Swedish University of Agricultural Sciences
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Master Thesis
No 89 2012

ISSN 1654-1367

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*Master Thesis, 30 ECTS credits* *Advanced level in Biology (EX0488)*
*MSc in Forest as Natural Resource 10/12*

*Supervisor SLU: Karl-Erik Johansson*
*Examiner SLU: Jan-Erik Nylund*

## Dedication

Before and first, thanks and praised be to GOD for giving me power to finalize this work. I would like to dedicate all my family for all things they did for me to know education besides their grateful support. A special dedication and thanks to my younger brother Abel Ketsela for his supportive idea and encouragement. Finally a grateful thanks to my ***Mother*** even though she cannot see my achievement.

## Abstract

Different eucalyptus species have an ability to grow in a wide range of ecological conditions and are found almost all over the world, mostly in tropical and subtropical countries. Small scale farmers in least developing countries plant eucalyptus widely compared to other tree species. Hence, the aim of this study was to contribute to the pros and cons of eucalyptus in different regions. Eucalypts have several important qualities for the smallholders; they are easy to establish even on degraded land and easy to manage, and have few natural enemies, a wide ecological range, good survival, high growth rate, many important uses and a reliable source of cash income. The use of eucalypt is environmentally controversial; it is difficult to prove that the genus has particular negative effects compared to other common fast growing plantation species. It was further found that eucalypts have specific economic advantages for the smallholders; a stable and accessible market even in remote areas, produce high value particularly on small densely planted woodlots and give an early return on investment compared to other plantation species resulting in a more even cash flow. Thus, eucalyptus hold obvious potentials to contribute to poverty alleviate among smallholders.

***Keywords:*** *Eucalyptus, small-holder, environment, cash flow, wood-lots, tropics, undergrowth*

## Acknowledgments

The first and deep acknowledge goes to my supervisor Karl- Erik Johansson (Kalle) for his valuable and constructive comment, advice and for all he did to make this manuscript attractive. I am grateful to thank my Advisor Prof. Jan-Erik Nylund for giving me interesting highlight and his supportive comment.

Not least but last I acknowledge Anders Lindhagen for his timely coordination and organization of this course. I would like to thank also my brother Elias Ketsela for his support in collecting the field data among farmers and from concerned bodies.

# Contents



**List of Acronyms**

| | |
|---|---|
| CIFOR | Center for International Forestry Research |
| FAO: | Food and Agricultural Organization of the United Nations |
| KFS: | Kenya Forest Service |
| SLU: | Swedish University of Agricultural Sciences |
| EFAP | Ethiopian Forestry Action Plan |
| EPA | Environmental protection authority |
| ETB: | Ethiopian birr |
| NPV | Net Present Value |
| CSA | Center for statistical Agency |

# 1 Introduction

## 1.1 Background

The word eucalyptus comes from Greek words “Eu” and “Kalypta” with the meaning “Well” and “Cover” respectively and together gives a meaning “well cover”. Therefore the name eucalyptus refers to the small cap covering the closed flower and described as ever green flowering tree and shrubs concerning the specific habitats (Chappendal, 1973; FAO, 1988; Khan and Hasan, 2007). Turnbull (1999) pointed out the name for Australian eucalyptus was introduced by the French botanist Charles Louis L. and Heritier De Burutelle after the middle of eighteen century and they gave a suggestion that eucalyptus species appeared for the first time at the coast of eastern Australia. This has an implication for the current eucalyptus species hopefully to say that almost all eucalyptus species are originated from Australia and neighboring islands.

The total numbers of eucalyptus species are estimated to be more than 700, native to Australia and neighboring countries (Bonald *et al*., 1984; Gratapaglia and Sederoff, 1994); about 30 species are widely grown as exotics around the world. For example *Eucalyptus globulus* originated from South- East and established widely in the South-West of Australia (Cromer, 1996; Aggangan *et al*., 1998) to address the pulp wood problems; in these area *E. globules* was grown on different soil types and different rainfall conditions (between 700 and 1500 mm of rainfall) and used to solve shortage of pulp wood for these locality (western part of Australia). The fertility of the soil around these areas was very low (Fros, 1991; Aggangan *et al*, 1998); that is sandy and have low pH, although eucalyptus grown well at these site there is a shortage of some nutrients (like nitrogen and phosphorus that eucalyptus needs to grow well).

Currently eucalyptus grows at different parts of the world resisting various weather condition due to its ability to adapt and grow well in area where there is excess water (marshy areas) and plenty of nutrients; drought areas, poor soils (unfertile soils), fire attacked areas, and on degraded lands (Gindaba, 2006; Pojonen and Pukkala, 1990; Eldridge et al, 1994; Jagger and Pender, 2003). The growth of eucalyptus shows different height at different climatic condition and it ranges from 457 to 9753 centimeter (Chappendal, 1973; Khan and Hasan, 2007) on poor and good site condition respectively.

Among flowering plants, eucalypts is one of the fast growing species in the world that provide various functions. It used for construction material, transmission poles, pulp wood and timber (producing furniture), energy purpose, farm equipments (utilities), etc. Eucalyptus species takes the first place from all exotic species commonly known and planted throughout the world (Eldridge *et al*, 1993).

Planting eucalyptus has a persistence effect on the land use of both temperate and tropical areas by affecting the microclimate condition, decreasing soil fertility, attracting seed dispersers and depressing competitive grasses (Lemineh and Teketay, 2005; Lemineh *et al*, 2004; Lugo, 1997). There are plenty of documents that explain the impact of plantation forestry (Lemineh *et al*., 2004; Parrotta *et al*., 1997) for the recolonization of native tree and shrub species; these recolonization have both negative on the environment and positive effect in the social aspects particularly for small scale farmers. But little is known regarding the regeneration process of the indigenous woody species related to the ground cover, nutrient competition and effect of canopy. Knowing and identifying the causes that protect and adhere the regenerative capacity of native (indigenous) woody species beneath the crown covers

(canopy) of the cultivated tree species (i.e. plantation) is thoroughly important to plan, design and solve suppression effect giving the successive place for regeneration (Lemineh *et al*., 2004; Parrotta *et al*., 1997). Eucalyptus as an exotic species also creates different impacts regarding the regeneration of native species and various grasses relative to natural forests although it is a debating agenda.

As Michelsen *et al*. (1996) reported natural forests are degraded at alarming rate in tropical regions and leads to different environmental problems (drought, climate change, frequent fire, etc) because of high rate of deforestation and land degradation in the regions. Zewude (2008) pointed out that the deterioration (degradation) of tropical environment contributes directly or indirectly to the Global environmental problems (for example: Global Warming, Ozone Layer depletion, rising of Sea Level, Disturbance of Rainfall Regime).

The annual destruction (degradation) of forest area in developing countries (Tropical and subtropical) is estimated around 15.4 million ha (FAO, 2005; Zewude, 2008). On the other hand tropical forest is the main store house of biodiversity, and it accounts 52% of the total forest area of the world forest (Brady, 1984; Murphy and Lugo, 1986; Lemenih, 2004). This indicates that destroying the tropical forest is destroying biodiversity throughout the world. The evidence for the destruction of the tropical forest area is that the forest area of developing countries decreases from time to time and plantation forest takes over including developed countries. For example, 4 million ha of forest land goes away (deforested) every year only in Africa (FAO, 2005).

Especially in sub-Saharan countries the degradation of natural resources typically forest resources depleted rapidly and leads to a complete eradication of natural resource services (Water, forest, fertile soils, biomass or fuel), different natural hazards (flood, drought) and lack of modern technology for accessing food production (Smaling *et al*., 1996; Lemenih, 2004). To overcome the environmental challenges (environmental problems comes due to deforestation) and save the remaining natural forest planting of fast growing tree is the solution in order to satisfy the ever increasing demand for forest product. It gives a way for urgent problems though these fast growing exotic species (including the use of tissue culture and clones) is a viable opportunity to solve the current dilemma between conservation and livelihood needs. The study done in Ethiopian highlands by Pohjonen and Pukkala (1990) indicates fast growing exotic species were planted extensively to conserve degraded land, unfertile agricultural area and abandoned land in addition to its contribution to solve the shortage of forest product demand for various purposes, such as, construction materials, timber and energy consumption. These exotic species have been planted on unproductive forest areas which have low quality. In the year 1992 more than 200,000 ha of land in Ethiopia were covered with exotic fast growing species, out of this a minimum of 60% were covered with eucalyptus (Ashagre *et al.,* 2005; EFAP, 1994). Eucalyptus is considered currently as the main woody species to fulfill the shortage of forest products and a means to give economical benefits especially for small scale framers in developing countries.

For example, in Ethiopia and other tropical countries the demand and supply of forest product, like: for timber and fuel wood, are not equivalent to the forest resource. A 2010 estimate shows that 85 million $m^3$ of forest product is necessary in Ethiopia for different purposes but the obtainable amount of forest product is only 12 million $m^3$ (Desaleng and Taddese, 2010). These results indicate there is a huge gap (beyond 700 %) between the demand and actual supply of forest product the country has on the market without considering the environmental issues. Furthermore the deforestation rate is extremely very high from time to time and it is

suggested that each year between 0.16 and 0.2 million ha of forest cut down illegally (EFAP, 1994). In order to conserve the natural resource and bring the balance between the population increase and the needs of the wood biomass (for fuel, construction and cash) tree planting in developing countries, like Ethiopia, is necessary (Gindaba, 2005; EFAP, 1994; Negash, 1994).

Planting of different trees species helps to solve environmental problems. The use of these fast growing species rather than indigenous tree species will bring a balance between supply and demand (Negash, 1994; Gindaba, 2005). However to plant exotic species like eucalyptus might be difficult without compromising ecological sustainability. Planting of tree on the bare land, as in area closures or area that is degraded, have a positive impact; since these lands are waste and do not have any functional value both from social and environmental perspectives' (Pohjonen and Pukkala, 1990; Jagger and Pender, 2003; Gindaba *et al*, 2005). Eucalyptus used as a main source of income for small scale farmers besides solving shortage of wood demands.

## 1.2 Objectives

The aim of this study is not to examine the environmental consequences, rather to contribute to the pros and cons of eucalyptus woodlots in the context of the smallholders from socioeconomic perspectives:

1. What are the factors that make eucalyptus woodlots preferable for small scale farmers?
2. Do the environmental controversies of eucalyptus reduce its potentials as means to improve the livelihood of smallholders?
3. What are the specific economic advantages of the eucalyptus woodlots to the Ethiopian smallholder farmers?

# 2 Method and Materials

Secondary data from existing studies was used in order to answer research question 1 and 2; literature reviews were done through search in Google scholars, Agris, and Web of knowledge.

Primary data were collected from farmers in Gimbichu woreda, Areda Gora and Indode Imbus kebele and secondary data from other existing studies was used to answer research question 3. Comparative analysis (CA) and stepwise regression was used to analyze the data captured. Market prices of different assortment of eucalyptus were collected from central highlands of Ethiopia: in Gimbichu, Sendafa, Debrezeyit and Addis Ababa (Fig. 1). The average market value of eucalyptus outputs for each city (town) was considered convenient since there is a variation in different market areas in one city (for example in Addis Ababa).

Five independent variables were included in the stepwise test: 1) size of woodlot area in ha, 2) site condition index from 1-3 (very poor, poor and medium respectively), 3) rotation period in years, 4) number of seedlings planted per ha and 5) number of stems (single trees) sold. These variables were tested against the profitability per stem sold in Ethiopian birr (ETB). The step wise regression was done using forward selection and backward elimination at alpha 0.05 respectively.

But the data for economic advantages of eucalyptus woodlots for small holder farmers specifically were collected only from Gimbichu district (Ethiopia) (Fig. 1). Gimbichu woreda found in the central highland of Oromia Regional State with an average altitude 2400 m.a.s.l and annual rain fall 1100 mm. This district is one of the food sufficient Woreda due to its high productivity of cereals and pulse crops. The total population of Gimbichu district is 86,238 (male 44,792 and Female 41,446) (CSA, 2007). The dominant crops grown in the district are wheat (*Durum wheat*), teff (*Eragrostis teff*), chickpea (*Cicer aretinum*), and lentils (*Lens culinaris*). Especially chickpeas and lentils are considered as cash crops due to its high demand and price in the market.

