

Soil volume, Soil bulk density, Water content, Soil Porosity are calculated based on Arshad et al., Lowery et al. and Sarrantonio et al. 1996,

The inside diameter (d) of the core is 7 cm and its height is 5 cm.

1. Soil volume

$$V=\pi * (D/2)^2 * H$$

Where,
V is the volume of soil in a core sampler (cm^3)
D is the inner diameter of the core sampler (cm)
H is the height of the core sampler (cm) and
π is pie which is 3.14
Using the above formula, volume of one core sampler equals to

$$3.14 * (3.5 \text{ cm})^2 * 5 \text{ cm} = 192.325 \text{ cm}^3$$

2. Soil bulk density

$$BD = W_o / V$$

Where,

BD, is the bulk density (g/cm^3)

W_o is the oven-dry weight of the sample (g) and V is the volume of soil sample (cm^3).

3. Soil water content

$$G_w = [(W_m - W_o) / W_o] * 100$$

Where,

G_w, is the gravimetric water content in (%), W_m is the weight of moist sample (g) and W_o is the oven-dry weight the sample (g).

$$V_w = [(W_m - W_o) / W_o)] * 100 \text{ or } V_w = G_w * BD$$

Where,

V_w, is the volumetric water content[3] (%)

G_w the gravimetric water content (%),

BD is the soil bulk density (g/cm^3)

4. Total porosity

$$P = (1 - BD/PD) * 100$$

Where,

P is the soil porosity (%)

BD bulk density (g/cm^3)

PD, Particle density = 2.65 g/cm^3 (2650 kg/m^3

5. Water depth

$$D_w = V_w * d$$

Where,

D_w is the depth of water (cm)

V_w volumetric water content (%) and d is the soil depth (cm).

6. Pore space

$$WFPS = V_w / P * 100$$

Where,

WFPS or is the water filled pore space (%) it also called percent of saturation

V_w is the volumetric water content (%) and P is the soil porosity (%).

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[3] Volumetric water content is the volume of water per unit volume of soil and can be expressed in m^3 m^{-3}, (cm^3 cm^{-3}) or as percentage

$$P_a = P - V_w$$

Where,

P_a is the air filled porosity (%)

P is the total soil porosity (%)

V_w the volumetric water content from porosity (%)

$$S = V_w/P$$

Where, S is the percent saturation.[4]

Nutrient content per hectare (kg/ha) was calculated using the formula below:

$N_a = N * M/s$, where $M = BD * V$ and $V = A * d$

$N_a = [N * (BD * A * d)]/s$

$N_a = N * d * BD * 10$

Where, N_a is the amount of a nutrient (kg/ha), M is the mass of soil per hectare (kg/ha), N is the nutrient concentration (kg), s is the sample size (g), d is the depth of soil sample (m), BD is the bulk density (kg/m^3), A is the area (m^2/ha) and 10 is the constant or conversion factor.

The Calculation of cation exchange capacity

To determine the cation exchange capacity of the soil, the milliequivalents of K, Ca and Mg per 100g of soil (meq/100g of soil) were calculated by using the following formulas:

$$Y = (m * e)/w * 100$$

Where, Y is the amount of a cation in cmol/100 g, m is the weight of a cation in a sampled soil, e is its valence, w is the atomic weight or molecular weight of the element(compound).The amount of H^+ is also calculated in the same way.

The cation exchange capacity and the percent base saturation of the soil were calculated by using the following formula:

$$CEC\ (mmol_c/100g) = K^+\ (mmol/100g) + Mg^{2+}\ (mmol/100g) + Ca^{2+}\ (mmol/100g) + Na^+\ (mmol/100g) + H^+\ (mmol/100g)\ \text{at buffer pH}$$

[4] Percentage saturation is the amount of pores filled with water relative to total volume of pores

$$ECEC = CEC = K^+ (mmol/100g) + Mg^{2+} (mmol/100g) + Ca^{2+} (mmol/100g) + Na^+ (mmol/100g) + H^+ (pH)$$

$$H (buffer pH) = 8 (8.00 - buffer pH)$$

$$BS = (B (mmol /100g/ CEC)) * 100$$

Where, CEC is the total cation exchange capacity ($mmol_c$ /100g), ECEC is the effective CEC ($mmol_c$ /100g), B is the cation involved in the exchange sites and BS is the percent base saturation (%) of the soil (see the web link).

The total CEC (kg/ha) is calculated by multiplying cation concentration (cmol/100g) by the bulk density (kg/m^3) of the soil.

Percent organic matter in the soil is determined by the following formula:

OM = OC * 1.724 (J.Benton.Jones, 2001)

Where,

OC is organic carbon (%)

OM is organic matter content (%)

W_{105} is the weight of soil at 105°C (221°F) (g) and

W_{400} is the weight of soil at 400 °C (g) and

4.1.4 Data analysis

After soil properties were assessed for sample points inside and outside the tree canopy at the respective depths, the results were analyzed using SPSS for windows version 15.0. One way ANOVA was used to test if a pronounced canopy effect could be detected across the crown radius on soil physical and chemical properties on the measured and calculated parameters. For this analysis 1m, 0.5r and 1r sample points were taken together as the 'inside-canopy' points while 2r was considered as the 'outside' canopy. Pair wise comparison analyses were performed on the depth profile data. Soil water content and soil chemical characteristics are determined in light of the proximity to trees. Treatment means were separated by using student's t-test at p=0.05. Correlation analysis was also performed to know the relation between pH, organic carbon, nitrogen, P, K, Ca, Mg, Na, Mn, Al and using SPSS 15.0.

4.2 RESULTS

4.2.1 Physical properties of soils under *F. thonningii*

Though not significantly, the bulk densities in our study showed a decrease with depth along distances from the base of the tree (see table 4.2). Higher bulk densities were observed in 0.5r distance away from the tree in the 10-20 cm soil depth.

Soil porosity in 10 cm soil depth does not show significant difference with distance from the base of the tree in both depths. The total soil porocity is between 58.5-63% (see table 4.1 and). Air-filled and water-filled pore space are calculated and presented the table below.

Table 4.1: Soil physical properties under and outside the canopy of *F.thonningii* in a 10 cm soil depth

Distance from tree	Depth (cm)	BD (kg/m^3)	H_2O (%)	H_2O (cm)	Porosity%	Air-filled Porosity (%)
1m	0-10	1.09(0.05)	29.73(0.1.79)	2.97(0.17)	59.99(0.93)	29.2615501
	10-20	1.07(0.05)	26.09(4.36)	2.61(0.44)	59.43(0.92)	33.33386
0.5r	0-10	1.09(0.12)	24.16(1.18)	2.42(0.12)	58.63(2.02)	34.4638438
	10-20	1.14(0.07)	23.57(3.06)	2.36(0.31)	57.11(1.23)	33.54221
1r	0-10	1.07(0.05)	26.61(5.09)	2.66(0.50)	59.67(0.87)	33.0551622
	10-20	1.00(0.097)	25.61(3.91)	2.56(0.39)	62.17(1.65)	36.56493
2r	0-10	1.05(0.007)	28.77(4.85)	2.88(0.48)	60.36(1.16)	31.5845091
	10-20	1.04(0.10)	28.39(4.59)	2.84(0.46)	60.60(1.60)	32.20956
P values	0-10	>0.05	>0.05	>0.05	>0.05)	>0.05
	10-20	>0.05	>0.05	>0.05	>0.0.05	>0.05

The values in brackets are standard errors.

4.2.2 Chemical properties

4.2.2.1. Mineral nutrient contents of *F. thonningii* leaves

The chemical analysis of *F. thonningii* leaves showed the following element concentrations as indicated in table 4.2.

