Carbon Sequestration Potential of Tree Species at Isabela State University Wildlife Sanctuary (ISUWS), Cabagan, Isabela, Philippines

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Abstract

This study is conducted to assess the amount of carbon stored in the above-ground biomass of the tree species at Isabela State University Wildlife Sanctuary (ISUWS), Cabagan, Isabela, Philippines. A total of 34 different tree species were found with 285 individuals were identified with a total of 47.50 t/ha Carbon stock and 164.09 t/ha of accumulated CO₂. It was found in the study that Alstonia scholaris contains the largest amount of above-ground biomass (AGB) with a mass of 20.97 t/ha and Carbon stock of 9.44 t/ha followed by Samanea saman with a mass of 13.40 t/ha and Carbon stock of 6.03 t/ha. Based on the result and conclusion of this investigation, the following recommendations were drawn: Conduct a study concerning the carbon emission of the area to determine the relationship with its carbon sequestration potential; and conduct tree planting activity to open areas in the study site to increase its carbon stock potential and fully serve the purpose of the area as a wildlife sanctuary.

Keywords

Carbon Sequestration Potential, Tree Species, Isabela State University Wildlife Sanctuary

1. Introduction

Global warming is among the most dreaded problems of this millennium which just represents one aspect of climate change. This is caused mostly by increasing concentrations of greenhouse gases in the atmosphere resulting in changes in climate pattern. Greenhouse gases (GHGs) which are primarily carbon dioxide, methane, nitrous oxide and others have influenced the earth’s climate system.
Among the GHGs, carbon dioxide (CO₂) is the most important and abundant gas in the atmosphere and is responsible for more than half of radiative forces along with the greenhouse effect [2]. Forest ecosystem plays a very important role in the global carbon cycle by sequestering a substantial amount of CO₂ from the atmosphere [3]. Trees take up CO₂ from the atmosphere and store carbon in their biomass (roots, stems, and foliage) through the process of photosynthesis [4]. In 1990 alone, it is estimated that the world tropical forests were a net source of carbon (1.6 billion t) due to anthropogenic activities including land-use changes and forestry activities, primarily tropical deforestation [5]. The Philippine forests in particular, through massive deforestation, were found to have contributed about 3045 tons of Carbon to the atmosphere since the year 1500 up to the present era [2].

The Kyoto protocol provides flexible mechanisms, where Clean Development Mechanism (CDM) is most relevant for developing countries such as the Philippines [6] which have potential for carbon trading. Due to the importance of forest contributions to global climate change, research on Carbon budgets in forest ecosystem has been intensive in the Philippines. However, there are still significant gaps in the current understanding of the carbon sequestration potential of different plantation species in the country [2]. Hence, this study intends to assess the amount of carbon stored in the above-ground biomass of the tree species at the Isabela State University Wildlife Sanctuary (ISUWS).

2. Review of Related Literature
2.1. Method of Estimating Above-Ground Biomass

The mass of living organisms in a forest is called the biomass. Most of the biomass in a forest is in trees, and the focus of methods for estimating biomass is measuring the above-ground portion of trees [7]. It is the most important and visible carbon pool of the terrestrial forest ecosystem [8].

There are two approaches in measuring the above-ground biomass (AGB). The first one is the destructive method of tree biomass estimation and second is the non-destructive method. The former method is destructive and is not feasible for a large-scale analysis but experts generally agree that the harvest method is the most accurate and direct method in estimating the above-ground biomass and the carbon stocks stored in the forest ecosystems [3]. The latter method estimates the biomass of a tree without felling. This method of biomass estimation is applicable for those ecosystems with rare or protected tree species where harvesting of such species is not very practical or feasible [3].

2.2. Carbon Stock Estimation

Carbon stock is the term used for the carbon stored in terrestrial ecosystems, as living or dead plant biomass [9]. Estimation of the magnitude of sinks and sources of carbon requires reliable estimates of the biomass of forests and of individual trees [10]. As an overall estimate, the carbon content of biomass in the Philip-
pine ranges from 41% to 49% with an average close to 45%. This is a little lower than the IPCC default value of 50% [11]. A study conducted on the carbon content of wood samples collected from secondary forests from several locations in the Philippines and reported that for Philippine biomass, a default value of 45% could be used in determining carbon stock in trees [12]. Some studies in carbon stock assessment in the Philippines use this amount of carbon like in the study in the Reservation Area of Kalinga State University which computed a total of 475.25 t/ha of carbon in [13]. Also the 45% carbon content of the tree biomass were used in the study in Kapatan, Lanao Del Norte accumulated a total of 257.16 Mg/ha [14].

