Effect of *Eucalyptus camaldulensis* stand Conversion into Crop Production on Growth and Yield of Maize: the case of Koga Watershed Areas in northwestern Ethiopia

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ABSTRACT

Farmers in the highlands of Ethiopia commonly plant eucalypts on their farmlands. However, growing eucalypt is becoming a great concern due to its alleged long-term site effect. In view of this, a study was conducted in Koga watershed, northwestern Ethiopia, to investigate whether croplands afforested with *Eucalyptus camaldulensis* can be reused for annual crop production after its removal. In this study, we compared growth and yield of maize between adjacent clear-felled *E. camaldulensis* stands and continuously cultivated farms at three paired sites. Plant height, leaf area, dry matter production and grain weight were evaluated as parameters for maize growth and yield. Maize plants grown on clear-felled eucalypt stands were taller and developed larger leaf areas than those grown on continuously cultivated farms. Dry matter production and grain yield were also significantly higher in maize plants established on clear-felled eucalypt stands. Farmers also responded that the growth and yield of maize grown on the clear-felled eucalypt stands were better than those grown on continuously cultivated farms. The results suggest that contrary to the popular belief, agricultural lands afforested with eucalypts can be re-used for annual crop production.

Keywords: Clear-felled stands, Croplands, Crop performance, Farmers' perception, Ethiopia.

1. INTRODUCTION

In Ethiopia about 5-10 species of *Eucalyptus* are widely planted for various uses (Friis, 1995). In the highlands of Ethiopia, *Eucalyptus* species (hereafter referred to as eucalypts) are commonly integrated into the various farming systems and their planting has resulted in high economic profitability compared with agricultural use of land for crop production (Mulugeta Lemenih, 2010). Farmers' raised interest in eucalypt farm forestry has now caused for conversion of croplands into eucalypt woodlots (Dereje Jenbere et al., 2012). However, the uncontrolled expansion of eucalypts on productive farmlands has raised great concern, particularly as eucalypts are claimed to have detrimental effects on soil productivity (El-khawas and Shehata, 2005; Forrester et al., 2006; Jiregna Gindaba, 2006). Studies conducted in the highlands of Ethiopia have shown reduction in crop growth and yield when agricultural crops are grown close to eucalypts (Jagger and Pender, 2003; Jiregna Gindaba, 2003; Selamyihun Kidanu et al., 2004, 2005; Tilashwork Chanie et al., 2013). Eucalypts have been reported to cause crop loss by outcompeting crops for water and soil nutrients (Michelsen et al., 1993; Jiregna Gindaba, 2003; Tilashwork Chanie et al., 2013), through shading (Tilashwork Chanie et al., 2013) and producing allelochemicals (Lisanework and Michelsen, 1993; Ahmed et al., 2008).

Studies conducted so far mainly focused on reduction in crop growth and yield when eucalypt trees are grown on or close to farmlands (e.g. Jagger and Pender, 2003; Tilashwork Chanie et al., 2013). There has been also fear of crop loss owing to the perceived long-term site deterioration allegedly caused by eucalypts (Jiregna Gindaba, 2006). There is no sufficient scientific evidence regarding reclamation of farmlands planted with eucalypts for agricultural crop production. There is, therefore, a need to determine the extent to which growth and yields would be influenced when agricultural crops are cultivated on clear-felled and de-stumped eucalypt stands that replaced previous crop farmlands under the existing crop production systems. In this study, we aimed to: (1) examine growth and yield of maize cultivated on clear-felled and de-stumped eucalypt stands to assess whether farmlands replaced by eucalypt stands can be reused for annual crop production; and (2) assess farmers' observation on the growth and yield of maize cultivated on the clear-felled stands.

2. METHODOLOGY

2.1. Study Area

The study was conducted in Koga Irrigation and Watershed Management area, which is located at 11° 10' - 11° 25' North and 37° 02' - 37° 17' East (Fig 1) within the Koga Basin in Mecha District of the Amhara National Regional State, northwestern Ethiopia. The altitude in the watershed varies from 1,750 to 3,200 m. The dominant soil type in the watershed was Nitisol. The main rainy season extends from mid-June to mid-October with maximum rainfall occurring between July and August. The mean annual rainfall is about 1,560 mm and the mean annual temperature ranges between 16°C and 20°C.

