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Relationship of Floral Community and Soil Properties in Selected Riparian Banks of Lower Agusan River Basin, Philippines

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A B S T R A C T

Riparian zones are areas of transition between aquatic and upland ecosystems, offering numerous, yet often overlooked, benefits to wildlife and people. This study aims to determine the relationship of riparian flora community and soil quality observed on selected riparian banks of Barangays in Lower Agusan River Basin. Field surveys were conducted in the riparian banks of Barangay Masao, Lumbocan, and Pagatpatan for establishment of quadrants and collection of riparian flora and soil samples. A total of 301 combined trees, shrubs and grasses were accounted belonging to 25 species and 17 families including one endemic species (*Artocarpus blancoi*). The riparian banks of Barangay Pagatpatan had the highest species abundance and Shannon diversity index. The overall diversity and dominance index is low. Bray-Curtis Similarity matrix revealed that Barangays Lumbocan and Masao were more similar to each other in terms of species composition. Soil analysis revealed a slightly basic soil pH in Barangay Lumbocan. The average (%) organic matter in Barangay Masao is higher compared to the other sampling sites. Phosphorus (P) and Potassium (K) contents were highest in Barangay Masao. The result also showed that the lower Agusan River was largely a mixture of very fine silt to very course sand. Most of the tree species and including the vulnerable species, *Artocarpus blancoi* are highly associated to pH and very fine silt. Pearson correlation coefficient revealed that the floral community along the river banks of lower Agusan river has a significant positive correlation to potassium and phosphorus. The study highlights the importance of preserving the soil quality and riparian vegetation along the banks in order to protect this important buffer ecosystem.

Keywords: *Agusan River, Riparian flora, Soil Analysis*

1 Introduction

The riparian zone can be characterized as an environmental complex zone, which is directly adjoining a water body including floodplains and wetlands (Parson 1991, and Walker 1993) and can likewise incorporate irregular streams which once in a while run with water (Askey-Doran et al. 1996, and Tampus et al. 2013). Riparian zones typically consist of vegetated corridors adjacent to stream channels which are ecologically diverse and contribute to the health of aquatic ecosystems by filtering out pollutants. These areas are considered effective natural barriers, which prevent agricultural pollution from being exported and contaminating the broader ecosystem. Riparian vegetation and soil quality along riparian banks greatly influence the stability of the river banks. Bank stability is enhanced by the roots of large plants hereby reducing episodes of bank collapse (Perucca et al. 2007, and Eaton and Millar 2017).

The Agusan River is one of the major river system in Mindanao. Santillan et al. (2019) classified the land cover classes of Agusan River into agriculture, barren land, built-up land, forest, rangeland, water and wetland. At the mouth of Agusan River are various communities utilizing the various ecosystem services offered by the river. Barangays Masao, Lumbocan, and Pagatpatan are coastal barangays located at the lower Agusan River, Butuan City. These areas are known for tourist spot beaches, fisheries for livelihood (dela Cruz 2013), and conservation of wildlife and mangroves forests (Jumawan 2012).

Mangrove (Jumawan 2012) and fisheries assessment (Almadin and Jumawa 2016, and Solania and Seronay 2017); heavy metal analysis (Cabuga et al. 2016, and Demetillo and Goloran 2017), and habitat changes (Varela et al. 2013) along Agusan River have been conducted in the past. However, no studies have been conducted on floral composition and soil quality assessment in the river (except for mangroves by Jumawan 2012). The present study provides data on parameters important for riverbank stability and riparian flora in Agusan River.

2 Materials and Methods

Description of the Study Area

This study was conducted at the lower Agusan River located in the eastern part of Mindanao, Philippines. It is the third-longest river in the country with an estimated length of about 350 kilometers from its origin headwaters in Compostela Valley traversing the central part of Butuan City and draining in Butuan Bay (Sarmiento et al. 2017). Barangay Masao, Barangay Lumbocan, and Barangay Pagatpatan, are coastal barangays located near the river basin (Figure 1). Barangay Pagatpatan was named after a mangroves species “Pagatpat” (*Sonneratia alba*) which was once abundant in the area. Barangay Masao and Barangay Lumbocan are two local coastal barangays utilized as fishing grounds of Butuan City situated nearest to Butuan bay.

Establishment of Quadrats

A 5-m distance from the riverbank was established prior to the establishment of quadrats. In every station, three 10 m x 10 m vegetation quadrats were laid with an interval of 50 m between each quadrat. A total of nine quadrats were established in all three sampling stations. The coordinates and elevation of each quadrat were noted to geographically describe the area.

