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Correlation of soil and mangrove diversity in selected sites of Alabel and Maasim, Sarangani Province, Philippines

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Abstract. The diversity attributes of each sampling plots in Sarangani Province indicates the mangrove's ecosystem condition. This study aims to determine the soil particle size and correlate it with the biodiversity attributes in two sampling sites of Sarangani Province, Philippines. Sampling plots (10 m x 10 m) were established into coastal, middleward and landward. Different mangrove species were identified, counted and the data were used to compute the biodiversity attributes. Mangrove's biodiversity indices were determined using species richness, abundance, dominance, evenness and Shannon's diversity. Soil samples were collected at each sampling site and the particle size analyzed. The data on soil particle size and Shannon's diversity were correlated to establish biotic and abiotic relationships. The results show that twelve mangrove species were identified having *Sonneratia alba* as the most abundant species. The sampling site in Alabel has higher diversity attributes compared to Maasim. Gravel has the most abundant soil particle type in the two sites. The observed mangrove species in relation to soil particle size was also known. Using Pearson's correlation coefficient (r) the correlation of soil types to Shannon diversity was analyzed. The results show that there is a positive and negative correlation to each soil type and sampling sites.
Key Words: *Sonneratia alba*, diversity indices, soil particle size, biodiversity, species richness.

Introduction. Philippines are an archipelago having 7,100 islands bordered by 36,300 km of coastline along mangrove forests, sea grass beds and coral reefs (Primavera & Esteban 2008). Mangroves were defined as an association of halophytic trees, shrubs and other plants growing in brackish to saline tidal waters of tropical and subtropical coastlines (Mitsch & Gosselink 2007). Major and minor mangroves (Tomlinson 1986) in the Philippines total some 30 – 40 species belonging to 15 families. At the turn of the century, mangroves cover around 450,000 hectares (Brown & Fischer 1920) were so widespread to many coastal areas including the country's premier city of Manila. Mangrove forests were declining at a rate of 2,000 ha/year with only around 120,000 ha of mangrove forests remaining presently from the 160,000 ha 20 years ago (DENR 1995; White 1996). Accordingly, aquaculture remains the major cause of mangroves lost from 1951 to 1988 developed into aquaculture ponds (Agaloos 1994; Primavera 2000, 2004, 2005). The report from Philippine Council for Agriculture, Forestry and Natural Resources Research and Development in 1991, mentioned that 95 % of Philippine brackish water ponds in 1952 – 1987 were derived from mangroves. Another cause of mangrove depletion was also due to overexploitation of mangrove wood for housing materials, fuel wood and its commercial sale. Much of the ecological service of mangroves lies in protecting the coast from solar UVB radiation, green house effects, and fury of cyclones, floods, sea level rise, wave action and coastal erosion (Kathiresan 2003; Kathiresan & Bingham 2001).

The study on Philippine mangroves specifically in the Sarangani Bay was considerably few. Studies on mangroves in Sarangani Province largely come from anecdotal reports of local government units. Many research articles regarding mangroves were concentrated only in northern Philippines; hence, this study will provide baseline information of the diversity of mangroves in Mindanao area. The sites of the study were located in two municipalities of Maasim and Alabel, Sarangani Province. The study investigates the relationship between mangrove diversity and soil characteristics. Mangrove diversity attributes were limited only to species richness, abundance, evenness, dominance and Shannon's diversity. Soil's grain particles were considered. Appropriate statistical tools were employed to explore the biological and environmental parameters.

Material and Method

Study area. This study was carried out in Sarangani Province located in southeastern Mindanao, geographically lies between 5°33`25" - 6°6`15"N and 124°22'45"- 125°19`45"E (Figure 1). The researchers identified two areas as the study sites in the municipalities of Alabel and Maasim. The precise locations of each plot (Figure 2) were determined through the Global Positioning System (GPS).

