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Comparison of aboveground biomass estimation in two forest types using different allometric equations

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ABSTRACT

With the growing problems of climate change, quantifying above-ground biomass becomes an important analysis in order to strengthen mitigating efforts. Several allometric equations have been developed for above-ground and carbon stock estimation which provides varying results. Estimated values using different allometric equations were compared in two forest types, namely Tropical Evergreen Forest and Tropical Lower Montane Forest, in Mt. Apo Natural Park, Philippines. Two one-kilometer line transects with five plots were established for each forest type. Diameter-at-breast height (dbh), tree height and wood specific gravity of the trees (>10cm dbh) were obtained. Three allometric equations were used in estimating aboveground biomass including Chave et al. (2005), Brown (1997), which both consider dbh and Chave et al. (2005), which considers three variables (dbh, tree height and wood specific gravity). It was found out that the exclusion of wood specific gravity and tree height resulted to overestimation of AGB which was observed in the equations of Brown (1997) and Chave et al. (2005). The overall results of the study indicated that different forest types have different AGB values. Regardless of value differences, above-ground biomass estimates indicate that these forests have the potential to store large amount of carbon and play a major role in climate change mitigation.

Key words: MANP- Mt. Apo Natural Park; AGB- Above-ground Biomass; dbh- Diameter-at-breast height.

INTRODUCTION

Global temperatures have changed over the past 400 years (IPCC 2013). Currently, earth is warmer than it has been in the past few years. The Intergovernmental Panel on Climate Change (IPCC 2006), found out that year 1995-2006 is the warmest years in the instrumental record of global surface temperature. According to the data, from the Mauna Loa Observatory in Hawaii, the global concentration of the carbon dioxide in the atmosphere (primary driver of climate change) has reached 400 ppm.

Forest is a basic ecological unit dominated by trees. It covers a large fraction of the Earth's land area and account for most of its terrestrial biological output (Ollinger 2002). It is organized as a major carbon sink which is vital in maintaining environmental health. Forest trees absorb large amount of atmospheric carbon (Lorenz et al. 2009). In the new study of NASA, tropical forest absorbs 1.4 billion metric tons of carbon dioxide out of a total global absorption of 2.5 billion. According to the review of Bankoff (2007), about 90% of the land area was covered by the forest at the beginning of the Spanish colonization of the Philippines during the 16^{th} century. Recently, journal articles estimate that the remaining forest cover is as low as 17-18% of the total land area (Briones 2007). Forest can also provide different environmental benefits including its role in the hydrologic cycle, soil conservation and prevention of climate change (Sheeram 1993). By planting new trees, it may help in reducing the surface reflectivity; such that reduction in radiative forcing (warming) gained from increases in carbon sequestration is balance (Betts, 2000).

In the context of climate change, attention is given on carbon dioxide, which is the major constituent of greenhouse gases. The atmospheric carbon dioxide increases from 280 to 300 ppm in the year 1880 up to 335 ppm to 340 ppm in the 1980 (IPCC 2006). In the past two decades, deforestation on the tropical has been responsible for one of the largest share of CO2 released to the atmosphere which is from the land use changes (IPCC 2007). Deforestation is the conversion forest to a permanent non-forested land (Van Kooten & Bulte 2000). When forest is being cleared, some of their carbon is released to the atmosphere. Primarily, deforestation releases about 5.9 GtCO2 (gigatons or billion metric tons of CO2) annually. Due to the reason that tropical forest has the greatest potential for storing carbon, the most effective way to reduce carbon concentration in the atmosphere, is to lessen deforestation and allow forest to expand more (IPCC 2007).

Mt. Apo Natural Park is the Philippines' highest peak with an elevation of 2,934 meters above sea level, with a total land area of 64,000 hectares. It is one of the highest land-based biodiversity in terms of the flora and fauna per unit area. It has three distinct forest formations, from lowland tropical rainforest, to mid-mountain forests, and finally to High Mountain forests. MANP was declared a Protected Area and a component of the National Protected Areas System under Republic Act No. 9237 in 2003. Documentation on the biological richness of the area have been conducted, however, studies on carbon stock and forest biomass of various forest types is one of the research gaps that should be addressed. Estimating the amount of forest biomass is important to monitor and estimate the amount of carbon that is lost or emitted during deforestation, and it provides information on the forest's ability to sequester and store carbon (DENR 2009).

