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CARBON SEQUESTRATION POTENTIALITY OF DIFFERENT CROPLAND AGROFORESTRY SYSTEMS IN DINAJPUR DISTRICT

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ABSTRACT

A Field experiment was conducted in Kaharol upazila of Dinajpur district of Bangladesh to evaluate the carbon sequestration and climate risk adaptation potentiality in different cropland systems, during October 2018 to September 2019. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. There were two experiments; experiment1taking three cropland agroforestry systems *viz:*-boundary, composite and scattered cropland while experiment 2 taking nine agroforestry practices *viz:*-Mahagoni-Maize, Mahagoni-Rice, Eucalyptus-Maize, Mango-Vegetable, Mango-Rice, Lombu-Rice, Eucalyptus-Mahagoni-Maize, Lombu-Mango-Rice and Mahagoni-Jackfruit-Vegetable. So, there were total 36 experimental plots. Data were recorded on tree growth parameters (tree height and diameter at breast height) and under storey vegetations (herbs, shrubs and crops) in order to estimate the different cropland biomass accumulation. The results revealed that there were significant differences of carbon sequestration potentiality of different cropland systems and agroforestry practices. There were significant differences in tree carbon sequestration (t/ha) and total carbon sequestration in leaf litter, herb and grass (t/ha) under different cropland systems and agroforestry practices. Among different cropland systems, the highest total cropland carbon sequestration (328.11 t/ha) was recorded from composite cropland agroforestry system and the lowest (81.61 t/ha) was obtained from scattered cropland agroforestry system. Among the different agroforestry practices, the highest carbon sequestration (402.09 t/ha) was recorded from eucalyptus-mahagoni-maize practice and the lowest (9.75 t/ha) was obtained from mango-vegetable agroforestry practices. Therefore, the composite plantation gave the maximum carbon sequestration potentiality and the eucalyptus-mahagoni-maize practice showed the maximum carbon sequestration potentiality. In case of economic value of carbon sequestration, the composite cropland system gave the maximum (39713.95 $/ha) and eucalyptus- mahagoni- maize agroforestry practices gave the maximum (13987.38 $/ha) monetary return. Therefore, composite plantation can be suggested as a better option for cropland agroforestry system to reduce atmospheric carbon for mitigating the greenhouse gases and also contribute the climate risk adaptation potentiality.

Key words: Cropland agroforestry, carbon sequestration, biomass, value of carbon sequestration

INTRODUCTION

Agroforestry is the purposeful growing of trees and crops in interacting combination for various motives. Agroforestry is a collective name for land use systems and technologies where woody perennials (tree, shrubs, palms and bamboos) are deliberately cultivated on the same land management units as agricultural crop and/or animal, in some form of spatial arrangement or temporal sequence

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(Long *et al*. 2013). In agroforestry systems, there are both ecological and economical interactions among the different components (Nair 1990). Cropland Agroforestry (CAF) is a traditional land use system in Bangladesh where tree species like date palm (*Phoenix sylvestris*), palmyra palm (*Borassus flabellifer*), babla (*Acacia nilotica*), mango (*Mangifera indica*), khoer (*Acacia catechu*), mahogany (*Swietenia mahogany*), jackfruit (*Artocarpus heterophyllus*), eucalyptus (*Eucalyptus globulus*) and sissoo (*Dalbergia sissoo*) grow naturally or planted on agricultural lands and are purposely retained and maintained by the farmers for different household utilities, products and also for cash crop (FAO 2004). Trees are planted on the borders or within the field, systemically or at irregular intervals, usually with crops such as rice, wheat, pulse, jute, oilseed, sugarcane, vegetables and other crops, and farmers also grow shade-tolerant crops such as turmeric, ginger and aroids when trees (e.g. Jackfruit, Mahagoni) have high canopy coverage (Miah *et al.* 2002).

The role of land-use systems such as agroforestry as a climate-change mitigation and adaptation strategy has gained considerable importance lately following the realization of the ability of these systems to capture atmospheric carbon dioxide (CO_2) and to store the carbon (C) in plant parts and soil (Sharma *et al*. 2016; Nair 2012). Carbon sequestration is the removal of carbon from the atmosphere by storing it in the biosphere (IPCC 2007). It is also the capture and storage of carbon that would otherwise be emitted or remained in the atmosphere (FAO 2004). Carbon is sequestered in the process of plant growth as carbon and captured in plant cell formation and oxygen is released (Altieri *et al.* 2017). Carbon sequestration potential is one of the hopeful but little-studied characteristics of agroforestry system.

