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Full Length Research Paper

Integrated Utilization of *Eucalyptus globulus* grown on the Ethiopian Highlands and its Contribution to Rural Livelihood: A Case Study of Oromia, Amhara and Southern Nations Nationalities and People's Regional State Ethiopia

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Abstract
Eucalyptus is the species widely distributed and used in different parts of the world. Its rapid growth and adaptability to a range of conditions has made it preferable than any other exotic species grown in Ethiopia. The objectives of this study were to undertake an inventory in *Eucalyptus* species growing areas of Ethiopia and to investigate its contribution to livelihoods of the households and nation's development. A combination of field works, desk reviews, expert communications, and group discussions were employed in three Ethiopian regions (Oromia, Amhara and Southern Nations Nationalities and People's Regional State). The results showed that a wide range of benefits has been generated from *Eucalyptus globulus* to support both the local livelihood and nation's development initiatives. In terms of growing *Eucalyptus* species for different purposes, the Oromia region shares the highest area extent with 44% of the total *Eucalyptus* plantation areas of the three regions. The region possesses more than half of the overall industrial plantation estate (52%) with diversified species composition. Considering all species that contribute for industrial wood products, *Eucalyptus* took the highest share (45%) of spatial extent followed by Cypress (41%) compared to other species under consideration in this study. Non-industrial wood-lots and community plantations are mainly located in Amhara region and accounts about 87% of the total woodlots of the three regions. Considering land holdings, significant increase was observed on the crop (R^2=0.89, $p<0.001$) and homestead lands (R^2=0.45, $p<0.001$) following increasing in total land holdings. Majority of land size is allocated for crop land (71%) followed by homestead land (21%), grazing land (7%) and forest (1%). Thus, in countries like Ethiopia, where there are accelerating deforestation, the use of fast-growing plantation species such as the eucalypts is foreseeable as they are preferred to other species, because of their fast growth and useful products.

Key words: *Eucalyptus globulus, Industrial plantation, Land holding, Livelihood, Fast growing*

Introduction

Eucalyptus is the species most widely introduced overseas and is a long and ever green tree from Myrtaceae family (Rassaeifar1 *et al*., 2013). *Eucalyptus* was introduced to Ethiopia in 1894-1895 by the French railway engineer Mondon-Vidaillet and a British army captain O'Brien who advised Emperor Minilik II to introduce the species to Ethiopia (Breitenbach, 1961; Horvath, 1968). After its introduction, some people started planting and growing the species around their homesteads in Addis Abeba. It was planted on the hills of the central highlands of the country and it became one of the most extensively planted tree species in Ethiopia. Its rapid growth and adaptability to a range of conditions has made it preferable than any other exotic species grown in the country.

Nowadays, *Eucalyptus* plots and stands are seen allover of the Ethiopian highlands covering the range of highly sloppy and degraded areas. The farmers in the different agro ecological zones continued to plant the species for various purposes such as fuel wood, transmission poles for income generation and construction material for their own use (Zerfu, 2002). In order to feel the present gap of demand for fuel wood construction materials, plantation forest development is the only way to overcome deforestation and secure sustainable utilization (Montagu *et al.*, 2003, Pohjonen, V. and Pakkala, T. 1990).

About 70 species of *Eucalyptus* are available in Ethiopia, most of which are widely spread in many regions of the country, mainly in central highlands where higher population density. The most common and widespread *Eucalyptus* species include: *Eucalyptus globulus* Labill., *Eucalyptus camaldulensis* Dehnn., *Eucalyptus saligna* Sm., *Eucalyptus grandis* W.Hill ex Maid. and *Eucalyptus tereticornis* Sm. Planting *Eucalyptus* has been expanding from state owned forestry enterprises and projects to community woodlots, household and farm field boundaries (Friis, 1995 and Zewdie, 2008).

Eucalyptus globulus dominates the Ethiopian aforestation and reforestation programs connected with ever increasing demand for construction, fuel wood and industrial wood production purposes. Expansion of *Eucalyptus* forest plantations worldwide, including trees on farm in Chile, Uruguay, north east Argentina, Australia, Brazil, South Africa and rest of the world has recently increasing in many folds (Phonon, V. and Pakkala, T., 1990, Montagu *et al.*, 2003; Sanchez Acosta, M., *et al.*, 2008). Countries like South Africa, Chile, Spain, Brazil and Argentina have successfully managed to raise proportions of their solid wood productions to 100%, 95%, 81%, 60%, and 55% respectively from plantation forests, which are mainly from *Eucalyptus* species (Krzysik, 2001).