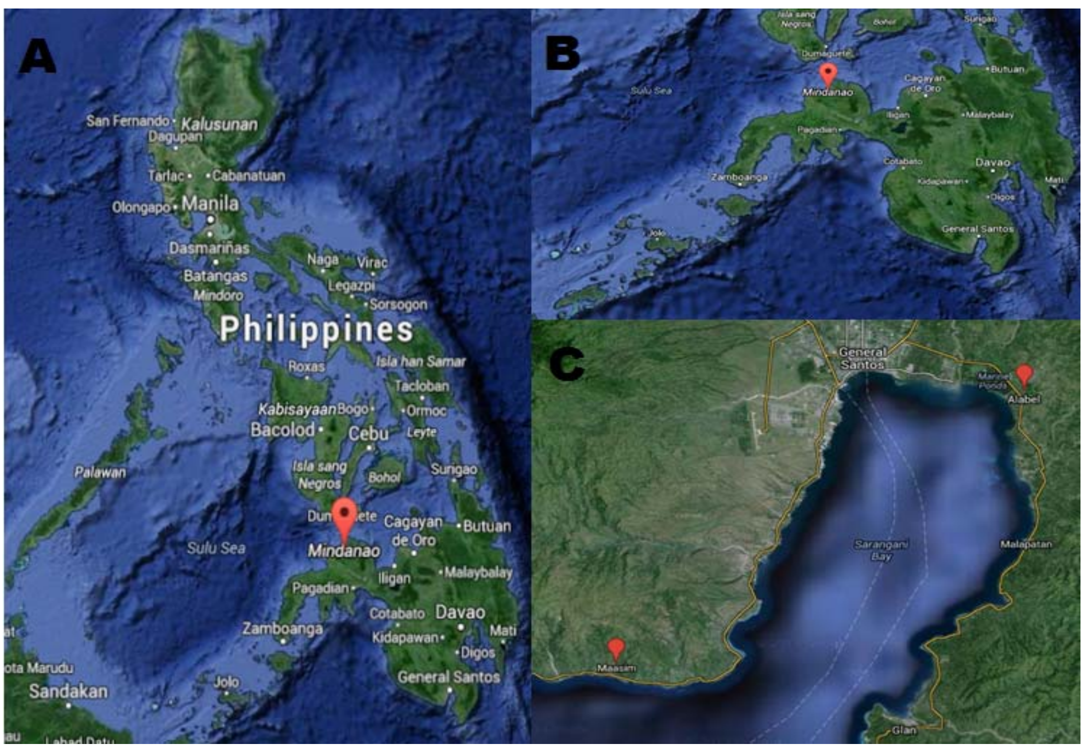

Figure 1. (A) Map of the Philippines, (B) Map showing Mindanao area, (C) Map showing the locations of the sampling sites in Maasim and Alabel, Sarangani Province (http://maps.google.com).

Figure 2. Sampling plots in Alabel and Maasim, Sarangani Province, Philippines.

Sampling plots establishment and measurements. Plots of each sampling sites were divided into zones that correspond to the inundation and enough mangrove cover. A purposive sampling was employed in the establishments of sampling plots. On this aspect, the plots were laid to areas with sufficient mangrove cover. The plot has dimension of 10 x 10 m which were established in the seaward, middleward and landward. In the sampling plots, mangroves were identified and counted individually. In each plot, 100 grams of soil samples were also taken at 0 - 30 cm depth and were subjected to air drying for 1 - 2 weeks (Kauffman & Donato 2012; Donato et al 2011). Soil samples were analyzed for particle size using soil sieve (WS Tyler brand).

Mangrove diversity analyses. Mangrove species were identified to the lowest taxon possible. PAST Software (Hammer et al 2001) was used for the assessment of diversity indices. Biodiversity measurements considered were species richness, abundance, dominance, evenness and Shannon diversity. Biodiversity values were compared in the two locations using T Test (de Winter 2013). Results were displayed in error bars using Microsoft Excel (www.tbisociety.org).

Analyses on mangrove and soil relationship. The soil particle sizes were characterized using the following dimensions: gravel (2.00 mm), very coarse sand (850 um), coarse sand (425 um), medium sand (180 um), fine sand (160 um), silt/clay sand (less than 160 um). The dominant soil type has been identified in each site. The mean soil particle sizes were summarized in the two sites and were correlated with the data on the expected abundant species observed in the sampling sites. Correlation on mangrove Shannon diversity and soil particle size was analyzed using Pearson's correlation coefficient (r). Significance of the values were tested using P = 0.05.