Biomass estimation determines the carbon that could be emitted to the atmosphere due to deforestation. This aspect of research has caught the attention of various research groups due to the issues on climate change. Furthermore, estimation of aboveground biomass is important in determining geographical patterns of carbon stocks. This study provides additional information on the forest biomass of different forest types in MANP. As stated, there are only limited studies on this aspect of research especially in tropical rainforest in the southern part of the Philippines. The results of this study can be included as a recommendation to strengthen policies towards forest conservation as well as its implementation. This can be also an eye opener to forest managers to enhance their forest management strategies. In this manner, impacts of climate change can be reduced through the reduction of carbon fluxes brought about by land use change.

MATERIALS AND METHODS

Study Site

The study area lies between 6°47' N and 7°07' latitude and between 125°09' E and 125°27' E longitude. It has original area of 76,900 hectares, with an elevation of 2,934 meters above sea level. Mt. Apo Natural Park forests are known as one of the highest land based biological diversity in terms of flora and fauna per unit area (DENR 2009). It has 3 different types of forest types including tropical lowland evergreen rainforest, lower montane forest and tropical upper montane forests. Tropical lowland evergreen rainforest is commonly known as dipterocarp forest due to the dominance of family Dipterocarpaceae including the species of the genera, *Shorea, Hopea, Vatica, Anisoptera,* Parashorea and *Dipterocarpus*. At the higher elevation which ranges from 750m 1,000 m is the lower montane forest. *Tanguile* is dominant along with the species of *Lithocarpus* and shrubs of Rubiaceae and Acanthaceae. It is also the habitat of many endemic orchids (Fernando et al. 2008).

Establishment of Sampling plots

Two one-kilometer transects was established in each forest type. Each transect was divided into five sampling points with a distance of 210m. Circular plot method was used wherein the circular plot, has a radius of 20m, and it was established in each sampling points. Each circular plot was divided into 4 sections which was used as replicates (Fig. 1).

Tree identification

Preliminary identification was done on-site based on the following guides: Botanical Identification Handbook on Philippine Diptercarps by Rojo & Aragones (1997) and Lexicon of Philippine Tress by Rojo (1992). Pre-identified samples were sent to local expert for confirmation.

Data Collection

Non-destructive sampling method was used in collecting data in estimating the AGB. Using this method, biomass estimation of a tree was done without felling. This was used since the sampling site was a protected area of DENR in which clearing the forest is not applicable. In each sampling site, trees with ≥10 cm dbh was included. Tree dbh was calculated based on the measured circumference. Circumference was measured using a meter tape. The circumference of the tree at breast height was divided by 3.1416. Data for wood specific gravity of every species was provided by the global database of wood specific gravity (http://hdl.handle.net/10255/dryad/235; Zanne et al. 2009; Chave et al. 2009). If species specific values were unavailable, genus-level values were applied. Likewise, where the genus level values were missing, family-level values were used.