It is not entirely coincidental that an exotic tree species, which does not resemble the indigenous trees by appearance, growing or ways of utilization, has become so common. *E.globulus* is preferred by the communities of the highlanders since it is fast growing and meets the needs of construction and fuel wood users. Moreover, the species is well suited to the existing ecological, economic and social conditions of the country.

Since the Ethiopian highlands are suffering from severe deforestation and biomass fuel crises, *E.globulus* is the prominent tree in government and community estate plantations because of its fast growing ability through coppicing, resistance to browsing by livestock, and through simple sawing and potted seedling propagation (Zewdie, 2008).

Despite its greater importance and the potential for *Eucalyptus* to improve rural livelihoods and national development initiatives, *E.globulus* is undermined by several scientists and communities related to the belief that "there are significant negative environmental externalities associated with *Eucalyptus* trees" (Zhang and Fu, 2009; Rassaeifar *et al*., 2013). Most criticisms are based on a range of technical, ecological and socio-economic arguments (FAO, 1988). According to Davidson (1989), many of the criticisms are unfair, biased, nationalistic or emotional. He noted that the criticisms would apply equally to other exotic trees planted in many countries; they are not peculiar to the *Eucalyptus*. On the one hand, the genus is highly popular with farmers as a cash crop but on the other hand the *Eucalyptus* are blamed for a great many evils, notably the drying up of water courses, suppression of other vegetation, a cause of erosion and adverse effects on nutrient cycling and soil properties (Munishi, 2009; Demel, 2000; FAO, 1988). *Eucalyptus* has been welcomed by many people as the savior of forest resources due to its rapid growth making it a renewable resource of timber, fuel wood and prevents deforestation. On the other hand, there are some people who regard *Eucalyptus* as weed that threaten to destroy the natural vegetation of an area. As a result, *Eucalyptus* has become the focus of uprising and open hostility between various experts, forestry officials and donors.

Several studies have been conducted on plantation forest in Ethiopia in relation with social, economic and environmental concerns (Luttge *et al*., 2002; Minda, 2004; Abiyu *et al*., 2011; Dessie and Erkossa, 2011). However, knowledge about the spatial extent and silvicultural management of the *Eucalyptus* species particularly *E.globulus* for higher value utilizations is still at its initial stage in Ethiopia (Hunde *et al*., 2002a; Hunde *et al*., 2002b; Jagger and Pender, 2003; Yirdaw and Luukkanen, 2003). Hence, lack of reliable information on *Eucalyptus* wood for higher value uses in Ethiopia in general is remaining serious impediment for innovations of wood processing sector. Despite of these and other determining factors, reports from Ethiopian Forest Products Research Centre showed that a few Ethiopian sawmills once tried to use *E. saligna* as sawn wood but did not continue as anticipated. This may be due to lower level of technical skills and poor status of the sawmills to handle the complex properties of the material. As was proved by many other researchers, aggressive end splitting and dimensional instability of *Eucalyptus* wood, including *E. saligna* are attributed to higher level of growth stress offered by the species (Nutto and Maestri, 2002; Nutto and Wirtu, 2012).

In countries like Ethiopia, where there are huge gaps between the demand and supply of wood as a result of ever increasing human population, accelerating deforestation, the use of fast-growing plantation species such as the *Eucalyptus* is foreseeable as they are preferred to other species, because of their fast growth and useful products. An interesting characteristic is that the aspect of *Eucalyptus* wood resembles tropical hardwoods; therefore it can be commercialized in replacement of these. It is not unusual that *Eucalyptus* boards are sold as cedar or mahogany (Sanchez Acosta M, et al, 2008). In this regard, studying the spatial extent and potential integrated benefits of *Eucalyptus* would have paramount importance for societal development. Thus, emphasis should be given by the government, the community and other forestry development institutions to supporting land users in selecting the right species for the appropriate plantation sites. This study is conducted based on the objectives including: (i) making an inventory in most *Eucalyptus* species growing regions; (ii) determine the spatial extent of *Eucalyptus* species in relation to other plantation forest; (iii) studying the type of products derived from *Eucalyptus* species; (iv) studying the contribution of *Eucalyptus* for household and nation's development.