Results and Discussion. Twelve mangrove species were identified in the two sampling sites of Sarangani Province. There were 6 families having 9 species present in Alabel and 4 families having 6 species present in Maasim, Sarangani Province. These species were listed in table 1 showing the abundance and species composition of the two sites. The family Rhizophoraceae has 6 species, the highest in a family of mangroves. Similarly, a well-developed mangrove forest from India shows that among the family members present Rhizophoraceae are the dominant species dwelling in all types of mangrove formation (Jagadeesh et al 2012). A total of 372 individual mangroves were observed in mangrove communities of Sarangani Province from the two sites with 215 individuals in Alabel and 157 in Maasim. This study shows that *Sonneratia alba* is the most abundant mangrove species contributing 32 % of total abundance. The most abundant species in Alabel were *Avicennia marina* comprises 30.50 % of the population, *Rhizophora apiculata* 23 % and *S. alba* 19.72 %. Maasim sampling site on the other hand has an abundance were *S. alba* 48 %, *Rhizophora mucronata* 29 % and *R. apiculata* 19 % as the most abundant species in the sampling site. The mangrove species observed outside the plots were *Pemphis acidula, Bruguiera cylindrica* and *Ceriops decandra.*

Table 1

Species composition and abundance of mangrove species in Alabel and Maasim, Sarangani province, Philippines

	Family		*Species*	*Alabel*	*Maasim*	*Total*
A	*Avicenniaceae*	1	*Avicennia marina*	*65*	*3*	*68*
B	*Combretaceae*	2	*Lumnitzera racemosa*	*2*	*0*	*2*
C	*Lythraceae*	3	*Pemphis acidula***	*0*	*0*	*0*
		4	*Sonneratia alba*	*42*	*77*	*117*
D	*Myrsinaceae*	5	*Aegiceras floridum*	*34*	*0*	*34*
E	*Meliaceae*	6	*Xylocarpus granatum*	*1*	*1*	*2*
F	*Rhizophoraceae*	7	*Bruguiera gymnorrhiza*	*1*	*1*	*1*
		8	*Bruguiera cylindrica***	*0*	*0*	*0*
		9	*Ceriops decandra***	*0*	*0*	*0*
		10	*Ceriops tagal*	*3*	*0*	*3*
		11	*Rhizophora apiculata*	*49*	*30*	*79*
		12	*Rhizophora mucronata*	*18*	*45*	*63*
			Total # of species per site	*9*	*6*	*12*
			Total # of individuals	*215*	*157*	*372*

**Mono-standing mangroves observed outside the sampling plots.

The level of the diversity of mangroves in Sarangani province of the two sites between Alabel and Maasim is shown in table 2.

Table 2

Statistical analysis of mangroves' on the two sampling sites of Sarangani province, Philippines

Site	*Dominance*	*Shannon*	*Evenness*	*Species richness*	*Abundance*
Alabel	0.4632857	0.9128619	0.856652381	3.047619048	10.14285714
Maasim	0.71083	0.450785	0.89206	1.9	7.85
T-test	0.0001093**	0.000032**	0.32979049^{ns}	0.0000410311**	0.050880534^{ns}

ns = not significant, and ** = highly significant at P=0.005 using T Test.

Statistical, T-test showed that there was a significant difference on dominance, Shannon's diversity and species richness while there was no significant difference on evenness and abundance on the two sampling sites. Shannon's diversity (0.9128619; P<0.001) and species richness (3.047619048; P<0.001) were higher in Alabel compared to Maasim. In contrast, dominance was higher in Maasim (0.71083; P<0.001) compared to Alabel. Mean values of the biodiversity attributes were considerably much better in Alabel than in Maasim. The summary of the figures were shown in the error bar graph in figure 2.