Seventeen small scale farmers with eucalyptus woodlots were randomly selected and interviewed using the questions presented in Appendix A. For the interview the farmers were selected randomly from two Kebeles, almost each farmer's in the Gimbichu Woreda have some eucalyptus tree in their plots of land (at least around the homesteads).

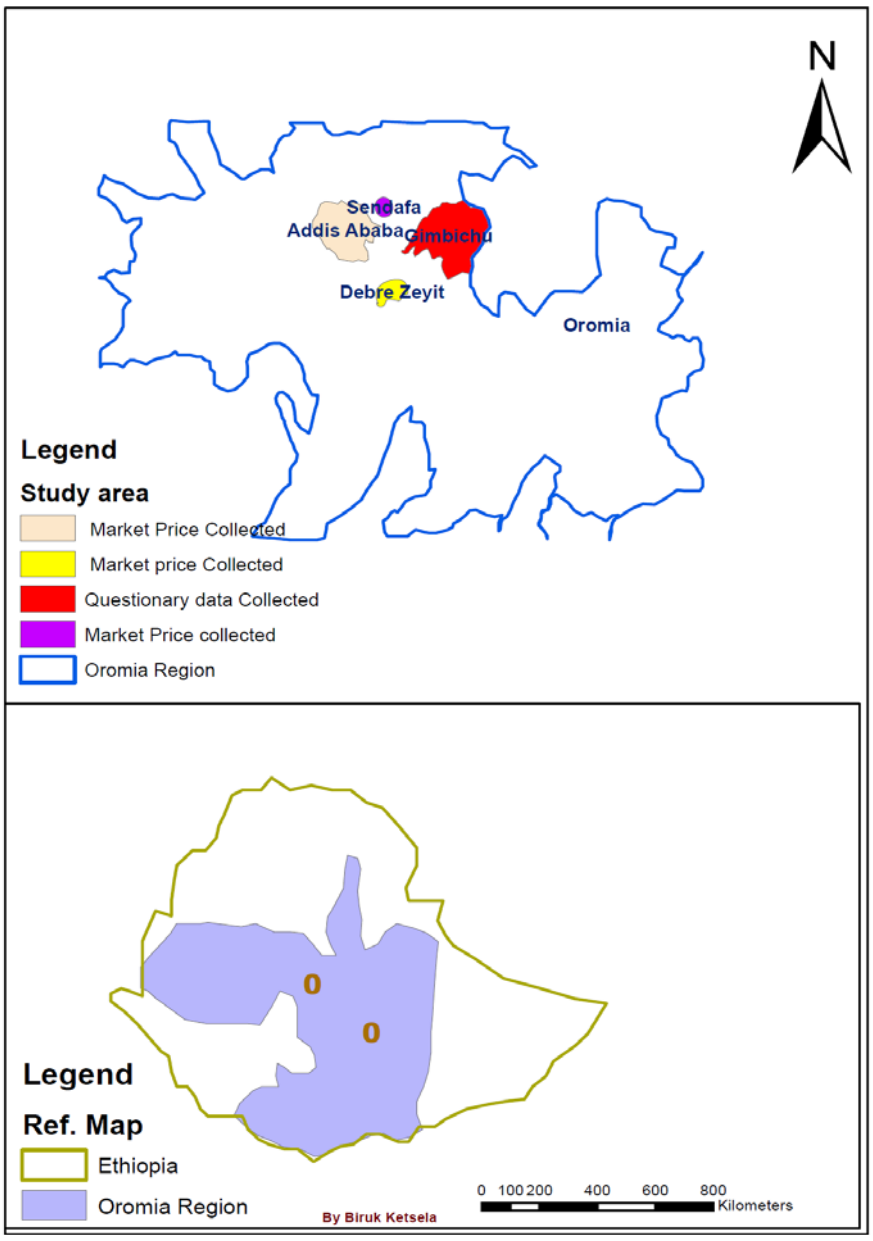


*Figure 1. Study Area (Obj. 3).*

The profit margin is used to measure profitability and includes income, revenue and cost. Before analyzing the profitability of every product (like biomass, agriculture crops knowing the cost of the land or land valuation (Land expectation value) helps to know the extent or degree of the profit (Kihiyo, 1996). Land Valuation is nothing but when capitalized the value of expected annual net income (URS, 2003). As Byran *et al*. (2008) indicated the profitability of biomass of forest as well as agricultural products calculated using the following values: NPV (Net Present value), IRR (Internal Rate of Return), and EAE (Equal Annual Equivalent). NPV, IRR and EAE are a tools mostly used to compare (for comparative analysis) agricultural crops and forest products. EAE is an indicator of the profitability of the cash flow of a project based on its yearly income. Comparative analysis (CA) is one of the evaluation methods for comparing the profitability of different products, such as eucalyptus biomass with agricultural crops or other tree species, by using the NPV. Land expectation value used for the analysis in order to consider the costs of land used for planting eucalyptus or to know what value the land

has without eucalyptus. Each of them has a distinct formula (Kihiyo, 1996; Byran *et al*., 2008; Kibebew and Ayele, 2010) and presented as the following ways.

$LE = \sum NR_{t*}(1+i)^{-t^*} + PV_T\,(1+i)^{-T^*}$

Where:

- LE = Land expectation Value,
- $NR_t$ = Net value at the beginning of rotation with discounting,
- I = Interest rate
- $PV_t$ = Present Value at a perpetual periodic annuity will be received every year t*
- T = Rotation period in years,
- T = Age in years
- t* = the number of years between annuity payment

The present value is used to calculate the income of eucalyptus plantation at each rotation period by considering its initial cost (like cost of land, labour cost, and input cost)

$$PV_T = \left( \sum_{t=T} NR_{t*}(1+i)^{-t} \right) \frac{(1+i)^{t^*}}{(1+i)^{t^*} - 1}$$

## 2.1 Assumptions

In this study it is assumed that artificial fertilizers and irrigation has not been used to promote the growth of trees Smallholders may apply animal dung and different wood residual in woodlots in a few cases, however this is assumed to vary randomly; this is because even to use artificial fertilizers for crops is very expensive for small scale farmers and animal dung is usually applied on high value agricultural or horticultural crops.

## 2.2 Limitations, Reliability and Validity of the Study

Different scientific literatures and empirical data were used to increase the validity of the results of the thesis. Regional and country wise considerations were taken for collecting data from the scientific articles based on the social, economical and environmental factors. The economical impacts of eucalyptus woodlots validated from primary data (formulating different questionnaires and interview) and strengthened by different scientific studies done for similar purposes.

Reliability of the data was evaluated using statistical test (step wise regression) and scientific literature searching tools. To make the test more reliable and checking correlation missed data in the collected information (questionnaires) was skipped. The correlation between different variables also considered to increase the reliability of the test results and also different steps taken by adding and removing the variables in to and from the test for the existed variables.

There was shortage of data / literatures in this study. Different articles reviewed have no enough data to support the aims and result of this study. Farmers were not voluntary to give all data, especially the income they get from eucalyptus woodlots; hence it was only possible to obtain reliable data from seventeen farmers. Some variables that were not considered in the field had negative impacts for the statistical test not to have a perfect correlation between each factor. Further, there are unknown factors that are not visible might bring additional influence but needs further investigation.

# 3 Literature Review

## 3.1 Factors that Makes Eucalyptus Preferable by Small Scale Farmers

Eucalyptus gives superior and versatile benefits (Table 2) compared to many other tree species due to this fact often farmers choose to plant eucalyptus, particularly smallholders in tropical and subtropical regions. The most commonly used eucalyptus species in eastern and southern Africa are *E. camaldulensis, E. grandis, E. globules,* and others (Table 1). Smallholders plant these species widely on their fragmented land such as around homesteads, on grazing land, boundaries, etc.

*Table 1. Common species of eucalyptus planted by small scale farmers in tropic and sub tropical countries*

| Country | Eucalyptus species commonly planted | Year of introduction |
|---|---|---|
| **Ethiopia** | *E. camaldulensis, E. saligna, E. globulus, E. ragnans, E. tereticornis* | Around 1890s |
| **Kenya** | *E. grandis, E. paniculat, E. camaldulensis, E. saligna, E. globulus, E. ragnans, E. maculata E. citriodora, E. Hybrids* | Early 1900 |
| **Rwanda** | *E. grandis, E. paniculat, E. camaldulensis, E. saligna, E. globulus, E. ragnans, E. maculata E. citriodora, E. tereticornis, E.microcorvs, E. maidenii* | 1900s |
| **Sudan** | *E. camaldulensis, E. microtheca* | - |
| **South Africa** | *E. nitens, E. bicostata, E. macarthurii, E. smithii, E. dunnii, E. grandi, E.globulus* | - |

Source: Friis, 1995; Oballa and Chikamai, 2010; Gavin *et al*, 2004; Komakech *et al.,* 2007; Dessie and EraKos, 2011. *NA: data not Available*

For instance, *Eucalyptus globulus (*Key Beharizaf*),* and *Eucalyptus camaldulensis (*Nech Beharizaf*)* are the most commonly used eucalyptus species in Ethiopia (Table 1). Because of its wide ecological range and multi-functional advantage farmers (those living in diverse soil and climatic conditions with different needs) can plant and use eucalyptus. Eucalyptus plantations have expanded considerably among smallholders and small forestry firms in Ethiopia are placing Ethiopia at the second place in the world in terms of area planted with eucalyptus (Getahun, 2010). The factors that contribute to the popularity of eucalyptus among smallholders can be grouped into five categories as presented in Table 2; establishment, ecological range, survival, management requirement, growth rate and opportunity investment.

**Establishment:** Accessibility of seeds from the mother tree (seed collection) is simple, locally available and do not require special treatment to keep (store) for long time (Amare Getahun, 2010; Selamyihun, 2004). Eucalyptus as a genus is also well known for its good coppicing ability, it usually forms a dense and productive stand if allowed to re-grow (Selamyihun, 2004). Moreover, the germplasm of eucalyptus species has proved to be easily adaptable to different environmental and climatic conditions compared to various species, like, *Cupressus lustinica,* and *Juniperus procera* that have been found to be susceptible to some naturally occurring pathogens besides having a slow growth rate *(*Kebebew and Ayele, 2010*).* Most eucalyptus species are easily established as bare root seedlings which are (Pohjonen and Pukkala, 1990) cheap and easily affordable to smallholders compared to a container or plastic bag that is labour demanding. However, Johansson (2001) found that establishment can be considerably improved if polythene tubes of different sizes are used to adapt seedlings to different site conditions reducing the problem of weed competition and dry spells.

A system such as raising a few seedlings at a time is particularly use full and adapted to smallholders. Using plastic bag/ containerized seedling are more costly even if labour is saved (on watering and weeding), easy to establish, and considerably higher survival rate compared to bare–root seedlings. The coppicing ability and its fast secondary growth is another important advantage of eucalyptus particularly to the small scale farmers (Zerfu, 2002; Mekonen *et a*l., 2007). Growing in densely populated stands in one to two years has little negative effect on both diameter and height development of most eucalyptus species (Whitesell *et al*., 1992). This is an added advantage from the perspective of the smallholders since there is frequently thinning done for woodlots to improve cash-flow. Getahun (2002) stated that the long-term experience that smallholders have with eucalyptus in Ethiopia (about 100 years) contribute to the extensive use and establishment of eucalyptus in the Ethiopian highlands. Pohjonen and Pukkala (1990) state that eucalyptus has fairly short nursery periods (a maximum of four months) and provide seed every year after the onset of flowering (i.e. after five years). Johansson (2001) found that the time in the nursery can be reduced if it is optimized with the nursery stock density to match specific site conditions at the planting site and still get improved establishment results.