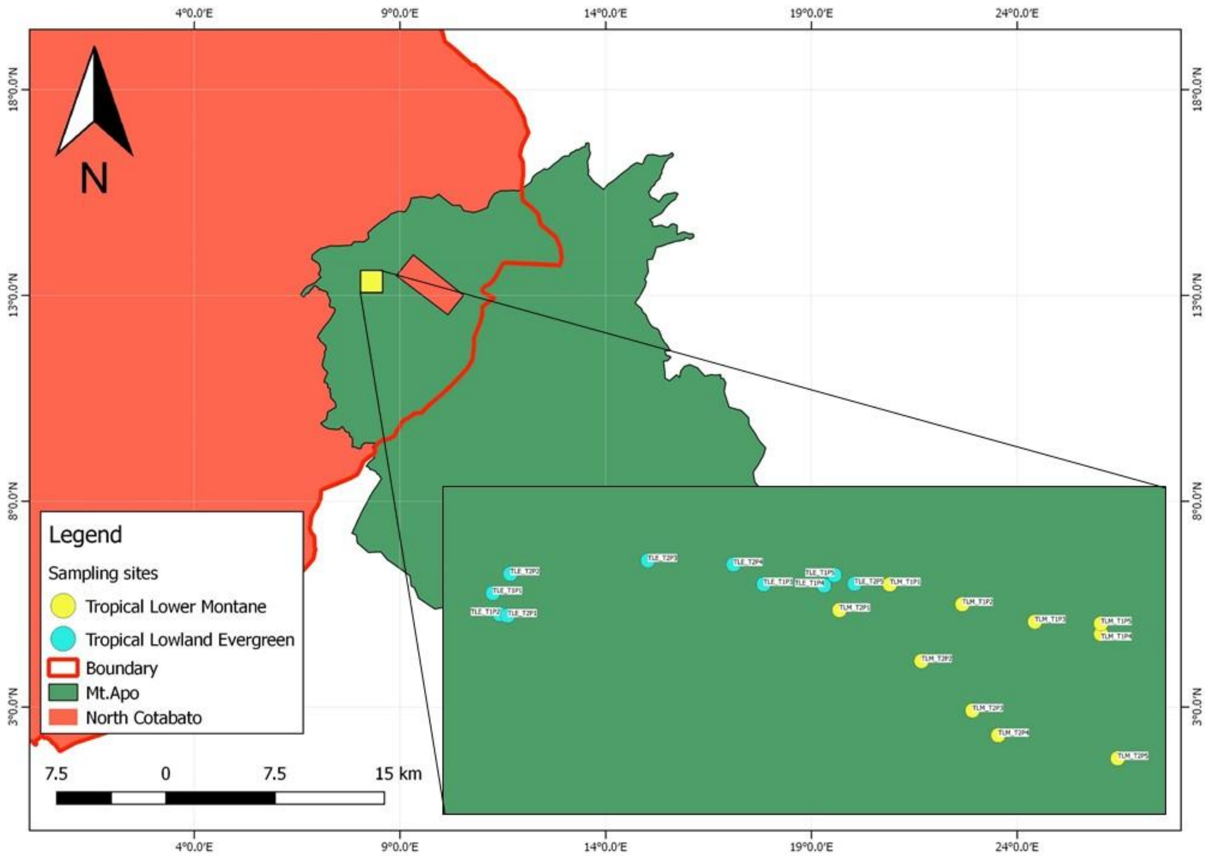

Fig. 1. Map of the established sampling plots.

Above-ground Biomass Estimation

Three allometric equations were used in this study: Chave et al. (2005), Brown (1997), which both consider only dbh and Chave et al. (2005), which considers three variables including dbh, tree height and wood specific gravity.

The allometric equation developed by Brown (1997) for tropical moist forest, given as:

AGB= exp[-2.134+2.53ln(D)]

where:

AGB = the total above ground biomass in kg/tree

D = the DBH in cm;

The allometric equations for moist tropical forest from Chave et al. (2005) given as:

AGB=

$$\exp\left(-1.499 + 2.48\ln(D) + 0.207(\ln(D))^2 - 0.0281(ln(D))^3\right)$$

for when tree height H (in m) is not available; and

AGB =

$$exp^{10}(-2.977 + \ln(\rho D^2 H)) = 0.0509 \times \rho D^2 H$$

for when it is, where ρ is wood specific gravity (g/cm^3), dbh is in cm.

Obtained AGB values from each equation for the examined trees were compared and the percentage difference was computed.

RESULTS

A total of 42 species of trees were identified and assessed. Thirty-eight (38) species were identified in tropical lowland evergreen rainforest and 23 species in tropical lower montane rainforest. Table 1 and 2 shows the number of individuals, height and dbh ranges per species in tropical lowland evergreen rainforest and tropical lower montane rainforest, respectively. In tropical lowland evergreen rainforest, 260 individuals were assessed while 129 individuals in tropical lower montane forest.