Global climate change is considered to be one of the most serious threats to the environment and it is at the center of scientific and political debate in recent years (Wardekker *et al*. 2009). Greenhouse gas from deforestation and degradation and the climate change mitigation potential of forested landscapes are well documented (IPCC 2007).

Agriculture is a significant contributor (10-12%) to global anthropogenic emissions of greenhouse gases (GHGs) (Smith *et al.* 2012), while IPCC recognized agroforestry with high potential for sequestering carbon under the climate change mitigation strategies (Watson *et al.* 2000; Chauhan *et al.* 2009). Agroforestry in developing countries has been attracted increasing attention for both adaptations to climate change and greenhouse gas mitigation (Thornton *et al.* 2009). Bangladesh is one of the developing countries in South Asia with a large population. Most of the people in the country depend on forest and agriculture. The establishment of agroforestry based land use system will help in substantial and productive agriculture and climate change mitigation. However, the amount of carbon that can be sequestered by this system is unknown.

Therefore, the present study was undertaken to identify the existing cropland system and agroforestry practices in Dinajpur district, to estimate the biomass and total carbon sequestration by cropland agroforestry systems to quantify the economic value of carbon credits in cropland agroforestry systems in Dinajpur district. And finally to establish and compare the amount of carbon sequestered by different agroforestry land use system.

MATERIALS AND METHODS

The study was conducted in different cropland agroforestry farms of Kaharol upazila under Dinajpur district during the period October, 2018 to September, 2019. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in each treatment. Total number of experimental plots was 36. The two experiments are-Experiment 1: Different types of cropland agroforestry (C_1= Boundary cropland, C_2= Composite cropland, C_3= Scattered cropland) and Experiment 2: Different cropland agroforestry practices (P_1= Mahagoni-Maize, P_2= Mahagoni-Rice, P_3= Eucalyptus-Maize, P_4= Mango-Vegetable, P_5= Mango-Rice, P_6= Lombu -Rice, P_7= Eucalyptus-Mahagoni-Maize, P_8= Lombu-Mango-Rice, P_9= Mahagoni-Jackfruit-Vegetable). The procedure for sampling of this experiment varied due to different cropland agroforestry systems. Only mature trees within the diameter of breast height greater than 5cm (DBH) were considered for this experiment. On the other hand, leaf litter, herb, grass was sampled using 1×1m quadrant method. All biomass was collected and fresh weight was recorded and then taken to laboratory and dried it at 80˚C for 72 hours. Dry weight was also recorded. A sample unit of 20m×20m transact line was laid in the boundary, composite and scattered cropland, number of trees was counted with their DBH and height were measured. The distance was then converted in 400 m^2 and finally in hectares. The stand density from different land use was measured using the following formulae:

Above ground tree biomass = 0.0595× ρD2H (kg/tree) (Chave *et al.*2005)
Where,
D = Diameter of breast height (cm), H = Tree height (cm), ρ= Wood specific gravity *(mgm^{-3})*

Below ground tree biomass =Aboveground tree biomass×0.26 (kg/tree)

Total tree biomass =Above ground tree biomass + Below ground tree biomass (kg/tree)

$$LGH = \frac{W\ field}{A} \times \frac{W\ subsample,dry}{W\ subsample,wet} \times \frac{1}{10000}\ (kg/m^2)\ \text{(IPCC 2006)}$$

Where,
LGH = Biomass of leaf litter, herbs, and grass [t ha^{-1}]; A = Size of the area in which leaf litter, herbs, and grass were collected [ha]; W field = Weight of the fresh field sample of leaf litter, herbs, and grass, destructively sampled within an area of size A [g]; W sub sample, dry = Weight of the oven-dry sub-sample of leaf litter, herbs, and grass taken to the laboratory to determine moisture content [g]; W sub sample, wet = Weight of the fresh sub sample of leaf litter, herbs, and grass taken to the laboratory to determine moisture content [g].

