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Correlating mangrove diversity and soil composition in a rehabilitated coastline of Hagonoy, Davao del Sur, Philippines

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Abstract. Soil is a vital component in the growth and development of plants. Understanding the relationship between mangrove diversity and soil composition might improve rehabilitation efforts in the study area. The study employed a purposive sampling in the rehabilitated mangrove landscape in Hagonoy, Davao del Sur. A total of 20 quadrates (10 m x 10 m) were installed. Mangrove species and soil samples were identified and collected. The results revealed 7 species belonging to 5 families of mangroves in the quadrates. Gravel was the most dominant substrate and *Avicennia marina* the most dominant species. Diversity is expected to be high in very coarse sand substrate (Pearson correlation $\rho = 0.272$). Using the principal component analysis, PC1 and PC2 gave 77.3% cumulative variation. The data suggested variability between soil structure and species diversity in quadrates.
Key Words: *Avicennia marina*, landscape rehabiliation, Pearson correlation, Principal component analysis, biodiversity, Davao del Sur.

Introduction. Soil is an important component providing a medium of nutrients and materials to plants, a basic life support components of biosphere (Pujar et al 2012). The ecosystem services that the soil provides are critical for existence of life. Soil can develop from volcanic ash depositions, breaking and weathering of rocks, or accumulation of organic debris from decomposed materials. As the substrate form, it supports life by the growth of plants and other organisms.

Soil type is a major determinant on the different plants inhabiting. The nature of soil primarily depends upon its continued change under the effect of physical factors (Solanki & Chavda 2012). The concept of soil quality would depend upon the ability to sustain plant and animal productivity, increase water and air quality, and to contribute plant and animal health (Doran & Zeiss 2000; Emnova 2004).

The soil composition of mangrove determines the diversity as well. Mangroves are salt-tolerant trees adapted to salty and brackish water environment. They vary in size from shrubs to tall trees along tropical mudflats, wetlands or in association with estuaries and lagoons. Mangroves thrive in saline muddy substrates where oxygen is poor but rich in nutrients (Sherman et al 1998). However, the unsustainable use, over exploitation, human settlements, degradation of its zones conducted to a worldwide catastrophe of mangrove decline (Field 1998).

Over the past decades, the Philippine mangrove ecosystems and beach forests have suffered severely. The long history of mangrove conversion into fishponds has been pointed as the biggest threat (Primavera & Esteban 2008). The degradation of the Philippine mangrove ecosystems continuous almost unabated for a number of reasons (Melana et al 2000).

Because of the decline, the Philippine government initiated mangrove rehabilitation activities across the country. However, rehabilitation efforts encountered several problems. The replanting consisted largely of *Rhizophora* species and the mono-specific culture had high mortality (Samson & Rollon 2008). Its poor rehabilitation performance could be due to poor site selection and stated to consider compatibility of species and sites with suitable soil (Castillo & Pintor 2010).

These problems could be probably addressed when soil and mangrove relationship is understood. Hence, it is the objective of the study to explore the variability of mangroves and correlate it to the characteristics of soils in the sampling area.

Material and Method

Study area. The soil sampling was conducted at Hagonoy, Davao del Sur located at Southern Mindanao, which geographically lies between 6°39′ 40.870'', N and 125° 22′ 50.901'', S (Figure 1).

Figure 1. Map of the sampling sites showing the Philippine map (A), Mindanao island (B) and sampling area in Hagonoy, Davao del Sur (C) (http://maps.google.com; http://googleearth.com).

Establishment of quadrates and species identification. Plots in the sampling area were divided into zones to include seaward, middle ward, and landward mangroves. A purposive sampling was employed in the establishment of sampling plots. On this manner, the plots were laid to areas with sufficient mangrove cover. Twenty quadrates were laid *in situ* with the interval of at least 30 m/quadrate. Each quadrate has a dimension of 10 x 10 m where mangrove trees were identified and counted (Natividad et al 2014). Mangroves were identified to the lowest taxon using reliable identification guides (Giesen et al 2006; Primavera et al 2004; Melana & Gonzales 2000). Species located inside the sampling quadrates were only considered for species inventory.