Materials and Methods

Study area

The research was conducted in three Ethiopian regions (Oromia, Amhara and SNNP) (Figure 2). These regions are selected because of their suitable agro ecological conditions for growing *Eucalyptus* plantations and the sites indicated in the figure below are principal commercial plantation sites.

Method of data collection and analysis

A combination of field works, desk reviews, expert communications, observation, interview, discussion, and process documentation were some of the methods employed during the study. Sampling sites were selected based on the information obtained from regional bureaus of agriculture of the three regions (Oromia, Amhara and SNNP).

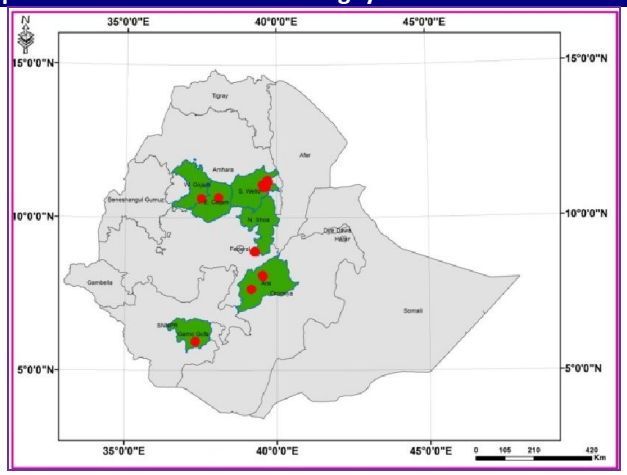

Fig 1. Map of the study area and the locations of principal commercial plantation sites

Inventory of Eucalyptus plantation

To ascertain the total number of trees per hectare and to classify the trees in different diameter classes and products, a systematic sample procedure was applied in specific selected plantation sites. In all *Eucalyptus* plantations a uniform procedure was used and product criteria were based on:

- Poles: Tree lengths meeting small and large end requirements for poles of 8-12 meter length and free of sweep.
- Saw logs: Tree lengths of diameter too large for poles, or not meeting straightness requirement for poles and >30 cm diameter.
- Veneer billets: Tree lengths not meeting straightness requirements for poles and between 18 – 30 cm diameter

Pole estimates were made to assess the potential for treated pole production in a later stage of the project, while more immediate needs were based on sawlog and veneer billet production. All wood meeting pole requirements would also meet requirements for veneer production. Under the above criteria it was possible for a single tree to produce more than one product, for example, a butt length may have a diameter too large for a pole and suitable for a sawlog, then above that, there could be a pole length, followed by veneer billet lengths. Information on the spatial extent of industrial plantation was collected from reviewing previous studies expert communications of relevant institutions.

Socioeconomic data collection

Samples of 60 households that grow *Eucalyptus* were purposely selected. Information on the total land hold, agro forestry, crop land, grazing land and forest land were collected through interview. An initial discussion was held with district officials, peasant association leaders and development agents to explain the purpose of the survey and obtain permission to conduct the study. Transect walks, along the plantation sites were made with the key informants to get an overview of the major use of *Eucalyptus*. Focus group discussions were conducted in each region. Structured and Semi-structured household interviews were conducted with the purposely selected households from each region. Data were collected that are related to how households perceived the use of *Eucalyptus*, how each actor established and managed *Eucalyptus* trees, socioeconomic importance of the species, medicinal uses of *E. globulus* tree products, Marketing of *E. globulus* tree products and its spatial extent in relation to other farming land holdings.

Data analysis

To detect statistically significant differences in wood volume of different forest products due to different growing sites, calculated mean values of volume, were compared using SPSS version 20. A one way analysis of variance was conducted to test whether statistically significant differences could be detected or not between the sites in wood volume at 0.05 level of significance.

Results and Discussion

Spatial extent of industrial plantation forest by species type

Based on the information generated from regional bureaus of agriculture of the three regions, Oromia region contains more than half of the overall industrial plantation estate (52%) with diversified species composition (**Error! Reference source not found.**).

Considering all species that contribute for industrial wood products, *Eucalyptus* took the highest share (45%) of spatial extent followed by Cypress (41%) compared to other species such as Juniperus (3%), Pine (2%), Gravillea (1%) and others (7%) (Figure 4).