Tree carbon storage = Biomass × 0.5 (tC/ha) (Pearson *et al.*2005).
LHG carbon storage = Biomass× 0.47 (tC/ha) (IPCC 2006)
Estimated carbon sequestration (t/ha) = Biomass carbon × 3.67 (Rajput 2010).
Total cropland carbon sequestration = Tree CO_2 sequestration + LHG CO_2 sequestration (t/ha)
The monetary value of one ton of net sequestrated CO_2 equivalent to U$15 Dollars (Jepkemei *et al.* 2010).

Data were statistically analyzed using the "Analysis of Variance" (ANOVA) technique with the help of Statistix 10 Software. The means difference was adjusted by Tukey HSD test and statistical difference was determined at $P \leq 0.05$ level of significance.

RESULTS AND DISCUSSION

Effect of agroforestry practices on carbon sequestration: The total tree carbon (C) sequestration was significantly varied in respect of different agroforestry practices (Figure 1). The highest C sequestration of tree (216.38 t/ha) was recorded from eucalyptus-mahagoni-maize agroforestry practices which was followed by mahagoni-maize and lombu-rice agroforestry practices. Again, the lowest C sequestration of tree (5.82t/ha) was also recorded from mango-vegetable agroforestry practices which was followed by eucalyptus-maize and mahagoni-rice agroforestry practices. Prasad *et al*. (2010) reported that carbon sequestration is also influenced by tree species to species. Based on these standing woody biomass, the carbon sequestration rate of trees (t/ha) was calculated by Rajput (2010).

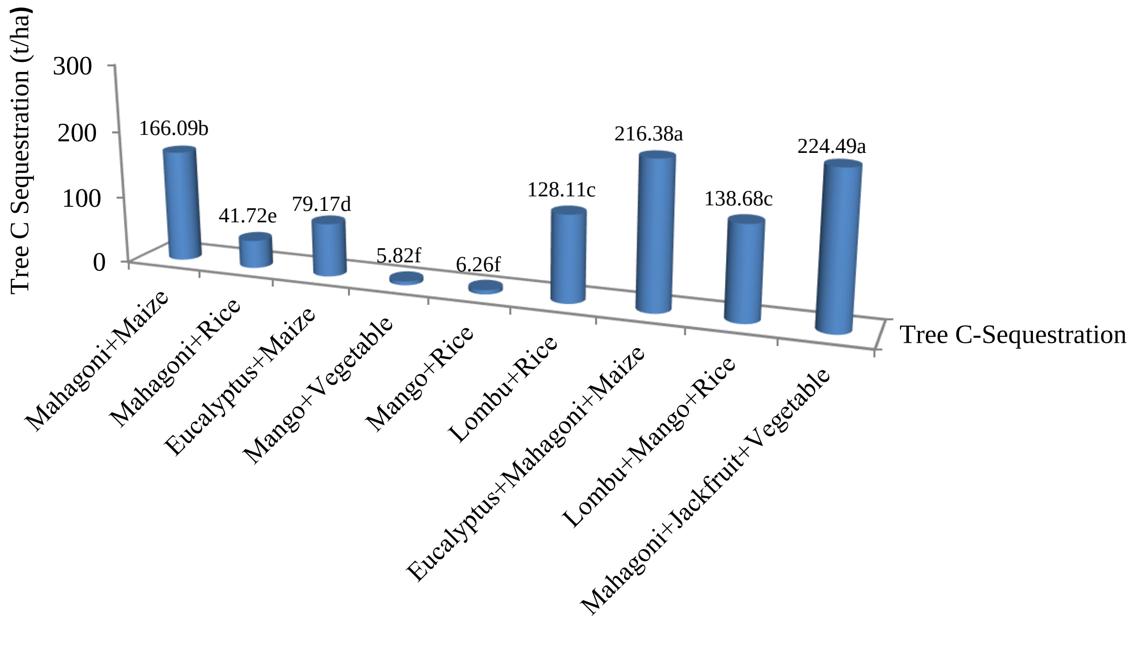

Figure 1. Effect of different agroforestry practices on the tree carbon sequestration estimation (t/ha) [In the figure, different letter(s) are significantly different at $P \leq 0.05$ level of significant by Tukey HSD test]

