ORIGINAL ARTICLE

Growth and Carbon Storage of Different Spaced Rubber Tree (*Hevea brasiliensis*) Plantation at Bebeka Coffee Farm, South-West Ethiopia

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ABSTRACT

The study on the growth and carbon storage of the seven years old *Hevea brasiliensis* plantation in Bebeka coffee farm was undertaken and analyzed through stratified randomized block design with sub-sampling analysis of variances. Four randomized stands per planting distance per block were taken as sample plots. The measured data were diameter at breast height (1.3m above the ground); total tree height; merchantable height has taken from field, while carbon density was calculated as = biomass density x 45%. The 2m x 4m dominated with a mean of 13.05 ± 0.3cm followed by 2m x 3m planting distance and the least is 2m x 2m diameter. The result of the study shows that the planting distance influences the diameter at breast height. The 2m x 4m were dominated with mean heights of 9.84 ± 3.13m and 5.9 ± 1.32m, respectively followed by 2m x 2m and the least is the 2m x 3m. The 2mx4m dominated in C density with a mean of 52.13 ± 8.71Mg ha^{-1} followed by 2m x 3m and the least is 2m x 2m implying that above ground biomass of the plantation is affected by planting distance. The 2m x 4m spaced plantation is significantly different from other spacings while the result of 2m x 3m and 2m x 2m spacing is not significant for both C and biomass density. C density is positively related to all growth traits of *Hevea brasiliensis*, which indicates is a good C sink bases on the finding of the present study.

Keywords: Biomass Density, Carbon Density, Planting Space

INTRODUCTION

Climate change is an alarming issue in the world that needs higher priority and immediate concern of every thinking stakeholder of the Earth. Deforestation and forest degradation, especially in the tropics, have contributed to 90% of the greenhouse gas emissions from Land Use, Land Use Change, and Forestry (LULUCF) (Mulugeta, 2004; Fang *et al.*, 2007; Correia *et al.*, 2010).

Forests are the largest terrestrial reservoir for atmospheric carbon while CO_2 is stored in the organic matter of trees (Nabuurs *et al.*, 1997; Bangroo *et al.*, 2011). The amount of carbon stored in a forest stand depends on species and productivity. Forest ecosystems store more than 80% of all terrestrial aboveground C and more than 70% of all soil organic C (Jobbgy and Jackson, 2000; Six *et al.*, 2002a).

Estimation of Carbon stocks of tree plantations is necessary to provide reliable estimates and inputs to the inventory of Green House Gasses. Carbon stocks can be determined through various methods where sampling is statistically valid (Sales, 2005; FAO, 2010). There are techniques and methods for sampling design and methods that accurately and precisely measure C pools, to be chosen based on commonly accepted principles of forest inventory (MacDicken, 1997; Nabuurs *et al*, 1997; Mulugeta, 2004, Bangroo *et al.*, 2011).

Tropical forests account for 40% of C stored globally in terrestrial biomass (Dixon *et al.*, 1994) and contribute as much as 36% of the net exchange between atmosphere and terrestrial vegetation (Melillo *et al.*, 1993). Thus, small changes in net C stock of tropical forests could result in significant storage or release of carbon to the atmosphere (Mulugeta, 2004). Since 1850, Knowledge of the total C content in tropical vegetation provides a critical initial condition for studies at multiple scales which examine C flux caused by natural and anthropogenic processes. However, the accurate estimation of structural characteristics (aboveground biomass or total amount of C within living tissues) of tropical forest vegetation remains a major impediment (IPCC, 2002; Mulugeta, 2004).

The allometric equations to estimate biomass C use mathematical relationships that convert external measurements, such as tree diameter and sometimes height, to total tree biomass (Losi, 1996). This non-destructive method to estimate biomass can achieve accuracies of up to 95% and provides a model for plantations growing in similar ecological conditions (i.e. location, topography, and climate) and within the same range of diameter and height (Montagnini *et al.*, 1995; Fang *et al.*, 2007; Correia *et al.*, 2010).