**Ecological range:** Eucalyptus can grow: in degraded land, swampy area, unfertile and exhausted soil, and in dry areas (Pohjonen and Pukkala, 1990). Eucalyptus can substitute many indigenous species that have diverse environmental and biodiversity functions for the surrounding area to specific and regional benefits to a large extent (Mekonnen, 2010; Keleb and Tadesse, 2010). This ecological advantage of eucalyptus helps the farmers not to be affected as a consequence of different ecological problems like drought, excessive runoff or water-logging. Jagger and Pender (2000) indicate that eucalyptus grows in a swampy or water logged area. In this case where eucalyptus can be used to dry up water logged sites it has an advantage for reduction of malaria. Eucalyptus also grows well in dry areas (Jagger and Pender, 2003) where there is a minimum amount of rainfall such as in northern part of Ethiopia (Tigray); most of the areas in this region get in average less than 800 mm rainfall per annum.

**Survival:** Another important reason contributing to the popularity of eucalyptus is its good survival rate. Leaves and barks of eucalyptus are not/less palatable to most browsers such as cattle or livestock and wild animals it can be established and grows without any physical damage (Getahun, 2002; Atkinson *et al*., 1992; Jagger and Pender, 2003; Pohjonen and Pukkala, 1990) weighed against other woody species, such as *Olea African, Cuprusus lustinica, Juniperus procera, Cordia African, Acacia albida, Gravilia robusta* that are browsed by different grazers starting from their seedling stage but eucalyptus not (Getahun, 2002; Jagger and Pender, 2003).Compared to most other commonly used exotic tree species eucalyptus species are not sensitive for the attack of different tree diseases/pathogens, pests, and environmental stress (water, and nutrient deficiency). The reason for this as White (n.d) stated is that the genetic diversity of eucalyptus by itself has a power to resist serious infectious disease and environmental factors (Table 2). High coppicing ability and its efficiency to convert the available soil resource to biomass production also contribute to its good survival (Getahun, 2002; Davidson, 1995; Jagger and Pender, 2003). The root collars of eucalyptus are resistant to fire even if the aerial part or above ground parts are burnt; the bark at early age not resistance against fire but when it gets older it is not burnt easily.

**Management requirements:** eucalyptus does not require intensive management hence reducing the labor cost. Farmers prioritize to plant eucalyptus on their pieces of land in different ways, e.g. on miscellaneous land, farm boundaries, around homesteads than other

plant species because of its simple management (Kebebew and Ayele, 2010; Getahun, 2002; Getahun, 2010). Dessie and Erkossa (2011) reported that small scale farmers use their traditional knowledge to collect and grow seedlings, transplant, and sell to the market without the presence of extension services. Since the root system of eucalyptus grow deep and extensive the need for irrigation and fertilizer are relatively low. However in less fertile area it is possible to increase the production by using natural fertilizers (locally available fertilizer) since commercial (artificial) fertilizers are not affordable to smallholders (Dessie and Erkossa, 2011; Whitesell et al., 1992). Management of the eucalyptus is dependent on the scale of plantation (small scale or large scale); at small scale level intensive management and advanced skill does not need. In Ethiopia, small scale farmers use their traditional knowledge to manage eucalyptus plantation (they collect seed from matured (dominant) tree, grow seedling, transplant, and sell to the market). Farmers in Rwanda plant eucalyptus in agroforestry systems for the sake of easy management.

**Growth rate:** If the planting sites have a good condition of nutrient and water eucalyptus can starts to give output from third or fourth year depending on the intention of the farmers (Getahun, 2002; Kebebew and Ayele, 2010; Pohjonen and Pukkala, 1990). The growth rate of eucalyptus depends on different management factors like spacing, site conditions, amount of rainfall, although eucalyptus provides yield in all ecological conditions. For example, the spacing used for growing eucalyptus by small scale farmers in different regions varies from the recommended one 2500 (2m by 2m) to 160,000 (0.25m by 0.25m) seedling per ha (Dessie and Erkossa, 2011; Keleb and Tadesse, 2010).

Kelemu and Tadesse (2004, 2010) state that in Northern part of Ethiopia eucalyptus provides a proportional increase for the income of the rural small scale farmers of 20% (excluding its value for house hold consumption such as fuel wood, construction) in the year 2008/09. Due to the increase of the income the land allocated for eucalyptus plantation increases around 30% from the year 2004/05 to year 2009/2010 (Kelemu and Taddesse, 2010). Furthermore farmers plant about 10,000 seedlings per hectare that start to give yield after four-year from planting and every three or fourth year after the first rotation. Before the final rotation of next rotation it has been known that the farmers carry out thinning and they make use of the thinned small tree for construction of wall, fuel wood, boundary fencing.

Selamyihun (2004) state that eucalyptus provides a better yield of return for the framers compared to crops (like wheat) in consideration of both labour cost and land use (land allocation) angles. Basically in Ethiopia eucalyptus takes over around 25 percent of the household annual cash income and farmers prefer eucalyptus due to its economic potentials and it has a good potential to improve the livelihoods of the small scale farmers. Urgent increase in demand and its best survival attracts farmers' attention (Mekonen *et al*, 2007; Kelemu and Tadesse, 2010).

**Multiple uses:** Small scale farmers consider eucalyptus as a Nature's gift; as a contribution to retirement owing to the different benefits it provides assisting in their daily livelihoods expenses. As FAO (2002) reported, eucalyptus is preferred by small holder farmers particularly on account of the following basic services;

- It is used for fuel woods for developing countries like, Ethiopia where the other energy source is not available or affordable (even if it is there like electricity not affordable for each poor households),

- Its uses as construction material, such as: as poles and stakes for construction of house, fencing, transmission pole,
- It can be used for making farm utilities (equipments),
- It generates income with a comparatively good cash-flow since it produces yield with a short period of time. Therefore, it is used as a cash crops by farmers to cover some of their daily overheads (costs),
- It can be used for production of charcoal,
- Farmers also suggests that planting of eucalyptus is the management strategy to prevent soil from being eroded or as an erosion controlling mechanism,
- Eucalyptus is also used as, shelter belt; drainage and wind break for their fragmented land (Selamyihun, 2004; Lemeneh, 2010),

Because of its fast development, farmers prefer eucalyptus to solve the growing demand for wood and wood products. For the reason that of its various benefits farmers started to change even their fertile farm land to eucalyptus plantation currently to generate income and address the ever-increasing shortage of wood products (Negussie, 2004; Dereje, 2009; Lemenih, 2010). With a proper planning for management and a good access of local market eucalyptus has comparatively good capacity to increase the income level of small scale farmers in addition to its role for alleviating farmers' constraints of fuel wood, construction materials and farm equipment. From dense plantation and increased density after coppicing, small-scale farmers used to plan thinning programs that give wood for construction and fire wood before the final felling (Selamyihun, 2004).

Lemenih (2010) reported that small holder farmers in Ethiopia believe eucalyptus is like money deposited in the bank, a tree bank, "safety net", "life savior". They regard it as means to get income easily at times, when they face a shortage of money just as withdraw money from the bank. For rural development and poverty alleviation eucalyptus as Lemenih (2010) stated is an" immense" asset. Giving only environmental focus has a different disadvantage for poor farmers but instead it is necessary to consider both social (the poor households) and ecological issues in order to achieve economical targets for small scale farmers. An important reason why farmers see eucalyptus as safe investment is its continued demand and good survival (Lemenih,2010).

*Table 2. Attributes and factors that contribute to make eucalyptus species preferable to smallholder compared to other commonly used plantation species in sub-tropical and tropical areas as reported by different scholars*

| Factor | Justification and examples | References |
|---|---|---|
| **1. Establishment** | In Ethiopia, the coppicing ability of most eucalyptus species is very good with higher increment in the second and third rotation, with a production reaching 2900 kg /ha/yr. Germplasm of the most common eucalyptus species are readily available everywhere in Ethiopia but other species not, e.g. *Cuprsus lustinica*, *Juniperus procera.* As it is traditionally well known in Ethiopia many smallholders raise seedling using their own resources (there is no need to purchase seed) and knowledge. The cost for coppicing rotations are close to zero. | Whitesell etal, 1992; Schonau and Coetzee, 1989; FAO, 1979; FAO, 2002; Zerfu, 2002; Mekonen *et a*l., 2007; Kebebew and Ayele, 2010; Dessie and Erkossa, 2011; Getahun, 2010; Getahun; 2002 |
| **2. Ecological range** | In Ethiopia, the ecological range of the genus eucalyptus shows a good performance from a mean annual rainfall of 800mm up to over 2000 mm and altitude between 2000 - 3500 m a.s.l. It can grow in a wide variety of soil and ground conditions from fertile to unfertile and degraded soil, from coarse to fine texture, and from dry to waterlogged conditions. | Mekonnen, 2010 Yirdaw and Luukkanen, 2003; Gemmechu, 1977; Whitesell, 1992; Ball, 1995; White, n.d; FAO, 1985; Selamyihun, 2004; FAO, 2002; Davidson , 1995; Pohjonen and Pukkala, 1990 |
| **3. Survival** | Some species of eucalyptus like *E. camadulensis* are not affected by the specific tree disease in Highland of Ethiopia. Leaves of eucalyptus are not palatable to browsers, domestic and wild animals' especially E. globules. It is also comparativel resistant to fire. . | Whitesell etal, 1992; White, n.d; Atkinson *et al*., 1992; Jagger and Pender, 2003; Pohjonen and Pukkala, 1990; Zerfu, 2002; Mekonen *et a*l., 2007; FAO, 2011, Getahun, 2002 |
| **4. Management requirement** | Since the root system of eucalyptus grow deep and extensive the need for irrigation and fertilizer are comparatively low. In Ethiopia, the well spread traditional knowledge for the establishment and management of eucalyptus is sufficient for the management of the small woodlots of smallholders. | Kebebew and Ayele, 2010; Dessie and Erkossa, 2011; Whitesell etal, 1992 |
| **5. Growth rate** | In favorable conditions most fast growing eucalyptus species/clone can be harvested at 3 years (even less) but have an average rotation period of 8 to 12 years, considerably shorter compared to other plantation species. The second rotation can be even less than 4 years in an adequate conditions (soil fertility and moisture is good enough) increasing between 20 – 50 % as compared to the first rotation. | Katsvanga *et a*l., 2006; Whitesell *et al.*, 1992; Mekonnen, 2010; Keleb and Tadesse, 2010; Selamyihun, 2004, Kidanu and Ayele, 2004 |
| **6. Multiple uses** | Eucalyptus can substitute many indigenous species. The wood of eucalyptus has many uses; fuel wood, construction material, farm equipment, poles, transmission poles, timber, pulpwood. In Ethiopia there is a market for the wood of eucalyptus of different uses at the local level. The buyers of eucalyptus the middle men reach in the remotest areas making farmers sure that the market is available. | Mekonnen, 2010; Keleb and Tadesse, 2010; Selamyihun, 2004, Kidanu and Ayele, 2004; Schönau, 1991; Yirdaw and Luukkanen, 2003; Whitesell *et a*l, 1992; Desalegn and Tadesse, 2010; Ball, 1995 |

In addition eucalyptus has a social value as its widespread use create employment opportunity for women and youths in rural areas where there are few other opportunities. Since degraded land is common everywhere in the Ethiopian highlands women and youth plant eucalyptus on this fragmented land as a means to create opportunity for income generation (Jagger and Pender, 2003). Kelemu and Taddesse (2010) discovered that planting of eucalyptus create job opportunities for females (about 60%) compared to males starting from seed collection up to the final logging. For example, raising seedlings digging holes, weeding, carrying logs and collection of remains of logs like branches, leaves, barks, etc is mostly done by females.