Table 4.2: Leaf nutrient contents of *Ficus thonningii*

Nutrients	N (mg/g)	P (mg/g)	K (mg/g)	Ca (mg/g)	Mg (mg/g)	Na (µg/g)	Mn (µg/g)	Al (µg/g)	Fe (µg/g)	S (mg/g)
Concentration	21.83 (1.24)	2.0461 (0.189)	9.095 (0.43)	18.05 (1.02)	3.572 (0.36)	166.4 (19.11)	34.3 (4.29)	191.1 (18.64)	258.3 (18.64)	1.5929 (0.09)

The values in brackets are standard errors

4.2.2.2 Soil pH

The results of soil pH measured in water and $CaCl_2$ are presented in the table below.

Table 4.3 The pH values of the Soil

Distance from the tree	Depth (cm)	pH (H_2O)	pH ($CaCl_2$)
1m (1m)	0-10	6.96(0.09)	6.40±0.15
	10-20	7.06(0.12)	6.50±0.13
Half crown radius(0.5r)	0-10	7.02(0.04)	6.42±0.08
	10-20	7.08(0.05)	6.46±0.12
One crown radius(1r)	0-10	6.98(0.02)	6.34±0.07
	10-20	7.06(0.01)	6.36±0.11
Twice crown radius(2r)	0-10	7.08(0.09)	6.40±0.08
	10-20	7.12(0.06)	6.44±0.09

4.2.2.3 Total organic carbon, total nitrogen and total phosphorus

The total average carbon we found is 23.15 mg/g under the canopy and 16.14 mg/g in the open pasture in the 0-10 cm soil depth. In the 10-20 cm soil depth, we obtained a total soil carbon of 15.78 mg/g and 13.13 mg/g respectively under tree canopy and in the pasture (table 4.4). There is no significant difference in carbon content with depth along the crown radii beneath the trees. Since the soil contains no carbonates it may be assumed that the measured carbon content comes from organic carbon.

Total average soil nitrogen was higher beneath the canopy of trees with 1.52 mg/g in the 0-10 cm soil depth and 0.98 mg/g in the 10-20 cm soil depth. The soils in the open pasture showed lowed N content as compared to soils under *F. thonningii*. However, we found no significant difference in total N contents for all the distances away from the base of the tree (see table 4.4).

The analysis showed better soil phosphorus under the tree crown with the highest at one meter distance away from the base of the tree though there are no significant differences among the treatment means.

Table 4. 4: Summary of Mean (±SE), total C, N, and P content (mg/g) and C/N in a 10 cm soil depth (oven dry basis) under and away from tree canopy (n=20, p=0.05)

Distance from the tree	Depth (cm)	Total C (mg/g)	Total N (mg/g)	Total P (mg/g)	C/N ratios
1m (1m)	0-10	23.6±2.87	1.4±0.26	0.94±0.09	17.89±3.72
	10-20	17.34±2.46	0.85±0.12	0.78±0.07	16.79±1.77
Half crown radius(0.5r)	0-10	23.06±3.21	1.58±0.22	0.84±0.08	14.45±1.47
	10-20	15.39±1.09	0.99±.10	0.65±0.09	15.95±2.86
One crown radius(1r)	0-10	22.77±4.76	1.58±0.36	0.85±0.13	115.72±5.52
	10-20	14.62±3.07	1.09±0.29	0.87±0.15	18.67±7.92
Twice crown radius(2r)	0-10	16.14±1.59	0.83±0.15	0.81±0.07	22.04±9.32
	10-20	13.13±0.62	0.61±0.06	0.75±0.07	21.25±7.64
P Values	0-10	>0.05	>.05	>0.05	>0.05
	10-20	>0.05	>0.05	>0.05	>0.05

4.2.2.4 Exchangeable cations

The contents of exchangeable cations we found in our analysis of the soils are presented in the table below.

Table 4.5: Major cation content of the soil under *Ficus thonningii* (n=20)

Distance from tree	Depth (cm)	K (μg/g)	Ca (μg/g)	Mg (μg/g)	Na (μg/g)	Mn (μg/g)	Al (μg/g)
1m	0-10	418(42)	3617(141)	1104(17)	98.88(20)	7.66(2.74)	1.40(0.007)
	10-20	322(30)	3646(187)	1131(23)	81.09(17.39)	3.12(1.28)	1.42(0.009)
0.5r	0-10	474(32)	3715(132)	1086(20)	68.27(15.37)	4.48(0.63)	1.42(0.008)
	10-20	358(33)	3645(77)	1124(22)	65.23(12.63)	2.77(1.14)	1.39(0.005)
1r	0-10	433(41)	3716(135)	1101(35)	52.99(10.44)	4.19(0.27)	1.39(0.005)
	10-20	398(35)	3765(161)	1137(39)	55.66(12.66)	3.38(0.72)	1.40(0.004)
2r	0-10	337(5)	3592(126)	1141(18)	51.46(11.68)	3.62(0.68)	1.44(0.031)
	10-20	312(16)	3664(151)	1155(17)	45.15(8.49)	1.58(0.18)	1.42(0.011)
P values	0-10	<0.05	>0.05	>0.05	>0.05	>0.05	>o.05
	10-20	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05

The values in brackets are standard errors

4.2.2.5 Cation exchange capacity and base saturation

The values calculated for base saturation is shown in the table below (see table 4.6).

Table 4.6: Summary of CEC (mmol$_c$/100g) and base saturation (%) and contribution of the major cations to CEC

Distance from trees	Soil depth (cm)	CEC K mmol$_c$/100g	CEC Ca mmol$_c$/100g	CEC Mg mmol$_c$/100g	CEC Na mmol$_c$/100g	CEC H mmol$_c$/100g	Total CEC mmol$_c$/100g	BS (%)
1m	0-10	2.09((1.73)	18.12(0.61)	5.59(0,09)	0.49(0.10)	12.80(1.21)	41.63(0.77)	67.44(2.32)
	10-20	1.61(1.29)	18.27(0.93)	5.73(0.12)	0.40(0.086)	12.00(1.04)	40.86(0.78)	68.50(2.37)
0.5r	0-10	2.37(2.01)	18.61(17.20)	5.50(0.10)	0.34(0.07)	12.64(0.64)	41.8(0.98)	67.98(1.28)
	10-20	1.79((1.48)	18.26(0.36)	5.69(0.11)	0.33(0.06)	12.32(0.93)	41.15(1.19)	68.06(1.46)
1r	0-10	2.16(1.80)	18.62(17.21)	5.58(0.18)	0.26(0.05)	13.28(0.54)	42.4(0.85)	66.69(1.41)
	10-20	1.99(1.68)	18.86(0.80)	5.76(0.20)	0.28(0.06)	13.12(0.86)	42.71(0.93)	67.23(1.97)
2r	0-10	1.69(1.33)	17.99(16.79)	5.78(0.09)	0.26(0.05)	12.80(0.67)	41.39(0.91)	66.81(1.36)
	10-20	1.56(1.25)	18.35(0.76)	5.85(0.09)	0.23(0.04)	12.48(0.70)	41.45(0.92)	67.60(1.49)
P value	0-10	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05
	10-20	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05

The values in brackets are standard errors.

4.3 DISCUSSION

4.3.1 Physical properties

Soil structure has a major influence on the ability of soil to support plant growth, cycle C and nutrients, receive, store and transmit water, and to resist soil erosion. Bulk density is one of the physical soil properties which measures how dense a soil is and its values also tell us whether a given soil is rich in organic matter or not. Breemen (2002) has explained the strong influence of soil texture and organic matter on bulk density. It varies from less than 0.5 g/cm^3 in organic matter rich soils to 2 g/cm^3 in poor soils (GLOBE, 2005)). Soil bulk density was used to convert soil nutrients from cocentrations to an amount basis (Kg/ha). The mean soil bulk density did not significantly differ with distance from the trees and with depths. However, differences were observed with location of the plots in relation to direction, i.e. the bulk density of north-east facing sample plots showed slightly higher bulk density than the south-west facing sample plots.

