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Carbon stock of trees in the lower montane forest of Mt. Kalatungan Range Natural Park in Mindanao, Philippines

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Abstract

A tree inventory and carbon stock assessment was conducted in three 50 x 100 meter randomly established sampling plots in the lower montane forest of Mt. Kalatungan, a protected area located in Mindanao, Philippines. A total of 31 species of trees belonging to 24 families that is dominated by Fagaceae, Lauraceae and Myrtaceae was recorded. The most frequent species are *Lithocarpus* spp., *Syzygium* spp., *Neolitsea* spp. Out of 833 tree species, 49.70% lies in the 21-28cm dbh class based on sturge's rule. The greatest dbh recorded was 73cm from *Syzygium spp.* of the family Myrtaceae. The site obtained a greater mean stand density of 555 trees ha^{-1}. The site also contained many trees with relatively greater dbh resulting to a high biomass and carbon stock estimate. The mean tree biomass density estimate was 628 ton ha^{-1} while the mean Carbon density estimate was 282 ton C ha^{-1}. These results provide a robust justification for an effective protected area management in order to salvage the area from further deforestation and forest degradation. The conservation of forest resources, especially trees in Mt. Kalatungan would be very crucial in the Philippine's efforts to mitigate climate change.

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Introduction

Trees in forests are both sources and sinks of carbon (C). They are crucial in the sequestration of carbon dioxide (CO_2) from the atmosphere, a greenhouse gas that is one of the leading causes of global warming which can result to climate change. Trees store C into the production of woody biomass through the process of photosynthesis. Trees also increase soil organic carbon content (Brown and Pearce 1994), a relatively permanent stock of carbon in forests. Globally, forests act as a natural storage for carbon, contributing approximately 80% of terrestrial above-ground, and 40% of terrestrial belowground carbon (Kirschbaum 1996). Chave (2005) reported that tropical forests hold great stores of carbon, and is the most persistent carbon sink compared to boreal forest and temperate forest (Pan *et al.,* 2011). Current efforts to mitigate the impact of climate change are through ways of increasing carbon sequestration (Sedjo and Salomon 1988) and/or mitigating carbon emission (Lasco *et al.,* 2004). Thus the simple way to increase carbon stocks is to plant more trees and manage them properly (Lasco *et al.,* 2004).

In the recent past, CO_2 has gained a lot of attention as a greenhouse gas, as it has the potential to influence the climate pattern of the world. Anthropogenic activities like deforestation and forest degradation have caused an increase in the level of CO_2 in the atmosphere and disrupted the global carbon cycle. As the environmental effects of such activities have started to influence climate, many programs have been launced in order to mitigate climate change. Since the forestry options have been proven to be very viable because of its cost effectiveness, many were convinced that carbon sequestration through forest conservation is the most practical option. Forest conservation has a potential to form a chief component in the mitigation of global warming and adaptation to climate change. Carbon sequestration from the atmosphere can be very advantageous from both environmental and socioeconomic perspectives. The environmental perspective includes the removal of CO_2 from the atmosphere, the improvement of soil quality, and the increase in biodiversity (Batjes and Sombroek 1997); while socioeconomic benefits include increased yields (Sombroek *et al.,* 1993) and monetary incomes from potential carbon trading schemes (McDowell 2002). People, especially those who are from the agricultural and forestry sector will likely benefit from good yields due to the reduction of climate change related hazards.

