The influence of Urbanisation on Phytodiversity and some edaphic properties in urban and peri-urban riverine fresh water wetlands of Bamenda Municipality

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Abstract

Aims

In urban areas, human activities result to the discharge of a variety of chemical substances to the environment, playing a substantial role in soil quality, plant species diversity and human security. In order to suggest appropriate management strategies that ensures soil quality, their sustainable utilization and human security in the midst of urbanization, this study assesses the relationship between macrophyte diversity and some soil characteristics of wetlands in Bamenda Municipality, Cameroon at different stages of urbanization. It examines (i) macrophyte diversity and soil characteristics of wetlands adjacent urban and peri-urban areas.

Methods

Plant communities were sampled for species composition and relative abundance, using the Braun-banquet method. Species richness was evaluated using the Simpson's diversity index. Twenty-one soil samples (0 - 25 cm depth) were also randomly collected within the wetlands and analyzed for their physico-chemical characteristics using standard methods. The hierarchical cluster analysis (HCA) was used to group the area under managing units.

Results

From the results, 50 macrophytes species distributed in 28 families were documented in the area. The species observed were mostly emergent herbaceous plants (grasses) with only few shrubs and trees. The Simpson indices of diversity were 0.94 and 0.96 for the urban and control sites, respectively. The soils were slightly acidic. Sand, pH-H₂O, pH-KCl, Na were consistently least variable across the three sites. Two significant clusters representing a combination of urban and peri urban/rural were formed from the hierarchical dendrograms for classification of the chemical variables for the surface soils wetlands with associations to plants species. The Mann-Whitney U test, revealed a significant lower ($P < 0.05$) concentration of the chemical constituents of the control site and the urban sites indicating contamination.

Conclusion

Intensification and extension of urbanisation is reducing the diversity of the wetlands of the Bamenda municipality warranting monitoring.

Introduction

Human activities either direct and/or indirect ranging from global warming, landscape alteration, agriculture and urbanisation represent an existential problem between nature and society in relation to phytodiversity and soil quality (Solbrig, 2000; Pena-Claros et al., 2012; Arruda et al., 2015; Germ et al., 2021). Phytodiversity is one of the indicators often used to measure wellbeing of ecological systems (Borgwardt et al., 2019). In tropical regions, the structure and diversity of vegetation are determined by several biotic and/or abiotic factors, which act in different spatial and temporal scales (Dale, 1999).

Topography and soil type are among the major abiotic factors that play a major role in the heterogeneity of habitats and species, thus contributing to physiognomic differentiation of the vegetation (Baldeck et al., 2013; Guerra et al., 2013).

In urban areas, human activities results to the discharge of a variety of chemical substances to the environment that play a substantial role in altering the quality of the soil. This ultimately results in changes on the structure of plant community, their species diversity and human security.

According to Yerima and Van Ranst (2005), plants and soils are intricately related to an extent that changes in any of them would alter the other significantly. This could be partly associated to the fact that the fertility of soils is strongly influenced by the types of plants that grow. The types of plants influence the development of soil profiles (Yerima and Van Ranst, 2005).

Wetlands in urban and peri-urban areas can provide a range of important ecosystem services and benefits to people. However, in many countries, just as in Cameroon, as a result of spreading urbanization, wetlands are increasingly becoming degraded. The deposition of wastes in these zones also defies the Cameroon law on the Environment, Section III article 31(1) that forbids the deposition of waste into natural drains (MINEP, 1996). Todd (1980) and Malida (1981) observed that industrial and domestic wastes deposited in water add large amounts of organic and inorganic substances ranging from trace metals, to acids and alkalis that are potential pollutants in aquatic systems. The deposition of wastes into these systems therefore portends danger-necessitating studies. Macrophytes are important components of wetlands where they grow vigorously in enriched areas with a species variety that is strongly related to the chemical constituents of the environment. Indeed, macrophytes have high remediation potentials for macro and micronutrients because of their general fast growth and high biomass production in contaminated areas. In this regard, emergent and floating species especially those commonly used in the treatment of wastewater (Greenway, 2003) are good indicators of environmental degradation in wetlands.

This study assesses the relationship between macrophyte diversity and some soil characteristics (physical and chemical) of wetlands in Bamenda Municipality, Cameroon at different stages of urbanization.

It is hypothesized that (i) macrophyte diversity and soil soil characteristics do not differ among the wetlands originating from different ages of urbanization, (ii) soil characteristics do not influence the vegetation structure and plant diversity. These findings would help to suggest appropriate management strategies that will ensure soil quality, their sustainable utilization and human security in the midst of urbanization.

