Potential Carbon Storage of Rubber Plantations

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ABSTRACT
The study was conducted at the three Municipalities of Cotabato province Southern Philippines between January to May 2011. The study aimed at determining the Carbon budget of the different age rubber plantation through field sampling and modeling. Actual field measurement of dbh, were done for the estimation of above-below ground biomass. The major carbon pools, such as above-ground biomass, below-ground biomass, litter and understory vegetation were added and multiplied with 45% default value by IPCC to obtained the carbon density in Mt/ha. The total estimated biomass of the rubber plantation in Antipas were 103.91Mt/ha (10 years) and 573.21Mt/ha (20 years) with carbon density of 46.79Mt/ha and 257.95mt/ha respectively. For the Arakan plantation, the following were revealed in the estimation: (a). the 40 year plantation has total biomass of 1041.54Mt/ha biomass (468.69Mt/ha C), (b). the 11 year plantation has 158.79Mt/ha biomass (71.46Mt/ha C), (c). the 35 year plantation has total biomass of 246.23Mt/ha (110.8Mt/ha Carbon density), and (d). the 12 year plantation has 355.60Mt/ha biomass (160.02Mt/ha C).

In Matalam Cotabato, the two different age rubber plantations has an estimated biomass density of 149.47Mt/ha  in 8 years with 67.26 Mt/ha C and 70.82Mt/ha biomass density for the 6 year old plantation with 31.87 Mt/ha C.

The soil organic carbons found in each plantation were: Antipas; 100.25t/ha (10 years) and 203.54t/ha (20 years), Arakan; 202.55t/ha (40 years), 142.67t/ha (11 years), 86.1t/ha (35 years) and 129.53t/ha (12 years), Matalam; 53.32t/ha (8 years) and 62.04t/ha in the 6 year plantation. T-test reveals significant differences of the biomass and carbon density of the rubber plantation with respect to age range (6-12 years and 20-40 years). This implies that biomass production and carbon storage potentials of rubber plantation is very much dependent on plantation age. Pearson regression-correlation analysis of the carbon density of each plantation with carbon pools found to be highly significant.

Introduction
Global warming is one of the major issues that humans are facing today. It refers to the observed variations in climatic patterns and occurrence of extreme weather fluctuations. It is largely brought about by excessive accumulation of greenhouse gases, primarily carbon dioxide in the atmosphere which is expected to continue and alter atmospheric condition[1].

Forests are one of our most important defenses against global warming. They are like giant sponges, soaking up huge amounts of carbon dioxide (CO₂) throughout the world. People are destroying forest at an alarming rate. It has been assessed that destruction of the world’s forest contributes about 2 billion (B) tons (t) of carbon each year to the atmosphere[2]. Deforestation increases carbon dioxide (CO₂) levels in the atmosphere in two basic ways. When trees decayed, and
burned, they released the CO$_2$ they have absorbed over their entire lifetime. Without the forest specifically the trees, carbon dioxide that would have been absorbed for photosynthesis remains in the air. The Philippine forests in particular, through massive deforestation were found to have contributed about 3.7 Pg (1 Pg = 10$^{15}$ t) of C to the atmosphere since 1500 up to present time [3]. Tree farming opens wide opportunities to small scale farmers who are then destroying forest resources through shifting cultivation or kaingin making. With the growing demands of rubber and wood products in the world market, it is important to shift the “kaingin” (slash and burn) farming practices to rubber and tree farming venture. Rubber tree farming could be viewed as a strategy to cope with the food, wood, energy, ecology and poverty crises in the nation. This is to lessen the deforestation rate of our leading forestlands and converting agricultural, and other potential government lands to productive rubber tree plantations.