Table 1. Industrial plantation area (ha) by species and region

Regional states	Eucalyptus	Cypress	Juniperus	Pinus	Gravillea	others	Total	% *E.globulus*	%Total plantation
Oromia	29,700	32,100	4400	3,500.00	1,300	7800	78,800	44	52
Amhara	18,000	23,400	300	100	-	2800	44,600	26	30
Southern Nations	20,300	7,000	-	-	-	-	27,300	30	18
Total	**68,000**	**62,500**	**4700**	**3,600.00**	**1,300**	**10,600**	**150,700**	**100**	**100**

Source: Bekele (2011)

In terms of the growing *Eucalyptus* species for different purpose, the Oromia region shares the highest area extent with 44% of the total *Eucalyptus* plantation areas of the three regions (Figure 3).

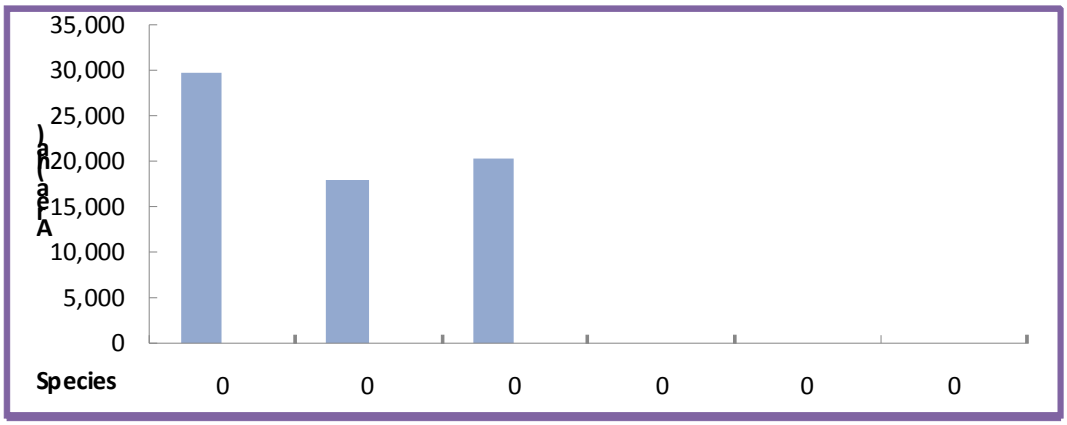

Fig 3. Spatial extent of Eucalyptus plantation among the three Ethiopian regions

Spatial extent of industrial plantation forest by product objectives

About 50% of the total plantation estate is recorded to be managed for saw timber (
Table **1**), which would also meet specification for peeler billets. While some initial inventory work has been carried out by Fortune Engineering, much further work will be needed to determine overall resources suitable for solid wood products. Consequently, 41% of the plantation is managed to produce pole, 13% for fuelwood and 8% for pulp wood.

Table 1. Industrial plantation area (ha) by management objective and region

Regional states	Sawn timber	Poles	Fuelwood	Pulp wood	Total
Oromia	36,100	29,700	13,000	-	78,800
Amhara	11,500	12,000	6,100	15,000	44,600
Southern	27,300	-	-	-	27,300
Total	**74,900**	**41,700**	**19,100**	**15,000**	**150,700**
(%)	**50**	**28**	**13**	**10**	**100**

Non-industrial plantations

Non-industrial wood-lots and community plantations are mainly located in Amhara region and accounts about 87% of the total woodlots of the four regions (**Error! Reference source not found.**). Most of these plantations generally are utilized on a short-length coppice rotation to produce small diameter poles for domestic construction and firewood and would not be expected to be able to produce wood for solid wood products.

Inventory results of Eucalyptus plantation

Although all sites were greater than 20 years of age, the results of this inventory showed a very large difference in the sawlog (pole+billet) volume ratio from different sites, ranging from >50% to zero, mainly due to differences in site quality rather than management practices. Figure 5 demonstrates these differences in stocking (trees/ha) and site quality.