Total porosity is calculted from bulk density and the particle density. It reflects the impact of compaction arising from activities such as tillage and other trampling by animals. There is an increase in porosity outwards along the crownradii. In this study the porosity is lowest under crown half radii distance in both depths with 10-20 cm soil being 57.11%. The soil at 1r radius distance from the base of the tree has a prosity of 62.17% in the 10-20 cm (Fig. 4.1 and 4.2). The size of soil pore and its distribution is influencd by mangement in addition to texure and organic matter.The air-filled porosity is important for the micrbial activity involved in C and N cycling and is promising in both soil depths i.e, greater than 50% of the pore space is occupied by it (Parkin et al.1996).

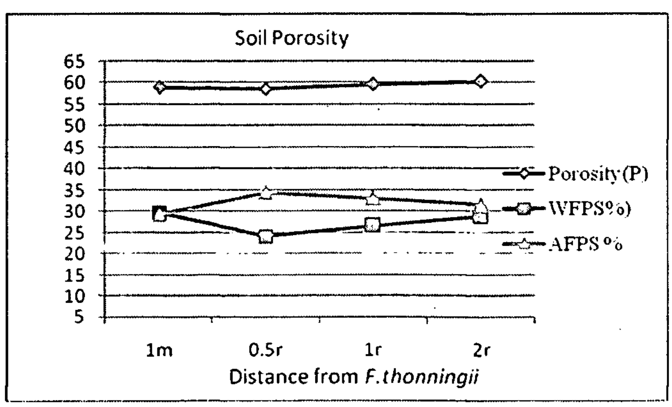


Figure 4.1: Total, water and air-filled porosity in the 0-10 cm soil depth per 10 cm

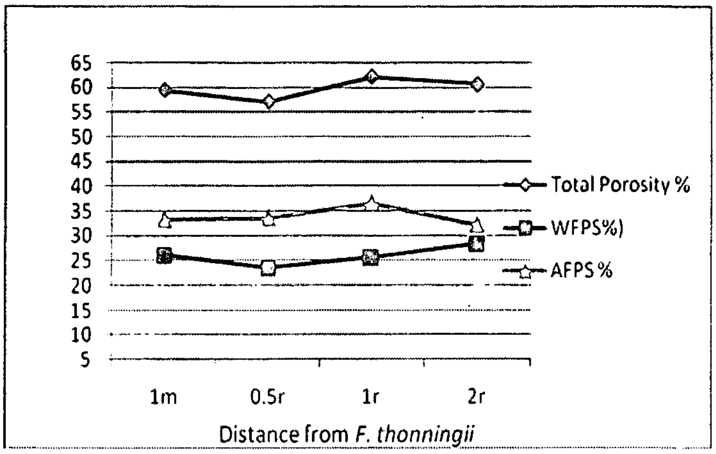


Figure 4.2: Total, water and air-filledin the porosity10-20 cm soil depth per 10 cm

4.3.2 Chemical properties

4.3.2.1 Nutrient content of *F. thonningii* leaves

The leaf nitrogen content of *F. thonningii* was smaller than the reports by (Gindaba et al., 2004) which have been 24.85±0.192 *mg*/g for *C. macrostachyus* and 22.13±0.139 *mg*/g for *M. ferruginea*. *F. thonningii* P content (see table 1) in our study on the other hand, was higher than *C. macrostachyus* (1.63±0.038mg/g) *M .ferruginea (1.13* ±0.006) reported by the same author. As compared to *Gmelina arborea* (Chijoke, 1980), N was higher in *F. thonningii* and lower in *S. sesban (*Ghai et al., 1985), *L. leucocephala,* (Kang et al., 1984). The leaf P in *F.thonningii* was higher than *L. leucocephala, G. sepium.* The K content in *F.thonningii* leaves was higher than *G. arborea and L. leucocephala* and lower than *G. sepium* while Ca content of *F. thonningii* was higher than all the three species. These differences element contents may probably be due to the soil type and species in which *G. sepium* and *L. leucocephala* fix atmospheric N.

4.3.2.2 pH of soils under tree canopy and open pasture

We found No significant differences for the soil samples analyzed for soil pH related to distance from the tree and depth of soils sampled. The measured soil pH in water increases with increasing distance away from the base of the tree i.e. it is lower beneath the trees and slightly higher in the open pasture. Soil pH (H_2O) is lower in 0-10 cm soil depth and higher in the 10-20 cm soil depth. We observed an exceptional trend at 1r distance away from the base of the tree where the soil has the lowest pH for all depths in our measurement. At 0-10 cm depth, the average soil pH (H_2O) values were 6.98 beneath the tree canopy and 7.08 in the open pasture while the value for the 10-20 cm soil depth were 7.07 beneath the tree canopy and 7.12 in the open. The pH values for soils measured in 0.01 M $CaCl_2$ were lower than the values for soils measured in water. The values increase with distance away from the base of the trees and with depth. The average pH value of the soil with 0.01M $CaCl_2$ beneath the tree crowns were 6.38 and 6.40 respectively for 0-10 cm and 10-20 cm soil depths. Likewise, the values for the open pasture were 6.4 for 0-10cm soil depth and 6.44 for 10-20 cm soil depth (see table 4.4). These results indicate the influence of the exchangeable base cations under the tree's canopy.

4.3.2.3 Soil organic carbon

Organic carbon makes up approximately 58% of the soil organic matter by weight (Sikora, 1996). OC is directly used to determine the amount of organic matter in the soil. Since the organic matter content of the soil varies widely among the soils, the amount of organic carbon may vary between 45-60% of the organic matter content of soils (Breemen, 2002).The primary source of soil organic matter is the carbon fixed through photosynthetic reactions that may reach the soil from plant remains and root exudates (Sensi and Loffredo, 1999). The death and decomposition of biomass from animals, decomposers, saprophytes and anthropogenic processes also provide secondary sources (Brady, 1990 cited in Graves et al., 2001, and Sensi and Loffredo, 1999).

Trees are the major sources of primary organic matter additions. According to (Brady, 1990 cited in Graves et al., 2001), plant biomass constitutes 44% carbon, 40% oxygen, 8% hydrogen, and 8% ash, which includes compounds of mineral nutrients such as nitrogen, phosphorus, potassium and the micronutrients. Most of these are used as the building blocks for carbohydrates (60%), lignin (25%), proteins (10%), fats, waxes, cellulose and tannins (5%). It is one of the important natural resources and basis of soil fertility. However, soil organic matter contains 5%-25% carbohydrates, 15%-45% N, lipids 2% in forest soils to 20% in acid peat soils and 33%-75% humic substances (Sensi and Loffredo, 1999). Organic matter plays an important role in the physical and chemical properties of soils. It influences the soil physical conditions, cation exchange capacity, and anion retention, synthesis of humic substances, carbon metabolism, and interaction with metal ions and mineral colloids and biological activity of the soils.

The calculated organic matter content in the soils under *F. thonningii* canopy is 3.99% in the 0-10 cm and 2.78% in the 10-20 cm soil depths while soil organic matter in the open pasture is 2.72% and 2.26% respectively for 0-10 and 10-20 cm depths. About 2% of soil organic matter was considered the least requirement for plant establishment (Brady, 1990 cited in Graves et al., 2001. The litter and root turnovers are important for the balanced supply of nutrients and protection against leaching until released by mineralization which in turn improves soil fertility (Young, 1989). The mean soil carbon content obtained in the 0-10 cm soil depth in our study is 23.15 mg/g under the tree canopy and 16.15 mg/g in the open pasture. We also found values 15.79 mg/g and 13.13 mg/g of organic carbon in the respectively for canopy and open pasture soils 10-20 cm soil depths. Total carbon increased 47% on average from the open to beneath the trees in the 0-10cm and 22% in the 10-20 cm soil layer. These indicate the existence of carbon inputs into the soil from litter and biomass under the canopy of *F. thonningii.* The amount of total carbon (k/ha) in the soil related to location from the tree canopy is shown below (Fig. 4.3).