The carbon sequestration of LHG was also influenced by different agroforestry practices (Figure 2). The highest carbon sequestration of LHG (185.75 t/ha) was observed in eucalyptus-mahagoni-maize agroforestry practices which was followed by mahagoni-jackfruit-vegetable and lombu-rice agroforestry practices. Whereas, the lowest carbon sequestration of LHG (3.52 t/ha) was also observed in mango-rice agroforestry practices which was followed by eucalyptus-maize and mahagoni-rice agroforestry practices. The variation in LHG might be due to the variation in biomass accumulation under different trees of agroforestry practices. Practices like tillage, plant residue management and manure or fertilizer application have been identified to affect C sequestration in under-storey biomass (Bhattacharya *et al.* 2016). The study also found that, total carbon sequestration of the cropland per hectare was highly influenced by the effects of different agroforestry practices (Figure 3). The highest carbon sequestration (402.09 t/ha) was recorded from eucalyptus-mahagoni-maize agroforestry practices which was followed by mahagoni-maize and lombu-rice agroforestry practices. However, the lowest carbon sequestration (9.75 t/ha) was recorded from mango-vegetable agroforestry practices which was followed by eucalyptus-maize and mahagoni-rice agroforestry practices. Several studies have been conducted to explore the effect of agroforestry practices on carbon sequestration and and other biophysical factors that affect the system (Mbow*et al.* 2014). Carbon Sequestration is also by tree species (Pérez-Cruzado *et al*. 2012). Result reported by Rajput (2010) with mean maximum rate of carbon sequestration ability support the results of the present study. He also revealed that the rate of CO_2 sequestration potential was higher in Agrisilviculture land use system, which however remained significantly higher than horticulture land use system and forest.

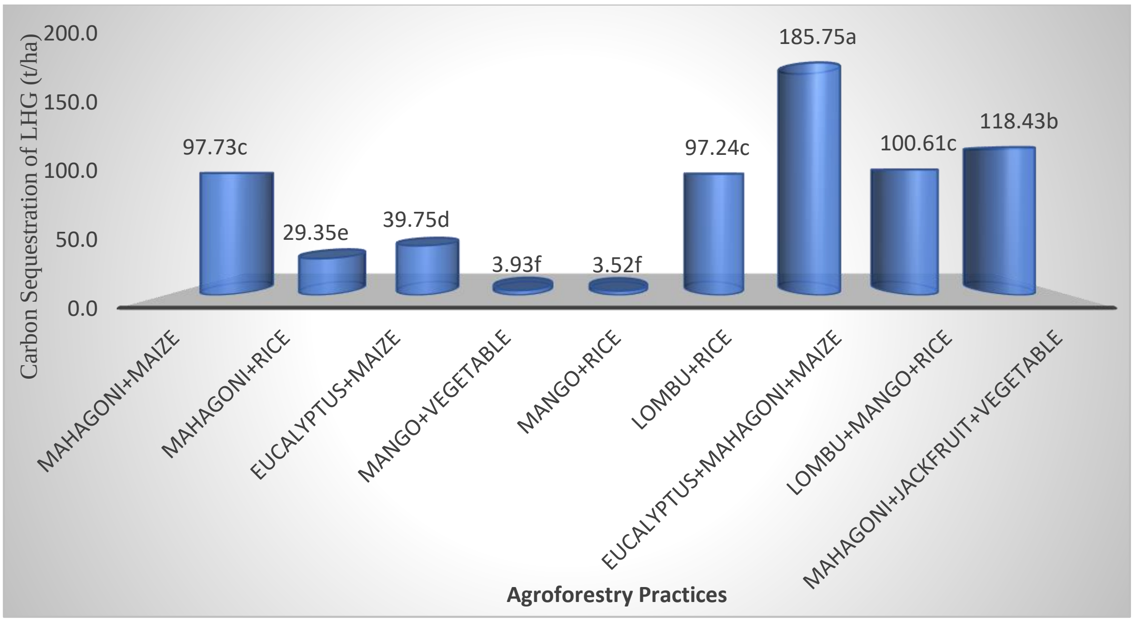

Figure 2. Effect of different agroforestry practices on the LHG carbon sequestration estimation (t/ha) [In the figure, different letter(s) are significantly different at P ≤ 0.05 level of significant by Tukey HSD test]