Being situated in the tropics, Philippine tropical forests are important sink of carbon (C). However, the continued reduction of the country's forest cover is undermining its potential to contribute to global carbon sequestration for climate change mitigation. In 1992, the Philippines passed the National Integrated Protected Areas System (NIPAS) Law which is aimed for the conservation of biodiversity and sustainable development. Several protected areas known as natural parks were established in many parts of the country including in Mindanao. A recognized natural park by virtue of the NIPAS law, Mt. Kalatungan, the sixth highest mountain in the country with an elevation of 2,824 (9,265 ft) masl in Mindanao is not exempted from the continued decline in forest cover. The reduction of forest cover also implies removal of trees which will result to reduced carbon sequestration and storage potentials. Despite the many previous studies that carried out estimation of tree biomass and carbon stocks in the area, there remains a need to do the activity periodically in order to track changes and make decisions on the necessary interventions. It is therefore for this reason that the study was conducted. This study aimed to furnish stakeholders such as students, future researchers, and especially policy makers a credible data as basis for decision insofar as how the area would be managed, protected and conserved. Specifically, the study site shall be the lower montane forest (1300-1600m) of Mt. Kalatungan.

Materials and methods

Study site

The study was conducted in the lower montane forest of Mt. Kalatungan located in Pangantucan, Bukidnon. It covers an area of approximately 213km² (82 mi²). It is one of the few areas in the province covered with old growth lowland and montane forests. About 114km² (44 mi²) is identified as part of the critical watershed area declared under Presidential Decree 127, issued on June 29, 1987 (Muleta-Manupali Watershed). The water from two Rivers Muleta and Manupali, is supporting the multimillion dam project of the National Irrigation Administration (NIA) of the Philippines. The rivers drain into the Pulangi River, which is the site of the hydroelectric dam of the National Power Corporation. Mt. Kalatungan falls under the Type III climate which is characterized as having short dry season lasting only one to three months and no very pronounced maximum rain period. Average temperature is 24.7 °C. The area receives the highest amount of rainfall in the month of June while the driest month is March. The relative humidity varies from 71% in May to 86% in September. The area is virtually cloud-covered throughout the year.

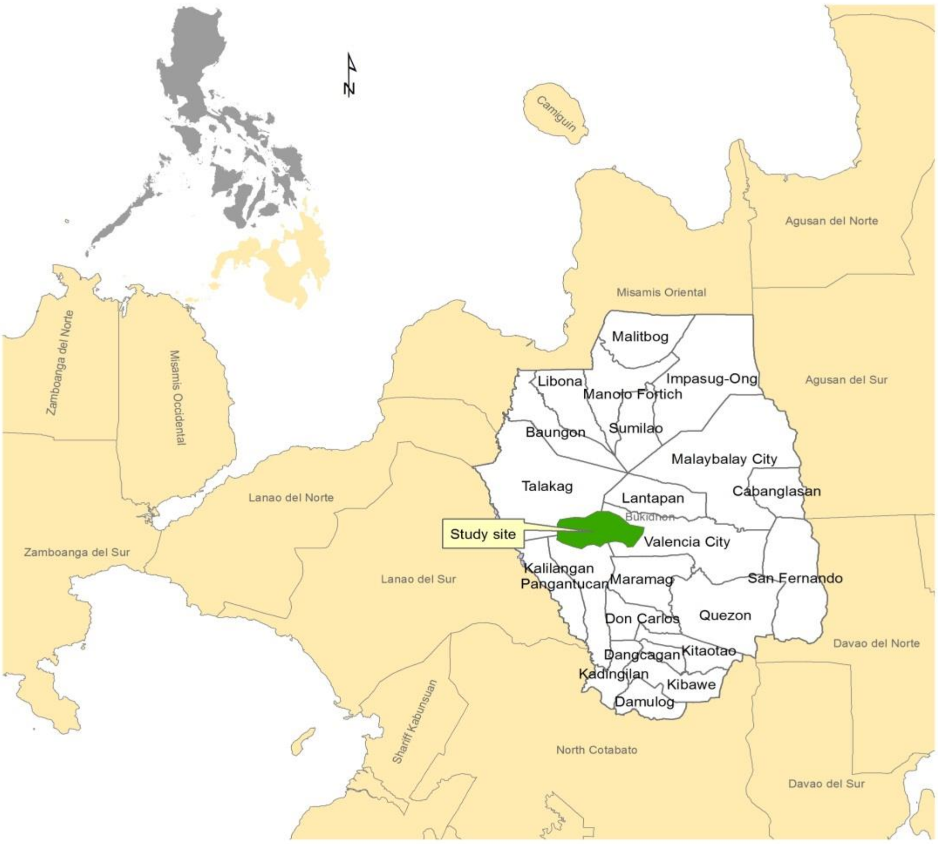

Fig. 1. Location map of the study site.