Table 1. Summary of ranges of collected DBH and tree height data per species in Tropical Lowland Evergreen Rainforest.

Species	No. of Samples	Ranges of Height (m)	Ranges of DBH (cm)
1. *Acer laurinum* Hassk	4	5-8.2	15-45
2. *Aglaia edulis* (Roxb.) Wall.	6	3.2-7.4	11-43
3. *Artocarpus odoratissimus* Blanco.	8	3.1-11.5	12.6-62
4. *Astronia cumingiana* var. *bicolor* (Merr.) Maxwell	5	4-10.1	35-82
5. *Calophyllum blancoi* Pl. & Tr.	4	4.5-9.2	17-67
6. *Castanopsis evansii* Elmer	5	6-21.4	24.5-75.8
7. *Celtis luzonica* Warb.	1	3	11.3
8. *Cinchona pubescens* Vahl.	1	6.9	15
9. *Dillenia philippinensis* Rolfe	2	13-15	37.2-37.6
10. *Dipterocarpus grandiflorus* (Blanco) Blanco	2	6.5-8.5	57-83
11. *Duabanga moluccana* Blume	3	3.6-8	12-35
12. *Ficus balete* Merr.	2	6.6-21	49-87
13. *Ficus heteropoda* Miq.	1	4.7	26
14. *Ficus nota* (Blco.) Merr.	5	4.4-13.5	15-80
15. *Garcinia dives* Pierre	4	2.3-7.9	14.2-25.5
16. *Intsia bijuga* (Colebr.) O. Ktze.	1	7	115
17. *Litsea* sp.	1	4	11.26
18. *Lithocarpus apoensis* (Elmer)	3	4-14	10.2-70
19. *Lithocarpus bennettii* (Miq.) Rehd.	2	3.5-4.8	13.4-22.3
20. *Lithocarpus ovalis* (Blco.) Rehd.	35	3.5-22.8	10.8-153
21. *Litsea glutinosa* (Lour.) C.B. Rob.	1	12.3	22
22. *Macaranga tanarius* (L.) Muell.-Arg.	1	4.8	15.3
23. *Melia* sp.	2	6.1-8.1	18.8-24.5
24. *Parashorea malaanonan* (Blanco) Merr.	4	4-8.3	10-18
25. *Phoebe lanceolata* (Nees) Nees	1	3.5	11.46
26. *Semecarpus philippinensis* Engl.	1	2.7	20.05
27. *Shorea almon* Foxw.	53	3.5-29	10.5-121
28. *Shorea contorta* Vidal.	31	3.3-23.9	11.14-98.7
29. *Shorea negrosensis* Foxw.	17	4.6-18.5	11.1-68.4
30. *Shorea palosapis* (Blanco) Merr.	15	3.1-15	12.1-79
31. *Shorea polysperma* (Blanco) Merr.	2	6-7.2	12.4-17.5
32. *Spathodea campanulata* Beauv.	4	4.8-7.8	19.1-47.4
33. *Syzygium cumini* (L.) Skeels	1	6.9	34.1
34. *Syzygium hutchinsonii* (C.B. Rob.) Merr.	17	4.2-11	12.1-60
35. *Syzygium nitidum* Benth.	16	2.8-20.5	12-175
36. *Syzigium panduriforme* (Elm.) Merr.	3	7.1-12.8	14.3-78.6
37. *Terminalia calamansanai* (Blanco) Rolfe	1	4	21
38. *Trema orientalis* (L.) Blume	1	20.1	44.88
Total	**260**		

Table 2. Summary of ranges of collected DBH and tree height data per species in Tropical Lower montane Forest**.**