Hence, smallholders in Ethiopia prefer to plant eucalyptus due to its positive influence on their livelihood, and the contribution to job opportunities for all ages and particularly for women. There is no other exotic tree species that can play such a vital role for farmers benefit at such a large scale (Gemmechu, 1977; Whitesell, 1992; Ball, 1995; Yirdaw and Luukkanen, 2003; Jagger and Pender, 2003; Selamyihun, 2004). Even though the small scale production of eucalyptus may not be

sustainable and transferred to next generation but for them to consider sustainability is difficult, since they struggle hard with their own every day survival rather than thinking about the benefit of the coming generations.

## 3.2 The Environmental Controversies over Eucalyptus

Eucalyptus species are generally assumed to cause different environmental problems. However, different researchers investigating the positive and negative environmental aspects of eucalyptus plantations do not have a common agreement on its disadvantages. Some of the most important controversies of eucalyptus are:

1. Whether eucalyptus consume too much water or not
2. Whether eucalyptus takes up excess nutrients from the soil or not
3. Whether eucalyptus decreases the biodiversity in the undergrowth or not
4. Whether eucalyptus improve the control of soil erosion or not

### *3.2.1 Water Consumption*

It appears from the result presented in table 3 that there are a number of situation in which the water consumption is less than that of other species; for example potatoes need around 1000 liter of water to produce one kg of biomass on the contrary eucalyptus needs about 510 liter of water to produce one kg of biomass. Except maize and sorghum many other tree species and even crops may consume more water per produced kg of biomass relative to eucalyptus. Additionally, eucalyptus species if planted at the area where there is excess amount of rainfall, provide protection of runoff, protect flooding and reduce formation of water logging area by taking up more water for its high biomass production (Jagger and Pender, 2000).

*Table 3. Eucalyptus water use (EWU) and Crops (tree) water use (CWU) in different countries*

| Eucalyptus | Water use ( L /Kg) | Crops / tree | Water use ( L /Kg) | EWU /CWU | Ref |
|---|---|---|---|---|---|
| **Hybrid** | 480 | *Acacia Auriculiformis* | 720 | 0.67 | Senelwa *et al* (2009) |
| **Species** | 785 | *Acacia* | 1320 | 0.59 | Davidson, 1989, 1995 |
| **Species** | 785 | *Dalbergia species* | 1483 | 0.53 | Davidson, 1989, 1995 |
| **Hybrid** | 480 | *Pongamia pinnata* | 880 | 0.55 | Tiwari and Mathur, 1993; oballa *et al*, 2010 |
| **Camaldulensis** | 930 | *Dalbergia sisso* | 890 | 1.04 | Zahid and Nawa, 2007 |
| **Species** | 785 | *Syzygium species* | 1017 | 0.77 | Davidson, 1989, 1995 |
| **Hybrid** | 480 | *Acacia auriculiformis* | 720 | 0.67 | Patil, 1995 |
| **Hybrid** | 480 | *Syzygium cumni* | 500 | 0.96 | Tiwari and Mathur, 1993; oballa *et al*., 2010 |
| **Species** | 785 | *Cotton/coffee* | 3200 | 0.25 | Davidson, 1989, 1995 |
| **Hybrid** | 480 | *Albizzia lebbek* | 550 | 0.87 | Patila, 1995 |
| **Species** | 785 | *Soya bean* | 1430 | 0.55 | Davidson, 1989, 1995 |
| **Hybrid** | 480 | *Pongamia pinnata* | 880 | 0.55 | Patila, 1995 |
| **Hybrid** | 785 | *Potato* | 1000 | 0.79 | Davidson,1989 |
| **Hybrid** | 510 | *Maize* | 500 | 1.02 | Getahun, 2010 |
| **Hybrid** | 510 | *Sorghum* | 250 | 2.04 | Getahun, 2010 |

Jagger and Pender (2000) assert that eucalyptus is one of the exotic plant that convert water and other available resources to biomass and it is suitable for the benefit of rural small scale farmers in support of their daily livelihoods.

The negative impact of eucalyptus on the hydrology and nutrient content of the soil does not outweigh its livelihood contributions (Ghosh *et al*., 1978; Zewude, 2008) from small scale farmers' point of view. Jha and Pande (1984) reported that the soil under eucalyptus maintain higher moisture levels and helps to increase the PH of the area compared to the soil under natural forest. However, Walter (1984) concludes based on a review of different studies that eucalyptus creates water deficits in semi arid areas with a minimum rainfall. When stand age of eucalyptus increases the uptake of water also increases and as a consequence the moisture content of the soil under mature stands is less compared to that under younger stands, up to 250 m down in the soil.

Akhter *et al* (2005) wrote that the water use efficiency (WUE) of eucalyptus in dry areas is less than that of acacia species. They did a test for WUE of both *Acacia ampliceps* and *Eucalyptus camnaldulensis* grown for one year in a lysimeter and the result approved that *A. ampliceps* could use the water 5 times more efficient than *E camaldulensis* in low moisture soil (less watered) (50%), 9 times more efficient in medium moisture soil (75%) and 12 times more efficient in high moisture soil (well watered) (100%)*;* WUE of eucalyptus compared to Acacia decreases as moisture content of the soil decreases. According to Akhter (2005) although eucalyptus produces more biomass it has less water use efficiency. But Poore and Fries, 1985; Michelsen *et al*., 1996; Jagger and pender, 2000; Kidanu *et al*, 2004 stated that the WUE of eucalyptus is higher than most tree species. Anne (1997) argues that eucalyptus causes streams and rivers to dry and disturb the water balance by lowering the water table.

Different measurements about the hydrological impact of fast growing plant species particularly on eucalyptus analyzed by different researchers considering the physiology of the plant, the rainfall of the area, the moisture content of the soil and the amount of water absorbed by specific plant or tree conclude that eucalyptus does not have a unique negative impact (Davidson, 1990; Calder *et al.,* 1993; Anne, 1997). Calder *et al* (1993). They summarized from different articles that young eucalyptus plantation does not show any difference for uptake of water in a dry area up to 3 meter depth compared to indigenous plant species. In dry areas the water requirement of eucalyptus and native species are proportional to the amount of rainfall the area receive. A numbers of investigation shows that the water uses of forest (both indigenous and older eucalyptus) are greater than that of crops in dry zones of India (Calder *et al*., 1993). This is true for some crop species (Maize and Sorghum) in the Ethiopian case as interpreted by Getahun (2010) (Table 3). However, Teshome (2009) stated these crops take more water than eucalyptus; both Maize and Sorghum needs around 1000 liter of water to produce one kg of biomass. According to Calder *et al* (1993) there is no evidence that proves eucalyptus take more water than any other indigenous dry deciduous and exotic forest in India.

Teshome (2009) also concludes that eucalyptus does not consume more water than any tree species and crops in Ethiopia; rather it is efficient in using moisture around roots and converts to biomass. In a study in Ethiopia eucalyptus produced more biomass than coniferous and broad leave tree species growing within the same amount of rainfall regime, for example, in Nekemt area (Ethiopia) *E.saligna* and *E.camaldulensis* could produce 46.6 m3/ha/yr without affecting the water reserve in an area with 2158 mm of rainfall, while conifers, broad leaves and acacia produce lesser amount of biomass 16.4, 16.0 and 12.4 $m^3$/ha/yr respectively (Davidson, 1989; Teshome, 2009). These figures indicate the water use efficiency of eucalyptus species is comparatively good with the biomass produced.

In moisture deficit areas where the soil depth is greater than 8 m shows that forest particularly fast growing tree species tends to consume more water than the amount of rainfall the area receive. For instance: in some arid regions of Australia eucalyptus uses about 3600 mm of water per annum which is by far greater than the annual 800 mm of rainfall (Greenwood and Beresford, 1979; Calder *et al*., 1993) but from where the plant get the extra moisture is under investigation. According to Calder (1992) the moisture content in the soil depends on the transpiration and interception of a tree species. He, conclude that the development and water requirement of eucalyptus in dry area (water deficit site) have a linear relationship with the amount of water evaporated, which is the volume of growth of eucalyptus has a direct relationship with the volume of water transpired.

When the water consumption of eucalyptus is compared with different agricultural crops and tree species the result found from different literature approve that eucalyptus consumes less water (Calder 1992; Davidson, 1995; Tesfaye, 2009; Patil, 1995; Getahun, 2010). However others (notably Zahid and Nawa, 2007; and Getahun, 2010) conclude that eucalyptus consumes more water than other crops such as maize and woody species. Also, D. sissoo show a better water use efficiency compared to eucalyptus. From the small scale farmers' perspective the potential of eucalyptus to produce higher biomass from as little water as possible is a concerning issue. Farmers' live in different agro ecological zones, for those living in high rainfall areas the main concern may be maximum yield of trees whereas in low rainfall areas their main focus may also be maximum biomass production but with minimum disturbance on the water consumption without costing other important production. Basically water is necessary for all production, but eucalyptus exploits the available water more efficiently to produce higher yield during short period. The main problem comes when eucalyptus planted in large areas because of reducing the water supply for other crops. On the other hand planting eucalyptus in small plots helps to minimize the risk of competition for water.

### *3.2.2 High Level of Nutrient Uptake*

Another controversy of eucalyptus is its efficient nutrient uptake that gradually exhausts the soil nutrient. Eucalyptus is a non-nitrogen fixing tree and does not have capacity to replace the nitrogen it consumes like leguminous tree species.

*Table 4. The Status of Eucalyptus Nutrient uptake (ENU), and Crops or Trees Nutrient Uptake (C/TNU, kg/ha)*

| | Nutrient uptake (kg/ha) | | | | Nutrient uptake (kg/ha) | | | ENU /C(T)NU | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Eucalyptus** | **N** | **P** | **K** | **Crops / tree** | **N** | **P** | **K** | **N** | **P** | **K** |
| **species** | 76.0 | 6.0 | 43.0 | Rubber | 312.0 | 33.0 | 163.0 | 0.24 | 0.18 | 0.26 |
| **species** | 76.0 | 6.0 | 43.0 | Tea | 240.0 | 20.0 | 100.0 | 0.32 | 0.30 | 0.43 |
| **E. robusta** | 200.0 | 78.0 | 105.0 | C. equisetifolia | 560.0 | 119.0 | 210.0 | 0.36 | 0.66 | 0.50 |
| **E. robusta** | 200.0 | 78.0 | 105.0 | A.procera | 540.0 | 102.0 | 370.0 | 0.37 | 0.76 | 0.28 |
| **species** | 76.0 | 6.0 | 43.0 | Coffee | 110.0 | 9.0 | 120.0 | 0.69 | 0.67 | 0.36 |
| **Camaldulensis** | 148.6 | 10.5 | 124.3 | D.sisso | 72.4 | 2.5 | 18.0 | 2.05 | 4.20 | 6.91 |
| **E.robusta** | 200.0 | 78.0 | 105.0 | L .leucocephala | 210.0 | 23.0 | 107.0 | 0.95 | 3.39 | 0.98 |
| **species** | 76.0 | 6.0 | 43.0 | Maize | 160.0 | 30.0 | 150.0 | 0.48 | 0.20 | 0.29 |
| **species** | 76.0 | 6.0 | 43.0 | Sorghum | 120.0 | 21.0 | 95.0 | 0.63 | 0.29 | 0.45 |
| **grandis** | 185.4 | 12.2 | 84.5 | D.sisso | 72.4 | 2.5 | 18.0 | 2.56 | 4.88 | 4.69 |
| **species** | 76.0 | 6.0 | 43.0 | Sugar cane | 150.0 | 30.0 | 210.0 | 0.51 | 0.20 | 0.20 |

Source: Davidson, 1995; Hunter, 2001; Wang *et al*., 1991

Compared to the natural forest, Eucalyptus can potentially decrease the fertility of the soil (Teketay, 2003); since nutrients are recycled in natural forest, while eucalypt is harvested and nutrients removed. On the other hand an investigation carried out in Kenya to compare the nutrient content of tea plantation and eucalyptus showed that eucalyptus has high micro nutrient content compared to that of tea plantation (Oballa and Langat, 2002; oballa *et al*, 2010). Modeling the nutrient cycling for any forest type is not easy, since different environmental factors, like weathering of parent materials, affects the replenishment of nutrients (Tesfaye, 2009). The high and efficient nutrient uptake of eucalyptus is a debated environmental agenda all over the world. Some researchers argued that eucalyptus does not consume more nutrients relative to other tree species and crops (Table 4; Tesfaye, 2009) but others (Wang *et al*, 1991; Kidanu *et al*, 2006). Getahun (2010) stated that eucalyptus is not aggressive for the uptake of nutrient and water compared to other plant species and crops. It is logical that fast growing species in general, consume more nutrients and water to provide for the higher amount of biomass they produce. For poor smallholders to grow eucalyptus may be a question of subsistence and survival particularly for those that do not have an alternative. In this case the question is about the tradeoffs between eucalyptus outputs and environmental sustainability (Anne, 1997; Kidanu *et al*, 2006; Tesfaye, 2009; Zegeye, 2010).