The amount of carbon sequestered by a given stand can be computed given the total carbon density of the stand in Mg ha$^{-1}$ yr$^{-1}$. In the Philippines, the Environmental Forestry Program (ENFOR) of the College of Forestry and Natural Resources, University of the Philippines Los Baños (UPLB), conducted various studies on carbon stocks assessment of forest land uses through inventory. The methodology used a combination of small plot measurements and biomass regression equations for trees. The equations used came from who developed a substantial number of allometric equations for various climatic zones, forest types and tree species using a variety of algebraic forms and parameter values [4,5]. She stated also that an accurate estimate of C stocks and the rate of C sequestration of forest land uses are necessary to provide reliable estimates and inputs to the national inventory of GHGs of the country. Carbon stocks can be determined through various methods where sampling is statistically valid (Sales 2005). There are techniques and methods for sampling design and methods that accurately and precisely measure C pools, that can be chosen based on commonly accepted principles of forest inventory, soil sampling and ecological surveys [6].

The role of trees in the removal of atmospheric CO$_2$ for the build-up of their biomass during the process of photosynthesis cannot be denied. The planting of trees to sequester atmospheric CO$_2$ has been considered to be the most effective long-lasting means and a significant approach to address the problem of increasing amount of CO$_2$ in the atmosphere [7]. The best and most direct way of estimating above-ground carbon is through destructive sampling method that determines the biomass of trees, understory, litter and other forest components (Sales 2005). Live tree biomass measurements involve the establishment of 5m x 40m (200m$^2$) plots. Trees with more than 5 cm diameter at breast height (dbh), where dbh was measured at 1.3 m from the ground and within 2.5 m of each side of the 40m centerline, should be included as samples. If there are trees with more than 30 cm dbh within and outside the plots, a large plot with 20m x 100m should be established [8]. Accordingly, tree heights (total and merchantable) are parameters that should be directly measured from the field. Merchantable height (mh) is the height of tree measured from the ground level up to the tree's first major branch. Total height (th), on the other hand, is measured up to the highest growing point. An average of these measurements represents the mean stand height. However, dominant height was applied for irregularly spaced trees. Estimating tree heights is a relatively slow procedure, and impractical in measuring more than eight to 10 trees on a plot. In this case, not all tree heights can be measured due to errors involved in measuring such as human, instrument etc [9]. Moreover, this method is time consuming and costly and makes it difficult to estimate in close canopies [10]. It is thus safer to assume that the individual tree heights used for volume estimation are equal to the stand mean height because of height variations especially in many tropical species (Alder 1980) like that of Tectonagrandis; Acacia mangium; Eucalyptus deuglupta; etc. [5].

Rubber is a material having industrial, technologies and domestic uses. While rubber is considered a minor crop in the Philippines, it has high export potentials and is rated as one of the most profitable agro-industrial ventures. According to Dr. N. Yoganathan, from the National Institute of Plantation Management, Sri Lanka, organic technologies being used in rubber plantations slows down soil Carbon oxidation and increases Carbon fixation and storage. Rubber is a topical tree crop which requires a warm humid equitable climate. This paper however, tries to estimate the capacity of rubber tree in storing carbon from the atmosphere through field sampling techniques and modeling using Brown 1997 biomass allometric equation for determining above ground biomass and Cairns et al. 1997 for estimating root biomass [11-12].

Materials and methods

The study on potential carbon storage of rubber tree plantation was conducted through field survey in the three Municipalities of Cotabato Province, Philippines (Figure 1) namely Antipas (7°15'.1.45" N and 125°3'.20.87" E, 312m asl), Arakan (07°20.69" N and 125°05'.148m asl), and Matalam (geographically located 07°13.97" N and 124°50.28" E, 298m asl) from January to May 2011. Purposive sampling was used taking into consideration the year of establishment. Plantation ages chosen were: 40, 35, 20, 12, 11, 10, 8, and 6 years old [8]. A 5m x 40m (200m$^2$) transect was established in each plantation area as field sampling protocol adapted from All trees with in the sample plots were considered as samples and their dbh at 1.3 m were measured from the ground. Establishment of three 1m x 1m subplot within each experimental area were also done for the litter and understory vegetation samples. The following major carbon pools were measured: (a) above-ground biomass (b) root biomass (c) litter and underneath vegetation biomass and (d) Soil organic carbon. Allometric biomass equation (AGB = e[-2.134+2.530*Ln(dbh)]) developed by Brown (1997) was used for the estimation of above-ground biomass (AGB) of trees and that of Cairns et al. (1997) for the determination of root biomass (RB) = e[-1.0587+0.8836*Ln(AGB)]. Carbon budget
of the rubber plantation was calculated by adding all estimated biomass of trees, litter and underneath vegetation, multiplied by the IPCC suggested carbon content of 45% [8,11]. Soil samples were taken by driving an improvised metal canister (6 cm x 10 cm) into 20 cm soil depth. Samples for soil organic carbon content were collected at the same spot where bulk density samples were taken. Composite samples of 1 kg were taken to the CFCST laboratory for chemical analysis. Soil organic carbon was computed using the formula:

\[
\text{Soil Organic Carbon (SOC) per hectare} = \text{Weight of Soil (ton)} \times \% \text{SOC}
\]

Bulk Density (g/cc) = soil oven-dried weight/canister volume

\[
\text{Volume of 1ha} = 100 \times 100 \times 0.30 \text{m}
\]

\[
\text{Weight of Soil (ton)} = \text{bulk density} \times \text{volume}
\]

\[
\text{Carbon density (t/ha)} = \text{weight of soil} \times \% \text{SOC}
\]

Soil organic carbon (SOC) tends to be ignored or underestimated in tropical studies [5,7,11,13,14]. This pool is considered as the most important among other pools because carbon is stored for a long time in the soil.

**Data Analysis**

The carbon budget of the rubber plantation was determined through field measurement and modeling. Total biomass values in Metric tons/ha were estimated by adding aboveground biomass, root biomass, litters and underneath biomass. The carbon density (Mt/ha) was then estimated by multiplying the derived total biomass with carbon content default value of 45% based on the overall estimate of carbon content of biomass in the Philippines[14]. The standard value of 45% carbon content was used as proposed by IPCC (1996). Pearson moment correlation analysis was used in determining if there were significant relationships among the different carbon pools. T-test was used to determine if there exist differences between the different ageplantations.

**Result and Discussion**

**Above and Below Ground Biomass**

**Above Ground Biomass**

It shows in Table 1 and 2 that the biggest DBH tree has heaviest above ground biomass in kg per tree estimates irrespective of plantation location. It also shows that the older the plantation, the bigger its DBH and the heaviest its AGB. This finding support Corpuz et.al (2011) study on carbon budget of rubber plantation in Arakan Cotabato[16]. The findings indicated that the olderrubber plantation has the biggest DBH compared to the younger plantation with higher AGB and Carbon density.
**Below Ground Biomass**

Determining root biomass is both expensive and laborious hence the use of conservative estimates based on literature is a more practical approach in claiming carbon credits for this type of pool. In addition, root biomass varies considerably among tropical forests. Procedural difficulties exist in recovering them from soil depths. Roots often represent 10-40 percent of total biomass and it transfers large amounts of Carbon directly into the soil. Estimating carbon from root biomass can be determined by a). using conservative estimates based on literature, and b). Actually measuring of the root biomass[4, 6].

The estimated below ground biomass (RB) of the plantation in Antipas, Arakan, and Matalam all of Cotabato province shows that the larger the DBH of the tree, the higher also its above ground biomass Table 1, 2 and 3). Salibio et. al (2010) in their study on the carbon storage of 12 years and 35 years old para rubber (*Hevea brasiliensis*) found that Carbon density is highly and significantly related to DBH of rubber tree[16]. This means that carbon density of the particular tree species is dependent on its diameter breast height as well as tree biomass. The allometric biomass equation developed by Brown (2007) uses DBH as sole variable of the equation.

Table 1: Above ground and below ground biomass of the rubber plantation in Antipas, Cotabato Philippines