Materials And Methods

Description of the study area

Geographically, this study covers urban and peri-urban wetlands in the Bamenda City Council of the North West Region of Cameroon that have evolved concomitantly with different stages of urbanization (Figure 1). The area is part of the Bamenda escarpment located between latitudes 5° 55' N and 6° 30' N and longitudes 10° 25' E and 10° 67' E. The town shows an altitudinal range of 1200 - 1700 m, and is divided into two parts by escarpments; a low lying gently undulating part with altitudes ranging from 1200 to 1400 m, with many flat areas that are usually inundated for most parts of the year, and an elevated part at 1400 to 1700 m altitude that forms the crest from which creeks, and streams, supplying the low lying parts take their rise.

This area experiences two seasons; a long rainy season, (mid-March to mid-October) and a short dry season (mid-October to mid-March). The thermic and hyperthermic temperature regimes dominate in the area. Mean annual temperatures stand at 19.9°C. January and February are the hottest months with mean monthly temperatures of 29.1°C and 29.7°C, respectively. This area is dominated by the Ustic and Udic moisture regimes with the Udic extending to the south (Yerima and Van Ranst, 2005). Annual rainfall ranges from 1300 - 3000 mm (Ndenecho, 2005). The area has a rich hydrographical network with intense human activities and a dense population along different water courses in the watershed. The area is bounded on the West, North and East by the Cameroon Volcanic Line (made up of basalts, trachytes, rhyolites and numerous salt springs). The geologic history of this area originates from the Precambrian era where there was vast formation of geosynclinal complexes, which became filled by clay-calcareous, and sandstone sediments (Yerima and Van Ranst, 2005). These materials, crossed by intrusions of crystalline rocks, were folded in a generally NE-SW direction and underwent variable metamorphism (Yerima and Van Ranst, 2005). The Rocks in the area are thus of igneous (granitic and volcanic) and metamorphic (migmatites) origin (Kips *et al.*, 1987), which give rise to ferrallitic soils (Grass field Participatory-Decentralised and Rural Development Project: GP- DERUDEP, 2006).

Agriculture is the principal human activity in and around this (GP-DERUDEP, 2006). The area equally harbours the commercial centre that has factories ranging from soap production, and mechanic workshops to metallurgy, which may be potential sources of pollutants that can influence wetland Geochemistry. *Raffia farinifera* bush, largely limited to the wetlands (Valleys and depressions), is an important vegetation type in this area. *R. farinifera* provides raffia wine, a vital economic resource to the inhabitants who are fighting against the cultivation of these wetlands by vegetable farmers.

Methods of the Study

Macrophyte diversity study

Plant diversity of the wetlands was evaluated using quadrats in the dry season when wetlands are accessible. For each of the wetlands, transects were established on which representative plots were mapped out on each of them for the determination of plant species cover abundance and diversity. Each of these plots layed measured 10 x 10 m (100 m²) and was established in an uncultivated area. The plant communities were sampled for species composition and relative abundance. The Braun-banquet method was used (Braun-Blauquet, 1965) for the assessment of species cover abundance. Relative abundance and abundance ratings were determined using the Braun-Blanquet rating scheme (Table 1). Diversity studies involved the identification of a specific area called "relevé" by progressively increasing test quadrat size and sampling for specific diversity until the smallest area with adequate species representation was reached. The relevé size determined here was 1 m². For each site, 10 relevés were sampled and all plants species were enumerated. Most plant species in each of them were identified on the spot. For unidentified plants, appropriately collected were placed on to a plant press dried and identified in the herbarium of the Limbe Botanic Garden, using standard botanical techniques.

Simpson's diversity index

Species richness was evaluated using Simpson's diversity index. This index of diversity is more representative in pollution studies than the Shanon and Wiener index of diversity. Simpson's index (D) is a measure of diversity, which takes into account both species richness, and Table 1: Braun-Blanquet rating scheme for vegetation cover abundance and evenness of abundance among the species present. In essence it measures the probability that two individuals randomly selected from an area will belong to the same species. The formula for calculating D is presented as:

Table 1. Braun-Blanquet rating scheme for vegetation cover abundance.