Species	No. of Samples	Ranges of Height (m)	Ranges of DBH (cm)
1. *Acer laurinum Hassk.*	2	3.9-4	12.4-16
2. *Aglaia edulis (Roxb.) Wall.*	5	5.3-14	14.3-40.1
3. *Calophyllum blancoi Pl. & Tr.*	7	7-14	10.5-29
4. *Cananga odorata* (Lam.) Hook.*f.* & Thompson	1	20	59.21
5. *Castanopsis evansii* Elmer	1	15.1	120
6. *Dillenia philippinensis* Rolfe	1	20	38.2
7. *Dipterocarpus grandiflorus (Blanco) Blanco*	2	8-15	22.3-54
8. *Duabanga moluccana Blume*	1	8	27.1
9. *Ficus heteropleura Blume*	1	7	20.7
10. *Ficus nota (Blco.) Merr.*	2	7.2-9	20.4-20.7
11. *Melia* sp.	3	3.9-6.1	12-17
12. *Lithocarpus ovalis (Blco.) Rehd*	35	4.1-25	13-181
13. *Parashorea malaanonan (Blanco) Merr.*	8	8-17	13-48
14. *Saurauia sp.*	3	3.7-9	11-18.5
15. *Shorea almon Foxw.*	10	6-29	11-184
16. *Shorea contorta Vidal.*	25	7-26	11-203
17. *Shorea negrosensis Foxw.*	4	3.9-10	10-34
18. *Shorea palosapis (Blanco) Merr.*	2	19-23	92-101
19. *Shorea polysperma (Blanco) Merr*	8	6-14	10-31
20. *Syzygium cumini* (L.)	4	9-11	11-32
21. *Syzygium hutchinsonii (C.B. Rob.) Merr.*	6	4-12	14-27
22. *Syzigium panduriforme* (Elm.) Merr.	1	6	15
23. *Terminalia calamansanai (Blanco) Rolfe*	2	6.5-7	14-20
Total	**129**		

Using the equation developed by Brown (1997), tropical lower montane forest had a total of 2.33613E+45kg AGB while 9.39743E+44kg in tropical lowland evergreen rainforest (Table 3). In the equation developed by Chave et al. (2005), tropical lower montane forest had a total of 2.26653E+45 kg while in the tropical lowland evergreen rainforest, it had a total of 8.81236E+44 kg. The other equation which is also developed by Chave et al. (2005), a decrease in AGB value had been observed. In tropical lower montane forest, the AGB value was 759.6297612 kg while in tropical lowland evergreen forest, it was 633.5438826 kg. A large decrease of AGB values was observed in the second equation of Chave et al. (2005) due to the incorporation of tree height, DBH and wood specific gravity as variables.

Table 3. Total AGB of two different forest types using the three allometric equation for which the tree height, DBH and wood density was collected.

	Forest Type	
	Tropical Lowland Evergreen Rainforest	**Tropical Lower Montane Rainforest**
Brown (1997)	9.39743E+44kg	2.33613E+45kg
Chave et al. (2005)	8.81236E+44kg	2.26653E+45kg
Chave et al. (2005)	633.5438826kg	759.6297612kg

Figure 2 shows the graphical representation of the comparison of the computed AGB using three allometric equations in tropical lowland evergreen rainforest and tropical lower montane rainforest, respectively. It was observed that AGB computed using allometric equation of Brown (1997) and Chave et al (2005) without tree height and wood specific gravity are more or less have the same values. Values computed using these two allometric equations were higher compared to the equation of Chave et al (2005) with tree height and wood specific gravity.