Augmented establishment of tree plantations on cleared land in the tropics has long been suggested as a way of reducing the rate of increase in atmospheric CO_2 (Dyson, 1977). There are about 187 million ha of tree plantations worldwide, representing approximately 5% of the global forest area (FAO, 2010). In Ethiopia, there are about 509422ha plantation forests (FAO, 2010), which among 800ha is Rubber tree plantation. These plantations of the country will contribute 602 million metric tons of biomass C stocks accumulation beside economic benefits (FAO, 2010). However, there is no information how *Hevea brasiliensis* plantation is contributing for biomass C sequestration, and how planting distance is affecting tree C density through its effect on tree growth.
This study has estimated the carbon storage of seven years old *Hevea brasiliensis* plantation in relation to tree height, dbh, above and below ground biomass, stands volume and basal area with C density of the plantations; as the

growth performance of the plantations has affected by planting distance.

MATERIALS AND METHODS

General description of the study area

This study was conducted in Bebeka coffee farm (plantation), between June 1 and July 28, 2012. The study area was found in South-west Ethiopia located at 595 Kms from Addis Ababa. The altitude of the area lies between 1000 and 1350m above sea level with annual rainfall of about 1750mm. There are two major rivers in the area namely Aware and Gatcheb. The total area of the farm is 17164 hectares (Bench-Maji zonal Economy & Finance Development Department projected for the year 2007) distributed over 20 villages.

The measured data were diameter at breast height (dbh) at 1.3m above the ground; merchantable and total tree height has taken directly from field. The aboveground biomass has also computed using the allometric equation by Brown *et.al.* (1997) which is:

$Y = \exp\{-2.134 + 2.530*\ln(D)$

Where: Y = tree biomass (kg), and D = dbh (cm),

Below ground root biomass was estimated as:

$RB = 0.2 *Y$,

Where RB is root biomass.

Stand volume and basal area has been calculated by using:

$SV = 0.7854(D)^{2MH}$, where MH is merchantable height and D is dbh, and

$BA = 0.7854(D)^2$ respectively.

The above and below ground biomasses of all individual trees in a plot were summed to calculate total biomass for each plot, and the plot-level values of estimated above and below ground biomass were then converted to biomass per hectare (Mg ha^{-1}) for each plantation spacing. Then, the C density was calculated as:

Sampling design and analysis

The study on the growth and carbon storage of the seven years old *Hevea brasiliensis* plantation in Bebeka coffee farm was undertaken and analyzed through stratified randomized block design sampling system for different planting distances. At each planting distances, parameters were measured and their GPS coordinates were taken. A 100m x 100m size was selected and divided into 25m x 25m for subplots allocation. To choose the sample plot, each plot was numbered and lottery method was used for randomization. There were four randomized sample plots per planting distances, and about twelve sample plots are considered for the study.

$C= Y *0.45$ for above ground C, and

$C= RB *0.45$

Data analysis

The results were subjected to analysis of variance (ANOVA). All statistical computations were made by using SAS (2004) version 9.0 computer software. The least significant difference (LSD) at $P \leq 0.05$ was used to determine statistically significant differences within each variable at each plantation spacing. We conducted paired t-tests to test for significant differences in biomass and C density for each category of planting distances.

RESULTS AND DISCUSSION

Height and Diameter (dbh) distribution

The result of the present study shows that, the total and merchantable height was influenced by planting distances (Figure 1 and 2). The 2m x 4m planting distance were dominated with mean heights of 9.84±3.13m and 5.9±1.32m respectively for total and merchantable height followed by 2m x 2m, and the least is the 2m x 3m. This result is insignificant as revealed in the analysis of variances, which means that the growth of the plantation in Bebeka coffee farm is not affected by spacing in terms of total and merchantable height.