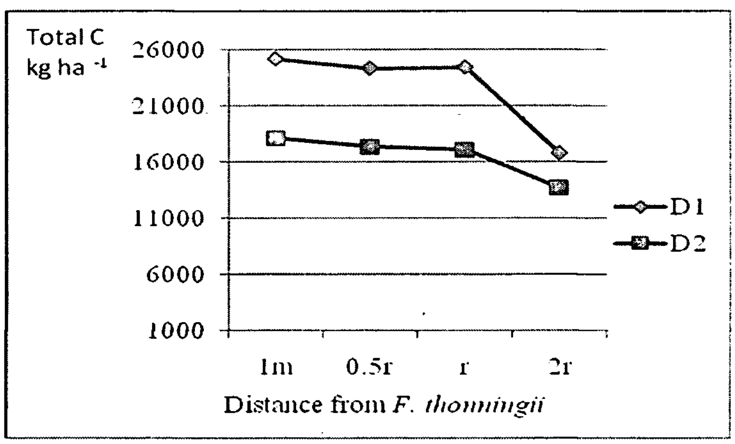


Figure. 4.3: Organic carbon in kg/ha with distance from *F. thonningii* and in the 01-10 cm (D1) and 10-20 cm (D2) soil depth

4.3.2.4 Soil nitrogen

The mean total soil nitrogen is 1623.53 k/ha under canopy and 877.15 kg/ha in the open pasture for the 0-10 cm soil depth. The N content in the 10-20 cm soil depth is 1032.37 kg/ha and 633.68 kg/ha respectively for under canopy and in the open pasture. Thus organic soils in the 0-10 cm soil depth contain much higher content of N than those in the 10-20 cm soil depth. Soils under all the tree canopies studied showed higher N than soils under the open pasture (see Fig, 4.4). Supporting results were found in a research by

Chamshma et al., (1998) in Morogoro, Tanzania at 0-20 cm depth for *L. leucocephala* (1831 Kg/ha) and *F.albida* (1814 kg/ha). The higher total N accumulation under the canopy of the trees as compared to the open pasture may be resulted from the high organic matter inputs from fine root degeneration and litter fall followed by microbial activities under tree crowns (see table 4.7) (Sànchez et al. (1997). The average total nitrogen under tree canopy increased by 85% in the 0-10 cm and 63% in the 10-20 cm soil depths as compared to soils in the open pasture. This value is higher than report on cropland where soils in the 0-15cm and 15-30cm depth under tree canopies had 22-26% for *C. africana* and 12-17% *C. macrostachys* higher N than the corresponding soils away from tree canopies (Gindaba et.al, 2005). The leaf N content of *F. thonningii* is 21.83 mg/g (table 4.4). The total nitrogen content per hectare basis is also presented in figure 4.4. Soil nitrogen had strong positive correlation (p 0 0.01) with organic carbon (Fig. 4.5. The relationship is explained by the regression equation.

$$y = 0.075x - 560.7$$

Where, y is the level of nitrogen (kg/ha) and x is the level of organic carbon (kg/ha) in 20 cm soil depth.

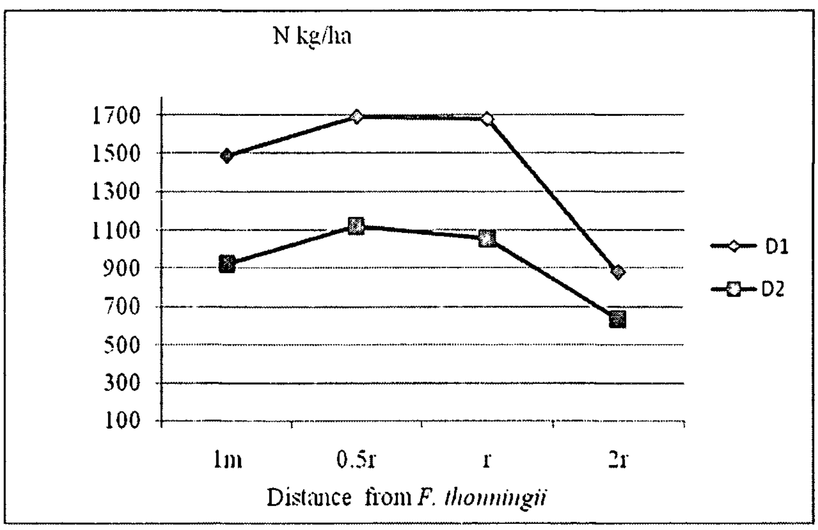


Figure 4.4: Total nitrogen per10cm soil depth beneath and outside *F. thonningii* canopy in 0-10 cm (D1) and 10-20 cm (D2)

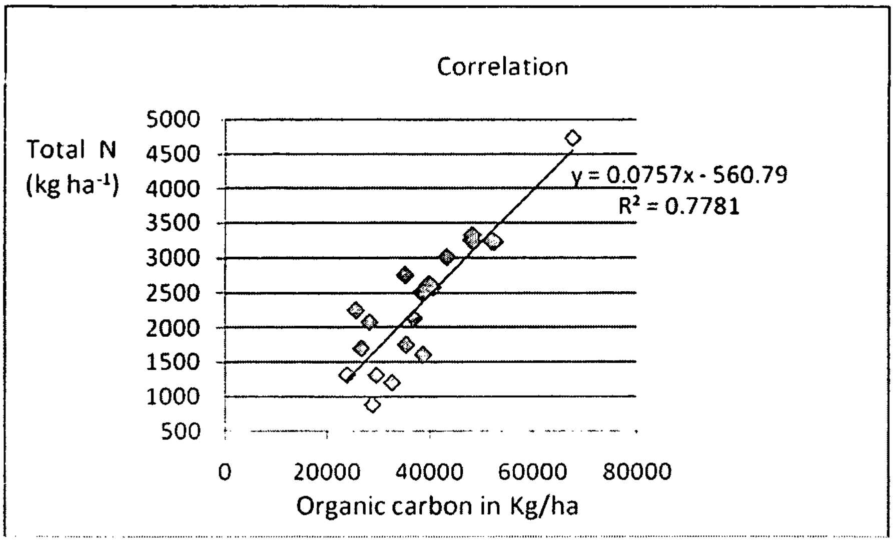
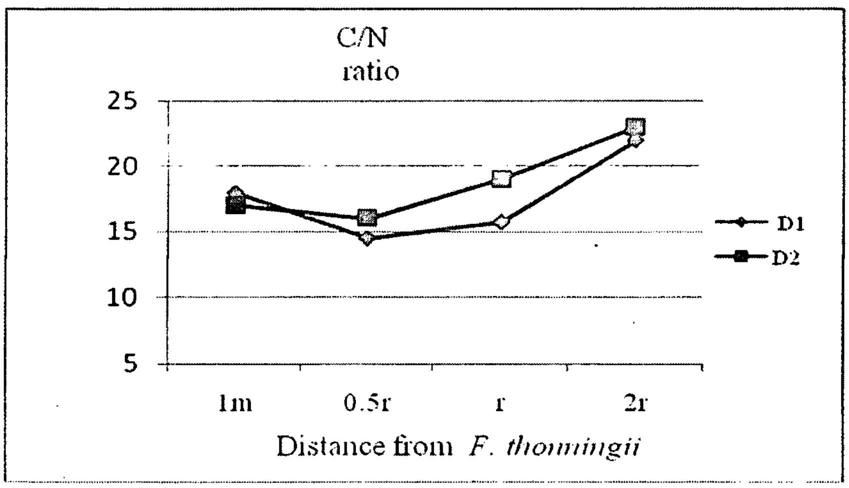


Figure 4.5: Correlation of total nitrogen with organic carbon per 20 cm soil depth



Figur 4.6. C/N ratio with distance from *F. thonningii* in 0-10 cm (D1) and 10-20 cm (D2) per 10 cm soil depth.