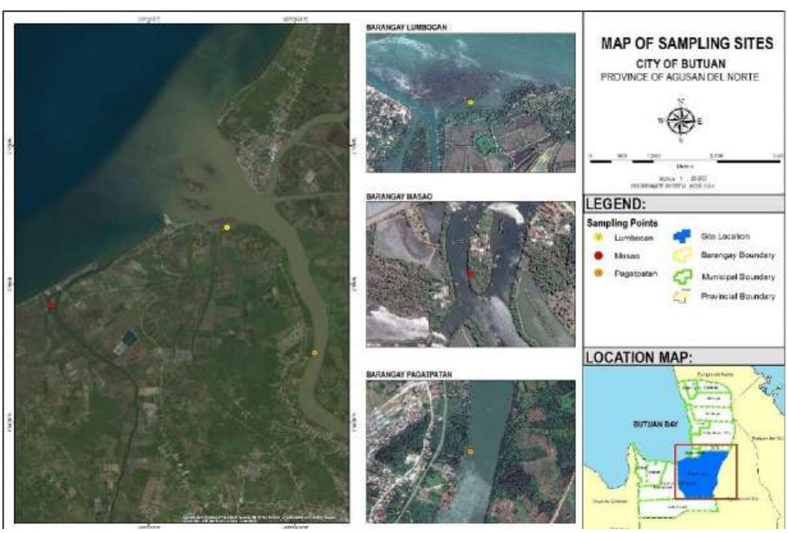

Figure 1. Map of the sampling stations along Agusan River Basin, Philippines.

Collection of Taxonomic Data

All plants observed within the quadrat were recorded. For grasses, sampling was done within a 1 m x 1 m quadrat inside each quadrat. Grasses were assessed using percent cover method. Field Information regarding the leaves, the height of the plant, the manner of branching, the color of flowers, local names and all other taxonomic characters considered vital in the identification process were recorded (Gomez-Roxas et al. 2005).

Plant Identification

Detailed photo documentation of each plant was carried out, photos of different species in the sampling were taken using a digital camera. The weeds, herbaceous plants, and grasses were initially identified using the book of Moody et al. (1984). Trees and other specimens were initially identified using taxonomic keys, books and internet sources, and verification of the species was done by experts from Caraga State University, Biology Department.

Soil sample collection and Soil Analysis

Soil samples were collected from three Barangays within the three-10 m x 10 m quadrats established. A composited sample was taken from each quadrat for each sampling area. Particle size was determined by dry sieve analysis, using a mechanical sieve of 8 mesh size numbers (14, 20, 30, 40, 50, 70, 100 and 120) following the American Standard Test method for Particle-size analysis. Approximately 250 g of air-dried soil was secured from each stations and placed inside a ziplock containers. Samples were brought to the soil laboratory of the Department of Agriculture, Caraga Region, Regional Soils Laboratory, Brgy. Taguibo, Butuan City for the analysis of pH (Potentiometric Method); Organic Matter content (Walkley-Black Method); Extractable Potassium (Cold Sulfuric Acid Method), Available Phosphorus (Olsen Method); and Soil Texture (Feel Method). For the available Ca, Mg, Zn and S, extraction method was done.

Conservation and Distribution Status

To know the conservation status of the species identified the IUCN Red List of Threatened Species (2018) was used through www.iucnredlist.org. Status of endemism was determined through various online resources. Data on invasion status was also determined using Global Invasive Species Database through www.iucngisd.org.

Data Analysis

Biodiversity indices (species richness, abundance, dominance, evenness, and diversity), and cluster analysis were computed using Paleontological Statistics (PAST) Software ver. 2.17c. Cluster Analysis was computed to determine the similarity of floral community abundance across the three sampling sites. Canonical correspondence analysis (CCA) was calculated using the PAST to determine the relationship between the soil profile and the floral composition. CCA was separated for trees and herbaceous plants. Pearson's correlation was generated using SPSS ver 16 to determine correlation between the species count and the soil pH, K, and P.

3 Results and Discussion

Floral Composition and Diversity

Species Richness

Inventory of the vegetation in the sampling plot revealed a total of 301 combined trees, shrubs and grasses counted from the different sections of riparian zones of the study areas. The combined data accounts a total of 25 species belonging to 17 families (Table 1 and Figure 2) with one species- *Artocarpus blancoi* Merrill identified as vulnerable and endemic to the Philippines due to it high risk of extinction in the wild (IUCN 2018). The most common species in all of the sampled area was *Rhizophora mucronata* (85), followed by *Nypa fruticans* (68), and *Sonneratia alba* (28). *Rhizophora mucronata* and *N. fruitcans* were abundantly recorded from the mangrove survey of Goloran et al. (2020) along Butuan Bay. Furthermore, *R. mucronata* have the highest regeneratation rate in Butuan Bay (Jumawan 2012).