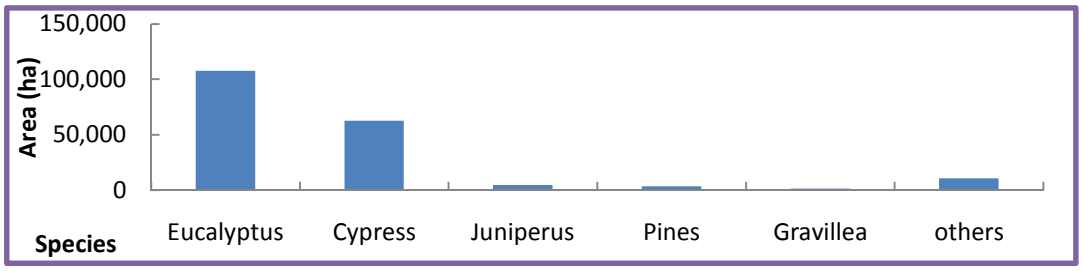

Fig 4. Spatial extent of *Eucalyptus* plantation in relation to other industrial plantations

Table 3. Non-industrial plantation area (ha) by region

Regional states	Area of non-industrial plantations	Area of peri-urban plantations
Oromia	27,800	26,700
Amhara	639,400	0
Southern	64,000	0
Total	**731,200**	**26,700**

Wood volume is also varies among different plantation sites under consideration. For instance the total merchantable wood volume is higher for Minjar site followed by Gidole site in relation to other plantation sites considered by this study (Table 4). However, the volume of sawlog is by far higher for Gidole site compared to other sites indicating good quality site for the management objectives of growing *E. globulus* for sawn timber (Figure 6). On the other hand, the number of poles is higher for Minjar sites as compared to other industrial plantation sites (Figure 7).

Gidole, Southern Peoples Republic **Farta, Gondor Region**

Fig. 5 Two *E. globulus* plantation sites, similar age but different number of stems/ha and tree diameters resulting from differences in site quality

Spatial extent of Eucalyptus plantation in relation to other land holdings

Allocation of total land for different land uses such as crop land, homestead, grazing land and agroforestry varies among land uses under consideration. For instance, significant increase was observed on the crop and homestead lands following increasing in total land holdings. Majority of land size is allocated for crop land (71%) followed by homestead land (21%), grazing land (7%) and forest (1%). Land allocated for grazing land and forest land did not show significance difference with increasing total land holdings. However, 63 % of the source of fuelwood and 46% of the construction wood is collected from the remnant forest land.

Contribution of Eucalyptus plantation

Generating income

The relative cash values of *Eucalyptus* are incredible and can complement crop production. Even though *Eucalyptus* is mostly planted everywhere in Ethiopia, its processing and marketing are not linked well. This is due to lack of knowledge and experiences during sawing, drying and processing of the various commodities produced for the wood of Eucalyptus (Bekele, 1994). A tree aged between three and four years can be sold for Birr 80 or more and is usually used for firewood while the one aged between five and eight years

is sold for more than Birr 160 and is mostly used to make poles. This can translate to profits of between Birr 800, 000 and Birr 1.6 million per hectare, all from an initial crop of tree seedlings that can be bought for about Birr 1.

Table 4. Inventory results of *E.globulus* products obtained from different selected sites

Site	Volume (m^3)					Pole number	Area (ha)
	Total merchantable	Poles	Sawlog	Billets	Residue		
Gidole	159,286	23,007	80,351	55,927	21,238	44,256	**485**
Zazie	28,325	5,314	8,485	14,525	2,832	13,730	**101**
Limu sites	27,238	5,755	1,336	20,155	2,727	13,164	**144**
Munesa/Negele	54,449	5,793	31,344	17,312	5,445	15,600	**150**
Kofele	74,673	12,077	24,288	38,332	7,478	33,184	**212**
Gusha	11,962	2,262	2,412	7,288	1,196	6,380	**129**
Hada Dixis	12,483	7,341	1,878	3,264	1,248	20,360	**154**
Hankicha	5,094	575	0	4,519	509	1,890	**113**
Minjar	160,702	42,043	51,144	67,515	16,070	114,000	**530**
Total	**534,212**	**104,166**	**201,239**	**228,839**	**58,745**	**262,565**	**2,018**