Total soil N and C content did not significantly differ with all the depths. Tree planting has also been shown to alter C: N ratios of the soil and soil organic matter content (Young, 1989). In our study, soil carbon content was determined to observe the differences in C: N when there is no tree component in the system. The evidences from our results suggest that the C: N increases with distances away from the canopy of the tree (see table 3). A special case may be seen 1meter from the tree, where higher C: N ratio than 0.5r distances from *F.thonningii* is found due to the higher C inputs from decaying fine roots. On average, the C: N ratios under the tree canopy are 15.22 for under canopy soils and 16.1 for the open pasture in the 0-10cm soil depth. The C: N increased in the 10-20 cm depth and the values are 19.44 for soil under canopy and 21.42 for the open pasture soils(see table 4.6).

4.3.2.5 Soil phosphorus

About 15%-80% of the total P in soils is organic in origin (Sensi, 1999). In our study, the P content is between 3.5% and 3.8% of the organic matter and the C: P ratio 26 and 21 respectively under the canopy and in the open pasture in the 0-10 cm soil depth. It drops to 20 under the tree and 18 in the open in the 10-20 cm soil depth. The phosphorus content in the 0-10 cm soil depth is 0.88 and 0.81mg/g respectively under canopy and in the open pasture and 0.77 and 0.75 in the 10-20 cm soil depth showing slight decrease with depth and distance away from the base of the tree. There is no significant difference in total phosphorus content between the soils under canopy and open pasture. Its content decreases with depth in almost the same way as organic carbon (see Fig. 4.7).

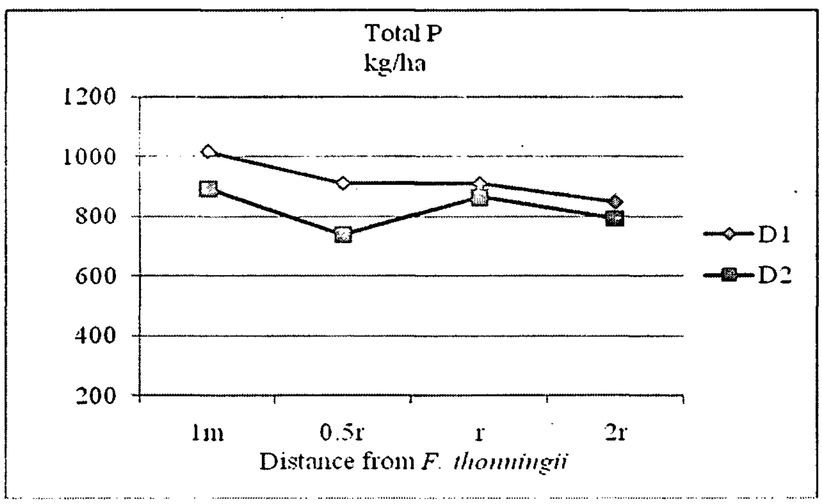


Figure 4.7 Trends in total phosphorus with distance from the tree in the 0-10 cm(D1) and 10-20 cm (D2)

The average phosphorus content under canopy is 12% and 5% higher than the open pasture respectively in the 0-10 cm and 10-20 cm soil depths. Phosphorus showed significant correlation with organic carbon (p=0.01) and soil nitrogen (p=0.05). This indicates that phosphorus in these soils is predominantly found in organic forms not an in-organic chemical binding. The regression equation for phosphorus is given as follows:

$$y=0.028x + 616.7$$

Where, y is the level of phosphorus obtained (kg/ha) and x is the level of organic carbon (kg/ha) accumulation required (Fig. 4.8).

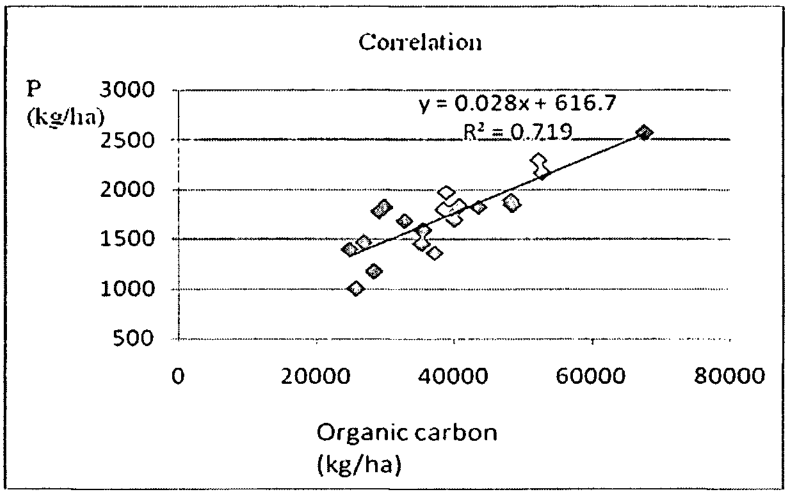


Figure 4.8 Correlation between total phosphorus and total organic carbon

Table 4.7 Summary of Mean (±SE) total carbon (oven dry basis), total N, and total P in 10 cm soil depth beneath and away from tree canopy (n=20, p=0.05)

Distance from tree	Depth (cm)	C (kg/ha)	N (kg/ha)	P (kg/ha)
1m	0-10	25236.4(5954.1)	1487.89(580.2)	1017.16(180.05)
	10-20	15792.1(6207.36)	921.92(325.38)	843.746(189.38)
0.5r	0-10	24389.3(533.3)	1694.54(34.30)	910.38(143.81)
	10-20	17398.7(2031.02)	1120.67(235.42)	738.30(235.93)
1r	0-10	24473.8(10485)	1681.67(806.45)	910.04(298.52)
	10-20	17121.9(5765.58)	1654.53(563..05)	864.19(296.99)
2r	0-10	16799.7(2903.3)	877.15(368.24)	847.44(120.88)
	10-20	13714.4(2067.33)	633.68(123.82)	792.85(211.01)
P values	0-10	>0.05	>0.05	>0.05
	10-20	>0.05	>0.05	>0.05

The values in brackets are standard errors.

4.3.2.6 Exchangeable cations

Some tree and shrub species can selectively accumulate certain nutrients (Nair, 1993). Large accumulations of potassium in Palm (Folster *et al.,* 1976), calcium in *Gmelina* *arborea* (Sanchez *et al.,* 1985) were observed. *Cecropia* species growing on acid soils appear to accumulate calcium and phosphorus (Odum and Pigeon, 1970 cit in Nair 1993). The amounts of exchangeable bases under *F.thonningii* are higher than in the open for 0-10cm and 10-20cm soil depth. The content of Mg increases with distance from the base of the trees i.e. higher Mg content was observed in the open pasture.This agrees with the research results found in *Acacia tortilis* by (Belsky et al.,1993).

Soil K decreases with distance from the base of trees in the 0-10 cm soil depth range. It shows significant difference in the 0-10cm soil depth (p=0.05).The content of Ca was similar at all points. Only outside the tree crown for 0-10 cm depth the lowest Ca content could be observed. K and Ca contents of the soil were very high at 0.5r distance away from the tree in all depths. The Mg content of the soil is comparable at all points with slightly higher Mg in the 10-20 cm soil depth. Soils under the canopy of *F.thonningii* showed higher Na content in both depths. Soil under the crown of the tree at 1m from base of the tree showed very high Mn content and decreases with distance from the tree with the lowest in the open. Al content is comparable at all sample points and in all depths. Ca & Mg were higher in the 10-20 cm than in the 0-10 cm soil depth (Table 4). K showed significant difference ($p<0.05$) for 0-10 cm soil depth.