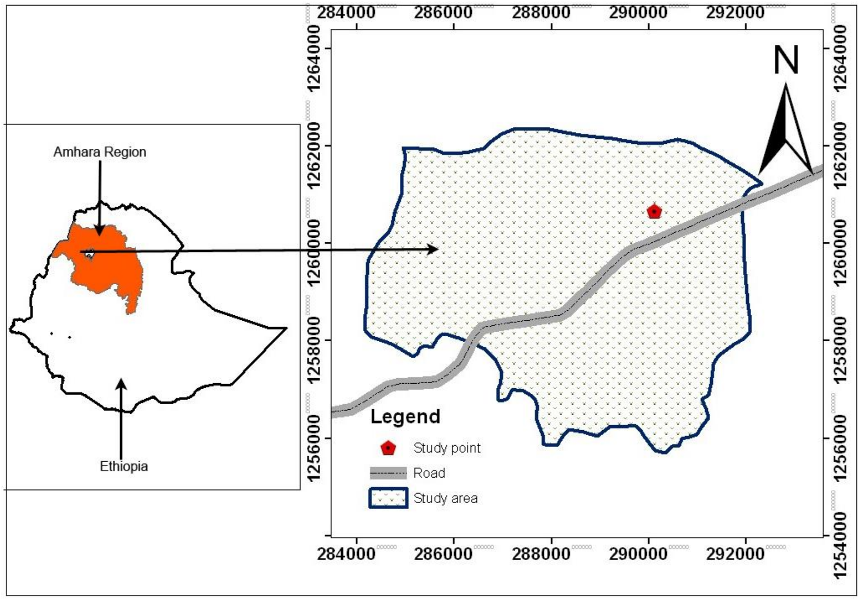

Figure 1. Map of Ethiopia showing the study area.

Figure 2. Partial view of Koga irrigation and watershed management.

Koga Irrigation and Watershed Management area (Fig 2) was designed primarily to sustain food security in the area by harnessing the water resources of Koga River to irrigate about 6,000 ha of the command area. The farming system is traditional with a mixed farming system that integrates crop and livestock, mostly cattle. Cultivation involves oxen-plow with simple and shallow plows. Farmers living in the watershed area commonly planted *Eucalyptus camaldulensis* Dehnh on their farmlands followed by plantations along farm boundaries and the main road. They preferred eucalypt because of its fast growth and high economic return though they perceive that eucalypt could lead to the exhaustion of productive lands (Tilashwork Chanie et al., 2013). Now, the farmers have cleared and de-stumped large areas of *E. camaldulensis* stands for crop production and harvesting at least twice a year through irrigation. The stands were cleared and de-stumped using bulldozer during irrigation development and the cost was totally covered by the government.

2.2. Experimental Farms and Crop

Three pairs of farms, i.e. a total of six experimental farms, were used in the study. Three of the farms were obtained from clear-felled *E. camaldulensis* stands, while the other three were crop fields adjacent to these clear-felled stands. The clear-felled stands were in the first and second coppice of trees that used to be managed with rotation age ranging between 5 and 6 years (Table 1). Both clear-felled stands and the adjacent croplands had similar land use history prior to afforestation. The paired plots were more or less on a similar slope, and treated with similar fertilizer application dose, sowing date and weeding intensity.

Table 1. Stand characteristics of the *E. camaldulensis* stands at the sampled farmlands in the study area before clear-felling*.

Farmland	***Age (years)***	***Density (stem ha^{-1})***
Farmland 1	7, 1st coppice	20,000
Farmland 2	7, 1st coppice	20,000
Farmland 3	15, 2nd coppice	24,000

*In all farmlands weeding was done once during stand establishment and there were no use of inorganic fertilizer and litter fall removal.