2.3. Carbon Stock in the Philippines

Tropical forests have a valuable role in relation to climate change, being a source and sink of carbon. The study of Lasco and Pulhin reviews the state of knowledge on carbon stocks and rate of sequestration of various forest ecosystems in the Philippines [6]. Carbon density ranges widely from less than 5 t/ha to more than 200 t/ha in the following order: old growth forests; secondary forest; mossy forest; mangrove forest; pine forest; tree plantation; agroforestry farm; brushlands; grasslands. Carbon sequestration ranges from less than 1 t/ha/yr in natural forests to more than 15 t/ha/yr in some tree plantations. Land-use change and forestry make an important contribution in the national emissions and sinks. It is estimated that Philippine forest lands are a net sink of greenhouse gasses (GHG) absorbing 107 Mt CO₂ equivalent in 1998, about equal to the total Philippine GHG emissions. The clean development mechanism (CDM) presents a clear opportunity for Philippine forestry, if the threats are properly addressed [6].

3. Materials and Methods

3.1. Materials

The materials used in the establishment of sampling quadrats are bolo, pegs and nylon rope. In the collection and preservation of leaf specimens, field note, presser, pruning shear, denatured alcohol, packing tape, specimen tag and sacks were used. After randomly choosing the coordinates of the base corner of sample plots, they were located with the used of Global Positioning System (GPS) and the base stake was placed on the ground.

3.2. Establishment of Quadrats and Transects

The 20 sample plots having the size of 20 m × 20 m were laid out within the study area (Figure 1) using completely random sampling [7]. The approach in laying out the sample plots is by choosing random numbers from within the latitude and longitude of the study site. After randomly choosing the coordinates of the base corner of sample plots, they were located with the used of Global Positioning System (GPS) and the base stake was placed on the ground. It was located
in the southwest corner of the plots and oriented north-south as followed from Condit [7]. Within each sample plot, all trees having 10 cm and above in diameter at breast height (dbh) were recorded as followed from Brown (1997) [13].

3.3. Survey and Data Collection Procedure

The data gathered in this study was the dbh of every individual tree species. The dbh of every tree sample was measured at 1.3 m above the ground [15]. For forking trees below breast height, the dbh were taken and treated individually (plate 3). The dbh of a leaning tree was taken along its lower side, not the upper [7].

3.4. Data Analysis

The allometric equation developed by Banaticla was adopted to determine the above-ground biomass (AGB) of the tree species (Equation (1)) [10]. The carbon stock of the tree was determined by multiplying the computed AGB to 45% (Equation (2)) which is the average carbon content of wood samples collected from secondary forests from several locations in the Philippines [12]. The weight of CO2 sequestered was determined by multiplying the carbon stock of the tree to 3.67 (Equation (3)) which is the ratio of carbon to carbon dioxide [16].

Equation (1). Determination of above-ground tree biomass [10].

\[
Y \text{ (kg)} = 0.342 \times (\text{dbh})^{2.073} \quad (1)
\]
where: \( Y \) = the above-ground biomass in kg.
\( \text{dbh} \) = the measured diameter at 1.3 m above the ground in cm.

Equation (2). Determination of Carbon Stock \cite{12}.

\[
C = \text{AGB} \times 45\% 
\]

Equation (3). Determination of CO2 Sequestered \cite{16}.

\[
\text{CO}_2 = C \times 3.67 
\]

where: \( \text{CO}_2 \) = carbon dioxide sequestered by tree species
\( C \) = carbon stock of tree species
3.67 = ratio of \( \text{CO}_2 \) to \( C \)

4. Results and Discussion

4.1. Tree Species in ISUWS

The 20 sample plots established within the study area were covered with different vegetation such as grasses and patches of forests (natural and manmade). The emphasis of this study is the tree covers where the tree species were identified and the number of individuals were counted. The 20 sample plots were covered with 34 tree species with an individual average number of 14.25 or a total of 285 individual trees. Table 1 shows the different tree species with their common name and their corresponding scientific name, number of individual trees and the plots where they were found. In the study it was found out that. ISUWS also homes some of Native endangered species.