| Plantation Age | DBH (cm) | AGB (Mt/ha) | RB (Mt/ha) |
|----------------|---------|-------------|------------|
| **10 Years**   |         |             |            |
| 10.90          | 49.87   | 10.97       |
| 14.90          | 109.99  | 22.07       |
| 14.50          | 102.67  | 20.77       |
| 8.50           | 26.58   | 6.29        |
| 18.50          | 190.17  | 35.81       |
| 12.25          | 67.02   | 14.25       |
| 14.50          | 102.67  | 20.77       |
| 14.50          | 102.67  | 20.77       |
| 11.25          | 54.03   | 11.78       |
| 14.50          | 102.67  | 20.77       |
| 10.50          | 45.37   | 10.09       |
| 13.25          | 81.73   | 16.98       |
| 26.30          | 463.13  | 78.63       |
| 24.50          | 387.08  | 67.11       |
| 22.90          | 326.28  | 57.70       |
| 28.65          | 575.09  | 95.21       |
| 33.00          | 822.34  | 130.60      |
| 21.40          | 274.89  | 49.59       |
| 34.70          | 933.78  | 146.12      |
| 23.25          | 339.05  | 59.69       |
| 17.25          | 159.32  | 30.63       |
| 29.35          | 611.31  | 100.49      |
| 27.35          | 511.35  | 85.82       |

| **20 Years**   |         |             |            |

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Table 2: Above and below ground biomass of rubber plantation in Arakan, Cotabato Philippines

| Plantation Age | DBH (cm) | AGB (Mt/ha) | RB (Mt/ha) | Plantation Age | DBH (cm) | AGB (Mt/ha) | RB (Mt/ha) |
|----------------|---------|-------------|------------|----------------|---------|-------------|------------|
| 40 Years       |         |             |            | 12 Years       |         |             |            |
| 20.50          | 246.57  | 45.05       |            | 18.00          | 177.44  | 33.68       |            |
| 41.50          | 1468.51 | 218.00      |            | 16.00          | 131.71  | 25.88       |            |
| 37.00          | 1098.41 | 168.66      |            | 14.00          | 93.95   | 19.21       |            |
| 34.00          | 886.86  | 139.61      |            | 17.00          | 159.55  | 29.64       |            |
| 27.50          | 518.47  | 86.88       |            | 14.00          | 93.95   | 19.21       |            |
| 36.00          | 1024.85 | 158.64      |            | 18.70          | 195.42  | 36.68       |            |
| 35.00          | 954.35  | 148.96      |            | 17.30          | 160.49  | 30.82       |            |
| 36.00          | 1024.85 | 158.64      |            | 13.60          | 87.31   | 18.00       |            |
| 18.00          | 177.44  | 33.68       |            | 17.10          | 155.84  | 30.03       |            |
| 18.00          | 177.44  | 33.68       |            | 16.60          | 144.57  | 28.11       |            |
| 16.00          | 131.71  | 25.88       |            | 16.00          | 131.71  | 25.88       |            |
| 14.00          | 93.95   | 19.20       |            | 12.50          | 70.53   | 14.91       |            |
| 26.56          | 474.80  | 80.38       |            | 13.50          | 85.69   | 17.71       |            |
| 24.54          | 388.68  | 67.35       |            | 20.35          | 242.03  | 44.32       |            |
| 18.75          | 196.74  | 36.90       |            | 31.45          | 728.11  | 117.28      |            |
| 17.35          | 161.67  | 31.02       |            | 26.03          | 451.37  | 76.87       |            |
| 23.60          | 352.11  | 61.72       |            | 24.15          | 373.24  | 64.98       |            |
| 27.10          | 499.60  | 84.08       |            | 23.28          | 340.34  | 59.89       |            |
| 26.65          | 478.831 | 80.99       |            | 27.29          | 508.42  | 85.39       |            |
| 25.65          | 434.717 | 74.35       |            | 25.14          | 412.97  | 71.06       |            |
| 22.55          | 313.816 | 55.75       |            | 22.35          | 306.99  | 54.68       |            |
| 23.55          | 350.229 | 61.43       |            | 36.23          | 1041.13 | 160.87      |            |
|                |         |             |            | 22.01          | 295.15  | 52.81       |            |
| 22.01          | 295.15  | 52.81       |            | 26.13          | 455.59  | 77.50       |            |

