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Stand Structure and Aboveground Biomass of a 12-Year Old Narra (Pterocarpus Indicus) Plantation in Biliran, Biliran (Philippines)

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***Abstract*-**Climate change is one of the pressing environmental concerns globally. As a result, the Philippine government implemented programs and established offices with the goal to combat climate change and attaiin forest sustainability. Stand structural attributes such as diameter and height are widely known as indicators for forest sustainability. This current research was conducted to describe the stand structure and estimate the aboveground biomass of a 12 year-old plantation in Biliran, Province of Biliran. Statistical tool software R package "Biomass" and "fitdistrplus" were used for this study. Our results showed that Narra plantation can be of great potential in the context of forest sustainabilty as well as the carbon sink. At the same time, this species as describe as critically endangered species will be saved restored and saved from the possibility fo extinction. The research will serve as baseline information of the potential of this species in response to climate change mitigation and adaption, and to help restore the forest resources in the country.

***Keywords-** Stand Structure, Aboveground Biomass, Plantation*

I. INTRODUCTION

One of the most pressing environmental concerns globally is climate change. According to Lasco et al. (2006), greenhouse gases such as methane, nitrous oxides, carbon dioxide (CO2) and chlorofluorocarbons absorb thermal radiation emitted by the earth's surface. In the case of the tropics, shifting cultivation attributed to large scale forest degradation which is considered as the major source of uncertainty of the forest carbon accounting (Mukul et al., 2016). However, research had been conducted that tropical forests have the great potential to mitigate climate change through conservation of existing carbon pools (Brown et al. 1996, Brown et al. 2000). As a result of these international concerns, the Philippines established a Climate Change Commission office as an independent and autonomous body which is chaired by the President of the Philippines (CCC, 2011). The Climate Change Commission is the lead policy-making body mandated by the government to coordinate, monitor and evaluate programs and action plans of the government relating to climate change pursuant to the Climate Change Act of 2009. In addition, the government created the National Framework Strategy on Climate Change (NFSCC), which has been approved by the President (CCC, 2011). The NFSCC outlines the 12-year plan of the country with regard to climate change mitigation and adaptation. Furthermore, the government implemented the National Greening Program (NGP) (Executive Order 26) to reduce poverty, resource conservation and protection, and climate change mitigation and adaptation. The program aims to plant 1.5 Billion trees to cover an about 1.5 Million hectares of land from 2011 to 2016.

The foregoing information suggests that the Philippines has a strong interest to combat climate change in line with mitigation and adaptation, biodiversity conservation, reduced deforestation and forest degradation, reduced carbon emissions, and poverty alleviation (Lasco et al., 2013). In the same way, native species can restore degraded lands to its original forest cover and thus promotes biodiversity conservation (Milan and Margraf, 1994) and help mitigate climate change through carbon sequestration. Consequently, Narra (Pterocarpus indicus Willd) is a native species of the Philippines. According to the DENR Administrative Order (DAO) No. 01 series of 2007, this species is under category A, which is critically endangered species (DENR, 2007) and needs immediate action in order to save this species. In addition, this species is the national tree symbol of the Philippines. In addition, this species could give multiple benefits such as in saving threatened species, carbon sequestration and in the same way restore and conserve the forest in the Philippines which is in line with the government's program on forest conservation. Thus, this research has been carried out to describe the stand structure and to estimate the above ground biomass of narra plantation on a stand - based level. Specifically it aims to describe the forest structure of the stand (e.g diameter distribution) and to estimate the aboveground biomass of each tree of the stand.

II. MATERIALS AND METHODS

A. *Study Area*

Biliran is a small province in Eastern Visayas with a total land area of 555.5 m2 (Fig 1). The 0.5 hectare narra plantation with 3 m x 3 m planting distance planted back in 2006 and managed by the Department of Forestry of Naval State University-Biliran Campus (now Biliran Province State University – Biliran Campus) (Fig. 2). Based on the record from the Community Environment and Natural Resources Office Naval, plantation registration was 134 tree farms, 145, 713 trees planted with the average of one hectare farm area (Germano et al., 2007). The climate of the province belongs to

Type IV based on the Modified Coronas Classification of climate all over the Philippines with rainfall more or less evenly distributed throughout the year (Biliran, 2016). The commonly known Northeast Monsoon, prevails during the months of November towards February. In addition, the southwest monsoon comes during the months of July to September, while the trade winds which generally come from the east prevail the rest of the year whenever the Northeast Monsoon and the Southwest Monsoon are inactive. The mean seasonal temperature (from 1971-2000) in the months of June, July and August at an average temperature of 28c (Biliran, 2016).