Table 1. Tree species found in ISUWS.

| Common Name | Scientific Name | No. of Trees | Plot Occurrence/s |
|-------------|-----------------|--------------|-------------------|
| 1. Narra    | Pterocarpus indicus | 12           | 1                 |
| 2. Mahogany | Swietenia macrophylla | 13           | 1, 3, & 15        |
| 3. Fringon pula | Bauhinia purpurea | 4            | 1, & 6            |
| 4. Binayuyu | Antidesma ghaesembilla | 10           | 1, 15, & 16       |
| 5. Ipil-ipil | Leucaena leucocephala | 5            | 1, 8, 11, & 15    |
| 6. Pagsahingin | Canarium asperum | 36           | 2, 4, 5, 8, 12, 15, & 20 |
| 7. Kamiring | Semecarpus cuneiformis | 68           | 2, 4, 8, 11, 12, 15, 18, & 20 |
| 8. Alim     | Melanolepis multiglandulosa | 15           | 2, 4, 11, & 15    |
| 9. Sablot   | Litsea glutinosa | 19           | 2, 4, 5, 14, 15, 16, 18, & 20 |
| 10. Banato  | Mallotus philippensis | 9            | 2, 15, 16, & 18   |
| 11. Alagaw | Premna odorata | 8            | 2, 5, & 11        |
| 12. Niyog-niyogan | Ficus pseudopalma | 2            | 2                 |
| 13. Dita    | Alstonia scholaris | 3            | 2, 4, & 9         |
Continued

| No.  | Tree Species            | AGB Class | Notes |
|------|-------------------------|------------|-------|
| 14   | Bagras Eucalyptus deglupta | 23         | 3, & 16 |
| 15   | Anchoan dilaw Senna spectabilis | 5         | 3     |
| 16   | Palosanto Triplaris cumingiana | 1         | 3     |
| 17   | Manalu Semecarpus longifolius | 6         | 5, & 12 |
| 18   | Kalios Streblus asper | 3         | 5, & 8 |
| 19   | Kalumpang Sterculia foetida | 1         | 5     |
| 20   | Takulau Milusa vidalii | 1         | 5     |
| 21   | Japanese acacia Acacia auriculiformis | 2         | 6     |
| 22   | Yemane Gmelina arborea | 14        | 6, 7, 14, 15, & 20 |
| 23   | Neem tree Azadirachta indica | 2         | 6, 16 |
| 24   | Binunga Macaranga tanarius | 6         | 6, 11, & 14 |
| 25   | Balinghasai Buchanania arborscens | 4         | 8, 12, & 15 |
| 26   | Uas-puas Harpulia arborea | 3         | 8, 20 |
| 27   | Hauli Ficus septica | 2         | 9     |
| 28   | Kahoy dalaga Mussaenda philippica | 1         | 9     |
| 29   | Bolong-eta Diospyros pilosanthera | 2       | 11    |
| 30   | Bulala Nauclea orientalis | 1         | 11    |
| 31   | Duhat Syzygium cumini | 1         | 11    |
| 32   | Anubing Artocarpus ovatus | 1         | 12    |
| 33   | Rain tree Samanea saman | 1         | 18    |
| 34   | Salingkogi Albizia saponaria | 1         | 20    |
|      | **Total**                |            | 285   |

4.2. AGB of the Tree Species in ISUWS

Biomass was used to provide an estimate of the carbon reservoirs in ecosystems based on the fact that about half of it is Carbon [13]. Biomass density (expressed as dry matter per unit area) indicates the potential amount of CO₂ that can be released to the atmosphere when vegetation is burned or cleared [8]. Table 2 shows the total above-ground biomass (AGB) of the selected tree species at ISUWS is 105.56 t/ha. The AGB of ISUWS is slightly lower than some of the secondary forest in the Philippines such in Cebu City with AGB of 195.13 t/ha [17] and Mindanao with AGB of 262 t/ha [14]. While in Kaliwa Watershed the computed AGB densities of secondary forests were 149.70 t/ha [18].

Among the 34 individual species, Alstonia scholaris contains the largest amount of AGB with a mass of 20.97 t/ha followed by Samanea saman with the mass of 13.40 t/ha. The study of Udayakumar et al. [19] shows that Samanea saman contains 2.16 t/tree of AGB while the study of Marak et al. [20] shows that the AGB of Alstonia scholaris is 4.42 t/ha. The result of this study may be affected by their diameter as the both species belong to the highest diameter class. According to Guiabao [13], while the diameter of trees increases, the AGB also increases respectively.
**Table 2.** Calculated above-ground biomass (AGB) of selected tree species.