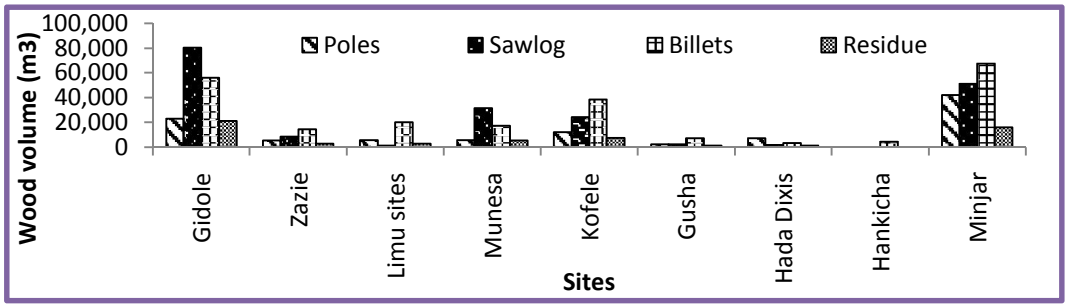

Fig 6. Wood volumes of different *E.globulus* growing sites

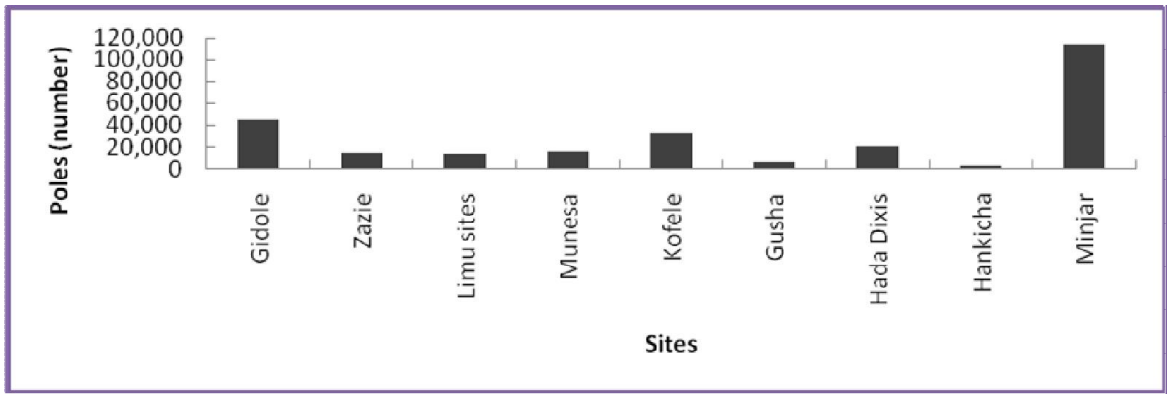

Fig. 7 Number of potential poles from E.globulus at different plantation sites

Contribution of Eucalyptus plantation

Generating income

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Veneer products

Indigenous species such as *Juniperus*, *Cordia*, *Hagenia* and *Podocarpus* species have been the major resource in the past, but high demand of construction; panel and furniture products are requiring the use of substitute materials. Experiences in Chile, Uraguay and Brazil and Australia indicated that growing *E. globulus* plantation is a satisfactory replacement of solid wood in the form round wood, sawn wood, engineered products such as glue laminated wood and veneer products for structural and decorative purposes. Remanufactured products for use in furniture, doors, windows, frames and other house parts. Fuel wood, pulp wood, other fibre products and ecosystem services – is inevitably growing due to local, regional and global drivers (Robert. *et al*., 2003, Sánchez Acosta *et al*., 2008).