Mangrove diversity analysis. The assessment of the diversity indices was conducted using Paleontological Statistics (PAST) software (Hammer et al 2001). Diversity indices include species richness, abundance, and Simpson diversity. Mangrove diversity was correlated with data in soil composition using Pearson correlation (ρ).

Soil sampling and analysis. The soil samples in the sampling quadrates were collected. Samples of at least 100 g/quadrate at 30 cm depth were gathered. The samples were properly mixed and air dried up to 1 week under room conditions. Using the analytical balance, the dried soil samples were weighed at exactly 100 g for granulometric soil analysis (Kauffman & Donato 2012; Donato et al 2011). Soil samples were sieved using USA Standard Test Sieve (WS Tyler brand) and characterized as gravel (>1.4 mm), pebbles (850 μm - 1.3 mm), very coarse sand (600 μm - 849 μm), coarse sand (425 μm - 599 μm), medium sand (300 μm - 424 μm), fine sand (212 μm - 299 μm), very fine sand (180 μm - 211 μm), clay (150 μm - 179 μm) and silt (<150 μm) as shown in Figure 2.

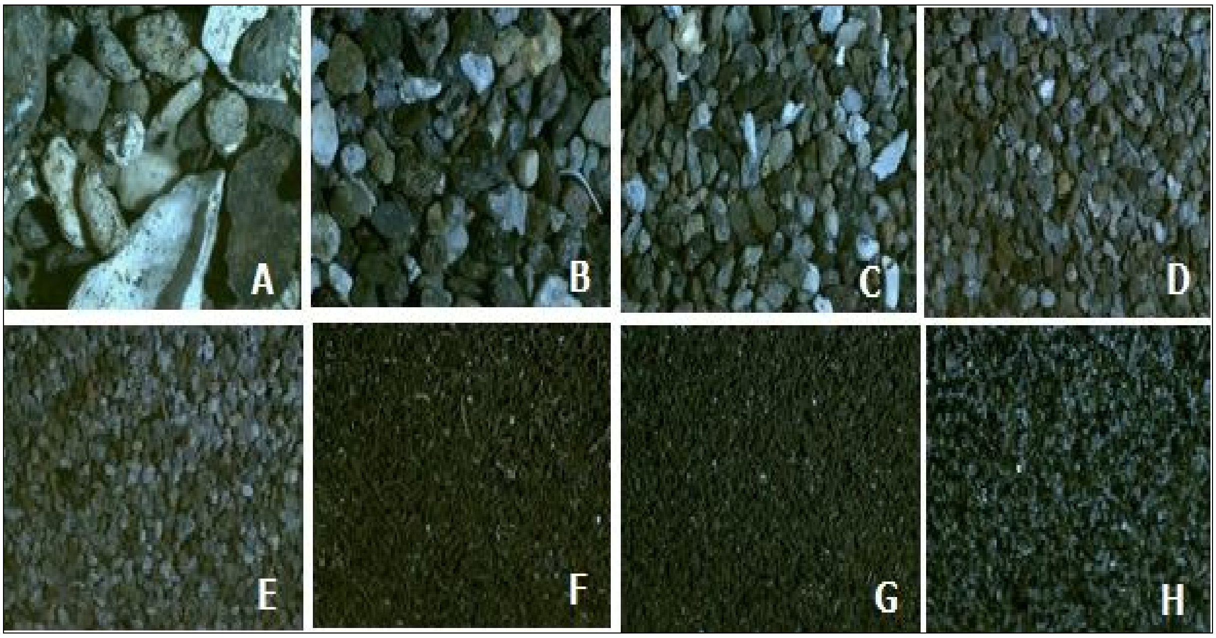

Figure 2. Soil particles viewed under 7x magnification of photomicroscope (A) gravel, GVL; (B) pebbles, PBL; (C) very coarse sand, VCS; (D) coarse sand, CSD; (E) medium sand, MSD; (F) very fine sand, VFS; (G) clay, CLY; (H) silt, SLT.