| Scientific Name                  | ABG kg/Sp. | ABG (t ha⁻¹) |
|----------------------------------|------------|--------------|
| 1. *Alstonia scholaris*          | 838.95     | 20.97        |
| 2. *Samanea saman*               | 535.90     | 13.40        |
| 3. *Gmelina arborea*             | 361.24     | 9.03         |
| 4. *Eucalyptus deglupta*         | 295.09     | 7.38         |
| 5. *Canarium asperum*            | 385.43     | 9.64         |
| 6. *Semecarpus cuneiformis*      | 327.43     | 8.19         |
| 7. *Acacia auriculiformis*       | 233.80     | 5.84         |
| 8. *Acacia auriculiformis*       | 206.31     | 5.16         |
| 9. *Semecarpus longifolius*      | 172.58     | 4.31         |
| 10. *Litsea glutinosa*           | 133.06     | 3.33         |
| 11. *Swietenia macrophylla*      | 83.10      | 2.08         |
| 12. *Mallotus philippensis*      | 77.37      | 1.93         |
| 13. *Macaranga tanarius*         | 59.80      | 1.49         |
| 14. *Melanolepis multiglandulosa*| 57.70      | 1.44         |
| 15. *Pterocarpus indicus*        | 53.88      | 1.35         |
| 16. *Sterculia foetida*          | 48.94      | 1.22         |
| 17. *Harpulia arborea*           | 44.78      | 1.12         |
| 18. *Premna odorata*             | 44.11      | 1.10         |
| 19. *Leucaena leucocephala*      | 37.07      | 0.93         |
| 20. *Buchanania arborescens*     | 35.75      | 0.89         |
| 21. *Senna spectabilis*          | 34.65      | 0.87         |
| 22. *Streblus asper*             | 31.82      | 0.80         |
| 23. *Nauclea orientalis*         | 28.13      | 0.70         |
| 24. *Miliusa vidalii*            | 22.84      | 0.57         |
| 25. *Antidesma ghaesembilla*     | 15.11      | 0.38         |
| 26. *Ficus septica*              | 12.17      | 0.30         |
| 27. *Ficus pseudopalma*          | 5.71       | 0.14         |
| 28. *Diospyros pilosanthera*     | 9.70       | 0.24         |
| 29. *Syzygium cumini*            | 8.16       | 0.20         |
| 30. *Azadirachta indica*         | 7.41       | 0.19         |
| 31. *Mussaenda philippica*       | 4.43       | 0.11         |
| 32. *Albizia saponaria*          | 4.25       | 0.11         |
| 33. *Triplaris cumingiana*       | 3.54       | 0.09         |
| 34. *Artocarpus ovatus*          | 2.11       | 0.05         |
| **Total**                        | **4222.30**| **105.56**   |

4.3. Calculated Carbon Stock of Tree Species at ISUWS

In general, the total carbon stock of tree species at ISUWS is 47.50 t/ha (Table 3). The carbon stock of the selected trees in the study is lower than the mean...
Table 3. Calculated above-ground biomass (AGB) of selected tree species at ISUWS.

| Scientific Name         | Carbon Stock (kg/sp.) | Carbon Stock (t/ha) |
|-------------------------|-----------------------|---------------------|
| 1. Alstonia scholaris   | 377.53                | 9.44                |
| 2. Samanea saman        | 241.15                | 6.03                |
| 3. Gmelina arborea      | 162.56                | 4.06                |
| 4. Eucalyptus deglupta | 132.79                | 3.32                |
| 5. Canarium asperum     | 173.44                | 4.34                |
| 6. Semecarpus cuneiformis | 147.34             | 3.68                |
| 7. Acacia auriculiformis| 105.21                | 2.63                |
| 8. Acacia auriculiformis| 92.84                 | 2.32                |
| 9. Semecarpus longifolius| 77.66               | 1.94                |
| 10. Litsea glutinosa    | 59.88                 | 1.50                |
| 11. Swietenia macrophylla| 37.40                | 0.93                |
| 12. Mallotus philippensis| 34.82                | 0.87                |
| 13. Macaranga tanarias  | 26.91                 | 0.67                |
| 14. Melanolepis multiflorula | 25.97            | 0.65                |
| 15. Pterocarpus indicus | 24.24                 | 0.61                |
| 16. Sterculia foetida   | 22.02                 | 0.55                |
| 17. Harpilia arborea    | 20.15                 | 0.50                |
| 18. Premna odorata      | 19.85                 | 0.50                |
| 19. Leucaena leucocephala| 16.68                | 0.42                |
| 20. Buchanania arborscens| 16.09               | 0.40                |
| 21. Senna spectabilis   | 15.59                 | 0.39                |
| 22. Streblos asper      | 14.32                 | 0.36                |
| 23. Nauclea orientalis  | 12.66                 | 0.32                |
| 24. Miluus vidalii      | 10.28                 | 0.26                |
| 25. Antidesma ghaesembilla| 6.80                 | 0.17                |
| 26. Ficus septica       | 5.47                  | 0.14                |
| 27. Ficus pseudopalma   | 4.36                  | 0.11                |
| 28. Diospyros pilosantha| 3.67                  | 0.09                |
| 29. Syzygium cumini     | 3.33                  | 0.08                |
| 30. Azadirachta indica  | 2.57                  | 0.06                |
| 31. Mussaenda philippica| 1.99                  | 0.05                |
| 32. Albizia saponaria   | 1.91                  | 0.05                |
| 33. Triplaris cumingiana| 1.59                  | 0.04                |
| 34. Artocarpus ovatus   | 0.95                   | 0.02                |
| **Total**               | 1788.50               | 47.50               |