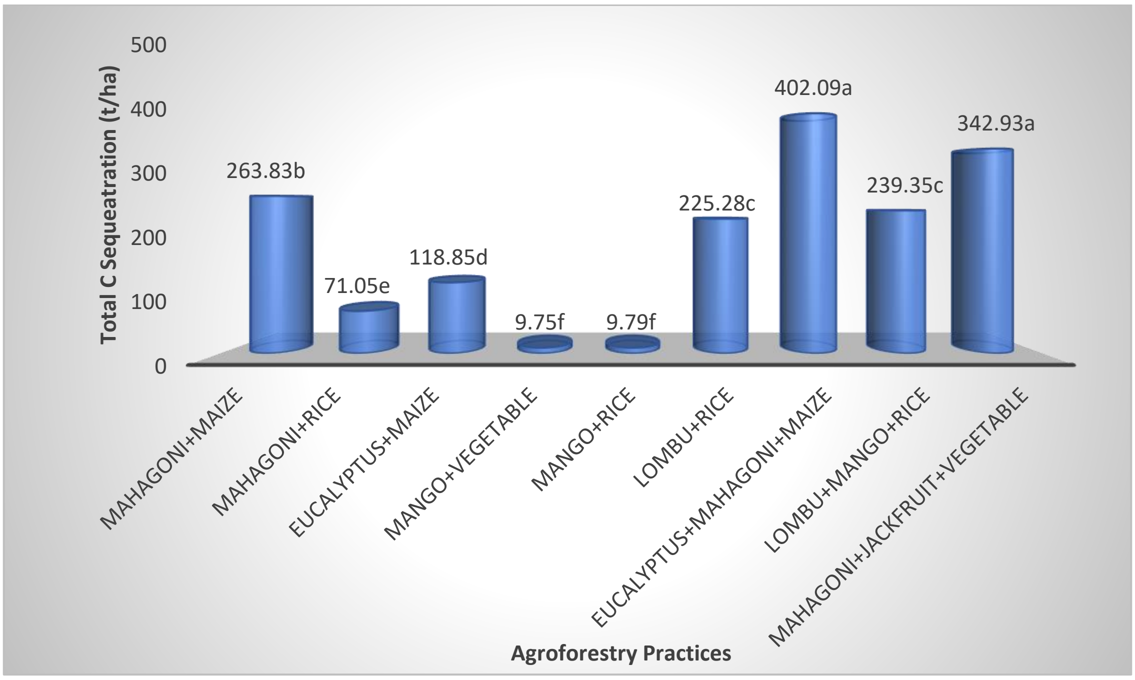

Figure 3. Effect of different agroforestry practices on the total carbon sequestration estimation (t/ha) [In the figure, different letter(s) are significantly different at P ≤ 0.05 level of significant by Tukey HSD test]

Effect of different cropland system on carbon sequestration: Total tree carbon sequestration (CST) was significantly influenced by different cropland systems (Figure 4). The highest tree carbon sequestration (CST) (193.18 t/ha) was recorded from the composite cropland agroforestry which was followed by boundary and scattered cropland agroforestry. On the other hand, the lowest tree carbon sequestration (CST) (46.73 t/ha) was recorded from scattered cropland agroforestry which was followed by boundary and composite cropland agroforestry. Based on these standing woody biomass, total carbon sequestration rate of trees (t/ha) were calculated (Kiran and Kinnary 2011).