In general, proportions of contribution for the major cations to CEC varied for K 6.09-6.80%, Ca 52.82-53.76%, for Mg 15.80-16.31% and for Na 0.76-1.44%, under the canopy and 35.36% for Ca, 17.15% for Mg 5% for K and 0.76% for Na, and in the open pasture in the 0-10 cm soil depth. This indicates that the soil studied has adequate Ca and Mg and low content of K. The soil Na content was significantly lower in the exchange site of both under the tree canopy and in the open land. The presence of the tree in the system had no significant influence on the CEC of soils. The results obtained for K (see table 4.7) are similar with results of the study by (Gindaba et al., 2005) on *C.macrostachyus.* Under canopy soils had higher K (see Fig. 4.10), Na, and Mn in the first depth than the second while soils at 0.5r from base of trees showed a relatively higher Ca and Mg amounts (see Fig.4.11 and 4.12). Na and Mn (Fig 4.13 and 4.14) were very low in the open as compared to under canopy soils. High CEC and exchangeable Ca and K were found in an improved fallow of *Leucaena leucocephala* resulted from the pruning mulch turn over (Guo, and Lal 1977 in Nair, 1993).

4.3.2.7 Cation exchange capacity and base saturation

The results of ANOVA for CEC revealed no significant differences with distance from the base of the tree in both depths towards the open pasture. Ca constitutes the highest contribution to the CEC of the soils both under canopy and in the open. The CEC of the soil was slightly higher under *F.thonningii* than in the open land in all depths with slightly higher CEC level in the 0-10 cm depth than the 10-20 cm. The CEC is closely related to soil texture and organic matter (Jones, 2001) and accordingly the soil under this study are clay with the CEC 40 $mmol_c$/100g.The higher CEC was resulted from the high clay and organic matter content of the soils and Ca is the largest contributor to the CEC in this study. The ECEC of the soil is higher the CEC by two units.

4.3.2.8 Correlation between soil organic carbon and NPK

The nitrogen, phosphorus and potassium in the soil had positive significant correlation (p=0.01) with organic carbon in 0-10cm and 10-20 soil depths. Magnesium had negative significant correlation with OC, N, P and K concentrations. The presence of strong correlation between organic carbon and nitrogen content was also reported by Mekonnen (2007). The correlation between K and Oc (kg/ha) is explained in the following functions:

$$y = 0.0103x + 416.03$$

Where, y is the level of potassium (Kg/ha) obtained and x is the level of organic carbon (kg/ha) required to obtain y (see Figure below).

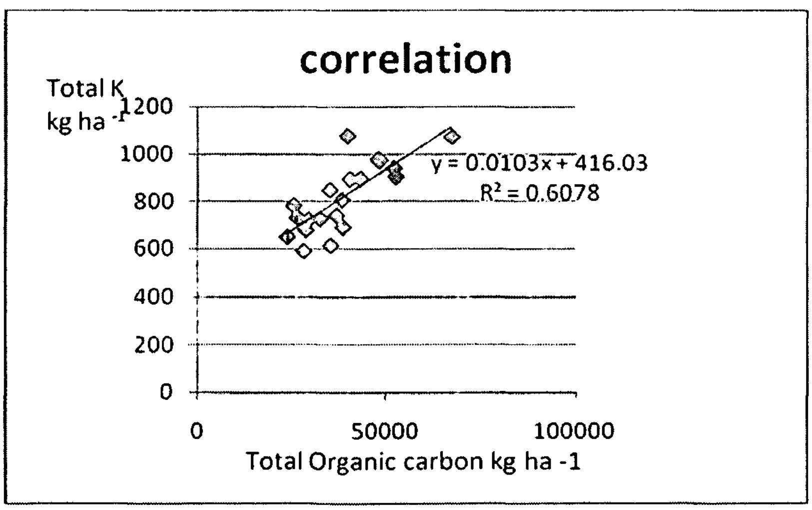


Figure 4.9 Correlation between total K and total OC per 20 cm soil depth

Table 4.8: Pearson correlations between the content of pH, C and major cations, in 0- 10 cm soil depth (n=20)

Parameter	pH	OC(mg/g)	N(mg/g)	P(mg/g)	K(µg/g)	Ca(µg/g)	Mg(µg/g)	Na(µg/g)	Mn(µg/g)	Al(µg/g)
pH	1									
OC(mg/g)	-0.036	1								
N(mg/g)	0.086	.899(**)	1							
P(mg/g)	-0.309	.839(**)	.603(**)	1						
K(µg/g)	-0.05	.836(**)	.876(**)	-.573(**)	1					
Ca(µg/g)	0.408	0.076	0.132	-0.202	0.156	1				
Mg(µg/g)	0.203	-.761(**)	-.651(**)	-.720(**)	-.688(**)	0.273	1			
Na(µg/g)	-.518(*)	-0.029	-0.013	0.054	0.036	-0.109	0.144	1		
Mn(µg/g)	-.647(**)	0.263	0.229	0.34	0.36	-0213	-0.148	.840(**)	1	
Al(µg/g)	0.102	-0.165	-0.217	-0.03	-0.098	-0.181	0.146	-0.24	-0.162	1

Table 4.9: Pearson correlation between soil pH, C and major cations in 10-20 cm soil depth (n=20)

Parameter	pH	OC(mg/g)	N(mg/g)	P(mg/g)	K(µg/g)	Ca(µg/g)	Mg(µg/g)	Na(µg/g)	Mn(µg/g)	Al(µg/g)
pH	1									
OC(mg/g)	-0.331	1								
N(mg/g)	-0.08	.847(**)	1							
P(mg/g)	-0.23	.767(**)	.613(**)	1						
K(µg/g)	-0.042	.793(**)	.797(**)	.668(**)	1					
Ca(µg/g)	0.326	-0.292	-0-151	-0.336	-0.026	1				
Mg(µg/g)	0.275	-.756(**)	-.594(**)	-.783(**)	-.591(**)	0.363	1			
Na(µg/g)	-0.297	-0.234	-0.022	-0.401	-0.255	0.086	0.225	1		
Mn(µg/g)	-0.365	.504(*)	.561(**)	0.332	.511(*)	-0.085	-0.264	.463(*)	1	
Al(µg/g)	-0.205	-0.103	-0.166	0.071	-0.298	-0.1	0.255	0.101	0.222	1

** Correlation is significant at 0.01 levels (2-tailed). * Correlation is significant at 0.05 levels.

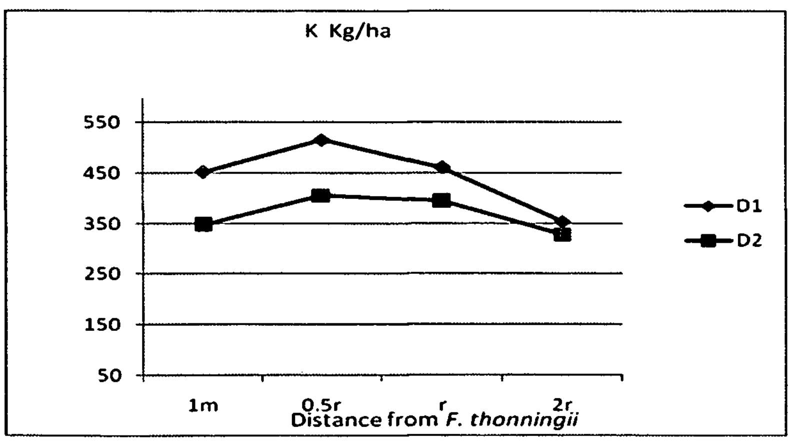


Figure 4.10 Amount of exchangeable K under and outside *Ficus thonningii* canopy

in the 0-10 cm (D1) and 10-20 cm (D2)