carbons stock (207.9 t/ha) of the following secondary forest: Makiling, Mindanao and Leyte [14]. On the other hand, the study on the carbon stock found in
the reservation area of Kalinga State University shows a total of 475.25 t/ha [15]. Compared to other studies, the carbon content of the tree species at ISUWS is relatively lower. The primary reason is that some of the sampling plots don’t have trees to measure. ISUWS have vast patches of forest stands but some of the areas are open.

4.4. Accumulated (CO₂) of Tree Species in ISUWS

The total amount of accumulated CO₂ of the tree species at ISUWS is 164.09 t/ha (Table 4). A total of 88.17 kt was observed to be the CO₂ sequestration capacity of the forest stand in the reservation area of JRMSU—Tampilisan campus [16]. The variation in the amount of CO₂ sequestered and stored in the species within the forest stand was affected greatly by the stand density of trees of their total population and the area planted to these trees, aside from their biomass [16].

**Table 4.** Accumulated (CO₂) of the selected tree species at ISUWS.

| Scientific Name             | Accumulated CO₂ (kg/sp.) | Accumulated CO₂ (t/ha) |
|-----------------------------|--------------------------|------------------------|
| 1. *Alstonia scholaris*     | 1385.54                  | 34.64                  |
| 2. *Samanea saman*          | 885.02                   | 22.13                  |
| 3. *Gmelina arborea*        | 596.60                   | 14.90                  |
| 4. *Eucalyptus deglupta*    | 487.34                   | 12.18                  |
| 5. *Canarium asperum*       | 636.52                   | 15.93                  |
| 6. *Semecarpus cuneiformis* | 540.74                   | 13.51                  |
| 7. *Acacia auriculiformis*  | 386.12                   | 9.65                   |
| 8. *Acacia auriculiformis*  | 340.72                   | 8.51                   |
| 9. *Semecarpus longifolius* | 285.01                   | 7.12                   |
| 10. *Litsea glutinosa*      | 219.76                   | 5.51                   |
| 11. *Swietenia macrophylla* | 137.26                   | 3.41                   |
| 12. *Mallotus philippensis* | 127.79                   | 3.19                   |
| 13. *Macaranga tanarius*    | 98.76                    | 2.46                   |
| 14. *Melanolepis multiglandulosa* | 95.31                 | 2.39                   |
| 15. *Pterocarpus indicus*   | 88.96                    | 2.24                   |
| 16. *Sterculia foetida*     | 80.81                    | 2.02                   |
| 17. *Harpalia arbores*      | 73.95                    | 1.84                   |
| 18. *Premna odorata*        | 72.85                    | 1.84                   |
| 19. *Leucaena leucocephala* | 61.22                    | 1.54                   |
| 20. *Buchanania arborscens* | 59.05                    | 1.47                   |
| 21. *Senna spectabilis*     | 57.22                    | 1.43                   |
| 22. *Stryablis asper*       | 52.55                    | 1.32                   |
| 23. *Nauclea orientalis*    | 46.46                    | 1.17                   |
| 24. *Miliusa vidalii*       | 37.73                    | 0.95                   |
5. Conclusion and Recommendation

Based on the study conducted, the 285 individual trees found at ISUWS contain a total of 105.56 t/ha of AGB. The estimated carbon stock of the trees in the area is 47.50 t/ha with 164.09 t/ha of accumulated CO₂. The researcher concluded that the tree species at ISUWS is lower than most of the secondary and urban forest in the Philippines but is still considerable to sequester high amount of carbon in the area. It was also concluded that the AGB was greatly affected by its diameter as this is the only data to estimate it. Based on the result and conclusion of this investigation, the following recommendations were drawn: Conduct a study concerning the carbon emission of the area to determine the relationship with its carbon sequestration potential and conduct tree planting activity to open areas in the study site to increase carbon stock potential and fully serve its purpose as a wildlife sanctuary.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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