Jagger and Pender (2000) found that for degraded land and waste land eucalyptus helps to conserve the top soil of hill sides and improve the fertility (nutrient content) of the soil through litter fall. Hence, planting of eucalyptus in degraded and non fertile area (barren land) getting trees to survive add both value and improve sustainability of the land. The negative impact of eucalyptus might be clearly visible if planted near the annual crops (competition for nutrients); but the details of how much nutrients is depleted and how much organic matter contributed is not clearly identified (Jagger and Pender, 2000). From their study in Ethiopian highland on Nitosol, Kidanu *et al* (2004) found that the yield of crops like wheat *(Triticum aestivum)* show a significant reduction within a distance of the first 8 m during the first rotation and within a distance of 16 m during the second rotation of eucalyptus due to insufficient nutrient, light and water.

Similarly in India Saxena (1991) found a reduction in crop yield due to eucalyptus plantation around crop fields and in those fields used for cultivation adjacent to eucalyptus woodlots. From interviews he found that most farmers had destroyed their eucalyptus plantation after the first rotation and turned the land into crop production since the benefits of eucalyptus was less compared to annual crops. In India (Muzaffarnagar and Nainital, North west part) the loss of crop yield due to the effect of eucalyptus start from the first two year after planting; 0% in crop yield during the first and second year, 8.2% in the third year, 13.6% in the sixth year, 26.4% in the seventh and eighth year and 48.8 % in the ninth and tenth year. The loss in crop yield was attributed the completion of eucalyptus for nutrient, water and light (Ahimed, 1989; Saxena, 1991). Saxena (1991) noted that the losses of crop depend on the spacing between rows (stem density), application of water and other management regimes. Some nutrient like potassium, phosphorus, calcium and magnesium will be returned to the soil during the logging and post logging burns (Nobel, 1992; Davidson, 1995). These findings highlight the importance of nutrient management during the cutting cycle of eucalyptus an important aspect to be considered by the smallholders as they normally lack access to fertilizer.

DeBell (*et al*., 1985) demonstrated that inter-planting of leguminous tree in eucalyptus stands in Hawaii was the best solution to reduce the depletion of nutrients. In a field trial (about 6 years) eucalyptus mixed with Acacia and Albizzia was compared with the pure stand of eucalyptus. The result showed the mixed stand of eucalyptus (both with Albizzia and Acacia) have better performance both in diameter and height (63 percent taller and 55 percent larger in diameter with mixed stand of Albizia, and 25 percent taller and 28 percent larger in diameter with mix of Acacia) than the pure stand (DeBell *et al*., 1985). The mixed stand of eucalyptus also gave higher yield per hectare than the pure stand. Likewise,

in Brazil the mixed stand of *E. camaldulensis* and *Anadenanthera peregina* shows better growth (diameter and height) than the monoculture plantation of eucalyptus (Pagano *et al*., 2008). The advantage of intercropping over monoculture of eucalyptus is that the species like *Acacia*, *Albizia* and *A. peregina* support the nutrient cycling to the soil and organic matter return particularly for degraded, unfertile and arid areas (DeBell *et al*., 1985).

Kidanu *et al*. (2006) compared the macronutrient content (N, P, K) of foliage and wood part for seven tree species in Ethiopian highlands (*Acacia decurrent, Chamaecytisus palmensis, Chamaecytisus proliferus, E. camaldulensis, E. globules, Grevillea robusta,* and *Hagenia abyssinica*); the results show N content at 64 months was higher in the wood part of *E.globulus* and *C. proliferus* (3.34 and 3.42 mg/g respectively) relative to other species. Eucalyptus also has high P (0.3 mg/g) content in addition to N in its wood part. But eucalyptus has lower nitrogen content in the foliage part. *Acacia* and *Chamaecytisus* species foliage has a higher content of N (32 and 31 mg/g respectively) compared to eucalyptus (Table 4). *H. abyssinica* (indigenous) had a higher P (3mg/g) and K (19 mg/g) content from the foliage and have higher K (4.57 mg/g) from its wood (Kidanu *et al*., 2006) compared to that of eucalyptus. Wang *et al.* (1991) indicate that *eucalyptus* have higher amount of P (0.70 $mgg^{-1}$) concentration in its wood tissue than bark (the bark of eucalyptus has low concentration of nutrients) compared to *Leucaena leucocephla*(0.42 $mgg^{-1}$), *Albizia procera* (0.56 $mgg^{-1}$) and *Casuarina equisetifoli* (0.53 $mgg^{-1}$). Hence, the above figure shows that eucalyptus (wood) is a good source for some macronutrients to the soil if there is a good management during logging and other activities.

The amount of nutrient uptake by different species is different in different ecological zones and eucalyptus is one of these species. Small scale farmers plant eucalyptus in fertile, unfertile and degraded land (Jagger and Pender, 2000; Davidson, 1995; Tesfaye, 2009). The ability of eucalyptus to grow in all types of soil has an advantage for rural farmers since it can help them to get benefit from land that is otherwise unproductive. The yield harvested from these degraded or unfertile areas is variable and may not be sustainable in supporting the daily livelihoods.

Mixing eucalyptus with other tree species (like Acacia) can help smallholders to increase the yield of their woodlots in support of their livelihood on a more sustainable basis (Wang *et al*. 1991; Kidanu *et al*. 2006). To have sustainable production for smallholder farmers from eucalyptus farmland needs specific management considerations starting from site preparation up to final harvest. Wang et al. (1991) found that leaving branches and barks during logging help to increase soil fertility. Such kind of management is within each smallholder farmers hand and does not incur extra cost. The question is rather if the poor smallholders can afford to refrain from using these residues.

### *3.2.3 Eucalyptus Decrease Biodiversity in the Under Growth*

Even if eucalyptus has an allelopathic effect there is no concrete evidence and agreement that prove its detrimental effect on the undergrowth species. On the contrary some studies show that regeneration of undergrowth species is better under eucalyptus than other exotic tree species and natural forest (*C.lustinica,* and *P. patula*) (Table 5).

On the other hand Alem and Weldemariyam (2009) study the undergrowth of different species of eucalyptus plantation and natural forest and found that the condition for under growth is more conducive in natural forest for shade tolerant plant species (52 species) compared to eucalyptus (46 species); the density of understory growth in eucalyptus was 3282 stem per ha and that of natural forest 4122 stem/ha. This difference is too small compared with the livelihood benefit eucalyptus gives to smallholders and to justify a ban of eucalyptus. Debushe *et al*. (2010) also shared the above concept from their findings; about 68 plant species with 55 genera and 32 families was investigated in eucalyptus plantation in Entot (Ethiopia) of which 41 are naturally regenerated woody species. This

result proves that the negative effect of monoculture eucalyptus stands on the regeneration of under growth is not as serious as has been maintained in the past.

Management regimes are important to consider as management by itself has an effect on the regeneration of understory species particularly stand-density (Debushe *et al*., 2010) and management of the canopy. The species growing under eucalyptus plantation at its younger stages are mainly grasses (Holgen and Svensson, 1990) but when older (more than 10 years) the under growth include different woody species, shrubs and herbs. In relation to water consumption Poore and Fries (1985) reported that eucalyptus are not a good biological conservation methods both for soil and water since the ground cover of under storey plant species is suppressed by the roots of eucalyptus. On the contrary Tesfaye (2009) argue that if eucalyptus is planted in a wider space it favor the under growth (Table 5), allowing the entrance of light to the surface that almost all plant species needs to grow, therefore it helps to protect soil erosion (runoff) if planted at the right spacing.

Lisanewerk and Michelsen (1993) analysed the impact of *eucalyptus* species (*E. camaldulensis* and *E. Saligna*) and *C. lustinica* on different crops showing a negative impact on the germination and growth of wheat, teff, chick pea, and maize attributed to the allelopathic effect the eucalyptus leaves. The toxicity proved higher in eucalyptus leaf compared to C. *lustinica*. Similarly, Jagger and Pender (2000) stated that eucalyptus have a negative impact on agriculture production (result reduction of crop yield) also attributed to allelochemicals production.

In Congo, Loumetto and Huttel (1997) found that until the age of 10 years eucalyptus have allelopathic impacts, especially on the regeneration of woody species. However, this effect did not prove significant beyond ten years. On the contrary, in Brazil eucalyptus could not reveal any negative impact (colonization) on the understory regeneration of plant species (Junior *et al* 1995; Loumetto and Huttel, 1997). In Ethiopia, *E. grandis* used as shades in coffee plantation (Alem and Weldemariyam, 2010) had a density of coffee stems nearly similar to that of the natural forest (1022 stems per ha in eucalyptus plantation and 1042 stems per ha in natural forest). Proper land use and planning is used to protect the allellopathic effect of eucalyptus including other exotic tree species particularly in areas with poor rainfall and unfertile soil that limit growth and in turn increase its competitiveness with the crops (Malik and Sharma, 1990).

Several studies (Table 5) approves that there is no special factors that makes eucalyptus different from other exotic and endogenous tree species in relation to the undergrowth of various species like shrubs, climbers, herbs and other tree species. Comparatively better under storey is found under eucalyptus compared to that under other tree species (especially from exotic once) giving increasing evidence to conclude that eucalyptus has no particular negative impact on the under storey growth (Holgen and Svensson, 1990; Junior *et al* 1995; Loumetto and Huttel, 1997; Alem and Weldemariyam, 2010). In some other studies understory regeneration is by far better in terms of diversity and richness in natural forest compared to that of eucalyptus.