The test crop used for this study was maize variety BH 543, a widely planted variety in the study area during data collection period. The crop was planted during 15-20 June 2011 and harvested towards the end of November 2011. It was fertilized with 100 kg DAP (Di-Ammonium phosphate: a water soluble compound fertilizer applicable to the nitrogen and phosphorous needs of various crops) at planting time and 100 kg Urea (A white crystalline solid containing nitrogen, which is used widely as a nitrogen fertilizer) 40 days after planting per hectare. The spacing was, on average, 75 cm between lines and 25 cm between plants. Growth and yield of maize were assessed on the three paired farmlands. In each farm, three plots of seven rows, 75 cm apart and 18 m long, were chosen randomly. Three subplots of 4.5 m^2 each were randomly chosen from three medium rows of each plot for yield and growth measurement. The experimental design was randomized complete block design, considering the three farmlands as blocks.

2.3. Data Collection and Analyses

Twelve weeks after sowing, four maize plants from each subplot (n = 9 subplots x 4 = 36 plants) were randomly chosen for determining height and leaf area. Plant height was measured with a ruler from the ground level to the uppermost leaf tip. The area of each leaf was calculated using length-width method: Leaf area = 0.75 (leaf length x leaf width) and the total leaf area per plant was obtained by summation (Saxena and Singh, 1965). The leaf width was determined at the widest point. At the same time, four plants were cut at ground level and oven-dried at 80 °C for 72 hours to estimate aboveground dry matter production (Yang et al., 1993). Later, at crop maturity, the subplots were harvested by hand at ground level and cobs were de-husked and shelled. Then grains were sun-dried to 13% moisture content and dry grain weight values were converted to tons per hectare.

Thirty farmer respondents who were growing maize or other crops in their clear-felled stands were chosen in the study. Detailed information regarding the effect of reuse of areas previously planted with eucalypts for crop production on soil fertility as well as growth and yields of crops was, then, explored through interviews using a semi-structured questionnaire. The farmers were asked the following questions: What changes did you observe in the height and leaves of maize plants grown in the clear-felled stands and croplands? Did clear-felled stands or croplands give higher maize yields? Did you perceive that replacing farmlands with eucalypts increased soil fertility?

We used SPSS (version 16) for all statistical analyses. Differences in growth and yield of maize between land-use types among farmlands were assessed using ANOVA according to general linear model (GLM) procedure followed by Tukey's test to determine any significant difference. At each farmland, Students t-test was used to identify differences in growth and yield of maize between land-use types. To all citations of significant differences in the text, differences between means were considered significant when $p < 0.05$.

3. RESULTS

3.1. Plant Height and Leaf Area

Only land-use had significant effects on maize height and leaf area growth (Table 2). Maize plants in the clear-felled eucalypt stands were significantly ($P < 0.001$) taller and had significantly larger leaf areas than in the continuously cultivated farms (Fig. 3). The mean plant height and mean leaf area per plant were 256 ± 3.2 cm and 7703 ± 222 cm^2 in the clear-felled eucalypt stands and 226 ± 2.7 cm and 5713 ± 297 cm^2 in the continuously cultivated farms, respectively. In the three continuously cultivated farms, the heights of maize plants ranged between 199-253, 208-237 and 215-252 cm compared to 238-275, 214-279 and 252-281 cm of the corresponding three clear-felled eucalypt stands. Leaf area of maize plants in the three continuously cultivated farms ranged between 4608-5666, 4617-7854 and 4983-6923 cm^2 compared to 6077-9429, 6882-9721 and 6920-8781 cm^2 of the corresponding three clear-felled eucalypt stands.

Table 2. Summary of ANOVA results comparing growth and yield of maize plants between land-use types and farmlands.