Figure 1. Location of Narra plantation in San Isidro, Biliran, Province of Biliran, Philippines

Figure 2. The 12 year – old narra plantation planted by Department of Forestry of Naval State University –Biliran Campus (now Biliran Province State University – Biliran Campus)

B. Data Collection

There were 177 trees of narra measured the circumference using the ordinary tape. Three repeated measurements were conducted to minimize the error in estimating the diameter. The average was then converted to diameter at breast height (DBH) using the derivation formula; Diameter = Circumference (cm) / π (3.1416). In addition, due to inaccessibility of equipment in measuring the tree height, merchantable height was adapted. The merchantable height was measured using the four- meters stick length. Although this may produce error but this was the only method we can apply. The data was then encoded to the database and run in the R language and environment for statistical computing (R Development Core Team, 2018).

C. Stand Structure

In this paper, the R package "fitdistrplus" (Delignette-Muller & Dutang, 2018) was used to fit the predefined diameter distribution models. Prior to the fitting distribution, six different diameter distribution model such as exponential, lognormal (Bliss and Reinker, 1964), Weibull (Bailey and Dell, 1973), and gamma (Nelson, 1964). These are commonly adapted and used diameter distributions so far. Before setting one or more distributions to a data set, we first choose good candidates among the predefined set of distributions. We started with plots of the empirical distribution function and histogram (density) following the suggestion of (Delignette-Muller & Dutang, 2018) using the *plotdist* function and the fitdistrplus package. In addition to this, descriptive statistics may help to choose candidates to describe a distribution among a set of parametric distributions. For this, we used *descdist* function proposed by Cullen and Frey (1999) as cited by Delignette-Muller & Dutang)2018) intended for empirical distribution. On the other hand, the computation of different goodness-of-fit statistics was proposed in the fitdistrplus package in order to further compare fitted distributions. Thus, the predefined diameter distributions was tested using the Kolmogorov-Smirnov and Anderson-Darling statistic and Chi-Squared statistic, and Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) to compare which distributions will give the best fit.

D. Aboveground biomass

Aboveground biomass was calculated using the R package "Biomass" (Réjou-Méchain et al., 2019).The main idea for the biomass calculation was to compare the estimated wood density by region. The package automatically gives you the estimated wood density based on the default region. For this analysis, we tried to compare the wood density of Narra based on three different regions (e.g. World, Southeast Asia, and Southeast Asia Tropical). On the hand, since the package "Biomass" gives you the default unit to tons (t), we converted the tons into kilograms (kg). In addition, to get the overview of the simple descriptive statistics, we used the library package in R "pastecs" and "psych" (R Development Core Team, 2018).

III. RESULTS AND DISCUSSION

A. Stand Structure

Stand structural attributes are widely known as indicators for forest sustainability. Stand attributes such as diameter and height are crucially important for the maintenance of species diversity (Clark, 2010), forest functioning (Yuan et al., 2018) and enhance stand productivity or aboveground biomass (Dănescu et al., 2016). With our current research, we tried to describe the 12 year old narra stand plantation in terms of diameter distribution and height. Although, our data is limited in terms of number of samples. We had only 177 trees with the minimum of 0.65 cm and the maximum of 7.96 cm (Table 1). The mean annual increment of the diameter was 0.28 cm while the height was 0.17 cm. Our results were comparable from the reforestation trials in Leyte, Philippines where Schneider et al. (2013) found an increment for the diameter at 1.19 cm/year and for the height at 1.05 m/ year (limestone soil), and diameter increment at 0.81 cm/year and height increment at 0.78 m/year (volcanic soil). Similarly, Schneider et al. (2013) findings pointed out that native species performed well compared to the exotic or introduced species. Narra under the family fabaceae is native and grow naturally in the Philippines. This information suggests that this tree species will have great potential in the context of forest sustainability and can be used as tree planting material for the reforestation activity in the country. In fact, this species is planted as part of the national greening program in the country (PENRO, unpublished).

Diameter distribution showed no clear partterns. We hypothesized that the diameter distribution would be the same and even considering that it is a plantation.