*Table 5. Number of species in the under growth of eucalyptus stands (UE) compared to that of other species (UO) in different countries*

| Country | Eucalyptus species | under growth species (UE) | Other tree species | under growth species (UO) | UE - UO | UE/UO | Refrences |
|---|---|---|---|---|---|---|---|
| **Ethiopia** | Eucalyptus saligna (3rdcop.) | 27 | Cuprsus lustinica (seedl.) | 16 | 11 | 1.7 | Feyera *et al*., 2002 |
| | Eucalyptus globules (2ndcop.) | 17 | Cuprsus lustinica (seedl.) | 16 | -13 | 0.6 | Feyera *et al*., 2002 |
| | Eucalyptus globulus (seedl.) | 13 | Pinus patula (10yr age) | 18 | -5 | 0.7 | Feyera *et al*., 2002 |
| | Eucalypus saligna (seedl.) | 18 | Pinus patula (28yrs) | 15 | 3 | 1.2 | Feyera *et al*., 2002 |
| | Eucalyptus saligna (3rdcop.) | 27 | Natural forest | 25 | 2 | 1.1 | Feyera *et al*., 2002 |
| **China** | Eucalyptus citriodora | 37 | S. superb + L. cubaba (mix) | 43 | -6 | 0.9 | Daun *et al*. 2010 |
| **Zimbabw** | Eucalyptus camaldulensis | 39 | Brachystegia (Miombo) | 56 | -17 | 0.7 | Tyynela, 2001 |
| **India** | Eucalyptus species (25 yr) | 64 | Ever green nat. forest | 100 | -36 | 0.6 | Selwyn & Ganesan, 2009 |
| **Malawi** | E.camaldulensis(<1yr old) | 71 | Unplanted site (control) | 58 | 13 | 1.2 | Bonne *et a*l., 1997 |
| | E.camaldulensis (8yr old) | 50 | Unplanted site (control) | 58 | -8 | 0.9 | Bonne *et al*., 1997 |
| **Vietnam** | E. camaldulensis | 12 | Acacia auriculiformis | 22 | -10 | 0.5 | Van, 2005 |
| | E. camaldulensis | 12 | Acacia mangium | 17 | -5 | 0.7 | Van, 2005 |
| | E. camaldulensis | 12 | Natural forest | 41 | -29 | 0.3 | Van, 2005 |
| | E. camaldulensis | 12 | Unplanted site | 9 | 3 | 1.3 | Van, 2005 |
| **India** | Eucalyptus species (40 yr) | 58 | Ever green forest (cleared) | 100 | -42 | 0.6 | Selwyn and Ganesan, 2009 |
| **Ethiopia** | Eucalyptus globulus | 24 | Pinus patula | 21 | 3 | 1.1 | Michaelsen *et a*l, 1996 |
| **Ethiopia** | Eucalyptus grandis | 26 | Natural forest | 31 | -5 | 0.8 | Michaelsen *et al*, 1996 |
| | Eucalyptus saligna | 23 | Natural forest | 31 | -8 | 0.7 | Michaelsen *et a*l, 1996 |
| **Ethiopia** | Eucalyptus globulus | 22 | Pinus patula | 30 | -8 | 0.7 | Yirdaw, 2002 |
| | Eucalyptus globulus | 22 | Gravilia robusta | 29 | -7 | 0.8 | Yirdaw, 2002 |
| | Eucalyptus globulus | 22 | Juniperous procera | 32 | -10 | 0.7 | Yirdaw, 2002 |
| | Eucalyptus globulus | 22 | Natural forest | 48 | -26 | 0.5 | Yirdaw, 2002 |
| **China** | E. exserta | 34 | A. mangium | 35 | -1 | 1 | Daun *et a*l., 2010 |
| | E. exserta | 34 | Pinus massoniana + C. laceolata (mix) | 36 | -2 | 0.9 | Daun *et a*l., 2010 |
| **Ethiopia** | Eucalyptus saligna (31 yrs) | 17 | Natural forest | 25 | -8 | 0.7 | Lemineh *et al*., 2004 |
| | Eucalyptus saligna (31 yrs) | 17 | Pinus patula (31 yrs) | 20 | -3 | 0.9 | Lemineh *et al*., 2004 |
| | Eucalyptus saligna (31 yrs) | 17 | Cuprsus lustinica (31 yrs) | 15 | 2 | 1.1 | Lemineh *et al*., 2004 |
| | Eucalyptus saligna (31 yrs) | 17 | Cordia Africana (28 yrs) | 19 | -2 | 0.9 | Lemineh *et al*., 2004 |
| **South Africa** | Eucalyptus species | 38 | Pinus patula | 38 | 0 | 1 | Geldenhuys 1997 |
| **Congo** | Eucalyptus species | 59 | Savana | 24 | 35 | 2.5 | Loumeto and Hutte, 1997 |
| | Eucalyptus species | 59 | Pinus caribeae | 47 | 12 | 1.3 | Loumeto and Hutte, 1997 |
| | Eucalyptus species | 59 | Natural forest | 97 | -38 | 0.6 | Loumeto and Hutte, 1997 |
| **Ethiopia** | Eucalyptus species | 59 | Acacia auriculiformis | 27 | 32 | 2.2 | Loumeto and Hutte, 1997 |
| | Eucalyptus globulus | 57 | Cuprsus lustinica | 21 | 36 | 2.7 | Michelsen *et a*l., 1993 |
| | Eucalyptus globulus | 57 | Juniperus procera | 31 | 26 | 1.8 | Michelsen *et a*l., 1993 |
| | Eucalyptus globulus | 57 | Natura forest | 35 | 22 | 1.6 | Michelsen *et a*l., 1993 |
| **Brazil** | Eucalyptus grandis | 123 | No control | No control | | | Da Silva *et a*l, 1995 |

Small scale farmers are aware about the negative impact of eucalyptus specially if it is planted as a boundary around the farm land close to the cultivated fields. The distance between the crops and tree should be more than 12 meter; if it is less the crop yield will be negatively affected due to chemicals released from the eucalyptus leaves. Even if there is compensation from eucalyptus production it will not make up for the loss in crop yield (Lisanewerk and Michelsen 1993). To improve the biodiversity under eucalyptus plantation it is vital to take the management into consideration. Although the small scale farmers' objective of planting eucalyptus is to get high biomass production but sustainability considerations are necessary to match higher production with

better biodiversity. To improve sustainability and at the same time increase production mixing eucalyptus with other tree species (Michaelsen *et al*, 1993) is one possible option. Changaipe (1985) indicated that intercropping of eucalyptus (age 1.3 year) with maize and beans have no disadvantage or depressing effect, rather the yield of the crop improves if the spacing between eucalyptus stems or seedlings is wide enough.

In more than 50% of the 36 experiment presented in Table 5 the number of species in the under growth of the eucalyptus stands is close to (90%), equal to or more than that of others including other common plantation tree species, leguminous tree species, open land, natural forest, savanna and agricultural fields. From this, it can be concluded that the effect of trees on the biodiversity of the under growth is variable probably depending on site conditions and management. The results presented in table 5 also show the difficulty to conclude that the effect of eucalyptus on the biodiversity of the under growth is more detrimental that of other species.

#### *3.2.4 Eucalyptus increases Soil Erosion*

It has been argued that eucalyptus plantation (monoculture) as well as natural forests including eucalyptus can decrease runoff through improved infiltration. The dense canopies of any forest (tree) helps to protect the ground from splash erosion (Davidson, 1995; Oballa, *et al*, 2010). In the past the control of soil erosion was mainly done using physical control measures. Today combinations of biological, agronomic and physical interventions are applied/ integrated with the local land-use system to conserve soil and water, and to improve soil fertility. Improving vegetation cover using almost any plant species helps to protect the soil from unexpected erosion (particularly to protect top soil) and nutrient depletion due to high runoff (Tesfaye, 2009). Planting of tree with appropriate spacing and observing recommended densities and proper management (like thinning) increase the species diversity and vegetation cover growth under the tree canopy; these under growth species with the accumulation of different plant derbies (litter fall) are used to reduce soil erosion (Dessie and Erkossa, 2011). In every plantation if there is enough spacing it helps to reduce the runoff and soil erosion because of species diversity.

In China, Jiayu and Siming (1996) reported a 99% decrease in runoff and in the movement of sand and mud in eucalyptus plantation compared to the previous conditions (without plantation). Planting of eucalyptus in areas where erosion is the main problem helps to control overland flow through increased infiltration. On the vertisols in Ethiopian highlands, Kidanu and Stroosnider (2004) compared the extent of erosion in three mono-cropping systems; Durum Wheat (*Triticum turgidum*), Chickpea (*Cicer arietinum*) and Teff (*Eragrostis tef*)) with the same crops cultivated in an agroforestry system with eucalyptus. The result showed a decrease from 2.5in 2002 to 12% in 2001 in soil erosion from agroforestry.

These results highlighted in different literature approved that planting of eucalyptus has a multiple function for small scale farmers, in addition to its social and economical value; it gives environmental functions as it contribute to protect the farm land from runoff/ floods, conserving the soil and water. Jagger and Pender (2003) indicated that eucalyptus has potential to reduce the top soil runoff and slows soil erosion in different climatic zones where there is maximum rain fall. Furthermore, eucalyptus contributes in decreasing the formation of degraded or waste lands in different regions (Jagger and Pender, 2003; Grewal et al., 1992).

### 3.3 Profitability and Selling Prices of Eucalyptus Woodlots for Small Scale Farmers

Small holder farmers harvest the yield of eucalyptus at the age of four years after planting. Moreover, eucalyptus supports the livelihoods of rural and urban dwellers at different site conditions (poor, medium and best), rotation period and spacing in addition to early harvesting.

Often eucalyptus can provide a better income compared to agricultural crops and other tree species depending on site condition. However, eucalyptus production is very high at best environmental conditions (in high rain fall area with fertile soil). Also eucalyptus generates good income when planted in a very dense spacing even if it depends on the site conditions (Kidanu and Ayele, 2004). As illustrated from Table 7 planting density have a positive effect for the farmers to increase their income depending on the site conditions; especially if the site condition is very good farmers plant from 10,000 up to 20,000 seedlings per ha and they sell at different time.

As summarized in Table 6 market price (if farmers sell directly to factory or consumers) of eucalyptus is different in different countries. For transmission poles selling Ethiopia took the least market price than Kenya and Rwanda but in construction wood Ethiopia have better price than Rwanda. Market price for construction wood ($m^3$) and transmission poles (a piece) in Ethiopia is USD 25-30 and 5-8 respectively while in Rwanda the prices for construction wood and transmission pole is USD 7-12 and 10-15 respectively but in Kenya transmission pole have highest price (USD 35 per piece)).

*Table 6. Price comparison of some Eucalyptus products from Ethiopia, Kenya and Rwanda*

| Products | Unit Price | Ethiopia (USD) | Price Rwanda (USD) | Price in Kenya (USD) |
|---|---|---|---|---|
| **Construction wood** | $M^3$ | 25-30 | *7-12* | - |
| **Transmission pole** | Piece | 5-8 | *10-15* | 35 |

Source: Dessie and Erossaa, 2011; KFS, 2011

*Table 7. Benefits of eucalyptus from different site conditions*

| Rotation period | Revenue (ETB) | Cost (ETB) | NPV (ETB) | Site Condition | Area (ha) | Planting density per ha |
|---|---|---|---|---|---|---|
| **4** | 12257 | 1905 | 6502 | poor | 1 | 10,000 |
| **6** | 8666 | 1545 | 3408 | poor | 1 | 10,000 |
| **6** | 15387 | 1925 | 6790 | medium | 1 | 10,000 |
| **5** | 14065 | 1905 | 6848 | NA | 1 | 10,000 |
| **6** | 27470 | 1905 | 13608 | Best | 1 | 10,000 |
| **6** | 8368 | 1935 | 2830 | poor | 1 | 20,000 |
| **5** | 7104 | 1915 | 2528 | poor | 1 | 20,000 |
| **6** | 22329 | 2355 | 10297 | Medium | 1 | 20,000 |
| **6** | 44569 | 2355 | 22856 | Best | 1 | 20,000 |
| **5** | 44486 | 2335 | 25322 | best | 1 | 20,000 |

Source: Teshome, 2004; Kebebew, 2002

# 4 Result

**Market price and contribution of Eucalyptus to Ethiopian small-scale farmers in Gimbichu Woreda**

Farmers in tropic and subtropical countries plant eucalyptus due to its economic advantages, compared to other exotic species eucalyptus grow fast and generate income to satisfy their daily expenses. The extra income generated from eucalypt can contribute to food security. Eucalyptus can start to provide income from age 3-4 in Ethiopian highlands excluding in-between benefits (Table 8, Table 9). Earlier thinning (two to four years and even less if the site is good) of dense eucalyptus plantations can provide stakes for the construction of walls of traditional houses. Also, leaves and branches can be used for fencing and fuel wood (Table 8). All the assortments, except leaves that used for fuel wood (baking injera and roasting grains), are used for construction of houses directly or indirectly (by splitting in to pieces), fencing of the residential areas (boundaries) to protect from illegal entrance of animals (including wild animals, like hyena that eat their domestic animals), and for fuel woods. The statistical test shows eucalyptus has better benefits for the small scale farmers.