Source of variation	***Height***		***Leaf area***	
	F	*P*	*F*	*P*
Land–use	32.1	0.000	32.3	0.000
Block (Farmland)	1.2	0.330	2.2	0.156
	Biomass		***Yield***	
Land–use	23.7	0.000	188.3	0.000
Block (Farmland)	3.4	0.110	2.4	0.134

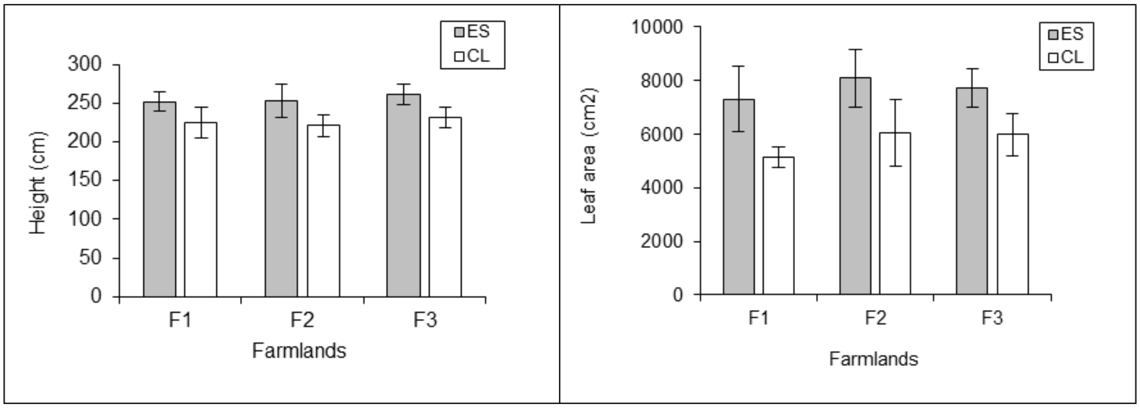

Figure 3. Variation in height and leaf area of maize plants grown in clear-felled stands (ES) and adjacent croplands (CL) at the three paired farmlands.

Table 3. Variation in aboveground dry matter production and yield of maize plants (mean ± SD) grown in clear-felled stands and adjacent croplands at 3 paired farmlands.

Farmlands	***Land-use***	***Dry matter production (g plant^{-1})***	***Yield (t ha^{-1})***
Farmland 1	Clear-felled	106.3 ± 12.9	5.96 ± 0.39
	Cropland	85.2 ± 5.0	3.71 ± 0.58
Farmland 2	Clear-felled	184.1± 20.3	6.35 ± 0.28
	Cropland	132.6 ± 23.0	4.12 ± 0.18
Farmland 3	Clear-felled	128.3 ± 5.1	6.11 ± 0.17
	Cropland	96.5 ± 4.9	4.14 ± 0.19

3.2. Dry Matter Production and Grain Yield

Like height and leaf area, dry matter production and yield of maize were only affected by land-use (Table 2). Dry matter production of maize sown on continuously cultivated farms (mean = 105 ± 14 g plant^{-1}) was significantly (P < 0.001) lower than that obtained on the clear-felled eucalypt stands (mean = 140 ± 23 g plant^{-1}) (Table 3). At the three continuously cultivated farms, biomass production ranged between 80-89, 106-148 and 80-108 g plant^{-1} compared to 94-119, 162-203 and 125-134 g plant^{-1} of the corresponding three clear-felled eucalypt stands. The maize grain yield was also significantly (P = 0.0001) lower in the continuously cultivated farms than that in the clear-felled eucalypt stands. Crop yields ranged between 3.14 to 4.32 t ha^{-1} in the continuously cultivated farms (mean = 3.99 ± 0.34 t ha^{-1}) and 5.51 to 6.63 t ha^{-1} in the clear-felled eucalypt stands (mean = 6.14 ± 0.22 t ha^{-1}) (Table 3).

3.3. Perception of Farmers

All farmers reported enhanced growth and yield of maize in the clear-felled stands compared with those in the croplands (Table 4). They also perceived that afforesting farmlands with eucalypts has improved soil fertility. However, they were not sure if sites, which were previously planted with eucalypt will remain productive for relatively long time compared with continuously cultivated croplands.

Table 4. Effect of land use change on soil fertility as well as growth and yield of maize as stated by respondents in the study area (n = 30).