TABLE I. SUMMARY OF DIAMETER FREQUENCY OF THE MEASURED TREES, DIAMETER AND HEIGHT INCREMENTS FOR 12 YEAR PERIOD

Variables	Sample size	Mean	Median	Min	Max	var	Std.dev	Coef.var	SE.Mean
Diameter (cm)	177	3.33	3.18	0.64	7.96	3.23	1.80	0.54	0.14
MT (m)	177	2.05	1.95	0.50	5.20	0.51	0.71	0.35	0.05
Diameter Increment	177	0.28	0.27	0.05	0.66	0.02	0.15	0.54	0.01
MT increment	177	0.17	0.16	0.04	0.4	0.00	0.05	0.35	0.00

* MT stands for merchantable height

However, we found opposite patterns. Further, we found a small density at small-sized diameter class (Fig. 3) somewhere between 0.0 cm to 1.3 cm, and then from approximately 2.0 cm to 8 cm showing the inverse J-shaped distribution pattern. On the other hand, based on the goodness of fit statistics using the Kolmogorov – Smirnov Statistic, gamma distribution was the best fit, but, for the Anderson- Darling Statistic, Weibull distribition was the best fit. In addition, based on the goodness of criteria, both Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) showed that Weibull distribution is the best fit. According to Aigbe & Omokhua (2014) where they modeled a diameter distribution in the tropical forest and pointed that there was no clear resolution as to which model is the most suitable for tree distributional modelling. In our study area, the stand has not been managed and no silvicultural treatment has been conducted. It would be interesting to look at the dynamics of this stand and make a repeated measurements in the future to monitor the growth and compare its diameter distribution.

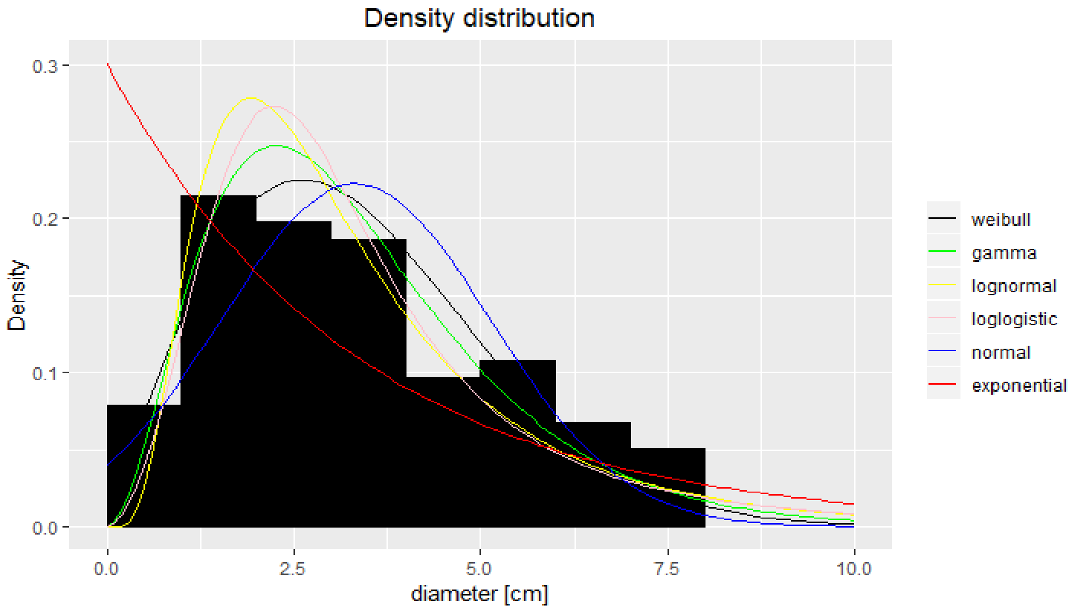

Figure 3. The observed and predicted relative diameter distributions of the narra stand. The histograms represent the observed distributions. The different colored line showing the suggested fitting diameter distribition.

TABLE II. SUMMARY OF GOODNESS OF FIT STATISTICS AND CRITERIA OF THE FOREST

Probability distribution	Goodness-of-fit statistics		Goodness-of-fit criteria	
	Kolmogorov-Smirnov statistic	Anderson-Darling statistic	Akaike's Information Criterion (AIC)	Bayesian Information Criterion (BIC)
Weibull	0.0666742	0.8916768*	687.88*	694.23*
Gamma	0.0659686*	0.9181139	689.14	695.49
Lognormal	0.0940359	1.7489871	700.71	707.06
Loglogistic	0.0745839	1.6234722	707.23	713.59
Normal	0.1082484	2.4998427	712.99	719.34
Exponential	0.2388883	15.7146345	781.53	784.70