Barangay Pagatpatan had the most number of species (S=13), followed by Masao (S=7) and Lumbocan being the least (S=6). Barangay Pagatpatan is located at the outlet of Agusan River where most waters drain from the upstreams. The soil is generally soft and muddy which is suitable for the growth of the predominant species. Some portions of Pagatpatan riverbanks support dense growth of the various ferns, herbs and shrubs such as *Imperata cylindrica* (100%), *Eremochloa ophiuroides* (60%), *Nephrolepis biserrata* (40%), *Mikania cordifolia* (40%), *Wedelia trilobata* (30%) (Table 1). Grasses are characterized to grow long and fibrous root systems that are good for erosion

Table 1. Species Composition of Plants, Conservation and Distribution Status, total number of species of three plant growth forms (ferns, shrubs & herbs) in selected Barangays in Lower Agusan River, Butuan City, Philippines.

Family	Species	Common Name	Conservation Status	GISD Status	Overall Species Abundance
Anacardiaceae	*Mangifera indica**	Mango	Data Deficient	Native to Asia	2
Arecaceae	*Rhapis excels**		Undetermined	-	5
Asteraceae	*Mikania cordifolia**	Chinese creeper	Undetermined	Native to Central and South America	40% (+P)
Asteraceae	*Sphagneticola trilobata**	Trailing daisy	Undetermined	Native to Central America	30% (+P)
Arecaceae	*Cocos nucifera**	Coconut	Undetermined	-	13
Arecaceae	*Corypha elata**		Undetermined	-	3
Arecaceae	*Nypa fruticans**	Nipa palm	Least Concern	Sri Lanka, Ganges delta, West pacific	68
Avicenniaceae	*Avicennia alba**	Api-api	Least Concern	-	13
Avicenniaceae	*Avicennia rumphiana**	Piyapi	Least Concern	-	21
Avicenniaceae	*Avicennia marina**	Gray mangrove	Least Concern	-	9
Combretaceae	*Lumnitzera racemose**	White Teruntum	Least Concern	t-	5
Combretaceae	*Term-inalia-- catappa**	Talisay	Undetermined	Native to Asia	12
Fabaceae	*Gliricidia sepium**	Madre de Cacao	Undetermined	-	1
Fabaceae	*Pongamia pinnata**	Pongam oil tree	Least Concern	-	4
Fabaceae	*Tamarindus indica**	Tamarind	Least Concern	-	4
Lythraceae	*Sonneratia alba**	Mangrove Apple	Least Concern	-	28
Lythraceae	*Sonneratia caseolaris**	Crabapple mangrove	Least Concern	-	15
Moraceae	*Artocarpus blancoi***	Antipolo	Vulnerable	-	3
Moraceae	*Ficus septica**	Septic Fig	Undetermined	-	2
Musaceae	*Musa acuminata**	Banana	Least Concern	-	10
Oleandraceae	*Nephrolepis biserrata**	Giant Swordfern	Undetermined	-	40% (+P) 30% (+M)
Poaceae	*Eremochloa ophiuroides**	Centipede grass	Undetermined	-	60% (+P)
Poaceae	*Imperata cylindrica**	Cogon grass	Undetermined	Native to Asia	100% (+P)
Poaceae	*Paspalum vaginatum**	Seashore paspalum	Undetermined	Native to North America	100% (+L)
Rhizophoraceae	*Rhizophora mucronata**	Loop-root Mangrove	Least Concern	-	85
Verbenaceae	*Gmelina arborea**	Gemelina	Undetermined	Native to Africa and Asia	3

Legend: *Non-endemic, **Endemic (Distribution Status), (+Percent cover % of ferns, herbs, shrubs), (P=Pagatpatan), (M=Masao), (L=Lumbocan).

control and soil stabilization. These grasses are good soil stabilizers; however, these are also serious weeds not only in crops but also in natural areas, causing serious economic and environmental damage (Sarmiento et al. 2017).

Biodiversity Indices of Trees

The riparian flora of Barangay Pagatpatan had the highest species richness because it is located in the area with least anthropogenic activities. Masao attained the lowest species richness as the riparian bank was exposed to high tide during the survey. However, Masao had the highest individual count of riparian flora as the area was located in the midstream part of the river (Table 2). Shannon-Weiner (H') increases with the number of the plant species in the riparian community. The overall diversity in the sampling areas is low (H'=1.8827). Nonetheless, among stations, Barangay Pagatpatan had the highest Shannon' diversity (H'=2.42) since it has also the highest number of species found, while Masao has the lowest Shannon' diversity (H'=1.467) (Figure 3). The low vegetation diversity coincides with the reduction of forest and the increased of built-up lands and range lands in Agusan river basin (Santillan et al. 2019).

