Diversity and carbon stock assessment of an indigenous Philippine tree farm

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Abstract. This study was conducted to determine the species diversity and carbon stock potential of the one-hectare Indigenous Tree Farm at Bohol Island State University-Bilar in the province of Bohol, Philippines. Following its establishment in 2014, trees within the project area have been monitored for species richness and growth rates. Growth rates were calculated using basal diameter, diameter at breast height, and total height. An allometric equation utilizing species presence and growth data was used to calculate projected carbon sequestering potential within the next five years. Forty-four species of trees, including endangered and vulnerable species, were identified within the project site. The species diversity within the site was found to be 2.90 (moderate). There were a total of 1,342 individual trees whose combined carbon load was calculated to be 9.21 tons.

Keywords: Carbon stock, species diversity

1. Introduction

Atmospheric carbon is increasing, possibly due to the anthropogenic growth and become an international concern [1]. Safe carbon storage techniques with low environmental impact are vital in carbon neutrality potential [2]. One safe and long-term method is plant matter sequestration [3].

The Philippines is ranked as seventh, amongst the top twenty tropical countries, for carbon stock potential [4]. One way in which the Philippines can increase their potential is agroforestry [3]. In 2003, agroforestry accounted for the highest percentage of forest cover in the Philippines [5].

The use of trees as carbon storage has many additional benefits including water conservation, soil restoration, and increased wildlife habitat [2]. Indigenous tree farms can be considered circa situm conservation which replicates former forest patches in an agriculturally modified landscape [6].

In this study, a mixed-species indigenous tree farm was analyzed for species diversity and carbon stock potential. It is proposed that small plots of land are able to maintain a wide array of native tree species as well as serve as a noteworthy source for carbon sequestration.

2. Materials and Methods

2.1 Study Site

The study was conducted on an indigenous tree farm at Bohol Island State University-Bilar campus, Zamora, Bohol. The tree farm is a one-hectare plot established in 2014. Prior to the reforestation, the...
site was pasture land for over 60 years. The study plot is routinely monitored for pests and diseases, and preventative or control measures are enacted as needed.

The study site is located at 320 meters above sea level and has an average annual rainfall of 2,000 mm. The site is situated near a river and an irrigation canal, should supplemental water be required. The average daytime temperature is 24-28 °C with temperatures up to 33 °C occurring during the summer months of March to May.

Trees are managed and monitored consistently through the forestry program. Basal diameter, total height, and diameter at breast height (DBH) are measured quarterly. These measurements are then used to calculate the growth rate and carbon sequestration potential.

2.2 Tree Measurements and Calculations

All trees within the plot are individually identified for consistent data collection. Primary data of basal diameter, DBH, and total height were measured for each tree using calipers and a calibrated pole. This data was then collated with historic data which included species name and previous measurements.

Species richness was calculated using the Shannon diversity index ($H'$).

\[
Species 
\text{diversity} = -\sum_{i} p_i (\log p_i)
\]

where,

\[
p_i = \frac{\text{number of individuals of a species}}{\text{total number of individuals of all species}}
\]

Biomass was calculated based on the biomass regression equations for a moist climatic zone [7].

Trees less than 60 cm DBH

\[
AGB = \exp\{-2.134-2.530*\ln(D)\}
\]

Trees greater than 60 cm DBH

\[
AGB = 42.69-12.800(D)+1.242(D^2)
\]

where,

AGB= above-ground biomass

D= diameter

The biomass was then converted to carbon content using a conservative 45% estimate [5].

3. Results and Discussion

A total of 44 tree species were identified and measured within the indigenous tree plot. Number of individuals per species ranged from one to 240 with a total of 1,342 trees measured (Table 1).

| Number of species | Range of number of individuals | Mean number of individuals | Median number of individuals | Mode of individuals | Total number of trees |
|-------------------|--------------------------------|---------------------------|-----------------------------|--------------------|----------------------|
| 44                | 1-240                          | 29                        | 10                          | 1                  | 1342                 |

Species diversity was calculated to be 2.90 which is a moderate $H'$ value.

When all species are combined, the biomass and total carbon potential were found to be 1.27 tons and 9.205 tons respectfully. All trees had a large enough individual or population biomass to contribute appreciable carbon sequestration. Total carbon tons per species ranged between 0.001 to 1.137 tons of carbon sequestration potential with a cross-species average of .198 tons carbons. The largest contributor
to the carbon storage was *Chisocheton cumingianus* which had 92 individual trees within the plot at 1.14 carbon tons. *Intsia bijuga* also showed substantial sequestration with 177 individual trees having a carbon potential of 1.003 tons. The smallest contributors were species in which only one tree was identified within the plot.