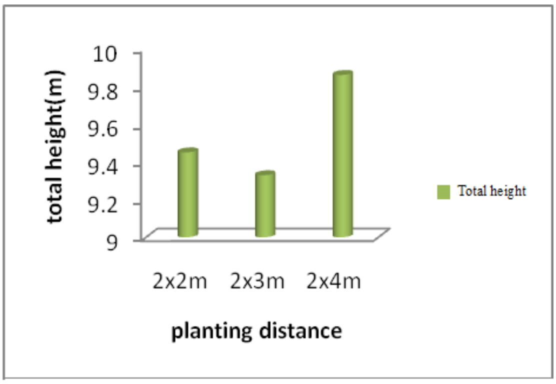

Figure 1. Total height (m)

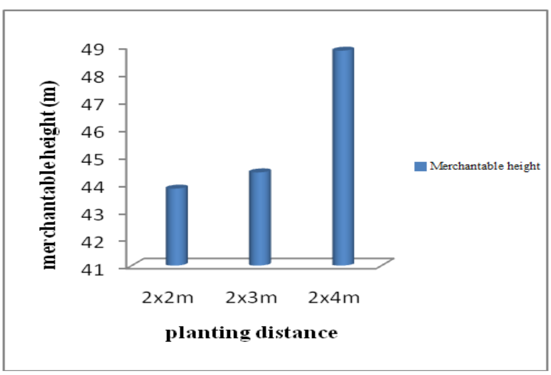

Figure 2. Merchantable height (m)

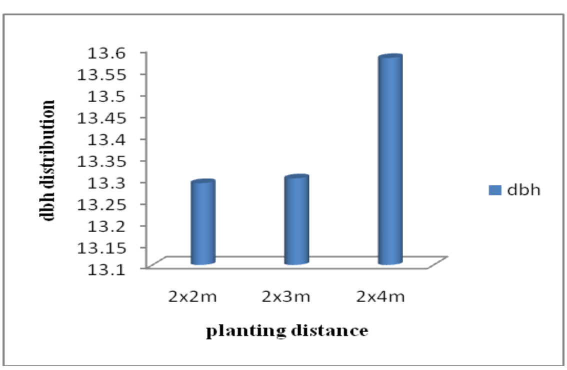

Figure 3. DBH distribution

On the other hand, the study also revealed that, the mean data of diameter at breast height (dbh) as influenced by planting distances (Figure 3). The 2m x 4m dominated with a mean of 13.05±0.3cm followed by 2m x 3m planting distance and the least is 2m x 2m. The result of the study shows that, the planting distances significantly influence the diameter at breast height (dbh). This implies that the growth of the plantation is affected by variation in planting distances in which the larger spacing enhances the dbh of a tree.

The output of the study species was similar to values reported for native tree plantations in pure stands established in the North, Caribbean and South regions of Costa Rica (Fang *et al.*, 2007; Montagnini *et al.*, 1995) as report expresses despite of the plantation condition. Similar studies had been also noticed in earlier measurements of the same types of plantations (Montagnini *et al.*, 1995; Petit and Montagnini, 2004) that shows the same results.

Stand Volume and Basal Area

The present study also reveals stand volume and basal area of *Hevea brasiliensis* as affected by planting distance (Figure 4 and 5). The 2m x 2m planting distance dominated with a mean of 35.38±5.21m^2/ha and 5.45 ± 3.15 m^2 ha^{-1} respectively for stand volume and basal area, followed by 2m x 3m and the least is 2m x 4m. This is true because the stand volume in the closer spacing is higher compared to the wider spacing. This result is insignificant as revealed in the analysis implies that, the stand volume and basal area per hectare of the *Hevea brasiliensis* plantation in Bebeka coffee farm, is just the same at different planting distances.