Out of the five tested factors; site condition, stems sold per ha, rotation period, number of seedlings planted per ha, woodlot area; a combination of the later three included in the model gave the highest degree of explanation ($R^2$ = 79.86, Adj. $R^2$= 70.91) influencing the benefit per single stem obtained by the farmers (Table 11 and 12). This result showed that farmers' profit per stem increase as rotation period increased, woodlot area decreased and the number of seedlings planted per hectare decreased. These three factors explain close to 80% of the total variation between the studied cases in terms of profit per stem sold. It is logical that a longer rotation period increase profits as wood volume normally increase with increasing rotation period. The reason for the increase in benefit with decreasing size of the woodlot may be that the farmers manage their small plots of land more intensively. It is also possible that within a specific rotation time trees grow in average faster in a small wood lots compared to a large woodlot as the proportion of trees growing at the edge is higher in a smaller woodlot. At the edge of the woodlots the availability of light, nutrient and water is normally better. The increase in benefit per stem with decreasing planting density does follow the logic of increasing wood volume per stem with decreasing density (higher price per stem). It is also possible that farmers selling a smaller lot manage to negotiate for a better price compared to those that have a large lot for sale.

Different parts of eucalyptus have different functions for small scale farmers and poor urban households such as branches, leaves, stems, roots, barks (Table 8, Table 10). Branches, roots and leaves are used for fuel wood while the stem can be used either for construction, fuel wood, or transmission poles. Small scale farmers use eucalyptus for fuel wood, fence and construction of houses or to generate income by selling parts or the whole tree (Cefeka, Mager, Weraj, Quwami, and fuel wood). Each of the above activities has different market value including leaves of eucalyptus (Table 8) in different areas. For instance, the price for one sack of leaves (used for baking of Injera) weighing about 25- 30 kg is ETB 10-15, one bundle of Cefeka (20- 25 single tree) is ETB 40-45, and Mager (one single tree) is ETB 10-12 in Sendafa town. In Addis Ababa the price for the leaves and the Chefeka is 80-100% more and for a single tree about 40% higher. Small scale farmers sell their product at small towns like Sendafa (farmers get somewhat small profit in contrast with the value sold in the big cities).

The average benefit per single stem is around 4 ETB and the average benefits per ha per year was about 15,105 ETB. Farmers can get more befits from small wood lots compared to large; the price per stem decrease to about half if a ha is added to the woodlot (i.e. from the 0.44 ha which is the average of the sample). To increase the rotation with an extra year (beyond the sample average of

7.7 years) will add about 16% to the benefit obtained per stem. For every 1,000 extra seedlings planted per ha (from the sample average of 10,843 seedlings per ha) the benefit per stem will decrease only with 3.25% giving a total gain in benefit per ha up to about 20,000 seedlings per ha (if decrease is constant and planting cost is not considered). This result shows that it may be more profitable to increase the density rather than the area explaining the high density found among smallholders. If 1,000 stems is added to the 0.44 ha woodlot reaching 1,143 the total income from the woodlot will increase with ETB 2,460. To add another year still from 7.7 years old eucalyptus woodlots will give an interest about three times higher than that of the Ethiopian banks. There were no significant influences found of these factors during the second rotation.

*Table 8. Market chain for different assortments of eucalyptus in central Ethiopia*

| Different assortment of eucalyptus | | Length | Diameter | Quantity | | years after | | Price at different locations/markets (ETB) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amharic names | | m | cm | Stem | kg/ $m^3$ | planting | coppicing | Sendafa | Addis Ababa | Debrezeyit | Gimbichu | ELPA |
| Cefeka | Thin wood used between poles | 2 - 4 | ≤ 2.8 | 20 - 25 | - | 2 - 3 | 2 | 40 - 45 | 80 - 85 | 50 | 70 - 75 | - |
| Mager | Used to connect both construction poles and roofs | 2 - 4 | 4.5 | 1 | - | 3 - 5 | 2 - 4 | 10 -12 | 14 - 17 | 18 | 10 - 15 | - |
| Quami, Seregela & Weraj | Construction pole; connect top of wall and roof | 4 - 8 | 7.2 | 1 | - | 4 - 8 | 3 - 6 | 35 - 40 | 45 - 50 | 40 | 20 - 40 | |
| Transmission poles* | | > 8 | 15.4 | 1 | - | >8 | >7 | 40 - 50 | 80 - 100 | 80 - 85 | - | 72 |
| Gindila | Tree trunk used for fuel wood | - | - | - | $1m^3$ | >12 | >10 | 400 | 430 - 550 | - | 300 - 500 | |
| - | Barks , branches in bundles | - | - | - | 25-45 | - | - | 13 - 16 | - | - | - | |
| Qitel | Leaves in sacks | - | - | - | 25-30 | - | - | 10 - 15 | 20 - 25 | - | - | |

Source: Survey, 2011 * Estimation from what the farmer and retailer says

*Table 9. Age of different assortments of Eucalyptus species in central Ethiopia based on small scale farmers woodlots*

| No. | Area (Ha) | No. of seedlings planted | Spacing (m) | Years wood would be available for use After Planting | | | | | | Years the wood would be available for use After first coppicing | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Cefeka | Atana | Mager Nall & Qorqor | Weraj | Sregela | Kuwami | Cefeka | Atana | Mager Nall & Qorqor | Weraj | Sregela | Kuwami |
| 1 | 0.250 | 2500 | 1.00 | 3.0 | 4.0 | 5.0 | 6.0 | 6.0 | 6.0 | 3.0 | 4.0 | 4.0 | 5.0 | 6.0 | 6.0 |
| 2 | 0.024 | 1000 | 0.49 | 3.0 | 4.0 | 5.0 | 5.0 | 7.0 | 8.0 | 2.0 | 3.0 | 3.0 | 4.0 | 4.0 | 5.0 |
| 3 | 0.250 | 1500 | 1.29 | 2.0 | 2.0 | 3.0 | 4.0 | 4.0 | 5.0 | 2.0 | 3.0 | 4.0 | 4.0 | 5.0 | 5.0 |
| 4 | 0.063 | 600 | 1.02 | 3.0 | 4.0 | 5.0 | 7.0 | 10.0 | 10.0 | 3.0 | 3.0 | 4.0 | 5.0 | 5.0 | 7.0 |
| 5 | 0.500 | 2000 | 1.58 | 2.5 | 3.0 | 4.0. | 7.0 | 8.0 | 8.0 | 2.0 | 2.0 | 2.5 | 4.0 | 6.0 | 6.0 |
| 6 | 0.250 | 6500 | 0.62 | 2.0 | 2.5 | 3.0. | 4.0 | - | - | - | - | - | - | - | - |
| 7 | 0.500 | 5000 | 1.00 | 2.0 | 3.0 | 4.0 | 5.0 | 5.0 | 6.0 | 2.0 | 3.0 | 3.0 | 4.0 | 4.0 | 5.0 |
| 8 | 0.250 | 2100 | 1.09 | 3.0 | 4.0 | 4.0 | 5.0 | 5.0 | 6.0 | 3.0 | 5.0 | 5.0 | 6.0 | 6.0 | 7.0 |
| 9 | 0.230 | 1000 | 1.52 | 3.5 | 5.0 | 5.5 | 6.0 | 9.0 | 10.0 | 3.0 | 4.0 | 4.0 | 5.0 | 5.0 | 6.0 |
| 10 | 1.000 | 5400 | 1.04 | 4.0 | 4.0 | 5.0 | 7.0 | 10.0 | 10.0 | 3.5 | 4.0 | 5.0 | 6.0 | 6.0 | 7.0 |
| 11 | 0.250 | 700 | 1.89 | 2.0 | 3.0 | 4.0 | 6.0 | 9.0 | 9.0 | 1.5 | 3.0 | 3.5 | 3.5 | 4.0 | - |
| 12 | 0.062 | 400 | 1.25 | 3.0 | 4.0 | 4.0 | 6.0 | 8.0 | 9.0 | 3.0 | 4.0 | 5.0 | 7.0 | 7.0 | 8.0 |
| 13 | 1.000 | 4500 | 1.49 | 4.0 | 4.0 | 4.0 | 5.0 | 6.0 | 6.0 | 3.0 | 4.0 | - | - | - | - |
| 14 | 0.060 | 700 | 0.93 | 3.0 | 4.0 | 5.0 | 6.0 | 8.0 | 9.0 | 2.0 | 3.0 | 4.0 | 4.0 | 6.0 | 6.0 |
| 15 | 0.050 | 1300 | 0.62 | 3.0 | 3.0 | 4.0 | 4.0 | 6.0 | 6.0 | 2.0 | 3.0 | 5.0 | 5.0 | 5.0 | 6.0 |
| 16 | 0.060 | 800 | 0.87 | 2.0 | 4.0 | 4.0 | 6.0 | 6.0 | 7.0 | 1.5 | 2.0 | 3.0 | 4.0 | 4.0 | 5.0 |
| 17 | 2.250 | 17000 | 1.15 | 3.0 | 4.0 | 4.0 | 4.0 | 5.0 | 6.0 | 2.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 |

Source: Survey, 2011

*Table 10. Profitability of eucalyptus woodlots at 17 different farms in Gimbichu Woreda, Areda Gora and Indode Imbus kebele in the Central Ethiopian highlands*

| No. | Area (Ha) | Site condition | Thinning 1st rotation | | Totals after first rotation | | | | Thinning coppicing rotation | | Totals after 1st coppicing rotation | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Quantity (number) | Price (ETB) | Quantity (number) | Income (ETB) | Cost (ETB) | Benefit (I - C) | Quantity (number) | Price (ETB) | Quantity (number) | Income (ETB) | Cost (ETB) | Benefit (I - C) |
| 1 | 0.250 | poor | 30 | 300 | 1000 | 4000 | 971 | 3029 | - | - | NA | Not sold | 316 | - |
| 2 | 0.024 | medium | 40 | 1000 | 500 | 7000 | 93 | 6907 | - | - | 2000 | 10000 | 30 | 9970 |
| 3 | 0.250 | poor | - | - | - | - | - | - | - | - | NA | - | - | - |
| 4 | 0.063 | medium | - | - | 150 | 2500 | 245 | 2255 | - | - | 1000 | 3000 | 80 | 2920 |
| 5 | 0.500 | medium | 800 | 3000 | 1400 | 7500 | 1943 | 5558 | - | - | Not sold | Not sold | 633 | - |
| 6 | 0.250 | NA | 1ST establishment | | | | | | - | | NA | NA | 316 | - |
| 7 | 0.500 | medium | - | - | 3000 | 12000 | 1943 | 10058 | - | - | 5200 | 18000 | 633 | 17368 |
| 8 | 0.250 | poor | - | - | 1000 | 5000 | 971 | 4029 | - | - | 2000 | 4000 | 316 | 3684 |
| 9 | 0.230 | poor | - | - | 200 | 6000 | 894 | 5106 | - | - | 500 | 3000 | 291 | 2709 |
| 10 | 1.000 | very poor | 50 | 200 | 1500 | 10000 | 3885 | 6115 | - | - | 5000 | 30000 | 1265 | 28735 |
| 11 | 0.250 | Very poor | 30 | 250 | 150 | 2000 | 971 | 1029 | - | - | Not sold | Not sold | 316 | - |
| 12 | 0.062 | medium | - | - | 170 | 3000 | 243 | 2757 | - | - | Not sold | Not sold | 79 | - |
| 13 | 1.000 | - | - | - | 700 | 5500 | 3885 | 1615 | - | - | Not sold | Not sold | 1265 | - |
| 14 | 0.060 | poor | 50 | 500 | 300 | 3000 | 233 | 2767 | 15 | 300 | 1500 | 7500 | 76 | 7424 |
| 15 | 0.050 | medium | - | - | 500 | 1500 | 194 | 1306 | - | - | 10000 | 18000 | 63 | 17937 |
| 16 | 0.060 | poor | - | - | 300 | 2000 | 233 | 1767 | - | - | 1100 | 8200 | 76 | 8124 |
| 17 | 2.250 | medium | 30 | 300 | 15000 | 23500 | 8741 | 14759 | 20 | 200 | 20000 | 35000 | 2846 | 32154 |

