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Establishment and diversity assessment of permanent monitoring plots in both natural and plantation forests in Southern Philippines

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Abstract

This study was conducted as an initial endeavor in understanding long-term dynamics and responses of both natural and plantation forests to changes in climate in terms of species diversity, composition and abundance. Grid-based database was made for each type of forest to be used for monitoring and analysis. A total of 111 species with 88 genera under 42 families out of 4,569 individuals were gathered from the two plots. Significant difference ($p < 0.05$) was observed between the two collections with only less than 10% common species. Findings showed that the species diversity in both types of forest is quite low. In the combined plots though, 31% endemism was observed with 21 threatened species suggesting the importance of the area as potential conservation site. Extending the sampling area in the natural forest is a future plan as supported by the rarefaction analysis performed.

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Introduction

Forests will comprise an indispensable resource especially at these times of changing climate. Its sustainable management is seen as a potential tool for global climate change mitigation and adaptation. The wide interest for tropical forests like in the Philippines as carbon sink is due to its cost effectiveness; high potential rates of carbon uptake; and associated environmental and social benefits (Moura-Costa 1996). However, there is a widespread concern in the country about the continued decline of forest resource base and its contribution to economic development (Cassels *et al.,* 2000) and so their associated environmental services such as carbon storage and habitat for biodiversity conservation. Reversing this trend of forest 'degradation' is therefore a huge challenge requiring not just strong political will and advocacy but a more science-based approach to forest management, conservation and development. Forest monitoring areas are critically important to meet this end. According to Jenkins *et al.,* (2002), monitoring identifies the "normal" range of variation in a forest, establishes temporal baseline from which changes may be detected and the need for management intervention is easily recognized. Since climate change is expected to alter forest ecosystem structure, composition, and productivity over time (Shugart *et al.,* 2003), monitoring through generation of series of empirical data will be a critical component for adaptive ecosystem management and may identify the need for scientific research to explain the causes of temporal change. Empirical data on the changes in forest condition over time is an important requirement for a sustainable forest management program. According to Noss (1999), among the common changes in forests over the past two centuries are loss of old forests, simplification of forest structure, decreasing size of forest patches, increasing isolation of patches, disruption of natural regimes, and among others.

Moreover, monitoring forest for a number of years encompasses many and varied opportunities of research areas including, but not limited to, forest carbon stocks, forest degradation and forest area changes (Holmgren *et al.,* 2007). Vanguelova *et al.,* (2007) also stressed that intensive monitoring will inform the future maintenance of biodiversity in managed forests, and is relevant to any greenhouse gas inventory process. In turn, this will aid the development of management strategies for the conservation of carbon in forests. Strayeret *et al.,* (1986) on the other hand, pointed out some benefits of long-term research to academic community in general. These include the following: demonstration sites for trainings, field area for research and thesis, offer tours to classes or to the general public to demonstrate either general ecological principle of specific research projects, which may provide also valuable educational service to the public by providing a tangible example of what science is and does. The study site is actually owned by and within a titled land of a state university where students and faculty members do excursions and normally conduct field experiments.

This paper serves as the initial and baseline information to understand the long-term dynamics and responses of both natural and plantation forests to changes in climate particularly in terms of species diversity, composition and abundance. Spatial analysis with the aid of Geographic Information System (GIS) techniques was conducted to evaluate the patterns and distribution of these species.

Materials and methods

Location and Gridding

The study site is part of the forest reserve of Central Mindanao University (CMU) under the supervision of Forest Resources Development Division (FRDD) in Bukidnon, Mindanao, Philippines (Fig. 1). Tree plantations are managed commercially to produce lumber and furnitures but there are areas not subject for logging including that being used in this study. Planted tree species include *Gmelina arborea*, *Swietenia macrophylla*, *Tectona grandis* and *Acacia mangium*. There are also various fruit trees as well as a rubber plantation. Natural forest on the other hand is considered to be lowland secondary growth lying between 320m - 550m above sea level (asl).

Human activities are prohibited in these forests which are found typically near water source acting as tributary buffers or on steep slopes ranging from 20% to more than 100%. Meanwhile, common agricultural crops being cultivated are rice, corn and sugarcane.

In the chosen natural forest, a 100 x 100 meter plot was established which was further subdivided into a 10 x 10 meter grids (Fig. 2). To properly identify each grid, posts were installed on all corners and intersections and each grid is designated with plot numbers. The posts are made of 2” (50.8mm) polyvinyl chloride or PVC pipe stuffed with concrete materials driven into the ground. The average elevation of the area is 439m asl.