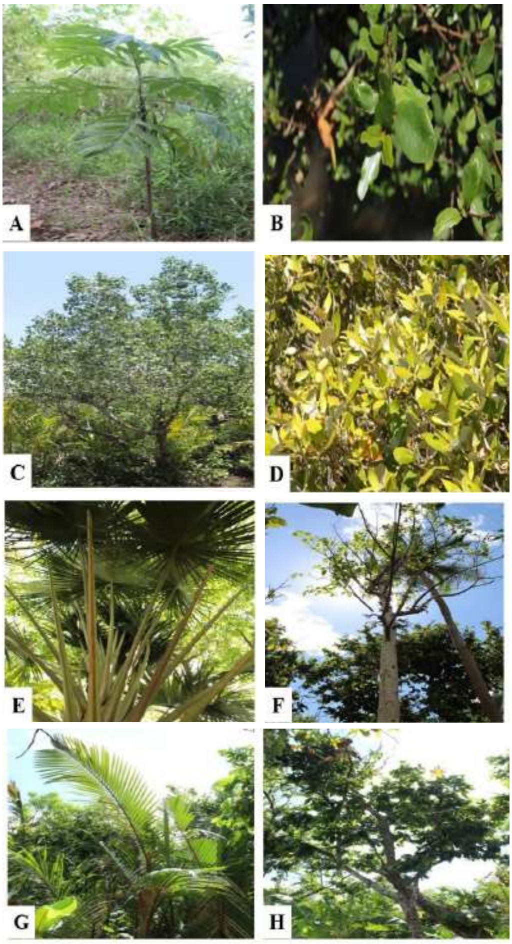

Figure 2. Some of the notable species along river banks of lower agusan river basin: A.) *Artocapus blancoi*, B.) *Avicennia alba*, C.) *Avicennia rumphiana*, D.) *Avicennia marina*, E.) *Corypha elata*, F.) *Ficus septica*, G.) *Nypa fruiticans,* and H.) *Pongamia pinnata.*

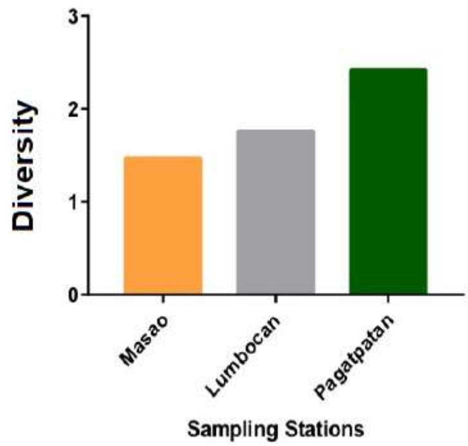

Figure 3. Trees diversity of the three sampling stations of the lower Agusan River Basin.

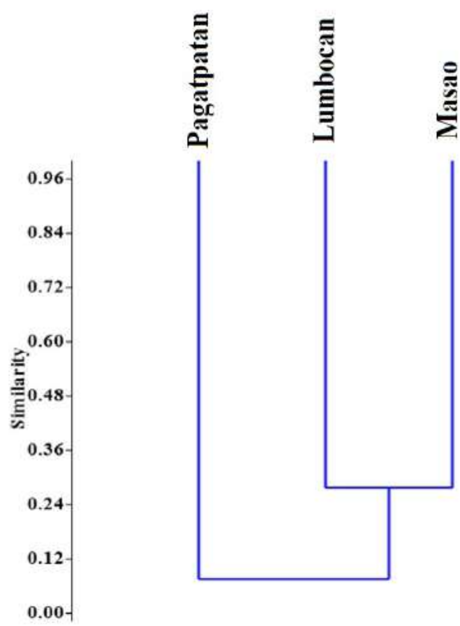

Figure 4. Over-all cluster analysis of abundance of riparian flora based on Bray-Curtis similarity index.

Furthermore, the negative impacts of the changes in flooding behaviour of the river caused by changes in land cover and industrialization could have also changed the geology of the banks leading to low plant diversity. The computed overall species dominance is very low (0.1904) with high species evenness (0.8179) indicating that there were no species dominating in abundance in all of the sampling stations (Table 2). The small number of trees can be attributed to the fact that trees are usually the preferred subject of harvesting, thereby reducing its chance to multiply as times pass by (Esperanza 2015). The Bray-Curtis Similarity cluster analysis of the three barangays revealed that barangays Lumbocan and Masao have a 40% similarity in terms of species composition and abundance, while Barangay Pagatpatan has 15% plant species similarity to the two barangays (Figure 4).

Table 2. Biodiversity indices of trees across sampling stations in lower Agusan River.