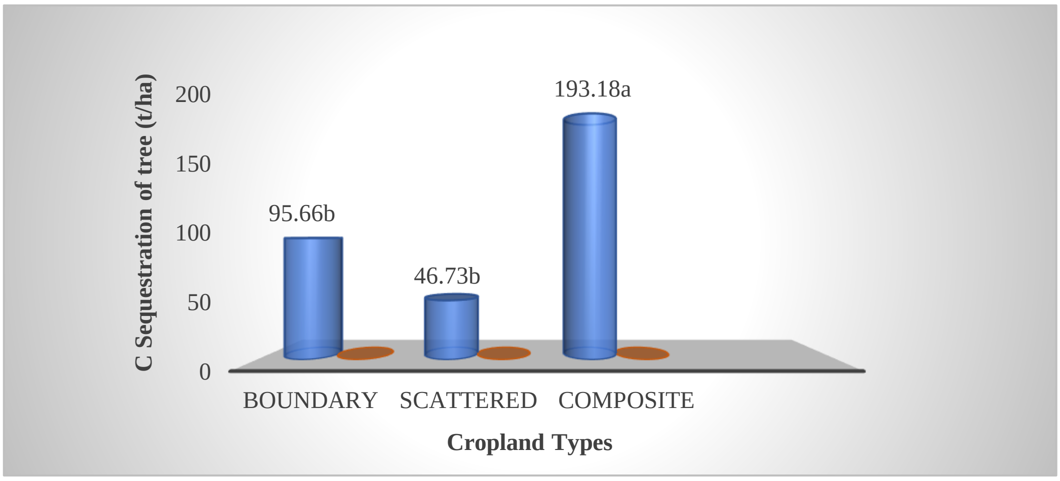

Figure 4. Effect of different cropland systems on the tree carbon sequestration estimation(t/ha) [In the figure, different letter(s) are significantly different at $P \leq 0.05$ level of significant by Tukey HSD test]

The leaf litter, herb and grass carbon sequestration (CSLHG) was also varied in different cropland systems (Figure 5) The highest CSLHG (134.92 t/ha) was recorded from the composite cropland agroforestry which was followed by boundary and scattered cropland agroforestry. On the other hand, the lowest CSLHG (34.87 t/ha) was recorded from the scattered cropland agroforestry which was followed by boundary and composite cropland agroforestry. Management practices like tillage, plant residue management and manure or fertilizer application have been identified to affect C sequestration in understory biomass (Bhattacharya *et al*. 2016).

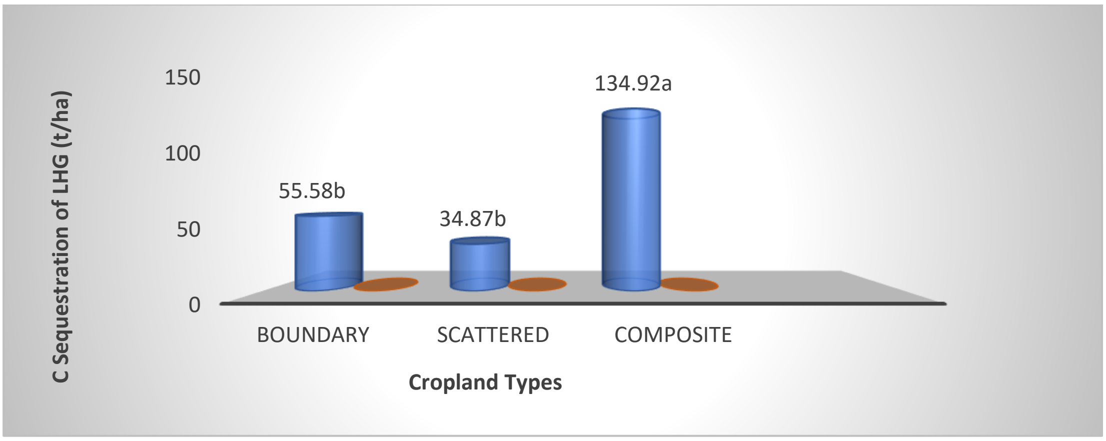

Figure 5. Effect of different cropland system on the LHG carbon sequestration estimation (t/ha) [In the figure, different letter(s) are significantly different at $P \leq 0.05$ level of significant by Tukey HSD test]