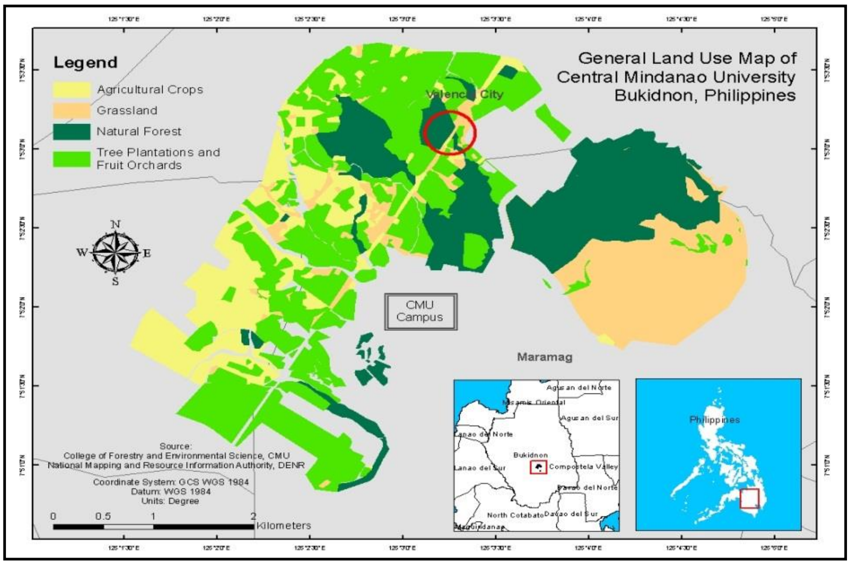

Fig. 1. Site of the permanent monitoring plots (encircled red) within the forest reserve of CMU, Bukidnon, Philippines.

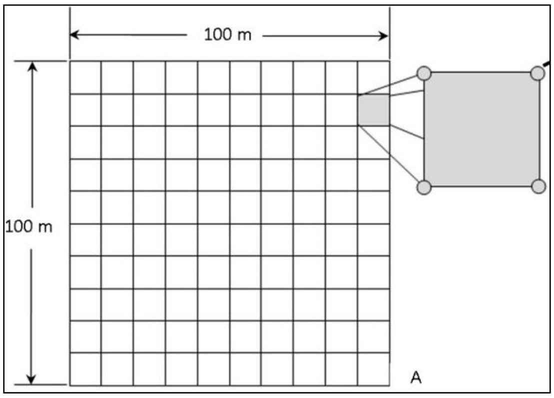

Fig. 2. One-hectare permanent plot in the natural forest subdivided into 10x10m grids.

About 250 meters away from the first plot, another sampling plot was established in an area planted with *T. grandis*. However, it was limited to 3,000 square meters only due to the presence of transmission towers, power lines and foot trails. The age of the stand is approximately 8 years old within which no felling of trees or any silvicultural activities were conducted.

The area is much flatter with slope ranging from 2.5% to 12% with an average elevation of 408m asl. The same gridding and posting was applied to this plot. The establishment of the two plots was conducted between October 2012 and January 2013.

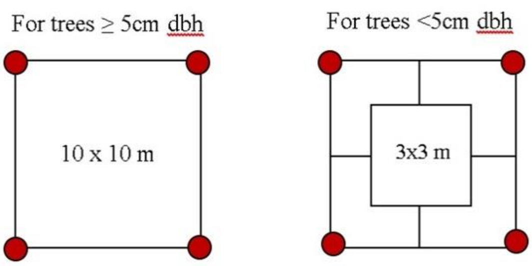

Fig. 3. Sampling plot design used in both natural and plantation forests.

Sampling and Data Collection

In each of the 10m x 10m grid, the following were conducted: species identification, measurements of diameter at breast height (dbh) and total tree height.

For trees with dbh ranging 5.0-9.9cm, total height was not recorded anymore. Meanwhile, frequency of wildlings (below 5.0cm diameter) was obtained by sampling a randomized 3m x 3m sub-quadrant per grid (Fig. 3).