The relationship between soil samples and sampling quadrates were also evaluated using principal component analysis (PCA). On this aspect, correlation of mangrove community and soil composition can be established. Analysis of PCA was conducted using Primer software (Clarke & Gorley 2006).

Results and Discussion

There were 7 species of mangroves belonging to 5 families accounted during the sampling. These were *Avicennia marina, Avicennia officinalis, Lumnitzera racemosa, Aegiceras corniculatum, Rhizophora apiculata, Rhizophora mucronata* and *Sonneratia alba* (Table 1).

Table 1

Species composition of mangrove in Hagonoy, Davao del Sur

Family	*Species*
Avicenniaceae	*Avicennia marina*
	Avicennia officinalis
Combretaceae	*Lumnitzera racemosa*
Myrsinaceae	*Aegiceras corniculatum*
Rhizophoraceae	*Rhizophora apiculata*
	Rhizophora mucronata
Sonneratiaceae	*Sonneratia alba*

Based on Figure 3, gravel has the highest percent composition which comprised 23%. This was followed by coarse sand (14%) and pebbles (13%). The soil composition of the sampling area generally consisted of the bigger soil particles. The lowest values were clay (4%), silt (6%), and very fine sand (6%) comprised the smallest soil particles.

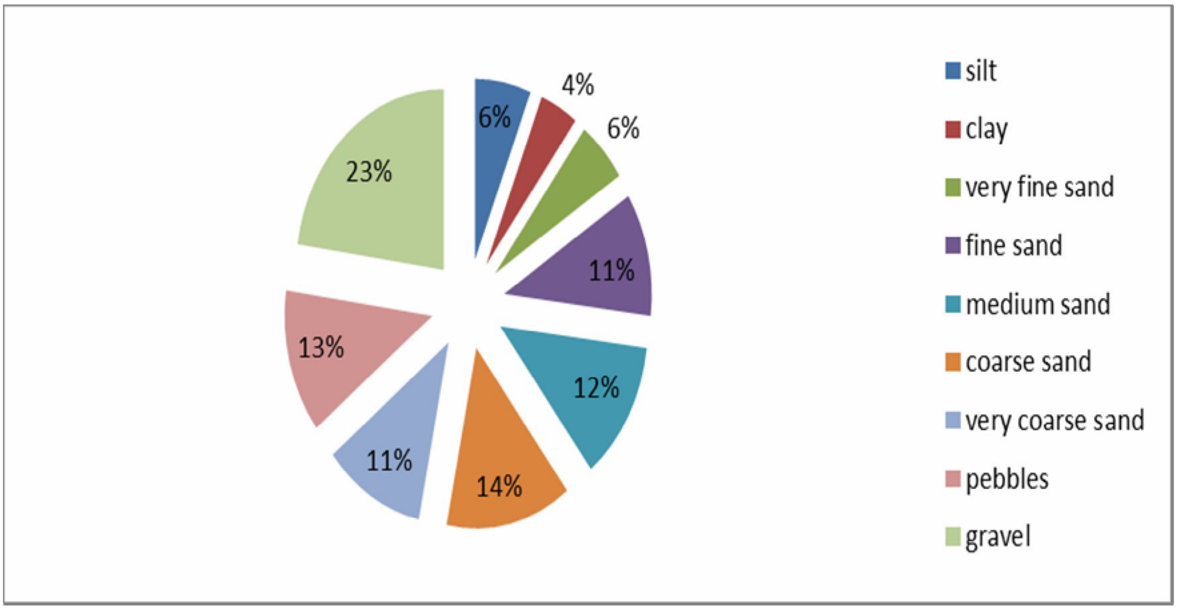

Figure 3. Soil chart, showing the different percentage of soil particles dominant in the rehabilitated mangrove area.