	Masao	Lumbocan	Pagatpatan	Overall
Richness (S)	7	6	13	26
Individuals (N)	171	81	54	306
Dominance	0.2933	0.177	0.1008	0.1904
Shannon (H')	1.467	1.761	2.42	1.8827
Evenness	0.6195	0.9694	0.8648	0.8179

Soil Profile of the Sites

Soil pH

The pH range from all stations indicates that the soils were slightly basic to neutral. Barangays Lumbocan and Pagatpatan, had slightly higher soil pH compared to Barangay Masao (Table 3). The probable reason of the slight acidity of soil from Barangay Masao could be the increasing aquaculture activities such as fish feeding and the rising number of fish cage establishments. These anthropogenic activities could have increase soil acidity.

In practical terms, soils between pH 6.5 and 7.5 were considered neutral. Soils within the range of 5.6 to 6.0 are moderately acid and below 5.5 strongly acidic. The dominant plants observed in the areas were *R. mucronata* and *N. fruticans*, an indicators that the soils were at optimum pH condition. Most plants grow best in soils with a slightly acidic reaction because in this pH range, nearly all plant nutrients are available in optimal amounts. Soil reaction or soil acidity changes for a variety of reasons. Heavy inorganic fertilizer application, particularly the ammonium containing fertilizers, increased soil acidity (Gomez-Roxas et al. 2005).

Organic Matter

Organic matter (OM) influences many soil chemical and physical properties and also enhances biological activity and productivity. The average percent organic matter in Barangay Masao is higher (2.33±0.48) compared to the other sampling sites (Table 3). Organic matter maintains the soil structure. It also acts as a buffer for chemical fertilizers, reducing their possible harm. In fact, the organic content and structure of the soil has to be managed as carefully as the nutrient content (Gomez-Roxas et al. 2005).

Geologically, Barangay Masao is located at lower part of the river basin where the water current is slow, promoting soil sediments to settle and accumulate in the mainland. As observed by Gomez-Roxas et al. (2005), high soil OM enhances the role riparian soil plays in filtering out nutrients and other harmful chemicals from surrounding land uses. Overall, the results proved that deposition enriches soils and suggests accumulation and possible stabilization of organic matter in these soils, especially in Barangay Masao.

Trace Elements

Barangay Masao had a very high P and K content (20.3±4.10 and 906±137.13, respectively)

Table 3. Soil Properties in the 3 sampling sites. Data presented as Mean ± SEM.

Sampling Sites	Texture	pH	%(O.M)	P (ppm)	K (ppm)	Ca	Mg	Zn	S
Lumbucan	Light	7.70± 0.02	1.1± 0.06	17±0.58	509.33± 48.49	S	S	MD	S
Masao	Light-Medium-Heavy	6.64± 0.33	2.33± 0.48	20.33± 4.10	906± 137.13	D-MD	MD	D	S
Pagatpatan	Medium	7.34 ±0.10	1.23± 0.13	4.67± 0.33	309.33± 9.70	S	S	D	D-MD

Legend:
D- Deficient MD- Moderately Deficient MS- Moderately Sufficient S- Sufficient
DBL- Below Detection UD- Undetermined (sample is unsuitable for the method of analysis) VH- Very High Particle Size

while Barangay Pagatpatan have moderately low amount of P although having sufficient amount of K. Similarly, content was assessed as moderately low. Soil in Barangay Pagatpatan has also deficiency of Zn and S but Ca and Mg is sufficient in the area (Table 3). The number of particular elements varies with the type of vegetation, elevation of the area and the size of the river. Small river have highest amount of nutrients compared to wide rivers. However, a large part of this element is likely to be removed especially during flooding (Weigelhofer and Waringer 1994). In the case of Barangay Pagatpatan, it is located in the upper portion of the river which is exposed to natural and environmental activities that may cause washing out of important elements in its soil.

Correlation of Soil Profile and Floral

The analysis of particle sizes indicates that the soil composition among the three barangays were largely a mixture of medium sand, very fine sand and very fine silt (Figure 5). Barangay Pagatpatan had large amounts of very fine silt, while Barangay Lumbocan was characterized of having large amounts of very fine sand and Barangay Masao have large amount of fine sand, medium sand and coarse sand and very course sand (Figure 5). The same type of soil observed by Almadin and Jumawan (2017) wherein most of the soil collected from the different sites in the upper part of the Agusan River Basin is composed of a large amount of very fine sand – silt – clay.

Canonical Correspondence Analysis (CCA) showed the relationship between the tree species and the environmental variables measured (Figure 6). The upper left quadrat shows that the species of least concern: *A. rumphiana*, *S. alba* and *S. caseolaris* are highly associated with high phosphorus content and very fine sand. *Rhizophora mucronata*, *L. racemosa*, and *N. fruiticans* were highly associated to high potassium content,

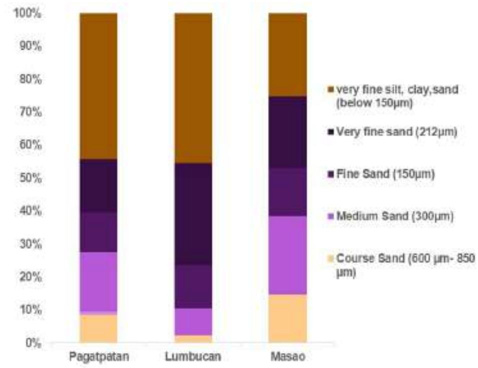

Figure 5. Comparison between soil particle sizes between the three sampling stations.