Table 3: Above and below ground biomass of rubber plantation in Matalam, Cotabato Philippines

| Plantation Age | DBH | AGB (Mt/ha) | RB (Mt/ha) |
|----------------|-----|-------------|------------|
| 8 Years        |     |             |            |
| 11.00          | 51.04333818 | 11.20334   |
| 15.20          | 114.7253884 | 22.91541   |
| 20.00          | 231.6442181 | 42.63524   |
| 16.50          | 142.3803167 | 27.73325   |
| 12.10          | 64.96247497 | 13.86376   |
| 14.50          | 102.6778157 | 20.77558   |
| 13.70          | 89.11       | 18.33       |
Biomass, Carbon Density and Soil Organic Carbon

Sales (2005) stated that models can be useful in establishing potential C benefits prior to the implementation of LUCF projects. In addition, they can be used to determine the likely benefits of field measurements in the intervening years. Because of the difficulty and sometimes impossibility of conducting field measurements, models will continue to be valuable tools in estimating C stocks of forest land-uses and plantation areas[5]. Mathematical models have also been developed to estimate the C stocks and rate of C sequestration of various land-uses. Some of the models that could be used for C estimation include: SCUAF for agriculture, forestry and agroforestry[17]. (Young et al. 1989), the CENTURY model for soil organic matter (Patterson et al. 1988 as cited by Lasco and Pulhin, 2003), CO-PATH for forest ecosystems (Makundiet.al 1995), and CO₂ FIX for forest, and soil organic matter and wood products [18,19]. MacDicken (1997) recommended the SCUAF model in calculating C because it is easy to use, relevant and useful in forestry and agroforestry, there is a default data present (especially when data is expensive to collect), low-cost and readily available, and has good documentation. However, SCUAF is a DOS-based program and does not seem to be compatible with a Windows operating system. COMAP, meanwhile, has been used to evaluate carbon mitigation projects for the whole Philippines[5]. It can calculate the carbon and economic benefits of various carbon mitigation projects over their lifetime[20].

Biomass and Carbon Percent of the Rubber Plantations

Table 5 presents the amount of C stock in terms of percentage of above- and below-ground (root and soil) biomass and carbon density based on the total computed values from the sampled plantations. More than 83% of biomass was above-ground for all plantation in the 3 Municipalities of Cotabato, while root biomass comprised less than 17% of the total biomass. It was found that about 51% of carbon was contained in the soil and only about 49% were found in the tree biomass.

| Biomass and Carbon Percent of the Rubber Plantations | 12.50 | 16.30 | 20.50 | 15.60 | 11.00 | 10.20 | 8.50 | 10.50 | 12.10 | 14.50 | 8.75 | 12.50 | 16.30 | 10.50 | 8.60 |
|----------------------------------------------------|-------|-------|-------|-------|-------|-------|-----|-------|-------|-------|-----|-------|-------|-------|-----|
| Carbon Density (Mt/ha)                             | 70.53 | 138.05| 246.57| 123.54| 51.04 | 41.64 | 26.58| 45.37 | 64.96 | 102.67| 28.61| 70.53 | 138.05| 45.37 | 27.38|
| Carbon Density of each rubber plantations were computed by estimating and adding the derived above and below-ground biomass multiplied by 45% default value. Table 4 shows the biomass, carbon density, and soil organic carbon (Mt/ha) of the different age rubber plantations in the three municipalities of Cotabato by age level. Plantations in Antipas with ages 10 and 20 years have total biomass of 110.91 Mt/ha (46.76Mt/ha C) and 573.21 Mt/ha (257.95Mt/ha C) respectively. For the plantations in Arakan, the 40 year rubber plantation has a total biomass of 1,041.54Mt/ha (468.69Mt/ha C); the 35 year old has 246.23Mt/ha biomass (110.8Mt/ha C); the 12 year has 355.6Mt/ha biomass (160.02Mt/ha C); and the 11 year has 158.79Mt/ha biomass (71.46Mt/ha C). The eight and 6 year plantations in Matalam reported(Table 4) to have 149.47Mt/ha biomass (67.26Mt/ha C) and 70.82Mt/ha biomass (31.87Mt/ha C). This findings were only applicable to the 3 Municipalities with the given plantation ages. Only tree diameter (DBH) is used for the estimation as an important variable in the computation of above ground biomass using the biometric equation developed by Brown (1997) for tropical tree species. The difference in biomass and carbon density of the rubber plantation is brought about by plantation age and soil fertility gradient, especially as growth of trees is primarily dependent on soil fertility. Highest soil organic carbon is found in the 20 year plantation in Antipas (203.54Mt/ha SOC) followed by 102.55Mt/ha (40 years) in the same Municipality. Highest carbon density was also noted in this place.