Sampling

At the study site, three plots with a dimension of 50 x 100 meters were randomly established. The centerpoint of each plot was located using a Global Positioning System (GPS) receiver. All trees with a DBH of 5cm and above within each plot were sampled and the species name and diameter (dbh) were recorded on the field notebook. Leaf samples were collected in some cases where a tree species cannot be identified in the field.

Computation of Tree Biomass

Tree biomass was analyzed using the updated Brown's allometric equation (Pearson *et al.,* 2005) as presented below.

$$\text{Aboveground biomass (kg)} = \text{Exp}\,(-2.289 + 2.649 \times \ln(\text{dbh}) - 0.021 \times (\ln \text{dbh})^2$$

$$\text{Belowground biomass (kg)} = \text{Exp}\,(-1.0587 + 0.8836 \times \ln(\text{ABD}))$$

In the given equation, dbh is the diameter at breast height and ABD is the aboveground biomass computed using the updated Brown's allometric equation (Pearson *et al.,* 2005). Since the site is a protected area, the use of these equations is very appropriate because it allows for a non-destructive method of tree biomass estimation.

Estimation of carbon stock

Carbon Content in biomass was measured using a default value of 45% which is the average carbon content from tree biomass from natural forests (Lasco & Pulhin, 2000).

Data analysis

The dbh data were summarized into a frequency distribution to be able to further condense it. Mean dbh, mean biomass density and carbon density were then analyzed using Microsoft Excel.

Results and discussion

Dendrological characteristics

With a total of sixty-one (61) individuals, *Lithocarpus sulitii* was the most frequent tree species on the site. It is followed by *Neolitsea villosa* with thirty-eight (38) individuals and *Syzygium* spp. with twenty-nine (29) individuals. *Lithocarpus* is a genus of the family Fagaceae which is also called as Philippine Oaks. Philippine oaks are locally known as *Ulayan* and it is reported as the most dominant species in the area (Mt. Kalatungan GMP). As a whole, our findings reflect that the most frequent plant families are Fagaceae, Lauraceae and Myrtaceae which were observed to be widely distributed in the area. Aside from being frequent, trees of the family Fagaceae and Myrtaceae were also found to be the most dominant trees with dbh that are generally greater than that of the other families. In the Philippines, these families are well documented to occur in montane forests where cooler climates prevail. Although total tree heights were not measured, it is evident that trees in the study site are considerably shorter than those in the lowland forest. Dominant trees were also observed as the emergent ones, they are less abundant and are smaller in dbh. Due to climate and topographic limitations, buttressing is uncommon in the area but the presence of non-vascular plants becomes more evident (Fernando, 2008).

Table 1. Dendrological characteristics of the site.

Site	Families	Genera	Species	trees	Mean DBH ±SE (cm)	Basal Area (m^2)	Stand density ha^{-1}
Plot 1	18	23	25	329	29.50 ±0.77	7396	658
Plot 2	18	23	26	270	31.44 ±0.89	5659	540
Plot 3	20	25	27	234	30.34 ± 1.04	3959	468
Mean	19	24	26	278	30.43± 0.09	5671	555
Total	24	28	31	833	N/A	17014	N/A

DBH distribution of trees

As shown in fig. 2, 49.70% out of 833 tree species has dbh ranging from 21-28cm. This information is consistent across the three sampling plots from which the greatest number of trees was recorded in plot no. 1. The greatest dbh recorded was 73cm from *Syzygium* spp. of the family Myrtaceae recorded also in plot no. 1.

Trees in montane forests have generally lesser dbh as compared to trees in the lowland forests. This is due to topographic, climatic and edaphic constraints which tend to limit tree growth that often results to stunting (Benner *et al.,* 2010).