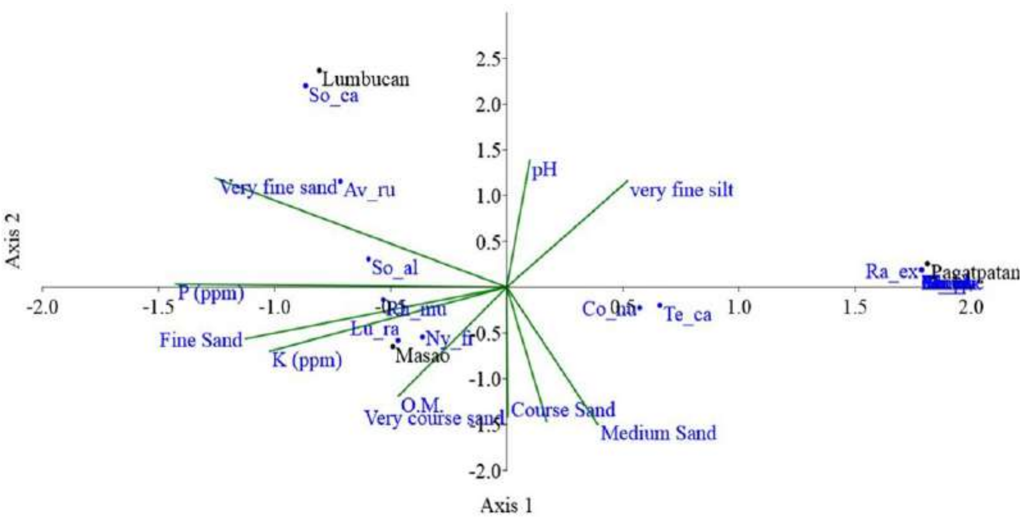

Figure 6. Canonical Correspondence Analysis showing the relationship between tree species composition and environmental parameters (Legend: Ar_bl= *Artocarpus blancoi*, Av_al= *Avicennia alba*, Av_ma= *Avicennia marina*, Av_ru= *Avicennia rumphiana*, Co_el= *Corypha elata*, Co_nu= *Cocos nucifera*, Fi_se= *Ficus septica*, Gl_se= *Gliricidia sepium*, Gm_ar= *Gmelina arborea*, Lu_ra= *Lumnitzera racemosa*, Ma_in= *Mangifera indica*, Mu_ac= *Musa acuminata*, Ny_fr= *Nypa fruiticans*, O.M.= Organic Matter, Po_pi= *Pongamia pinnata,* Ra_ex= *Rhapis excels*, Rh_mu= *Rhizophora mucronata*, So_al= *Sonneratia alba*, So_ca= *Sonneratia caseolaris*, Ta_in= *Tamarindus indica*, and Te_ca= *Terminalia catappa*).

high levels of organic matter, and fine sand to very course sand. *Cocos nucifera* and *Termialia catappa* are highly associated with medium to course sand while the rest of the tree species including the vulnerable *Artocarpus blancoi* were associated with pH and very fine silt.

Figure 7 shows the association between the herbaceous plants to the environmental variables. *Nephrolepis biserrata* was highly associated with fine sand, medium sand, very course sand, organic matter and potassium. *Paspalum vaginatum* was highly associated to pH, phosphorus, very fine sand, very fine silt. Hence, they preferably thrive on very find sediments. The rest of the herbaceous plants were inversely associated to phosphorus. The soil pH has a significant negative correlation to the number of plant species (Table 4). Baert (1995) stated that the soil acidity level affects the dispersal of other important nutrients in the soil, causing imbalance and eventually block a plants ability to absorb them. On the other hand, K and P have a significant, positive correlation to the number of plant species. Potassium is an essential plant nutrient and is required in large amounts for proper growth and reproduction of plants.

Potassium plays a major role in the regulation of water in plants; it is also known to improve drought resistance. Potassium has an important role in the activation of many growth-related enzymes in plants (Baert 1995). Increased of phosphorus availability might promote the coexistence of more plant species within community (Van Wambeke 1992).