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Table 5: Biomass and carbon density of the different age rubber plantation in Cotabato Province with soil organic carbon (SOC)

| Location | Years | Content | No. of Trees | AGB (Mt/ha) | RB (Mt/ha) | Total (Mt/ha) | SOC (Mt/ha) |
|----------|-------|---------|--------------|-------------|------------|---------------|-------------|
| Antipas  | 10    | Biomass | 12           | 86.29       | 17.62      | 103.91        | 100.25      |
|          |       | Carbon  |              | 38.83       | 7.92       | 46.76         |             |
|          | 20    | Biomass | 11           | 491.24      | 81.97      | 573.21        | 203.54      |
|          |       | Carbon  |              | 221.05      | 36.88      | 257.95        |             |
|          | 40    | Biomass | 9            | 901.08      | 140.46     | 1041.54       | 202.55      |
|          |       | Carbon  |              | 405.48      | 63.21      | 468.69        |             |
| Arakan   | 11    | Biomass | 14           | 132.83      | 25.96      | 158.79        | 142.67      |
|          |       | Carbon  |              | 59.77       | 11.68      | 71.46         |             |
|          | 35    | Biomass | 11           | 216.70      | 29.53      | 246.23        | 86.10       |
|          |       | Carbon  |              | 97.51       | 13.29      | 110.80        |             |
|          | 12    | Biomass | 14           | 269.50      | 86.10      | 355.60        | 129.53      |
|          |       | Carbon  |              | 121.27      | 38.74      | 160.02        |             |
| Matalam  | 8     | Biomass | 11           | 125.02      | 24.44      | 149.47        | 53.32       |
|          |       | Carbon  |              | 56.26       | 10.99      | 67.26         |             |
|          | 6     | Biomass | 11           | 58.38       | 12.43      | 70.82         | 62.04       |
|          |       | Carbon  |              | 26.27       | 5.59       | 31.87         |             |

Table 5: Percent biomass carbon density values of various pools

| Location | Plantation Age | %AGB Carbon | %RB Carbon | %Tree Carbon | %SOC |
|----------|----------------|-------------|------------|--------------|------|
| Antipas  | 10             | 83.047      | 16.952     | 31.80        | 68.19|
|          | 20             | 85.700      | 14.299     | 55.89        | 44.11|
|          | 40             | 86.514      | 13.485     | 69.82        | 30.18|
|          | 11             | 83.649      | 16.351     | 33.37        | 66.63|
|          | 35             | 88.007      | 11.992     | 56.27        | 43.73|
|          | 12             | 75.787      | 24.212     | 55.27        | 44.73|
| Arakan   | 8              | 83.646      | 16.353     | 55.78        | 44.22|
|          | 6              | 82.443      | 17.556     | 33.94        | 66.06|
| Matalam  | 8              | 83.047      | 16.952     | 31.80        | 68.19|
|          | 6              | 82.443      | 17.556     | 33.94        | 66.06|
| Total    |                 | 668.79      | 131.20     | 392.14       | 407.85|
| Mean     |                 | 83.59       | 16.40      | 49.017       | 50.98|

Comparison of Biomass and Carbon Density with Respect to Age Range

Biomass and carbon density of the plantations have been compared using T-test. Table 8 shows that older plantation has significantly higher biomass of 620.36Mt/ha biomass with carbon density of 295.55Mt/ha (Table 6 and Table 7). This finding supported the notion that older tree plantations have higher carbon storage than that of early aged or younger plantation especially age range from 6-12 compared to 20-40 year old plantations in this particular study.
Table 7: T- test comparison of biomass (Mt/ha) and carbon density (Mt/ha) by plantation age range

| Carbon Density (Mt/ha) | 6 - 12 years | 20 - 40 years |
|------------------------|--------------|--------------|
| 46.78                  | 257.95       |
| 71.46                  | 468.69       |
| 110.80                 | 160.02       |
| 67.36                  |              |
| 3.87                   |              |
| Total                  | 300.27       | 886.66       |
| Mean                   | 60.05        | 295.55**     |
| SD                     | 39.02        | 157.73       |
| T-test                 | 0.11778      |
| Probability            | 0.0011       |