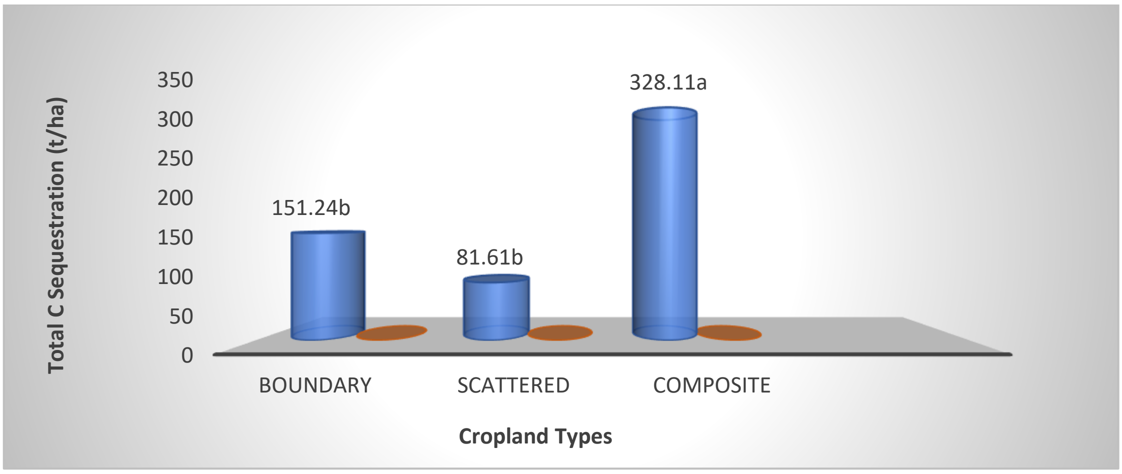

Figure 6. Effect of different cropland systems on the total carbon sequestration estimation (t/ha) [In the figure, different letter(s) are significantly different at P ≤ 0.05 level of significant by TukeyHSD test]

Total carbon sequestration (TCS) was significantly influenced by different cropland systems (Figure 6). The highest total carbon sequestration (328.11 t/ha) was recorded from the composite cropland agroforestry which was followed by boundary and scattered cropland agroforestry. On the other hand, the lowest total carbon sequestration (81.61 t/ha) was recorded from scattered cropland agroforestry which was followed by boundary and composite cropland agroforestry. Tree crop sequestered carbon at a higher rate than those containing only annual crops or grass lands. It can be showed that variability in the carbon sequestration potential under various agro-ecological zones depends primarily on climatic factors as rainfall, temperature and soil, which influenced the stand density and finally carbon sequestration ability (Kibret and Ayanssa 2014).

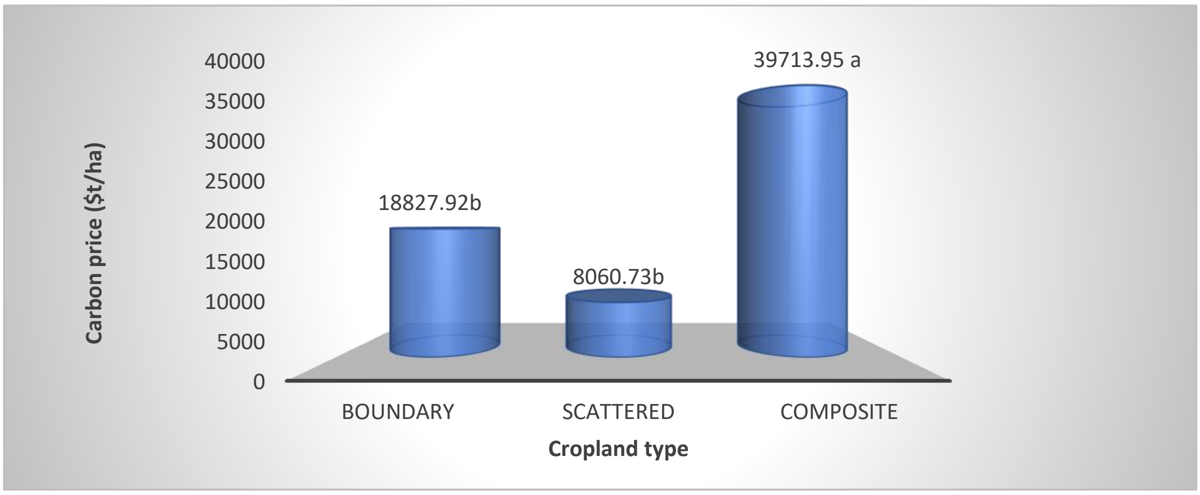

Figure 7. Economic value of carbon sequestration on the different croplands ($/ha) [In the figure, different letter(s) are significantly different at P≤ 0.05 level of significant by Tukey HSD test]