Data Analyses

Vegetational analysis was conducted using descriptive statistics described by Madulid (1996) and Pipoly and Madulid (1998) to determine the relative dominance, relative frequency, relative density and eventually the importance value of each species in the study site (table 1). Trees with the highest importance value will be those that exist in the greatest number or of the greatest size (e.g. basal area). Once importance value is determined, a specific community can be described in terms of its most important species. Thus, communities are often described by the species or genera that are determined to be the most dominant in the community (Smith and Smith, 2002).

Moreover, diversity indices such as Shannon-Weaver, Simpson's dominance index and McIntosh evenness were determined. A diversity index is a mathematical measure of species diversity in a community. Diversity indices provide more information about community composition than simply species richness (i.e., the number of species present); they also take the relative abundances of different species into account (Beals *et al.,* 2000). Table 2 below shows the details of the indices used in this study.

Table 1. Vegetation analysis used in the study.

Parameter	Formula
Density (*D*)	$\frac{\text{number of individual}}{\text{area sampled}}$
Relative Density (*RD*)	$\frac{\text{D}}{\text{total density}} \times 100$
Frequency (*F*)	$\frac{\text{number of quadrants the species occur}}{\text{total number of quadrants}}$
Relative Frequency (*RF*)	$\frac{\text{F}}{\text{total frequency value of all species}} \times 100$
Dominance (*C*)	$\frac{\text{basal area of the species}}{\text{area sampled}}$
Relative Dominance (*RC*)	$\frac{\text{C}}{\text{total dominance value of all species}} \times 100$
Species Importance Value (SIV)	RD + RF + RC

Table 2. Species diversity indices used in this study.

Name	Formula	Description	Reference
Shannon-Weaver (H)	$-\sum\left[\left(\frac{n_i}{N}\right)\left(\ln\frac{n_i}{N}\right)\right]$ n_i: number of individuals belonging to *i* species N: total number of individuals	▪ Species diversity ▪ Higher H value means species are rich and are evenly distributed ▪ Typical values: 1.5 to 3.5	Shannon and Weaver (1963)
Simpson's (D)	$1-\frac{\sum n_i(n_i-1)}{N(N-1)}$	▪ Abundance of species ▪ Close to one value means more species ▪ Range: 0 to 1	Simpson (1949)
McIntosh (E)	$\frac{(N-\sqrt{\sum(n_i)^2})}{N-\frac{N}{\sqrt{S}}}$ S: total number of species	▪ Species evenness ▪ High value means individuals are distributed equally	McIntosh (1967)

Furthermore, ecological status of each species was classified based on the International Union for the Conservation of Nature (IUCN) species classification thru their website (www.iucnredlist.org) and from the national assessment conducted by Fernando *et al.,* (2008) commissioned by the Department of Environment and Natural Resources (DENR). For additional comparison purposes, Rarefaction and Bray-Curtis cluster analyses were also performed for both plots.

Results and discussion

Floristic Composition

A summary of the inventory from the two different plots is shown in Table 3 below. From the combined total of 4,569 individuals, there were 42 families, 88 genera and 111 species tallied. The result generated from the natural forest is a little less than the typical value if the observation of Whitmore (1995) as cited by Hamann *et al.,* (1999) is to be followed that the number of species per hectare for Southeast Asian forest is accordingly between 100 and 150.

Table 3. Summary of the flora composition in both natural and plantation forest.

Plot location	Sampling size	Individuals	Species	Genus	Family
Natural forest	1.0 hectare	3,106	96	76	42
Plantation forest	0.3 hectare	1,463	49	44	25

Furthermore, when compared with similar studies conducted in the country using the same sampling size of one hectare and diameter requirements, it seems that the number of species is inversely related to the elevation (Table 4). This just confirms what Hamann *et al.,* (1999) claim that species richness generally declines with altitude.

Species Importance Value

Secondary Forest

Table 5 summarizes the top five species with highest Species Importance Value (SIV) taken from the natural forest plot. Based on the result, *Ficus balite* is the most dominant species because it occupies much more space (high RC). Though there were only five of it encountered, its average dbh is 120cm. The genus *Ficus* from the family Moraceae is the most common among 48 genera of its family that grows in all types of forests (The Plantlist, 2010). As a matter of fact, *Ficus* spp. also dominated a secondary forest in Bataan, Luzon (Madulid *et al.,* 2009). *Terminalia foetidissima* occured only twice but also has high mean dbh (104cm). The next top three species may have small diameters but they are the ones that occur most as manifested in higher RD. Among them however, *Canarium asperum* is the most scattered because of higher RF. This is also true to both studies of Arsenio *et al.,* (2011) and Hamann *et al.,* (1999).