Gravel was the most dominant soil substrate among the 20 quadrates considered. There were 6 quadrates where gravel was dominantly observed and these were quadrates: 3, 4, 5, 12, 15 and 20. The second most dominant substrate consisted of 3 quadrates were fine sand, coarse sand and medium sand. Further, *A. marina* was the most dominant, among the 7 mangrove species, observed in 13 quadrates. It was observed that quadrate 12 was highest in terms of species richness (7 species) and Simpson diversity (0.6759). Quadrate 20 was highest in abundance with 97 trees observed. Both quadrates 12 and 20 were composed of gravel as their dominant substrate and *A. marina* was also the dominant species. Although the soil composition and diversity values vary among the quadrates but higher values were observed in substrates with bigger sizes. This suggests variability of mangrove species in relation to soil substrate. The summary of values is shown in Table 2.

To determine which soil substrate was positively correlated to Simpson diversity, Pearson's correlation coefficient was used (Table 3). It showed that clay (0.020), very fine sand (0.078), fine sand (0.074), coarse sand (0.078), very coarse sand (0.272) and pebbles (0.059) were positively correlated to species diversity. It was the very coarse sand which gave the highest correlation to species diversity. In contrast, silt (-0.087), medium sand (-0.074), and gravel (-0.005) showed negative correlation. It was also in silt which gave the highest negative correlation to species diversity. The data established relationship on the dominant soil type with likely high diversity. To areas having dominant soil type and positively correlated with Simpson diversity were expected to have greater diversity values in the sampling areas. Nevertheless, this observation should be considered in other areas as well. As observed in this study, variability of soil structure and species diversity was frequent and no definite pattern was observed. The result of Pearson correlation between Simpson diversity and soil substrates is shown in Table 3.

Table 2

Summary of the soil substrate, dominant mangrove species and diversity metrics in the 20 quadrates

PN	*Substrate*	*DS*	*SR*	*AB*	*SD*
Q1	FSD	*Avicennia marina*	2	19	0.2659
Q2	SLT	*Avicennia marina*	3	11	0.314
Q3	GVL	*Avicennia marina*	2	48	0.07986
Q4	GVL	*Avicennia marina*	3	20	0.56
Q5	GVL	*Avicennia marina*	4	10	0.64
Q6	SLT	*Rhizophora apiculata*	3	12	0.2917
Q7	MSD	*Avicennia marina*	3	20	0.485
Q8	PBL	*Rhizophora mucronata*	1	64	0
Q9	VCS	*Avicennia marina*	3	17	0.6505
Q10	MSD	*Avicennia marina*	1	4	0
Q11	CSD	*Rhizophora mucronata*	3	69	0.2302
Q12	GVL	*Avicennia marina*	7	19	0.6759
Q13	CSD	*Rhizophora apiculata*	2	14	0.1327
Q14	PBL	*Rhizophoraapiculata*	3	20	0.445
Q15	GVL	*Avicennia marina*	2	24	0.4861
Q16	CSD	*Avicennia marina*	3	9	0.5679
Q17	MSD	*Rhizophora apiculata*	2	11	0.4959
Q18	FSD	*Avicennia marina*	3	22	0.4917
Q19	FSD	*Rhizophora apiculata*	3	9	0.4938
Q20	GVL	*Avicennia marina*	2	97	0.1513

PN - plot number; DS - dominant species; SR - species richness; AB - abundance; SD - Simpson diversity.

Table 3

Pearson correlation showing the positive and negative correlation of substrates and Simpson diversity

	SLT	*CLY*	*VFS*	*FSD*	*MSD*	*CSD*	*VCS*	*PBL*	*GVL*
Simpson	-0.087	0.020	0.078	0.074	-0.074	0.078	0.272	0.059	-0.005

Principal component analysis. The first principal component (PC1) has 50.3% and the PC2 has 27.0% combining a total of 77.3% cumulative variation. The PC1 axis can be interpreted as medium to big size of soil from medium sand to gravel while PC2 as medium size, from fine sand to very coarse sand. Positive factor loadings in PC1 and PC2 were observed in medium sand, coarse sand, and very coarse sand. Using Spearman correlation, these were strongly correlated to quadrates 9, 10, 11, 13, 16, 17. The data may imply relationship of soil characteristics to diversity in sampling quadrates. The interplay between mangrove community and soil characteristics might be affected by interaction of different factors in the sampling area.