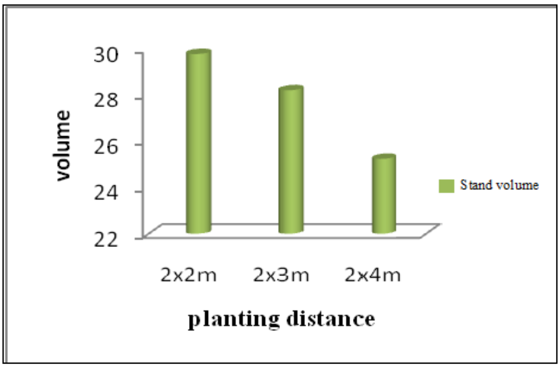

Figure 4. Stand volume

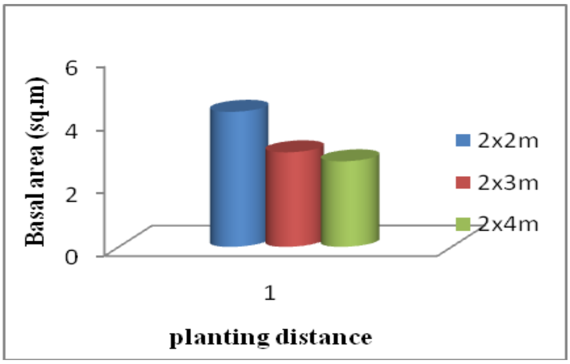

Figure 5. Basal area

Biomass and Carbon Density (Mg/ha)

The 2m x 4m dominated with a mean of 52.77 ± 3.13 Mg ha^{-1} followed by 2m x 3m with a mean of 46.31 ± 0.12 Mg ha^{-1} and the least was 2m x 2m with a mean of 46.11 ± 0.31 Mg ha^{-1} in biomass density. The widest spacing is significantly higher biomass than the closer spacing, as naked in the analysis of variance. This implies that the growth of *Hevea brasiliensis* plantation in terms of biomass density is influenced by planting distance.

The present study mainly concerned on C density of *Hevea brasiliensis* as affected by planting distance through its impact on biomass density. The 2m x 4m dominated with a mean of 23.75±1.32 mg/ha followed by 2m x 3m with a mean of 20.89±2.13 mg/ha and the least is 2m x 2m with a mean of 20.75±2.37 mg/ha. The 2m x 4m spaced plantation is significantly different from the other spacing's while the result of 2m x 3m and 2m x 2m spacing is not significant as revealed in the analysis of variance. This implies that the growth of *Hevea brasiliensis* plantation in Bebeka coffee farm shows that, the larger the spacing is the higher C density which is dependent on their biomass density. The study by Kauppi *et al.,* (1997) revealed that, the smallest C densities were associated with the highest stand volumes.

The carbon density values obtained from the present study were comparable to that reported by Sales *et al.,* (2005) on the C density at various ages of *Mahogany* and *Gmelina* species in the Philippines. Furthermore, CO_2 sequestration and storage were dependent on the amount of biomass of trees, specifically, on the variables dbh and total height. This conforms to the findings of Kurz *et al.,* (2009) who mentioned that C sequestration potential in the different forest types tends to be correlated to dbh and tree height. Koskela *et al.,* (2000) also compared labile and perennial C stocks in shaded cacao (*Theobroma cacao*) systems in Turrialba, Costa Rica, based on data from a study by Beer *et al.,* (1990) in which the shade trees were *Erythrina poeppigiana,* and *Cordia alliodora.* The implication of these findings is that, if anything, increasing planting density increases the proportion of fixed C used in stem production. However, other important factors such as wood quality or differences between total volume and merchantable volume must also be considered when choosing a planting density.

All the results show that, the scatter plot of the C density of the *Hevea brasiliensis* plantation with tree growth in which all traits were found to be positively related to C density. It was found that biomass density is perfectly related with C density (R^2 = 1) followed by the dbh (R^2 = 0.98), stand volume (R^2=0.71), and total tree height (R^2= 0.56). This implies that the increases in biomass of the plantation resulted to the increases of its C density. The bigger the dbh of the *Hevea brasiliensis* tree shows the more its biomass and its C density. In the present study, we can conclude that, stand volume, dbh and total tree height are highly related to C density which in line with the study of (Macdicken, 1997; Jason *et al.*, 2003; Lasco and Pulhin, 2003; Bangroo *et al.*, 2011).

Generally, the results of the study revealed that planting distance of *Hevea brasiliensis* significantly varied in terms of growth and C storage in the field. Further study may be undertaken in different species to verify whether C storage of the same species at different planting distance is just the same as what have been found in this particular study. Yearly gathering and analysis of data on the same plantation is also recommended to verify whether the observation is just the same at longer terms.

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