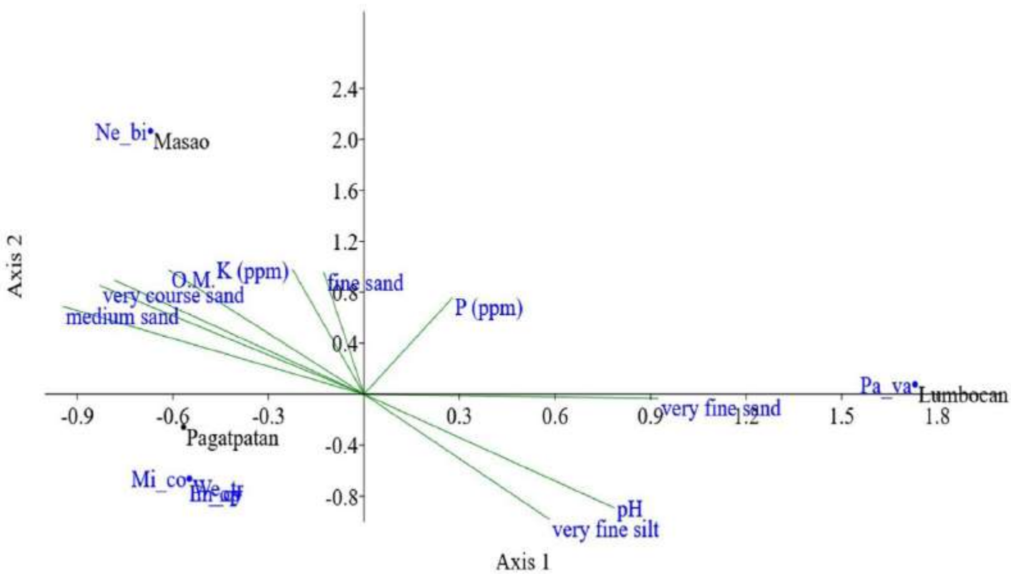

Figure 7. Canonical Correspondence Analysis showing the relationship between herbaceous plant species composition and environmental parameters (Legend: Er_op= *Eremochloa ophiuroides*, Im_cy= *Imperata cylindrica,* Mi_co= *Mikania cordifolia*, Ne_bi= *Nephrolepis biserrata*, and Pa_va= *Paspalum vaginatum*).

Table 4. Pearson's Correlation coefficient between plant species richness to soil parameters.

	pH*	K*	P**
Species Pearson Correlation	-0.853**	0.836**	0.720*
Sig. (2-tailed)	0.003	0.005	0.029
N	9	9	9

* Correlation is significant at the 0.01 level (2-tailed).
** Correlation is significant at the 0.05 level (2-tailed).

5 Conclusion

The riparian flora of lower Agusan River basin was shown to have an overall low species diversity (H'=1.88). The various anthropogenic disturbances and episodes of river bank erosion could have caused this observation. Particle sizes analysis indicated that the soil composition among the three barangays sampled was largely a mixture of very fine silt to very course sand. One vulnerable endemic species, *A. blancoi* was recorded in the area. This species is highly associated to pH and very fine silt. The results suggest the importance of preserving the river banks of the lower Agusan River to promote diversity and to protect the riverbank from erosion. Coordinated management of the riparian environment by concerned LGUs and inventory of riparian flora of all coastal barangays are recommended.

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6 Literature Cited

Almadin, F.J., & Jumawan, J.C. (2017). Description of breeding burrows of janitor fish (*Pterygoplichthys* spp.) in Agusan River, Butuan City, Philippines, *International Journal of Advances in Chemical Engineering & Biological Sciences*, **3**(2):187-190.

Askey-Doran M., S. Bunn, S., Hairsine, P., Price, P., & Prosser, I. (1996). Riparian management fact sheet 1. "Managing Riparian Lands." Land & Water Resources Research & Development Corporation. Rutherford I.

Baert, G. (1995). Properties and Chemical Management Aspects of Soils on Different Parent Rocks in the Lower Zaire. Ph.D. Thesis. Faculty of Sciences, Ghent University. Belgium, 318.

Cabuga Jr. C.C., Velasco J.P., Leones J.A.M., Orog B.Y, & Jumawan J.C. (2016). Levels of cadmium, copper, lead, nickel and mercury in the muscles of Pigok (*Mesopristes cancellatus*) and sediments collected at lower Agusan river basin, Brgy. Pagatpatan, Butuan City, Agusan del Norte. *International Journal of Fisheries and Aquatic Studies,* **4**(4): 206-215.

Dela Cruz, R.T. (2013). Increasing profit from Bangus through processing technologies. BAR Research and Development Digest. *Bureau of Agricultural Research*. **15**(3).

Demetillo M.T., & Goloran A.B. (2017). Determination of mercury accumulation of *Pistia stratiotes* in lower Agusan River, Butuan City. *Journal of Biodiversity and Environmental Sciences*, **11**(4): 48-53.

Eaton B., & Millar R. (2017). Predicting gravel bed river response to the environmental change: The strengths and limitations of a regime-based approach. Earth Surf. Process. *Landf.* **42**: 994-1008.