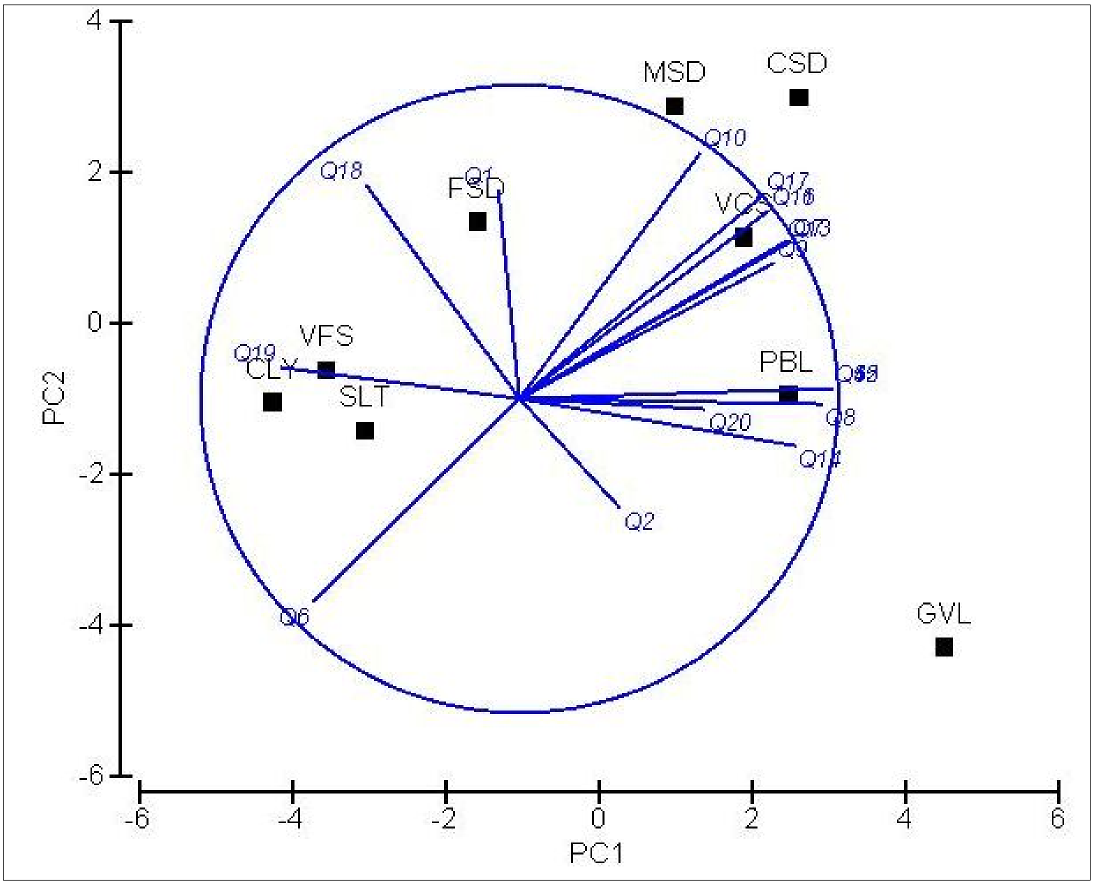

Figure 4. Principal Component Analysis with 77.3% cumulative variation of PC1 and PC2.

Conclusions. There were 7 mangrove species belonging to 5 families observed in the sampling quadrates. Gravel was the dominant soil composition while clay has the lowest value. Gravel also was the most dominant substrate type observed in 6 quadrates. The species *A. marina* was the most dominant observed in 13 quadrates. Among the quadrates, quadrate 12 gave the highest species richness and diversity while quadrate 20 has the highest abundance. Pearson correlation revealed strong diversity to very coarse sand while silt has the strong negative correlation. The PCA has cumulative variation of 77.3% and suggested strong variability between soil structure and species diversity in quadrates.