One of the key aspects of the indigenous tree farm is the diversity of species within a small plot. Mixed-species plots have been shown to benefit conservational aspects [2], increase carbon stock potentials [8, 9], and reduce potential negative effects on the soil of fast-growing trees [8]. Additionally, indigenous forests have been found to sequester more carbon than exotic tree plantations [10].

A particular benefit of agroforestry is the potential for more exact measurements of carbon stores. In monitored plots, tree age and biomass change can facilitate carbon stock calculations [5]. In the case of this study, the trees are routinely measured which means that the future carbon calculations can be compared to carbon predictions based on the tree growth patterns.

Reforestation, not only helps reverse atmospheric carbon but also serve to aid biological conservation. Indigenous tree farms are a unique type of conservation, *circa situm*, in which lands modified by industry are restored to more natural conditions [6] and provide habitat for local fauna [11].

While it may seem counter-intuitive, agroforestry for timber may have a net benefit for carbon storage. When a tree is harvested, the carbon remains stored in the biomass until the biomass is compromised through burning or decay [12]. Trees used for anthropogenic purposes (i.e. construction) keep the harvested lumber’s carbon stored [9]. This allows for new trees to be planted in place of the harvested timber and start a new carbon stock.

Seedlings produced by indigenous trees are removed from the plot and given throughout surrounding barangays/villages. This program enhances the indigenous tree plot and subsequently carbon sequestering in surrounding locales.

4. Conclusion
The indigenous tree farm is a multi-purpose project impacting many interests of agroforestry. Routine monitoring enhances the knowledge of tree growth rates and survivorship, and these rates can be used to calculate the carbon sequestration potential within the plot and for specific species. Additionally, this knowledge can be used to help implement the tree planting programs throughout the region with an emphasis on enhanced carbon sequestration.

References
[1] Zelek C, Shively G (2003) Measuring the opportunity cost of carbon sequestration in tropical agriculture. Land Economics 79:342-354
[2] Lal R (2008) Carbon sequestration. Philosophical transactions of the Royal Society 363:815-830
[3] Albrecht A, Kandji S (2003) Carbon sequestration in tropical agroforestry systems. Agriculture Ecosystems and Environment 99:15-27
[4] Trexler M, Haugen, C (1995) Keeping it green: Tropical forestry opportunities for mitigating climate change. World Resources Institute, Washington, DC
[5] Lasco R, Pulhin F (2003) Philippine forest ecosystems and climate change: Carbon stocks, rate of sequestration and the Kyoto Protocol. Annals of Tropical Research 25:37-51
[6] Dawson I, Guariguata M, Loo J, Weber J, Lengkeek A, Bush D, Cornelius J, Guarino L, Kindt R, Orwa C, Russell J, Jamnadass R (2012) What is the relevance of smallholders’ agroforestry systems for conserving tropical tree species and genetic diversity in circa situm, in situ and ex situ settings? A review. Biodiversity and Conservation 22: 301-324
[7] Brown S (1997) Estimating biomass and biomass change of tropical forests: a primer. Food and Agriculture Org. 134:11
[8] Montagnini F, Porras C (1998) Evaluating the role of plantations as carbon sinks: An example of an integrative approach from the humid tropics. Environmental Management 22:459-470
[9] Shepherd D, Montagnini F (2001) Above ground carbon sequestration potential in mixed and pure tree plantations in the humid tropics. Journal of Tropical Forest Science 13:450-459
[10] Omoro L, Starr M, Pellikka P (2013) Tree biomass and soil carbon stocks in indigenous forests in comparison to plantations of exotic species in the Taita Hills of Kenya. Silva Fennica 47: article id 935

[11] Gevana D, Pollisco J, Pampolina N, Kim D, Im S (2013) Plant diversity and aboveground carbon stock along altitudinal gradients in Quezon Mountain Range in Southern Mindanao, Philippines. Journal of Environmental Science and Management 16: 20-26

[12] Lippke B, Wilson J, Meil J, & Taylor A (2010). Characterizing the importance of carbon stored in wood products. Wood and Fiber Science 42: 5-14.

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