Plant Characteristics	***Change observed in the clear-felled stands compared to the croplands***	***Proportion of respondents (%)***
Plant height	Taller	100
Leaves	Longer and broader	90
Grain yield	Higher	100
Soil fertility	Increased	87

4. DISCUSSION

The results showed that growth and yield of maize on sites previously planted with eucalypts were higher than on continuously cultivated land. Similar results were reported for two crops, barley and finger millet, where greater growth and yields were obtained from crops grown in clear-felled stands of *E. camaldulensis* than in continuously cultivated croplands (Desalegn Tadele and Demel Teketay, 2014). Ceccon (2005) also found positive results when intercropping *E. camaldulensis* with agricultural crops. Enhanced growth and yield of maize in the clear-felled eucalypt stands might be due to improvement of soil nutrient conditions. Previous reports from the highlands of Ethiopia revealed increased soil nutrient status and organic carbon in sites planted to eucalypts. Zerfu Hailu (2002) reported improvement in total soil N due to land use changes from cropland to *E. camaldulensis* plantations in the highlands of Ethiopia. Birru Yitaferu et al. (2013) showed improved soil chemical properties (pH, CEC, N) and organic matter from farmlands reclaimed from *E. camaldulensis* plantations. Bekele Lemma et al. (2006)

and Shiferaw Alem et al. (2010) found increased soil nutrients and organic carbon in plantations of *Eucalyptus grandis,* one of widely planted eucalypts in Ethiopia (Friis, 1995), compared with adjacent croplands and natural forest.

Afforesting farmlands with eucalypts can improve soil productivity via translocation of nutrients from deeper horizons to the soil surface (Tchienkoua and Zech, 2004). Moreover, farmers in Koga watershed did no collect litter and this might have contributed to increased crop productivity. Guo et al. (2006) reported import of up to 24% of the total N uptake to the soil surface via litter fall in short rotation eucalypt forests. Jiregna Gindaba (2003) recorded lower soil N and P contents from 10 m away from the canopy of *E. camaldulensis* than the amount from under the canopy, which received litter fall.

In the croplands, however, farmers collected crop residue for animal fodder, construction (as a component for making mud), fuel and sale (own personal observation and communication). This practice would certainly lead to loss of soil fertility in the agricultural field by reducing recycling of nutrients to the soil surface. According to Zerfu Hailu (2002) potential macronutrient removals from the soil surface through harvesting of agricultural crops can exceed removals through wood biomass of eucalypt plantations. Crop residue removal would, therefore, contribute to the reduction of growth and yield of maize in continuously cultivated croplands.

Farmers also witnessed increased crop productivity in the farmlands reclaimed from eucalypt stands. According to their response, the growth and yield of maize on the reclaimed eucalypt stands was better than on adjacent croplands or crop growth and yield performance in earlier years. The respondents indicated that because of the high quality (in terms of size and color), the buyers in the markets were highly attracted to crops harvested on clear-felled eucalypt stands. Previously, these farmers perceived that eucalypt trees were exhausting the once productive land (Tilashwork Chanie et al., 2013) and, hence, were not interested to take farmlands afforested with eucalypts during land redistribution following the irrigation programme. Now their perception has changed and they prefer stands afforested with eucalypts.

5. CONCLUSION

The data collected in the field and farmers' responses showed improved crop growth and yield in the clear-felled stands suggesting that croplands afforested with eucalypts can be reused for annual crop production. The results are contrary to a great concern of planting eucalypt on croplands due to its alleged long-term site effect (El-khawas and Shehata, 2005; Forrester et al., 2006; Jiregna Gindaba, 2006). This calls for further studies of a wider range of *Eucalyptus* species, site conditions, management practices, soil properties and cost of removing stumps. Results of broader studies would help resolve controversies of land-use transformation using eucalypts. This is important because eucalypt plantation forestry has played and continues to play significant role in improving the livelihoods of rural communities, poverty reduction and reducing the pressure from remnant native forests in the highlands of Ethiopia.

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