Source: survey, 2011

*Table 11. Benefits analysis of Eucalyptus woodlots*

| No | area | site condition | original spacing (m) | seedlings planted /ha | FIRST ROTATION | | | | | COPPICE ROTATION | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | rotation (year) | stems sold/ha | benefit/ha/year (ETB) | income/stem (ETB) | benefit/stem (ETB) | rotation (year) | stem sold/ha | benefit/ha/ year (ETB) | benefit/stem (ETB) |
| 1 | 0.250 | poor | 1.00 | 10000 | 6 | 4000 | 12116 | 3.03 | 3.03 | - | NA | Not sold | - |
| 2 | 0.024 | medium | 0.49 | 41667 | 8 | 20833 | 28779 | 1.38 | 1.38 | 5 | 13333 | 41541 | 3.12 |
| 3 | 0.250 | poor | 1.29 | 6000 | 5 | 2000 | NA | - | - | 5 | NA | NA | - |
| 4 | 0.063 | medium | 1.02 | 9523 | 10 | 2381 | 15794 | 6.63 | 6.63 | 7 | 15873 | 46349 | 2.92 |
| 5 | 0.500 | medium | 1.58 | 4000 | 8 | 2800 | 11116 | 3.97 | 3.97 | 6 | NA | Not sold | - |
| 6 | 0.250 | NA | 0.62 | 26000 | - | NA | NA | - | - | - | Na | Not sold | - |
| 7 | 0.500 | medium | 1.00 | 10000 | 6 | 6000 | 20116 | 3.35 | 3.35 | 5 | 10400 | 34736 | 3.34 |
| 8 | 0.250 | poor | 1.09 | 8400 | 6 | 4000 | 16116 | 4.03 | 4.03 | 7 | 8000 | 14736 | 1.84 |
| 9 | 0.230 | medium | 1.52 | 4347 | 10 | 869 | 8200 | 9.00 | 9.00 | 6 | 2173 | 11778 | 5.42 |
| 10 | 1.000 | very poor | 1.04 | 2400 | 10 | 1500 | 6115 | 4.08 | 4.08 | 7 | 5000 | 28735 | 5.75 |
| 11 | 0.250 | Very poor | 1.89 | 2800 | 9 | 600 | 4116 | 6.86 | 6.86 | - | NA | Not sold | - |
| 12 | 0.062 | medium | 1.25 | 6451 | 9 | 2742 | 24468 | 8.90 | 8.90 | - | NA | Not sold | - |
| 13 | 1.000 | - | 1.49 | 4500 | 6 | 700 | 1615 | 2.31 | 2.31 | - | NA | Not sold | - |
| 14 | 0.060 | medium | 0.93 | 11667 | 9 | 5000 | 46117 | 7.22 | 7.22 | 6 | 17000 | 23733 | 1.40 |
| 15 | 0.050 | medium | 0.62 | 26000 | 6 | 10000 | 26120 | 2.61 | 2.61 | 6 | 20000 | 58740 | 2.94 |
| 16 | 0.060 | poor | 0.87 | 13333 | 7 | 5000 | 29450 | 5.89 | 5.89 | 5 | 18333 | 35400 | 1.93 |
| 17 | 2.250 | medium | 1.15 | 7555 | 6 | 6667 | 6559 | 1.00 | 1.00 | 4 | 8888 | 14290 | 1.61 |

Source: survey, 2011

*Table 12. Output values of the stepwise test*

| | Rotation period in year | Size of woodlot in ha | No of planted stems per ha |
|---|---|---|---|
| **P-value** | 0.024 | 0.007 | 0.008 |
| **Change in value per stem sold (ETB)** | +0.65 ETB / extra year | -2.35 ETB / extra ha | - 0.13 ETB / stem for every 1000 extra seedling planted/ha |

# 5 Discussion and Conclusions

The price for construction wood ($m^3$) and transmission poles (pieces) in Ethiopia is USD 25-30 and 5-8 respectively while in Kenya the prices for transmission pole is USD 35 (Table 6). The price eucalyptus products for different purposes have different value in different countries for small scale eucalyptus woodlot owners. Leaves of eucalyptus (especially *E. globules*) are a good source of fuel for baking Injera, traditional food in Ethiopia (Pohjonen and Pukkala, 1988). Poor households both from urban as well as rural areas sell one bundle of eucalyptus leaves (collected from eucalyptus plantation when leaves shade) and branches by 50 ETB (2.5 USD) with estimated weight 30 kg in two Ethiopian towns (Sendafa and Sululta) around Addis Ababa (Chiche and Kelemu, 2010). Such kind of tasks in Ethiopia is done mostly by females and children. Branches also used for fencing the boarder of their living compartment/boundaries besides fuel wood functions.

Furthermore, farmers have an experience of getting income from early stage of dense eucalyptus plantation (the planting density is denser and these helps farmers by generating income). For instance, revenue of eucalyptus wood lots from 20,000 and 10,000 seedling per ha in a best site condition is around 44569 and 27470 ETB within 6 years rotation respectively; but in poor site conditions the total revenue of eucalyptus woodlots from 10,000 and 20,000 seedling per hectare is about 12557and 8368 ETB within 4 and 6 years rotation respectively. This shows that if planting density of eucalyptus is higher in poor site conditions farmers cannot get good income rather wastage of labour and other expenses depending on the management. On the contrary if the site condition is best from higher planting density farmers get high income. The Net benefit from 0.024 ha eucalypt woodlot is around ETB 6907 eight years after first planting and 9970 ETB from the first coppicing, i.e. after 5 to 6 years (Table 7; Table 10; Kidanu and Ayele, 2005).

In Ethiopia Hagert (1991) compared the income of eucalyptus with *Acacia saligna*; the result found was that eucalyptus have a potential to subsidize the small holder farmers income giving high economic benefit than Acacia with application of similar input and management. Jalota and Sangha (2000) indicated also eucalyptus has higher net return or NPV 6 up to 8 years (2.92 times higher) than D. sissoo for small holder farmers in India. Similarly in Victoria eucalyptus have a potential to give high yield than *P. radiata* (URS, 2003). The economic benefits of eucalyptus was analysed in the Ethiopian highlands (Teshome, 2004; Kebebew, 2002) relative to the contribution of different land uses to the livelihood of smallholders and the result showed eucalyptus woodlots contributes about 50% more income relative to livestock and crops with 3500, 200 and 400 ETB respectively. A comparative analysis of the profit margin done in South West Ethiopia among rural poor farmers (Kidanu and Ayele, 2005) indicates planting of eucalyptus as a boundary around wheat fields give better income compared to sole wheat production; wheat with eucalyptus give an income/ NPV 9741 ETB while sole wheat have an income/NPV 7277 ETB, even though the wheat yield decreased from mixed stands, the total income (wheat + eucalyptus) was higher.

Jagger and Pender (2005) stated planting of eucalyptus in Northern Ethiopia (rural woodlots in Tigray region) gave a negative net income due to high labour cost, low management techniques for wood lots, and lack of proper market access around the small holder farmers' village. In this area (Northern Ethiopia) environmental factors like poor soil fertility, rainfall, and rough topography are additional factors contributing negatively for the profitability of eucalyptus plantations in contrast to other highlands.

Eucalyptus woodlots have a potential to take poor farmers and urban dwellers out of the poverty trap. In tropical and subtropical countries many farmers prefer to plant eucalyptus compared to other tree species and even to other cash crops. It is not a few strong qualities of eucalyptus that contributes to its popularity among smallholders but the fact that it posses many important and/or strong qualities that the smallholders appreciate. In addition to its ability to give high yields in a short period of time it does not require intensive input or skilled labor to raise seedlings, to establish or manage. Most eucalyptus species grow in a wide range of ecological and climate conditions including rainfall amount, soil and ground conditions, altitude and temperature ranges. Eucalyptus also provides a wide variety of benefits (used for construction of houses and others like fencing, fuel wood, farm utilities, and transmission poles). In some countries like Ethiopia farmers consider eucalyptus as "life saver" due to its high level and wide variety of benefits it contributes to their daily lives. The demand of different assortments, dimensions and parts of eucalyptus is consistently high even in the remotest areas minimizing the risk for the producer of eucalyptus.

Although eucalyptus holds an obvious potential to contribute to improve the livelihood of the poor smallholders the genus is afflicted with a number of environmental controversies that reduces the options to explore its full socioeconomic potentials. This is because consensus on the environmental impacts of eucalyptus is still lacking in some critical issues. Basically, eucalyptus has comparatively high water consumption per unit of time but if compared with the amount of water consumed per biomass produced it proves more efficient than many other commonly used plantation tree species and some crops specifically in sites with a positive water balance like large parts of the African highlands. Still in some countries like Kenya to plant eucalyptus around water bodies has been uniformly prohibited all over the country. The high nutrient uptake of eucalyptus is another issue that needs additional research. However, existing research show that in many conditions the depletion of soil nutrients are not greater than other commonly used plantation species; but compared to natural forest or indigenous tree species soil nutrients consumption is often higher under eucalyptus. Existing research on the influence on the undergrowth in eucalyptus stands compared to that of other vegetation cover varies depending on site conditions, stand density and the control species/vegetation compared with. In dense plantations there is normally a negative effect on the under growth species. The number of understory species under eucalyptus is normally not less diverse compared to that under other commonly used plantation species. But the diversity in the under growth is normally higher under natural forest. Hence it is not possible to jump to the conclusion that the understory growth under Eucalyptus stands is normally less diverse than that under other commonly used plantation species. The ability of eucalyptus to produce higher biomass from available resources relative to many other commonly used plantation tree species should be considered in the judgment of its environmental impact. This is because; more land and/or longer rotation period is needed to produce the same value from species with a lower production capacity that may result in a more extensive negative environmental impact. Moreover, with good management system and practices it is possible to decrease the negative influence of eucalyptus.

The income found from different assortments of eucalyptus satisfies the daily expenses and needs of smallholder farmers. Eucalyptus generates income to the owners from its early ages and this makes the cash-flow more consistent compared to other tree species. Every parts of eucalyptus (leaves, barks, stems and roots) have value at the local market and/or in the household of the smallholder. The management and input costs are very low and therefore contribute to higher net income and minimize the risk. Interestingly, the result of this study shows that an increase in planting density gives a higher return compared to an increase in

planting area. At the small scale farmers' levels there is still much research that needs to be done. All the environmental controversies need to be straightened out. Few studies have been done about the benefits and cash flow of the small densely planted woodlots (market wise as well as household level consumption) of eucalyptus including its return from early thinning; and further research is necessary to arrived to some concrete evidence. There are also management practices that have the potential to improve the sustainability of the small eucalyptus woodlots that needs to be further investigated like the inter-planting with leguminous trees and shrubs spatially or sequentially.

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# Appendices

## Appendix 1. Sample Interview Questions

Questionnaire No. one

Name of the farmer _____
Kebele _____
Gote (Village) _____
Wereda_____
Age _____
Marital status:
Married ☐ Not Married ☐
Name of the local Market _____

Questionnaire No.2

1. When do you start to grow eucalyptus?
2. How did you start growing eucalyptus?
3. Do you have enough plot of land for growing both eucalyptus and crops? If not, why you grow eucalyptus?
4. What is the area of eucalyptus woodlots?
5. How many years need eucalyptus to provide outputs after the first plantation?
6. How many years eucalyptus takes to give the first yield starting from the first coppicing?
7. What is the site condition you used for eucalyptus plantation?

Best (very fertile soil) ☐ Medium site (not have high fertility) ☐ poor site (not fertile) ☐

8. How many seedlings used to plant usually per hectare (4 Kert)?
9. For what purpose mostly plant eucalyptus in your plots of land?
10. If mostly used for selling (Q.9) which parts and at what stage (year) you sell?
11. Do you think market accessibility is enough at the local level? Do you sell other than the local market?
12. How much money you get from sell of first and second rotation?

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# The Department of Forest Products,
# SLU, Uppsala

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