Table 4. Comparison of similar studies conducted in the Philippines.

Sampled location	No. of species	Elevation (m, asl)	Reference
CMU forest reserve	96	408	This study
Mt. Mandalagan, Visayas	92	1,000	Hamann *et al* (1999)
Mt. Malindang, Mindanao	67	1,625	Arances *et al* (2004)
Mt. Kitanglad, Mindanao	43	2,212	Pipoly and Madulid (1998)

Table 5. Top five species with highest SIV in the natural forest permanent plot.

Species	RC	RF	RD	SIV
Ficus balite	21.81	0.58	0.34	22.72
Terminalia foetidissima	16.66	0.19	0.07	16.92
Calophyllum blancoi	0.09	4.17	10.84	15.10
Knema glomerata	0.04	4.66	9.70	14.40
Canarium asperum	0.02	5.72	8.46	14.21

In terms of family, Meliaceae is the most represented with ten species namely *Dysoxylum gaudichaudianum, Dysoxylum mollissimum, Melia dubia, Walsura pinnata and six (6) Aglaia species.* The genus Aglaia forms the largest of the subtropical and tropical angiosperm belonging to the family of Mahogany. Some of these species are important timber trees; others have edible fruits, scented flowers, or medicinal properties (Muellner *et al.,* 2005).

Plantation Forest

As anticipated, T. grandis garnered the highest SIV as it is the most dispersed and occurs in every sub-plot (Table 6). Surprisingly, Aryther littorelis is also manifesting almost the same characteristics to that of T. grandis. They are both well distributed but the former appears to be a typical wildings due to lower RC value. Together with Mischocarpus pentapetalous, these three showed strikingly high frequency and high density as opposed to the natural forest plot. This is a good indicator of assisted natural regeneration in promoting forest rehabilitation. Pterocarpus indicus and Ganopyhllum falcatum appeared seldom but possess relatively higher basal area compared to others. Both of them are economically important due to its known durable wood.

Table 6. Top five species with highest SIV in plantation forest plot.

Species	RC	RF	RD	SIV
Tectona grandis	6.90	11.54	16.65	35.09
Pterocarpus indicus	19.00	5.29	9.38	33.67
Aryther littorelis	2.55	11.05	15.38	29.00
Ganophyllum falcatum	11.17	6.73	9.55	27.45
Mischocarpus pentapetalous	3.30	11.54	12.59	27.43

Family Euphorbiaceae has the highest number of species with five namely *Antidesma ghaesembilla, Croton leiophyllum, Glochidion album, Macaranga tanarius* and *Melanopsis multigradulosa*. High frequency of individuals of Euphorbiaceae was also seen in Mt. Mandalagan, Negros (Hamann *et al.,* 1999).

Species Diversity and Similarity

Fig. 4 depicts the indices applied in plots from both plantation and natural forests. As predicted, the natural forest is more diverse than that of a plantation forest but has lower equitability of species' distribution or evenness as can be seen in the McIntosh index. Moreover, both the composition and diversity of the species between the plots are significantly different. This is not surprising since the percentage of similarity between the plots based on the Bray-Curtis cluster analysis is only less than 10%.

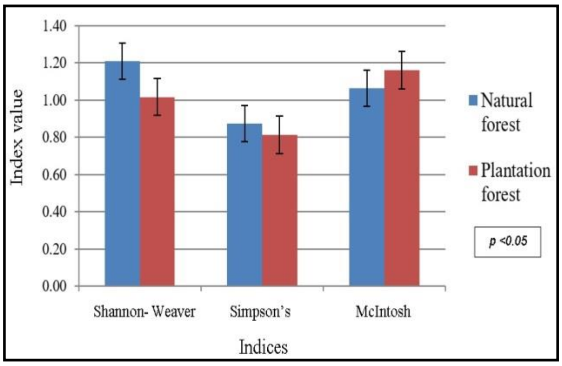

Fig. 4. Diversity indices between permanent monitoring plots both in natural and plantation forests.

However, both Shannon-Weiver and Simpson's index values of this paper are one of the lowest compared to other sites (Table 7). The study by Amoroso *et al.,* (2012) in this table was done using transect walks and sampling plots lower than one hectare so it can be inferred that their study sites are still much diverse. In fact, the total angiosperm (flowering plants that include trees) in that research revealed 873 and 698 from Mt. Malindang and Mt. Hamiguitan, respectively.