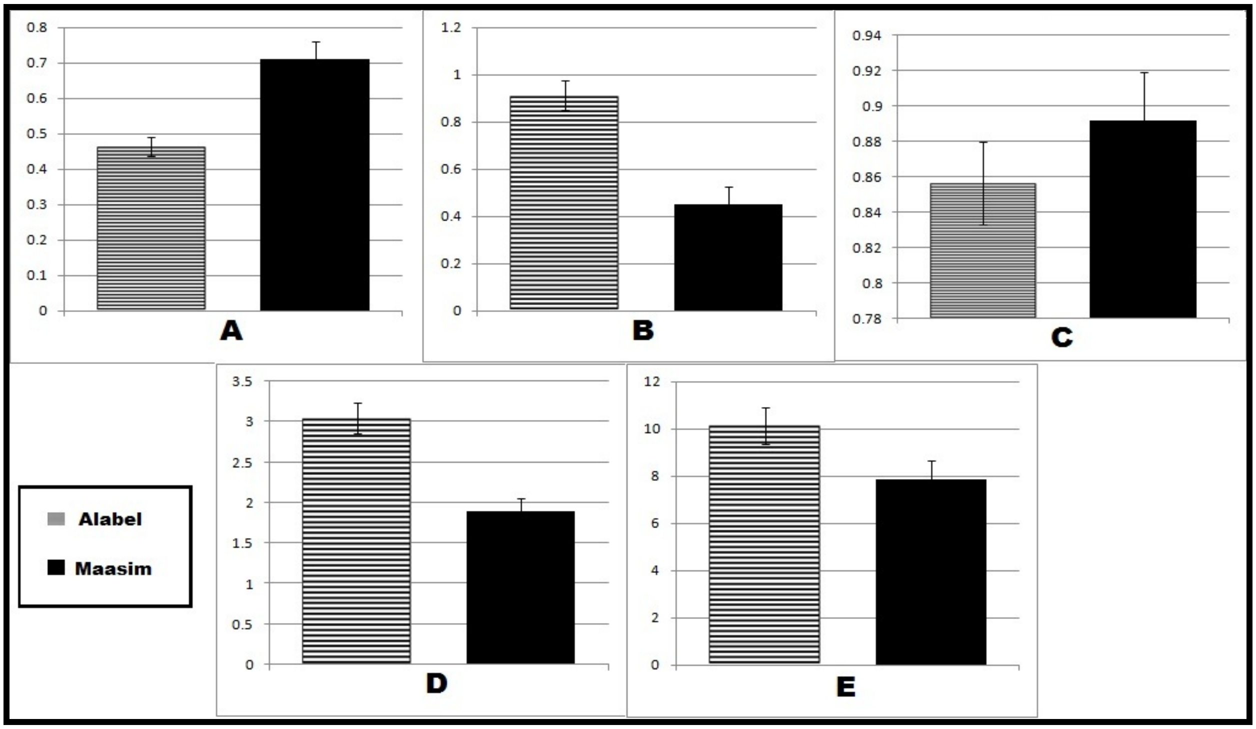

Figure 2. Error bar chart of the mean values of biodiversity attributes across area. Dominance (A), Shannon's diversity (B), evenness (C), species richness (D), and abundance (E).

Table 3 and figure 3 shows the mean percentage of each soil types on the two sites. In Alabel sampling site, the most dominant soil composition was gravel which comprised 37.76 % followed by medium sand (18.99 %), very coarse sand (16.44 %), coarse sand (10.61 %), silt/clay (11 %) and the lowest mean percentage was fine sand with 5.33 %. In Maasim sampling site, the most dominant soil composition is also gravel which comprised 26.33 % followed by medium (21.79 %), coarse sand (20.70 %), very coarse sand (16.30 %), silt/clay (9.65 %), and (5.49 %) of fine sand respectively.

Table 3

Mean percentage on grain particle size of collected soil samples from the two sites

Site	*Gravel*	*Very coarse*	*Coarse*	*Medium*	*Fine*	*Silt/Clay*
Alabel	37.76 %	16.44 %	10.61 %	18.99 %	5.33 %	11.30 %
Maasim	26.31 %	16.30 %	20.70 %	21.79 %	5.49 %	9.65 %