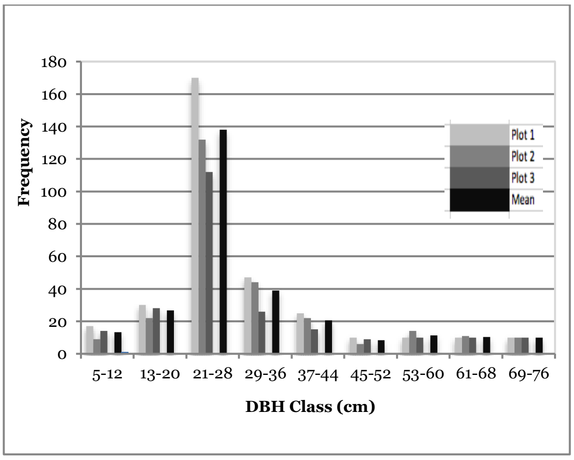

Fig. 2. Histogram of DBH of trees.

With trees of lesser dbh, it follows that the stand density would be higher. Nakashizuka *et al.,* (1992) reported that tree density increases with ascent in elevation. As depicted in Table 1., the mean stand density is 555 trees ha^{-1}. Various trees belonging to the two lower dbh classes were also recorded; this implies that the study site has a good growing regeneration stock.

Carbon Stocks

The montane forest of Mt. Kalatungan obtained a mean tree C stock of 282 ton C ha^{-1}. Belowground C stock constitutes around 13% of the mean tree C stock. According to Lasco (2002), natural forests in Southeast Asia typically contain a high C density (up to 500 ton C ha^{-1}). However, that fig. already includes C stock in other C pools. Considering only the C stock in trees, our results are within the range of values especially for similar forest types in the region. A significant number of trees that belonged to the upper dbh classes were also recorded.

As reflected in table 2, the BGB carbon density is roughly 6-7 times lesser than the tree C stock which supported the study of Harris (1992) that for most trees under normal conditions, the root-shoot ratio is 1:5 to 1:6 or simply, the top is 5 to 6 times heavier than the roots. If it were not for the weight of the trunk, however, the top and roots would weigh about the same. Although some roots may extend to great depths (Canadell *et al.,* 1996), the overwhelming proportion of the total root biomass is generally found within 30cm of the soil surface (Jackson *et al.,* 1996).

Table 2. Biomass and Carbon stocks of the site.

Site	AGB Biomass density (ton ha^{-1})	BGB Biomass density (ton ha^{-1})	Tree Biomass Density (ton ha^{-1})	AGB C stock Density (ton C ha^{-1})	BGB C stock Density (ton C ha^{-1})	Tree C stock density (ton C ha^{-1})
Plot 1	596	88	684	268	40	308
Plot 2	563	82	645	253	37	290
Plot 3	484	70	554	218	31	249
Mean	548	80	628	246	36	282

Implications on Conservation and Climate Change

Carbon stock in tree biomass account for roughly 57% (Lasco *et al.,* 2004) when soil, litter and understory vegetation are included. It is also this C pool that is highly dynamic and most vulnerable to disturbance. Considering the value of the area for C sequestration and storage and the perennial problem of deforestation and forest degradation, it is therefore imperative to enhance the management of the area for it to become more effective.

The area is also home to various indigenous cultural communities who consider some of the resources of Mt. Kalatungan significant to their culture. Thus in the context of sustainable development and social justice, the area must be protected not only in view of its impact on C sequestration but the welfare of the indigenous peoples as well.

Conclusions

Aboveground and belowground C stocks were slightly higher for the lower montane forest as compared with other similar sites. This was due to the high tree density and tree biomass of the area being a natural forest. With a mean tree biomass density of 628 ton ha^{-1} and a mean tree C density of 282 ton C ha^{-1}, the area therefore needs attention as to how its value for C sequestration could be maintained or even improved.

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