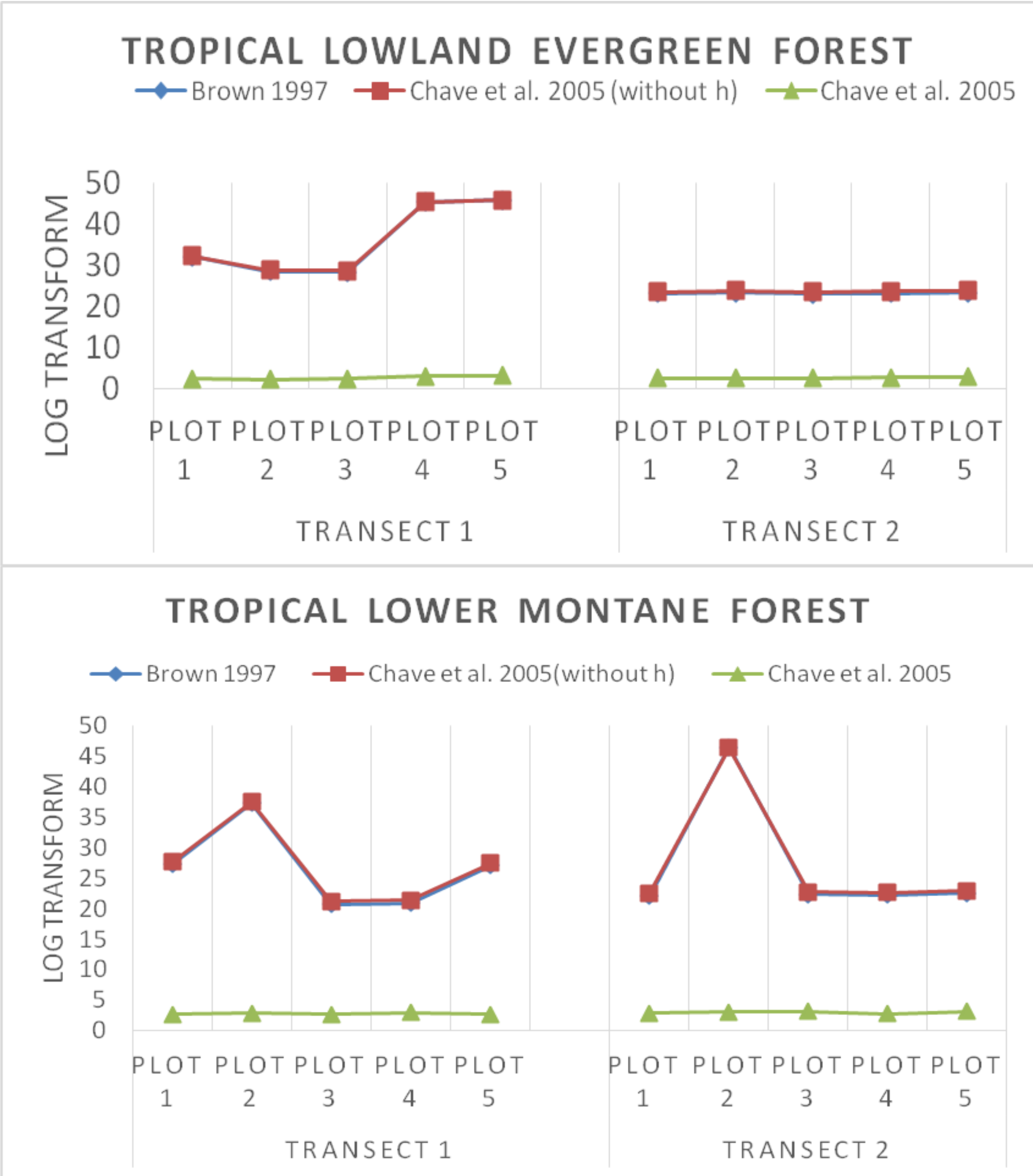

Figure 2. Comparison of AGB values per plot per transect in two forest types using different allometric equations. (Chave et al., 2005 (without h)- height and wood specific gravity are not included).

DISCUSSION

Higher number of species were identified in tropical lowland evergreen rainforest compared to tropical lower montane rainforest. According to Gentry (1988), in the tropics, tree species richness decreases with the increasing altitude. High species richness in tropical lowland evergreen rainforest may be due to lower altitudinal areas since increasing species richness at lower elevation is expected in case of trees (Phillips et al. 1994). Climatic factors were the central in terms of the distribution and the species richness patterns of some tree species (Valencia et al. 2004). Soil fertility of the tropical lowland evergreen forest can also be one of the drivers of species richness as suggested by Latham & Ricklefs 1993 and Tilman 1988.