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References

Castillo E. T., Pintor L. L., 2010 Rehabilitation and ecological restoration R & D for marginal and degraded landscapes and seascapes. A research compendium for marginal uplands. Department of Environment and Natural Resources Ecosystems Research and Development Bureau, p. 16.

Clarke K. R., Gorley R. N, 2006 Primer v6.1: User Manual/Tutorial. Primer-E, Plymouth, United Kingdom.

Donato D. C., Kauffman J. B., Murdiyarso D., Kurnianto S., Stidham M., Kanninen M., 2011 Mangroves among the most carbon-rich forests in the tropics. Nat Geosci 4:293-297.
Doran J. W., Zeiss M. R., 2000 Soil health and sustainability: Managing the biotic component of soil quality. Appl Soil Ecol 15:3-11.
Emnova E. E., 2004 Modern ecological concept of soil quality as a part of sustainable agriculture concept. AŞ RM Bulletin, Biological Sciences, Chemistry and Agriculture 4(294):63-70.
Field C. D., 1998 Rehabilitation of mangrove ecosystem: an overview. Mar Pollut Bull 37(8-12):383-392.
Giesen W., Wulffaraat S., Zieren M., Scholten L., 2006 Mangrove guidebook for southeast Asia. FAO and Wetlands International. Dharmasarn Co., Ltd.
Hammer O., Harper D. A. T., Ryan P. D., 2001 Past: Paleontological statistics software package for education and data analysis. Palaeontol Electronica 4(1):1-9.
Kauffman J. B., Donato D. C., 2012 Protocols for the measurement, monitoring and reporting of structure, biomass and carbon stocks in mangrove forests. Working Paper 86. CIFOR, Bogor, Indonesia.
Melana D. M., Atchue J. III, Yao C. E., Edwards R., Melana E. E., Gonzales H. I., 2000 Mangrove management handbook. Manila: DENR.
Melana E. E., Gonzales H. I., 2000 Field guide to the identification of some mangrove plant species in the Philippines. Ecosystems Research and Development Service. Department of Environment and Natural Resources, Mandaue City, Philippines.
Natividad E. M. C., Dalundong A. O., Patriarca A. B., Banisil M. A., Hingabay V. S., Paña B. H. C., Teofilo R. C. E., Salvatierra L. A. J., Dagoc V., Jumawan J. H., 2014 Correlation of soil and mangrove diversity in selected sites of Alabel and Maasim, Sarangani Province, Philippines. AAB Bioflux 6(2):145-153.
Primavera J. H., Sadaba R. B., Lebata M. L., Altamirano J. P., 2004 Handbook of mangroves in the Philippines - Panay. Southeast Asian Fisheries Development Center Aquaculture Department, Iloilo, Philippines, 106 pp.
Primavera J. H., Esteban J. M. A., 2008 A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. Wetlands Ecol Manage 16:345-358.
Pujar K. G., Hiremath S. C., Pujar A. S., Pujeri U. S., Yadawe M. S., 2012 Analysis of physico-chemical and heavy metal concentration in soil of Bijapur Taluka, Karnataka. Scientific Reviews & Chemical Communications 2(1):76-79.
Samson M. S., Rollon R. N., 2008 Growth performance of planted mangroves in the Philippines: revisiting forest management strategies. Ambio 37(4):234-240.
Sherman R. E, Fahey T. J., Howarth R. W., 1998 Soil-plant interactions in a neo-tropical mangrove forest: iron phosphorus and sulfur dynamics. Oecologia 115:553-563.
Solanki H. A., Chavda N. H., 2012 Physico-chemical analysis with reference to seasonal changes in soils of Victoria park reserve forest, Bhavnagar (Gujarat). Life Sciences Leaflets 8:62-68.
*** http://maps.google.com
*** http://googleearth.com

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