B. *Aboveground biomass*

Chave et al., (2014) has been widely used for estimating aboveground biomass (AGB) using the diameter and height variables. For our study, we were interested to look at the variability of AGB (kg) using a different methods in estimating the wood density. Our results showed that there are differences among the methods (Table 3; Fig. 4). We used the R package "Biomass" and adopted the wood density estimation given by the R package. Using the region, Southeast Asia (tropical) gives the lowest sum of AGB estimated at 166.81 kg while the region „Southest Asia gives the highest AGB estimated at 218.86 kg. These findings revealed that different methods would results to different estimation. In this case, since Philippines is in Southeast Asia and it is a tropical rainforest, we would just use the estimation by Southeast Asia. We tried to compare our results from the recent study of Ngo & Lum (2018) in Singapore published in Journal of Urban Ecology where they studied the aboveground biomass estimation of tropical street trees on a tree level. Our findings were not comparable as they found higher AGB both for three species under the fabaceae family, Peltophorum pterocarpum at 393 kg, Carallia brachiata at 2990 kg, and Samanea saman at 1497 kg. Although, Singapore may have different climatic condition and the species were not also comparable even though it has the same family name. Further, since we have a very small sample size, we can't derive a clear conclusion as to the accuracy of our methods. However, what we are trying to show that this species can be useful in the context of carbon sequestion and help attain in achieving the goals of the government's to combat climate change. With this, regular monitoring of this stand in terms of its stand structure and biomass accummulation will be beneficial. Smith & Applegate (2002) pointed that information on monitoring changes in the standing biomass of tropical forest forest under different management regimes is limited. Hence, regular monitoring on our studied stand would be beneficial.

TABLE III. SUMMARY OF AGB COMPARING THE DIFFERENT METHODS IN ESTIMATING WOOD DENSITY

Methods (wood density estimation)	AGB (kg)		
	min	max	sum
Chave et al., 2014	0.007	4.70	184.77
World	0.008	5.07	199.38
South-East Asia	0.009	5.57	218.85
South-East Asia (tropical)	0.007	4.24	166.81

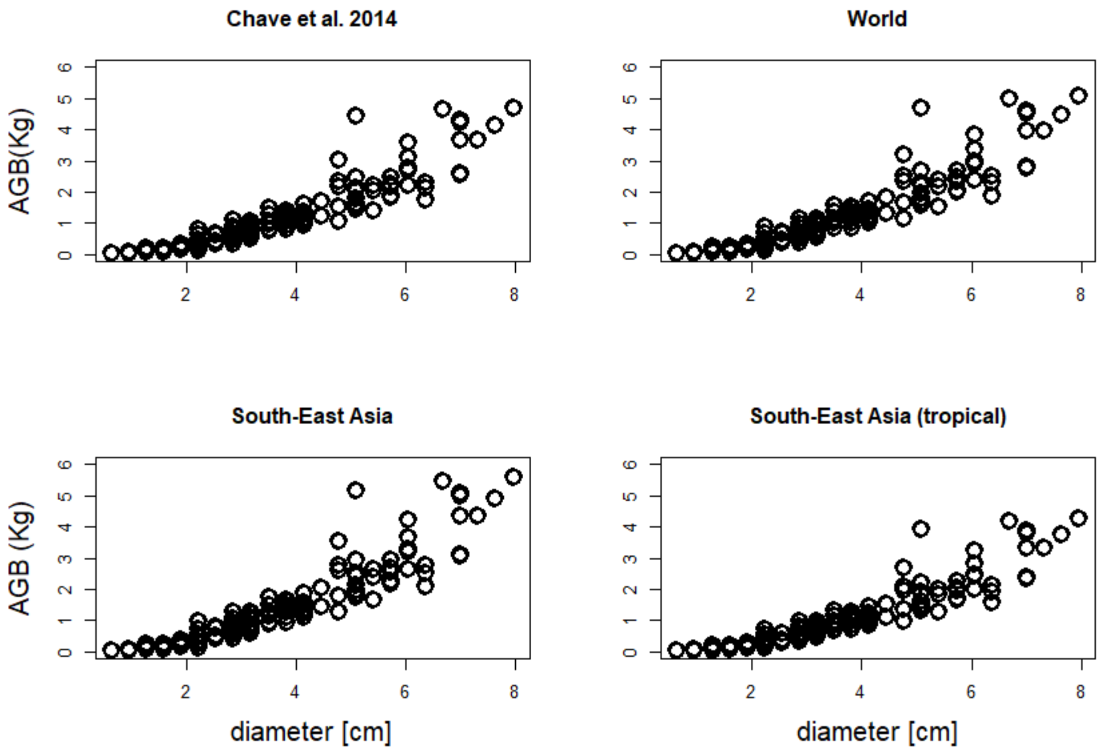

Figure 4. Aboveground biomass (AGB) in response to diameter (cm) comparing the different methods in estimating specific wood density.

IV. CONCLUSION

Stand structure in terms of diameter and height distribution of the narra stand were diverse. This information can be used as a baseline data if this stand will be managed in the future and what silvicultrual treatments will be applied. Aboveground biomass were not that interesting when compared to other studies, however, this research will be serve as guideliens for forest policy makers in the context of forest management and conservation.

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