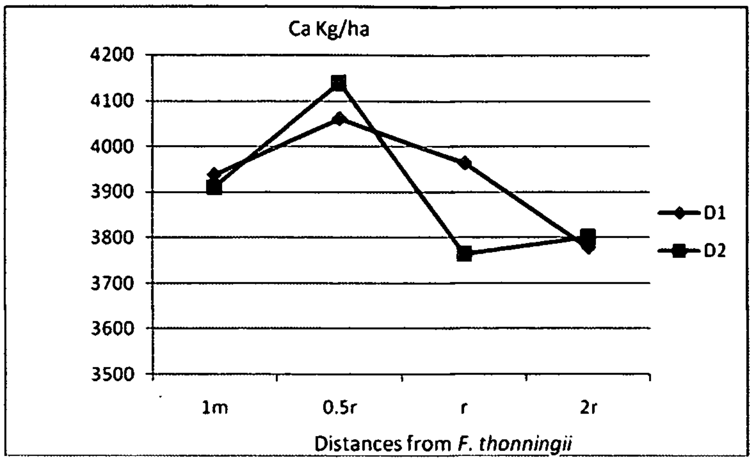


Figure 4.11 The amount of exchangeable Ca per 10 cm under and outside *Ficus thonningii* canopy in the 0-10 cm (D1) and 10-20 cm (D2)

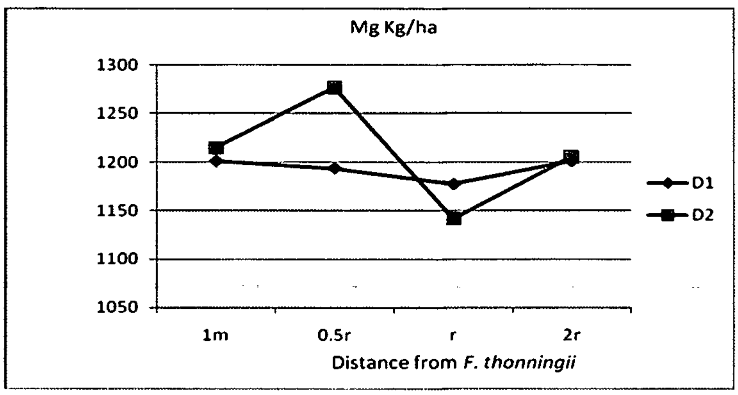


Figure 4.12 Amount of exchangeable Mg per 10 cm under and outside *Ficus thonningii* canopy in the 0-10 cm (D1) and 10-20 cm (D2)

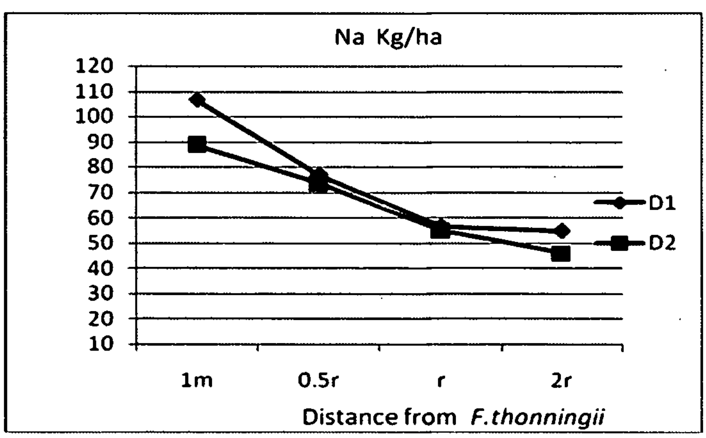


Figure 4.13 Amount of exchangeable Na per 10 cm under and outside *F. thonningii* canopy in the 0-10 cm (D1) and 10-20 cm (D2)

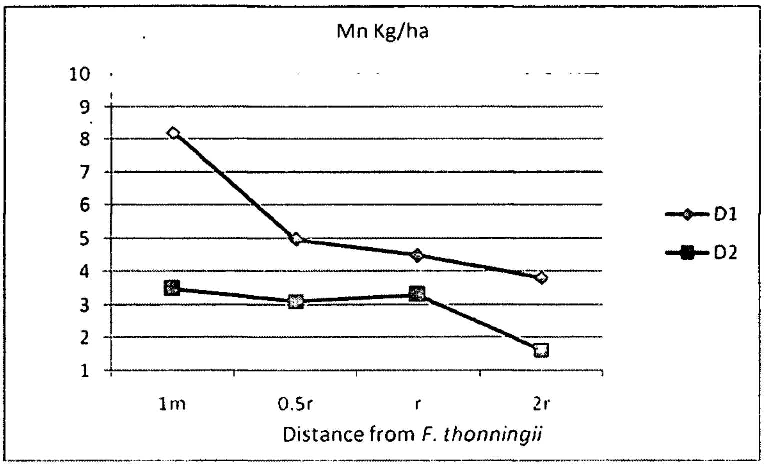


Figure 4.14 The amount of exchangeable Mn per 10 cm under and outside *Ficus thonningii* canopy in the 0-10 cm (D1) and 10-20 cm (D2)

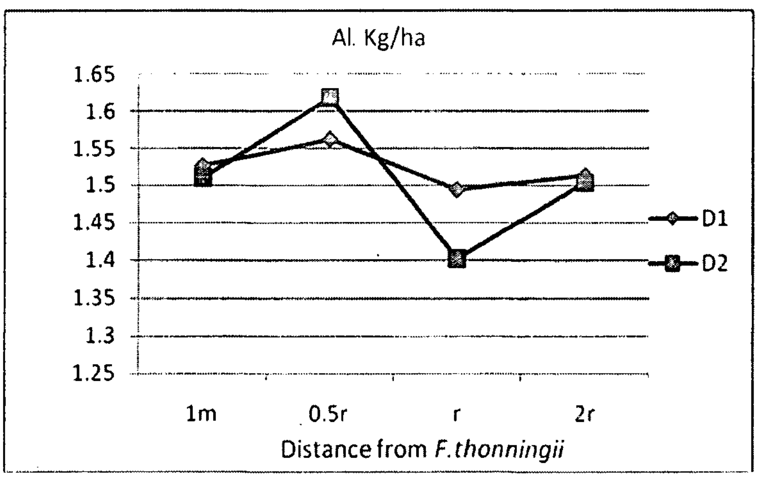


Figure 4.15 Amount of exchangeable Al per 10 cm under and outside *Ficus thonningii* canopy in the 0-10 cm (D1) and 10-20 cm (D2)

5. CONCLUSION AND RECOMMENDATION

Living organisms need the desired quantity and quality of mineral nutrients for proper physiological functions of various types. Mineral nutrients can function as a constituent of an organic structure (e.g. magnesium and micronutrients) predominantly of enzyme molecules where they are either directly or indirectly involved in the catalytic functions. Others like potassium or chlorine are important in osmoregulation and maintenance of electrochemical equilibrium in cells and the compartments and their regulation of enzyme activities. Minerals such as nitrogen, sulphur and phosphorus serve as a constituent of proteins and nucleic acids (Marschner, 1990). Thus, the life supporting nutrients in our environment need to exist in the required amounts sustainably in soils, and the atmosphere to serve for the continual existence and nourishment of plants and animals particularly mankind. Both extremes in their quantities are not helpful and especially the excess of one particular nutrient and the deficiency of the other often are indications for disturbed ecosystems. We need to manage the systems properly involving trees and shrubs in order to facilitate the availability for uptake and fixation.

Trees and/ or shrubs in agroforestry systems provide several socio-economic benefits and environmental services. Management of the components should focus on reducing competitive interaction with in the woody and non-woody components to maximize their cumulative outputs. Understanding the magnitude and rate of beneficial as well as adverse effects of trees on soils is the key to successful design and management of agroforestry systems (Nair, 1993 and Young, 1989). Studying the soil physical and chemical properties is important to characterize a given species based on the information and involve it in a farming system.