The number of species as well as the number of individuals assessed in two different forest can be attributed on the differences of the computed AGB values, using different allometric equations, in two forest types. There were 260 individuals assessed in tropical lowland evergreen rainforest and 129 in tropical lowland montane forest. Moreover, other measured and considered parameters such as dbh, tree height and wood specific gravity also provide plausible explanation on these results. Higher computed AGB values, in most allometric equations used in this study, was observed in tropical lowland evergreen rainforest. In this forest type, larger trees with higher DBH, up to 203 cm, were observed. According to Midgley et al. (2002) and Lewis et al. (2009), above-ground biomass accumulation is influenced by the presence of large diameter trees. These large diameters can be greatly affected by the climate as observed by Suratman et al. (2010) and having a stable wet climate is also important (Slik et al. 2010) which is the characteristic of the tropical lowland evergreen rainforest included in this study.

In the AGB values computed using three different allometric equations, the equation established by Brown (1997) and Chave et al. (2005) had the higher value compared to the other equations (Table. 5). Both tree height and wood specific gravity are not included in the allometric equation established by Brown (1997) and Chave et al. (2005) which can be attributed to the higher estimated AGB values (Baker et al. 2004 and Chave et al. 2009). All generic models relying upon the dbh only will yield to an overestimated in average biomass stocks compared to the model developed by Chave et al. (2005) wherein the DBH, the tree height and wood density were added as variables (Rutishauser et al., 2013). Moreover, larger dbh of the tree greatly affects the estimated value of AGB. This is in agreement with the study of Vieira et al. (2008) wherein two allometries were used in estimating the biomass in the Brazilian Atlantic Forest wherein the dbh was used as the only variable, resulted to an overestimate of biomass by 52%-68%.

According to the past studies (Chave et al. 2005 and Feldpausch et al. 2012), using equation developed by Chave et al. (2005) (dbh, tree height and wood specific gravity) in estimating the biomass would yield a better estimate and have higher precision (Devine et al. 2013) than using the equation of Brown 1997 and equation of Chave et al (2005) in which the dbh is the only variable included. This is due to the fact that important parameters like tree height and wood specific gravity are considered. Wood specific gravity is an important variable for improving estimates of carbon because it is used when inventories of bole volume are converted to biomass (Brown et al. 1989; Brown 1997; Houghton et al. 2001). Tree height is an important component of allometric equation in estimating AGB (Chave et al. 2005) since it is known to significantly improve estimates of the individual tree AGB (Feldpausch et al. 2012). According to the study of Rutishauser et al. (2013), including tree height generates the best model which has a lowest standard error and will result to less bias estimates. Furthermore, wood density and tree height improve the accuracy of the individual tree biomass estimation compared to the allometric equation in which the dbh was the only variable included (Chave et al. 2005; Feldpausch et al. 2012; Lima et al. 2012; Maia Araújo et al. 1999; Vieira et al. 2008). Chave et al. (2005) reported that the inclusion of tree height for standard level estimates of the biomass will reduce error from 19.5% to 12.8% across all forms of tropical forest and to the other continents. Ignoring the height of the tree would result in an overestimation of the forest AGB. Incorporating the wood specific gravity in estimating the AGB is not common, although it is known to result in substantial improvement. According to Nelson et al. (1999), incorporating the wood specific gravity as a variable in estimating AGB will help reduce error. Using this variable as a predictor is considerably improved the biomass equation (Deans et al. 1996). Thus it is a good indicator of AGB and multispecies biomass estimation (Chave et al., 2014). In addition, Baker et al. (2004) demonstrated that the inclusion of the wood specific gravity can explain the 20% to 30% AGB differences across Amazonian forest site. Wood specific gravity is highly variable across regions and it is the key determinant in large scale biomass models (Baker et al. 2004; Chave et al. 2006).

By this study, it was found out that the different forest types in Mt. Apo Natural Park (MANP) Philippines are an important reservoir of carbon, and can play in mitigating the global climate change. Thus, knowing the carbon stocks of Tropical Lowland Evergreen Forest and Tropical Lower Montane Forest is important as it contribute to the sustainable management of these forest ecosystems to support the Reducing Emission from Deforestation and Degradation (REDD+) process and is a useful tool in formulating further conservation strategies.

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