Esperanza J.C. (2015). Vegetation Analysis in the Riparian Zones of Angono Rizal, Philippines. *International Journal of Scientific and Research Publications,* **5**(10):1-6.

GISD. (2015). Global Invasive Species Database. www.iucngisd.org.

Goloran A.B., Calagui L., Betco G., Mulgado A.T. (2020). Species Composition, Diversity and Habitat Assessment of Mangroves in the selected area along Butuan Bay, Agusan del Norte, Philippines. *Open Access Library Journal*, **7**:1-11.

Gomez-Roxas, P., Boniao, R.D., Burton, E.M., Gorospe-Villarino, A., & Nacua, S.S. (2005). Community-Based Inventory and Assessment of Riverine and Riparian Ecosystems in the Northeastern Part of Mt. Malindang, Misamis Occidental, and Biodiversity Research Programme (BRP) for Development in Mindanao: Focus on Mt. Malindang and Environs, Technical Report, 1-136.

IUCN. (2018). The IUCN Red List of the Threatened Species" http://www.iucnredlist.org/.

Jumawan, J.H. (2012). Species composition and vegetation analysis of Mangrove forest along Butuan Bay, Philippines. *Transaction of the National Academy of Science and Technology*, **3**(1), 44.

Jumawan J.H., Cabuga Jr. C.C., Jumawan J.C., Cortez, E.M.B., Salvaleon S.M.N., Gamutan K.J.S., Dollisem M.G.G., Suico, A.L.G. Requieron E.A. & Torres M.A.J. (2016). Probing the exposure to environmental stress using fluctuating asymmetry of metric traits in Johnnius vogleri, (Bleeker, 1853) from lower Agusan River basin, Butuan City, Agusan del Norte, Philippines. *AACL Bioflux*, **9**(1): 122-132.

Moddy K., Munroe, C.E., Lubigan, R.T. & Paller Jr., E.C. (1984). Major weeds of the Philippines. Weed Sciences Society of the Philippines. University of the Philippines, Los Banos, Philippines.

Parson, A. (1991). Conservation & Ecology of Riparian tree Communities in the Murray- Darling Basin, New South Wales: literature review. Hurstville, N. S. W.: NSW National Parks and Wildlife Service.

Perucca E., Camporeale C., & Ridolfi L. (2007). Significance of the riparian vegetation dynamics on the meandering river morphodynamic. *Water Resource Research*, **43**(3).

Santillan J.R., Amora A.M., Makinano-Santillan M., Gingo A.L., & Marqueso J.T. (2019). Analyzing the impacts of land cover change to the Hydrologic and Hydraulic behaviours of the Philippines' third largest river basin. ISPRS Annals of the Photogrammetry, *Remote Sensing and Spatial Information Sciences,* **4**(3): 41-48.

Sarmiento R.T., Garcia, G.A.A. & Varela, R.P. (2017). Diversity of the Riparian Vegetation of lower Agusan River Towards Establishing the Sago-based Eco belt for Disaster risk reduction. *Journal of Biodiversity and Environmental Sciences*, **10**(4):70-80.

Solania C.L., & Calagui, L.B. (2016). Diversity and vegetation analysis in Delta Island, Lumbocan, Butuan city, Agusan Del Norte, Philippines. *Journal of Biodiversity and Environmental Sciences*, **9**(1): 400-409.

Solania C.L., & Seronay R.A. (2017). Reproductive aspects of the native Sharpnose hammer croaker, Johnius borneensis (Bleeker, 1850) from Agusan River Estuary, Caraga region, Philippines. *Journal of Entomology and Zoology Studies,* **5**(5): 220-228.

Tampus, A.D., Tobias, E.G., Amparado, R.F., Bajo, LM. & Sinco, A.L. (2013). Assessment of the riparian vegetation along the riverine systems in Iligan City, Philippines. *Advances in Agriculture & Botanics-International system Journal of the Bioflux Society.* **5**(2):102-114.

Van Wambeke, A. (1992). Soils of the Tropics, Properties and Appraisal. McGraw-Hill, Inc. New York. 343.

Walker K. (1993). Issues in the riparian ecology of large rivers. In: Proceedings of the 1993 workshop: Ecology & management of riparian zones. Marcoola Q. L. D., Bunn S., Pusey J., Price P. (eds), LWRRDC.

Weigelhofer G., & Waringer, J.A. (1994). Allochtonous Input of coarse particulate organic matter (CPOM) in a first to fourth order Australian forest stream. *International Reveiw of Hydrobiology* **79**:461-471.

Varela R.P., Fernandez E.V. & Degamo J.R.S. (2013). Agricultural Development and habitat change in the Agusan River Basin in Mindanao, Philippines. *International Journal of Development and Sustainability,* **2**(3): 2020-2030.