Table 8: Pearson correlation coefficient of Carbon density with AGB and RB

| Plantation Age | Variable | Parameter Estimates | Standard Error | T for HO: Parameter=0 | R       | Prob>|R| |
|----------------|----------|---------------------|----------------|-----------------------|---------|-------|
| 40             | AGB      | 0.5138              | 0.0007         | 661.33                | 0.9999**| 0.0001|
|                | RB       | 3.6201              | 0.0385         | 93.79                 | 0.9996**| 0.0001|
| 35             | AGB      | 0.5155              | 0.0005         | 973.96                | 1.0000**| 0.0001|
|                | RB       | 3.5380              | 0.0249         | 141.85                | 0.9998**| 0.0001|
| 20             | AGB      | 0.5167              | 0.0006         | 802.02                | 0.9999**| 0.0001|
|                | RB       | 3.4831              | 0.0292         | 118.90                | 0.9999**| 0.0001|
| 12             | AGB      | 0.5215              | 0.0004         | 1213.60               | 0.2236**| 0.0001|
|                | RB       | 3.2803              | 0.0170         | 192.88                | 0.2365**| 0.0001|
| 11             | AGB      | 0.5284              | 0.0003         | 1627.11               | 0.5583**| 0.0001|
|                | RB       | 3.0294              | 0.0106         | 283.81                | 0.5534**| 0.0001|
| 10             | AGB      | 0.5311              | 0.0006         | 572.79                | 0.9999**| 0.0001|
|                | RB       | 2.9411              | 0.0284         | 103.35                | 0.9995**| 0.0001|
| 8              | AGB      | 0.5275              | 0.0006         | 784.52                | 0.9999**| 0.0001|
|                | RB       | 3.0606              | 0.0226         | 135.15                | 0.9998**| 0.0001|
| 6              | AGB      | 0.5337              | 0.0007         | 682.52                | 0.9999**| 0.0001|
|                | RB       | 2.8648              | 0.0225         | 127.10                | 0.9997**| 0.0001|

** highly significant
Regression-Correlation of Different Carbon Pools

Relationship of the different carbon pools were analyzed through Pearson moment correlation analysis. The various carbon pools such as tree biomass (above ground biomass and root biomass) with respect to plantation age were correlated with carbon density of each plantation and further tested its significance through regression. Biomass of each plantations (AGB and RB) were all found linearly related with carbon density (Table 8). Highest R value (1.000) is found in 35 year plantation in Arakan Cotabato. Salibio et al. (2010) in their study found significant and positive relationship of above ground biomass with carbon density of rubber plantation in ArakanCotabato[17].

Conclusion

Rubber tree is an essential tree species that absorbed carbon (CO₂) in the atmosphere and stored both in its biomass, litter, and understory vegetation and in the soil. With this, rubber plantation can act as carbon sink. The Philippines, especially Mindanao has great potential for rubber plantation. Greenhouse gases in the atmosphere would be partially mitigated through carbon trapping of rubber plantations. With the potentials of rubber products (cup lump and rubber wood) for market and exports; food, wood, energy and ecological security would be attained that may slow down poverty and economic crisis in the country. Thus, rural development would be achieved via greener and improved environment.

Recommendations

The researchers recommend further study on carbon storage of rubber plantation employing destructive sampling to determine the exact values of carbon density of the particular tree species. By this method, an allometric equation specific for rubber species can be formulated. Moreover, based on the result of the study the researcher would like to call the attention of the Philippine Government to give more value on rubber tree species. By this method, an allometric equation specific for market and exports; food, wood, energy and ecological security would be attained that may slow down poverty and economic crisis in the country. Thus, rural development would be achieved via greener and improved environment.

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Conflict of interest statement

We declare that we have no conflict of interest.

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