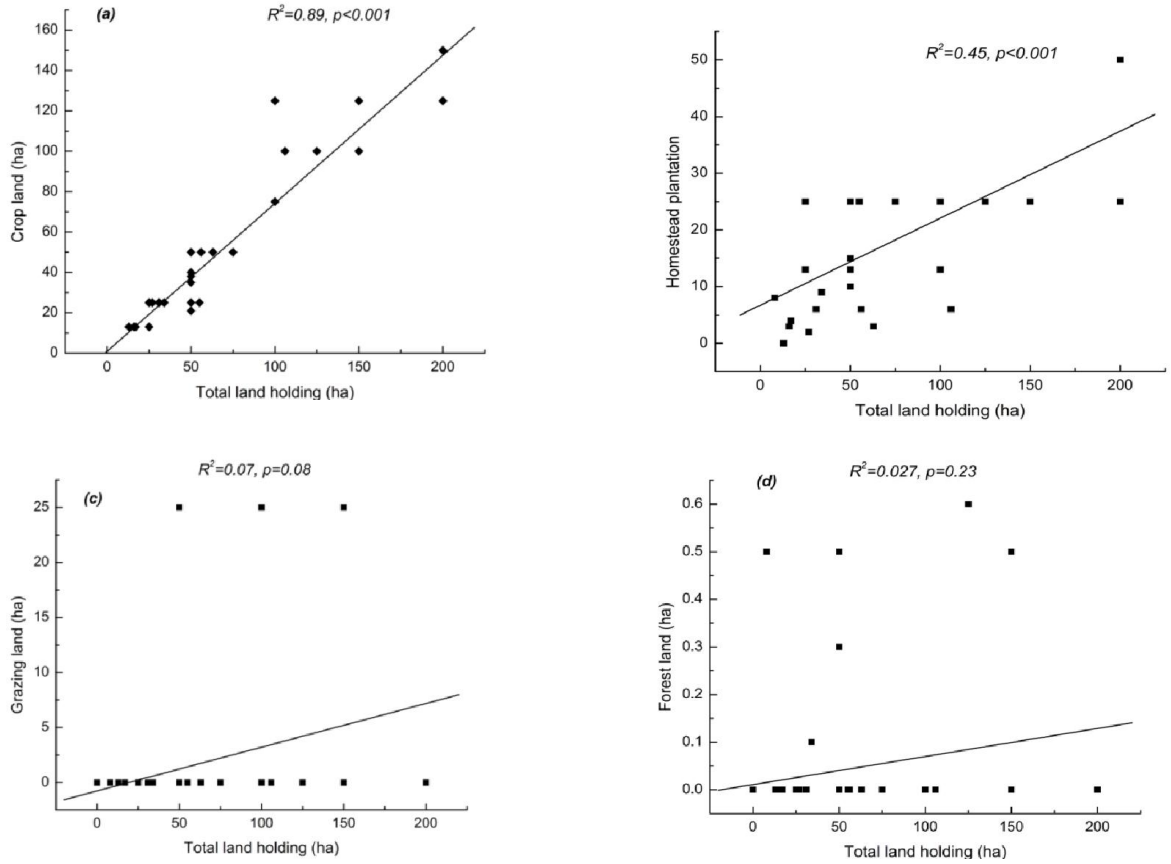

Fig. 8 (a) Proportion of crop land, (b) Proportion of homestead plantation, (c) Proportion of grazing land, (d) Proportion of forest land

Sawn products

E.globulus wood is of high strength, with a strength rating about four times that of most plantation softwoods. The wood is uniformly light in color and has a high hardness index. These characteristics make the wood suitable for both structural and appearance applications which attract significant market opportunities. However, it is well known as a difficult species to dry without degrade in the form of checking and collapse. If *E. globulus* correctly sawn and dried, it will well out perform imported softwoods and in globally would be marketed at a much higher price. If high market prices are to be achieved, effort will be needed in promotion and marketing.

Fuelwood

Fuelwood is also an important source of cash income for households located nearby the main roads. Stacks of *E. globulus* fuelwood were commonly observed along the highways of the study areas. Many smallholder farmers mostly sell fuelwood during the rainy season in order to supplement households' food security.

Contributions to household livelihood

E. globulus is used for a wide range of household uses. Farmers stated some of the major benefits for households: construction of houses, household utensils, cooking, heating, and handles of farm implements. The income generated from *Eucalyptus* is by far higher than the income generated from cereal crops, although many people felt that the livelihood of the farmers' totally depends on agricultural activities accounting for the largest proportion of land for agricultural activities. Similar studies in central highlands of Ethiopia (e.g. Kebebew and Ayele, 2010) showed that *Eucalyptus* contributed 50% of household income relative to cereal crops.

Medicinal values

The leaves of *E. globulus* are steam distilled to extract *Eucalyptus* oil. The oil has therapeutic, perfumery, flavoring, antimicrobial and bio-pesticide properties. *Eucalyptus* is used internally and externally as an expectorant, and to treat infections and fevers. It is also used topically to treat sore muscles and rheumatism (Armando and Rahma, 2009).

Contribution to national development

In many wood industries of the country the local commercially acceptable timbers are potentially available from natural forest or imported softwoods. Eucalyptus species can be used as alternatives to the natural timber species and serve as import substitution of wood products.