Table 7. Comparison of similar studies conducted in the Philippines.

Sampled location	H	D	Reference
Natural forest			
CMU secondary forest	1.21	0.87	This study
Mt. Mandalagan, Visayas	5.59	0.97	Hamann *et al* (1999)
Davao del Norte, Mindanao	1.79	-	Madulid *et al* (2009)
Mt. Malindang, Mindanao	1.21	-	Arances *et al* (2004)
Mt. Malindang, Mindanao	1.20 - 1.61	-	Amoroso *et al* (2012)
Mt. Hamiguitan, Mindano	1.20 - 1.61	-	Amoroso *et al* (2012)
Plantation forest			
CMU plantation forest	1.02	0.81	This study
Davao del Norte, Mindanao	1.60	-	Madulid *et al* (2009)

Rarefraction Analysis

The result of the Rarefraction analysis is illustrated in Fig. 5. The steep slopes within the first 100 individuals (x axis) in the natural forest plot indicates that increasing the plot would reveal additional kind of species, thereby increasing diversity.

In contrast, the curves in the plantation forest is less steep and is heading somewhat a plateau which means that even if the plot is widened, the diversity would not significantly change. This brings advantage to the researchers because incidentally, the area of the plot was made smaller than the original designed.

Conservation Status and Endemism

Table 8 is the list of the threatened species gathered comprising 19% of the total data with their specific conservation category. The rest were either least concerned or still unclassified. The overall endemism profile of the two plots is 31% (30 out of 96 species). This is just half to what Arances *et al.,* (2004) discovered in Mt. Malindang at 60%.

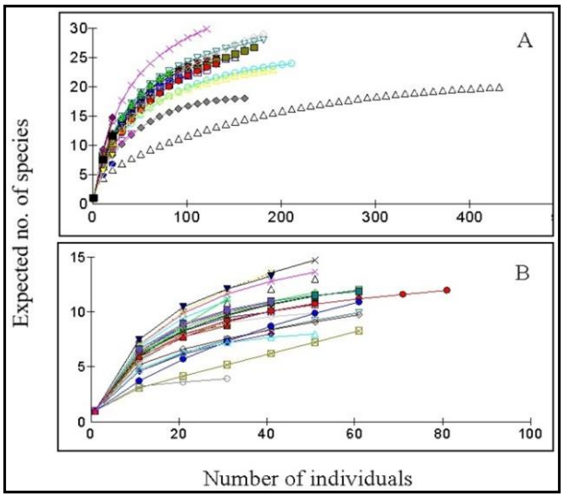

Fig. 5. Rarefraction curves from (A) natural and (B) plantation forest plots.

Table 8. Conservation status of the species from both natural and plantation forest plots.

Status	Species
Critically endangered	*Hopea plagata, Shorea almon, Shorea contorta, Diospyros discolour*
Endangered	*Afzelia rhomboidea, Mangifera monandra*
Vulnerable	*Aphanamixis polystachya, Artocarpus blanco, Cinnamomum mercado, Cryptocarya ampla, Diplodiscus paniculatus, Dracontomelon edule, Meristyca phillipinensis, Mitrephora lanotan, Neolitsea vidalii, Pterocarpus indicus, Terminalia nitens, Vitex parviflora*
Near threatened	*Orania decipiens, Aglaia luzoniensis, Aglaia edulis*

Conclusions

This study was designed to gather baseline information specifically for two more studies – regeneration dynamics and carbon stock assessment. Thus, conclusions and suggestions as to improve this research and produce more informative science-based papers are enumerated. Though tree species diversity is relatively low, some threatened species were recorded which command immediate protection and conservation of the area. A number of species having high SIV (e.g. *S. spectabilis*) may have possible influence on the low diversity – a threat to forest regeneration. Studies on their ecology and control are necessary. Further parameters must be incorporated such as the relationship between species diversity and environmental factors like soil properties, moisture regime and temperature fluctuation. Species diversity and composition between the natural and plantation forests are significantly different with the latter being less diverse. However, protection measures could be adapted to facilitate the natural regeneration of endemic species in the plantation forest. Future plans include the expansion of the sampling plot in the natural forest and modeling of the spatio-temporal distribution of the vegetation.

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