Ficus thonningii is one of the indigenous trees in Ethiopia which were not considered for their various benefits. In this study, the carbon, nitrogen, phosphorus and potassium content of the soil under its canopy were higher than the soil in the open pasture. It has high nitrogen, Ca and Na content in the leaves. The maize crop in the vicinity of the trees also showed better growth condition and crop productivity. Thus, the tree can be used in association with crops and/ or pasture plants to improve physical and chemical effects on soils. The tree has considerable nutritional importance and development works involving *F. thonningii* will play a great role for better livestock husbandry. The distribution of the tree varies among similar agroecologic districts largely due to the lack of transfer of be it local or expert knowledge on the management and values of the species and this calls for strong extension communication services to help farmers exchange new knowledge and to practice the innovations on a wider scale. Further studies on the rate of litter decompostion and biomass are deemed necessary.

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7 APPENDIX

Appendix A Questionnaire 1(Farmer Level)

Household No________

Name of Interviewer: ___

Date of Interview: ___

Demographic and socio-economic data

1. Age of respondent:__Sex:__Educational status__Marital status__Household size: __

2. What is the size of your land holding? _______________

3. Is your plot of land enough for the family? _______

4. Which crops you grow on your holding________________________________

5. Does *Ficus thonningii* increase soil fertility?

6. How it helps to increase productivity of your crops?__________________

7. Is the fertility of your piece of land increasing or decreasing from time to time? _____

8. If decreasing, do you use Ficus *thonningii* use to increase production? ___________

9. Which other trees you use for this purpose? ______________________________

10. Did this Village experience Soil erosion problem? ______

11. If yes, do you use *Ficus thonningii* for soil conservation practice and for which type of erosion control method? ___

12. Does the existing land tenure allow you for planting or keeping trees on farms? __________

13. Have you planted *Ficus thonningii* in your holdings? And if you have planted, did production surrounding the tree increase or decrease? ______________________

14. If yes, in which of your fields? ___and how do you establish it? Cuttings___Seeding__Seedlings___Others___

15. When do you plant *Ficus thonningii*? __ How do you manage it in your fields? Pollarding__Pruning__Other__

16. Do you face shortage of fuelwood for the family? _______

17. Is *Ficus thonningii used* for fuelwood? _________

18. Do you use energy saving stove? _______

19. If No, Give reasons____

20. Do you own animals? _____.If yes, which types and how many are each?

21. What do you fed your livestock? ___________________________________

22. Have you ever experienced any shortage of livestock feed in the past? ______

23. If yes, which animals are affected by lack/shortage of fodder? _________

24. Do you feed *Ficus thonningii* for your animals _____If yes, how at what times? ____

25. Which animals fed on 'the fodder of *Ficus thonningii*? ______________

26. What is' the result you have observed by feeding *Ficus thonningii*, fattening____ milk production____?

27. Which part of the tree is using for fodder and how you fed? __________________

28. What other trees do you use for animal fodder? ________________________

29. Where you collect these? Own holdings_____communal , pastures_____miscellanous lands_______?

30. Do you plant seedlings for this purpose? If not, your reason ____________________

31. Are there any tree species of known fodder importance severely endangered or lost in this area? If yes, which ones____

32. In which of the months of the year livestock feed is severely limiting and why? ________________

33. Which seasons/ months of the year does *Ficus thonningii* flower? _______________

34. What are the problems associated with *Ficus thonningii* when using it as fodder? ______________

35. What benefits *Ficus thonningii* provides to the people in the village other than fodder? _____

36. Do people use the tree for medicinal purpose? __If yes, which part/s and for what type________________

37. Does it have any medicinal value? ____________for animals_____for humans

38. Do you think that you have used the tree at its potentials? _____

39. If not, what are the constraints ____________________________________

40. Do they freely browse or you use cut and carry for your livestock? _________

41. To which agroforestry practices *Ficus thonningii* fits best?

Homegardens	Farm Boundary	Pasture lands	On crop lands

42. Where does *Ficus thonningii* naturally grow? ___

43. In which villages or Districts it is distributed __________________________?

44. Are there any taboos and beliefs regarding the use of *Ficus thonningii*? __If yes, what are these? _______

45. How many F.thonningii trees you have planted? _________________________

Questionnaire 2 (Expert Level)

1. How much *Ficus thonningii* is considered in development works, in agroforestry and soil conservation, in animal husbandry (fattening and dairy production__________________?

2. What are the uses of the species best considered by the farmers? And which parts of the plant are used as fodder____

3. What is the trend of development (including propagation) and utilization of the species by the farmers? ____________________

4. In which Villages the species is naturally potentially well developed/distributed__________

When does it flower and which time best suited for propagation of the species? ________

5. What practices are commonly employed by farmers in managing the species?

6. What are the opportunities for expanding its cover in the District? __________________

7. What are the constraints in expanding the species in agricultural lands (e.g. Farms and pasture or conservation works)?

Appendix B The socio-economic survey data

Data category	Response		Remark
	Frequency (n = 45)	Percent	
1.Age structure			
15-30	5	11.1	
31-45	13	28.9	
45-64	19	42.2	
>64	8	17.8	

2.Sex structure			
Male	39	86.7	
Female	6	13.3	
3. Marital status			
Married	40	88.9	
Divorced	3	6.6	
widowed	2	4.4	
4. Family size			
1-5	13	28.9	
6-10	29	64.5	
>10	3	6.6	
5. Educational status			
Illiterate	17	37.8	
Basic	13	28.9	
Clergy	3	6.6	
Formal(1-8 grades)	12	26.7	
6.Farm size(ha)			
0.25-1	5	11.1	
1.25-2	21	46.7	

2.25-3	19	42.2	
7.Size of Farm to support the family			
Enough	16	35.6	
Not enough	29	64.4	
8.Fertility of the holding With time			
decreasing	24	53.4	
increasing	20	44.4	
Not recognized	1	2.2	
9.Problem erosion on farms			
Exist	44	97.8	
Does not exist	1	2.2	
10. Influence of the Existing tenure on tr planting			
Negative	14	31.1	
Positive	31	68.9	
Planted *F. thonningii*	39	86.7	
Not planted *F. thonningii*	6	13.3	
11.Suitable areas for planting *F. thonningii*			

Homegardens	38	84.4	
pasture	44	97.8	
farm boundaries	26	57.8	
12.Source of planting material			
Private	42	93.3	
communal	3	6.7	
13.Time of planting			
March-April	16	35.6	
May-June	18	40	
June-July	11	24.4	
14. Management of *F. thonningii*	42	93.3	Other did not know
15.Shortage of wood for fuel for the family			
Exist	23	51.1	
Does not exist	22	48.9	
16.*F. thonningii* as source of fuel			
Use for fuel	39	86.7	
Does not use for fuel	6	13.3	
17.Crop Productivity near *F. thonningii*			

Decreased	28	62.2	
Increased (increased fertility)	9	20	
Did Not recognize	8	17.8	
18. Livestock feeding			
Free grazing and use of crop residue	45	100	
Use of hay (in addition to above)	31	68.9	
Shortage of feed recognize by	22	48.9	
Availability of feed	23	51.1	
19.Period of feed shortage			
March-April	8	17.8	
May-June	30	67.6	
May-August	7	15.6	
20. Use of *F. thonningii* as fodder			
For cattle	38	84.4	
For equines(besides for cattle)	41	91.1	
For sheep and goats besides Cattle and equines	21	46.7	
21. Problem with the species when used as fe		71.1	
palatability	9	20	

health	3	6.7	
22. Productivity of the fodder			
Milk increased	24	53.3	
Biomass increased	24	53.3	
23. Feeding F. thonningii to animals			
wilt leaves	33	73.3	
Fresh	6	13.7	
24. other species of fodder value under dang of local extinction	40	88.9	
25. Nr of F. thonningii planted in their holdin			
4-20	18	40	
21-40	8	17.8	
41-60	4	8.8	
61-80	3	6.7	
80-100	5	11.1	
>100	2	4.4	