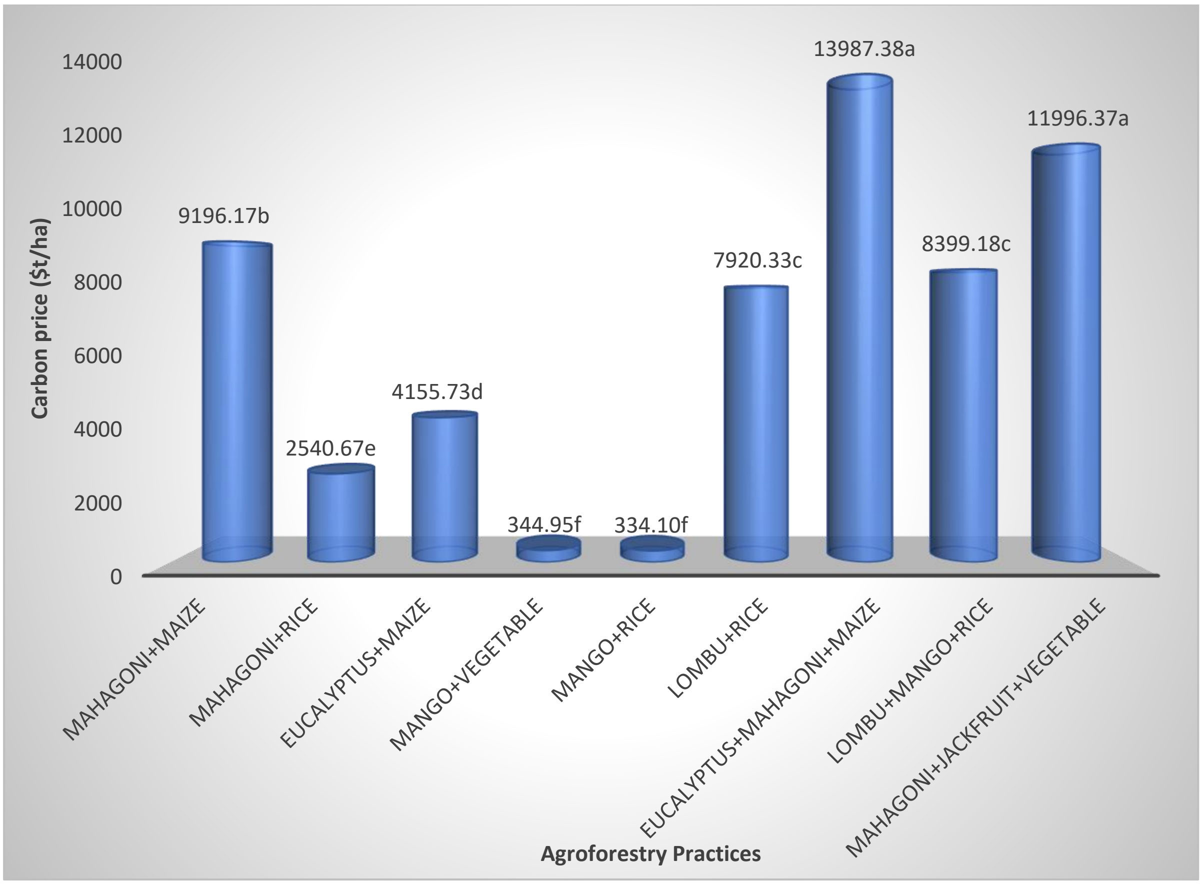

Figure 8. Economic value of carbon sequestration on the different agroforestry Practices ($/ha) [In the figure, different letter(s) are significantly different at P≤ 0.05 level of significant by Tukey HSD test]

Economic value of carbon sequestration (US$ /ha): The economic value of carbon sequestration provides market for greenhouse gases (GHG) reduction in monetary value (Fig. 7 & 8). According to Vivian (2010) 1 ton of carbon was sold at US$ 15. So, the highest carbon price (39713.95 $/ha) was recorded from the composite cropland agroforestry which was followed by boundary and scattered cropland agroforestry and the highest carbon price (13987.38 $/ha) was recorded from eucalyptus-mahagoni-maize agroforestry practices which was followed by mango- jackfruit- vegetable and mango- maize agroforestry practices. On the other hand, the lowest carbon price (8060.73 $/ha) was obtained from the scattered cropland agroforestry which was followed by boundary and composite cropland agroforestry and the lowest carbon price (334.10 $/ha) was obtained from mango-rice agroforestry practices which was followed by mango vegetable and mahagoni- rice agroforestry practices.

CONCLUSIONS

From the result of the present study it should be concluded that the composite cropland agroforestry and the eucalyptus-mahagoni-maize plantation sequestrated more carbon and a better option for reducing atmospheric carbon. Therefore, the composite cropland agroforestry system and eucalyptus-mahagoni-maize agroforestry practices seems to be a better option for large tree plantation coverage and reduction of CO_2 effects.

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