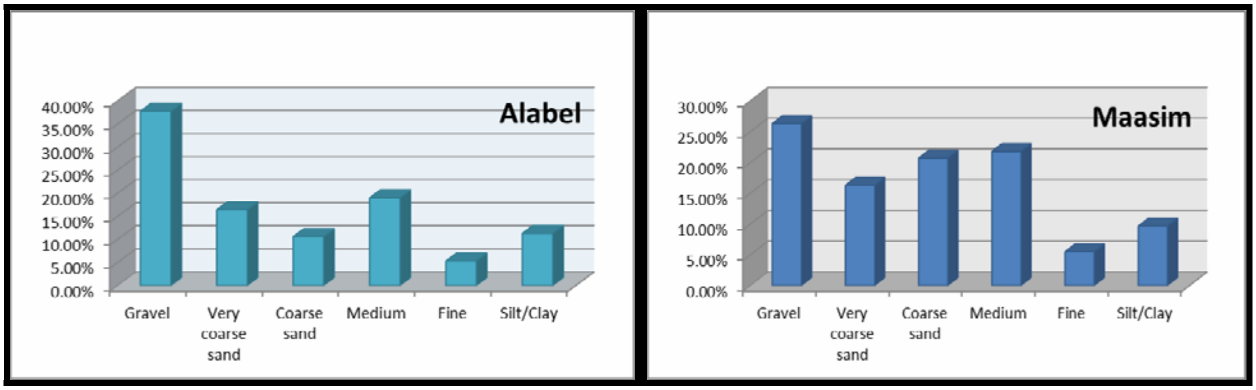

Figure 3. Grain particle size of the collected soil samples from Alabel and Maasim, Sarangani Province, Philippines.

It was observed that *R. apiculata* was dominant in gravel, very coarse sand, and medium sand. *R. mucronata and S. alba* were dominant in soil types of gravel, coarse sand, and medium sand, while *A. marina* was dominant in gravel and medium sand. *Aegiceras floridum* on the other hand was observed to be present only in gravel. Three species were known to be present in the different soil types and these were *R. apiculata, R. mucronata,* and *S. alba* (Table 4).

Table 4

Observed dominant mangrove species in relation to soil particle types

Soil Type	*Sampling area*	*Species observed*
Gravel	Alabel	*Rhizophora apiculata, Rhizophora mucronata, Sonneratia alba*
	Maasim	*Aegiceras floridum, Avicennia marina, Rhizophora apiculata, Rhizophora mucronata, Sonneratia alba*
Very coarse sand	Alabel	*Rhizophora apiculata*
Coarse sand	Maasim	*Rhizophora mucronata, Sonneratia alba*
Medium sand	Alabel	*Avicennia marina, Rhizophora apiculata, Sonneratia alba*
	Maasim	*Rhizophora mucronata, Sonneratia alba*

The correlation using Pearson's correlation coefficient (r) was used to determine relationship between soil particle types and Shannon's diversity in the two sampling sites (Table 5). In Alabel, there was a positive correlation of Shannon's diversity ($P>0.05$) to gravel, very coarse sand and coarse sand, while it was negatively correlated to medium sand ($P<0.05$), fine sand ($P>0.05$) and clay ($P<0.05$). In contrast, negative correlation ($P>0.05$) of Shannon's diversity was observed in Maasim to gravel, very coarse sand and coarse sand, while a positive correlation ($P>0.05$) was observed in medium sand, fine sand, and clay. The Shannon's diversity in the two sites seems to be opposite in correlation with soil particle type. Although the strength of the correlation seems to be low but it gives an idea that the two sites have opposite Shannon's biodiversity correlation in relation to soil types. The data gives an insight about the soil preference of the biodiversity is different between two sites. Future rehabilitation efforts in the sites should consider the soil medium when mangrove seedling will be transplanted in the two sites. Observations in the two sites only planted monoculture of *Rhizophora* with high mortality.

Table 5
Correlation coefficient matrix for soil types in relation to Shannon diversity

Soil	Shannon's diversity (Alabel)	Shannon's diversity (Maasim)
Gravel	0.3956 ^{ns}	-0.2084 ^{ns}
Very coarse sand	0.2608 ^{ns}	-0.2311 ^{ns}
Coarse sand	0.2041 ^{ns}	-0.0522 ^{ns}
Medium sand	-0.4709*	0.1610 ^{ns}
Fine sand	-0.011 ^{ns}	0.0955 ^{ns}
Silt/Clay	-0.4719*	0.0433 ^{ns}

ns = not significant, and significant: *P<0.05; **P<0.01.

Conclusions. The result of the study revealed that Alabel has a much better diversity attributes compared to Maasim. The two sites also have high biodiversity. Three species were dominantly observed across soil type in the two sites considered and these were *R. apiculata, R. mucronata,* and *S. alba*. In rehabilitation of mangroves, these species should be considered in transplanting of seedlings. The data also showed that the soil a factor affecting Shannon's diversity. The two sites also have contrasting Shannon's biodiversity correlation to soil particle types. Hence, it should also be considered in rehabilitation activities. It is recommended that other sites in the Sarangani Province should be considered for assessment and spatial variation of mangroves should be analyzed including the factors that may affect such variation.

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*** http://maps.google.com

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