The use of essential oils extracted from *E.globulus* as functional ingredients in foods, drinks, toiletries, and cosmetics is also gaining attention, both for the growing consumers' interest in the ingredients coming from natural sources, and also because of the increasing concern with harmful synthetic additives (Sacchetti *et al.* 2005). Due to their bioactive components, essential oils are indeed promising in view of their use as effective antibacterial, antifungal, and antioxidant agents. With the growing interest in the use of essential oils in both food and pharmaceutical industries, a systematic examination of the plant extracts has become increasingly important (Baratta *et al.* 1998).

Contributions to environmental management

E.globulus can provide essential contribution to soil conservation (rehabilitation of degraded land). The benefits derived in terms of slowing erosion and retaining soil moisture over the landscapes may compensate for the losses in crop production experience reported in some studies (Jagger and Pender, 2000).

Since 1895 *Eucalyptus* species have been introduced for satisfying the growing demand of wood for fuel, construction material and to reduce the pressure on the remaining natural vegetation. It's with this conception that Menilek II has introduced fast growing exotic species for plantation development and as a means for restoring the long lasting deforestation of natural forests of the country, particularly the *Juniperus procera*, *Olea europea* subsp. *cuspidata*, and *Podocarpus falcatus* stands around large towns of the country (Breitenbach, 1961). Thus, *Eucalyptus* tree should not be considered as an evil species for the other plants as proper site selection and management strategies are put in place (Aramde and Hailu, 2013). Several scientists in Ethiopia have confirmed that the introduction of *Eucalyptus* species to Ethiopia was a great success for the survival of indigenous species (Feyera and Demel, 2001; Eshetu, 2001; Mulugeta and Demel, 2004). It was also reported that the *Eucalyptus* number of stem per unit area matters the growth of under story and it is proved that the low stem density *Eucalyptus* stand exhibits the growth of higher species diversity as compared to high stem density *Eucalyptus* stands (Fikadu *et al.,* 2010).

Therefore, if proper management is put in place, *Eucalyptus* plantation can have a catalytic effect on the regeneration of native species and can be used as a management tool for restoration of degraded forest lands in Ethiopia (Lugo, 1997; Yitebtu, 1998; Engelmark, 2001; Eshetu, 2001; Feyera *et al*., 2002; Mulugeta *et al.,* 2004; Getachew and Abyot, 2006).). Plantation forests can play an important role in creating low-carbon benefits and decrease pressure on forest resources since these produce raw materials for various uses which otherwise sourced from exiting forests.

Following COP 15 accord in Copenhagen 2009, Ethiopian Environmental Protection Authority has submitted nationally appropriate mitigation actions with regard forest development of Ethiopia. Accordingly, it is planned to enhance district level reforestation actions for the increment of vegetation cover of 214,440 square kilometers of degraded lands, lands affected by gullies and slopes including through the management of community areas closed off to grazing. Some 28737, 4391, 60360 and 198175 square kilometers of natural high, deciduous forest land, national parks, existing forests that are providing non-timber forest products maintained as buffer area for mitigating forest area will be sustainably managed in order to reduce GHG emissions from deforestation and forest degradation, respectively. Moreover, 52,695 square kilometers of forest in exhaustion or production forests established and sustainably managed for the purpose of sequestrating carbon and 51,496 square kilometers of wetlands wisely managed and sustainably used where E.globulus plays significant role in this regard (EPA, 2010).

Conclusion

In the face of growing economy and increased demand for wood products, *Eucalyptus* remains to be the desired species that grows fast and produce wood to at least meet the demand of wood for fuel, construction and furniture materials. This makes the species still valid in the present and future plantation forestry of Ethiopia. Planting of *E. globulus* still is justified under the present circumstances in Ethiopia where reducing poverty has become the key objective of the Ethiopian Government. However, the result showed that the area under plantation forest is very low as compared to the cropland.

In countries like Ethiopia, where there are huge gaps between the demand and supply of wood as a result of ever increasing human population, accelerating deforestation, the use of fast-growing plantation species such as the *Eucalyptus globulus* is foreseeable as it is preferred to other species, because of its fast growth and useful products. Thus, the potential of *Eucalyptus globulus* plantations as fuel, timber and industrial wood in Ethiopia will be one of the relevant issues to be considered by the newly established Ministry of

Environment and Forestry of Ethiopia and emphasis should be given by all stakeholders including the community and other forestry development institutions to supporting land users in selecting the right species for the right site.

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