Class	% range of cover	Mean	Rating
5	75 – 100	87.5	Very numerous
4	50 – 75	62.5	Numerous
3	25 – 50	37.5	Not numerous
2	5 – 25	15.0	Occasional
1	1 – 5	2.5	Sparse
R	<1	-	-

Source: Braun-Blauquet, 1965

$$D = \frac{\sum n_i(n_i - 1)}{N(N - 1)}$$

where n_i = the total number of each individual species

N = the total number of individuals of all species

The value of **D** ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. That is, the bigger the value the lower the diversity.

Alternatively, **Simpson's Diversity Index**, = $1 - D$,

1-D rather than **D** used as a measure of diversity; As it's more logical and less likely to cause confusion. The scale then gives a score from 0 to 1 with higher scores showing higher diversity (instead of being associated with low scores).

The Simpson index is a dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect the diversity.

Soil sampling and analysis

Twenty-one soil samples (0 - 25 cm) were randomly collected within the wetlands (Figure 1) and taken to the laboratory in black plastic bags. The soil samples were air-dried and screened through a 2-mm sieve. They were analyzed for routine parameters in the Environmental and Analytical Chemistry Laboratory of the University of Dschang, Cameroon. Particle size distribution, cation exchange capacity (CEC), exchangeable bases, electrical conductivity (EC) and pH were determined by standard procedures (Pauwels *et al.*, 1992). Soil pH was measured both in water and KCl (1:2.5 soil/water mixture) using a glass electrode pH meter. Part of the soil was ball-milled for organic carbon (OC) (Walky and Black method) and Kjeldahl-N as largely described by Pauwels *et al.*, (1992). Available P was determined by Bray I method. Exchangeable cations were extracted using 1 N ammonium acetate at pH 7. Potassium (K) and sodium (Na) in the extract were determined using flame photometer and magnesium (Mg) and calcium (Ca) were determined by compleximetric titration. Exchangeable acidity was extracted with 1 M KCl followed by quantification of Al and H by titration (Pauwels *et al.*, 1992). Effective cation exchange capacity (ECEC) was determined as sum of bases and exchanged acidity.

Apparent CEC (CEC at pH7) was determined directly as outlined by Pauwels *et al.*, (1992). Based on critical values of nutrients established for vegetables, nutrients were declared sufficient or deficient.

Statistical analysis

The data were subjected to statistical analysis using Microsoft Excel 2007 and SPSS statistical package 20.0. Soil properties were assessed for their variability using coefficient of variation (CV) and compared with variability classes (Tables 2).

Where: Sd = standard deviation; = $\bar{X}$ arithmetic mean of soil properties.

Table 1. Grouping coefficient of variation into variability classes

. CV (%)	Variability grouping (class)
< 15	Slightly variable
15-35	Moderately variable
>35	Highly variable

The hierarchical cluster analysis (HCA) was use to group the area under managing units. The hierarchical agglomerative cluster analysis main goal is to spontaneously classify the data into groups of similarity (clusters) searching objects in the n-dimensional space located in closest neighborhood and to separate a stable cluster from other clusters. Usually, the sampling sites are considered as objects for classification, each one determined by a set of variables (chemical concentrations of the soils in this case).

Results

Macrophyte Biodiversity Study

Semi aquatic and marshland plant species in the wetlands were mainly herbaceous and shrubby. Most of the plants showed discoloration in patches throughout the wetland (Figure 2). Human activities involving cutting, of raffias and woody species resulted to an open vegetation with shrubs scattered all over the wetlands.

Table 2 presents a checklist of plant diversity in agricultural wetlands in the Bamenda Municipality (Mile 4 – Foncha fish pond segment (MF): Ayaba - Ngomegham segment (AN) and a control site at Mbelewa Nkwen (MB). Where: – = *absent*, + = *observed*, 1 = *covering less than 5% of surface*; 2 = *present covering at least 5-25% of surface*; 3 = *present covering more than 25% of area*).

Table 2: Checklist of macrophytes diversity in the wetland in Bamenda at Mile 4 – Foncha fish pond segment (MF): Ayaba - Ngomegham segment (AN) and a control site at Mbelewa Nkwen (MB)

Family	Species Name	Abundance				
		Class	Common name	MF	AN	MB
Acanthaceae	<i>Brilantasia nitens</i> Lindau.			1	+	1
	<i>Decliptera laxata</i> C. B. Clarke			1	1	1
	<i>Justicia obliquifolia</i> Standl.	Dicot	Blood medicine	+	+	+
	<i>Justicia flava</i> (Forssk.) Vahl	Dicot	Blood medecine	-	-	1
	<i>Nesonia canescens</i> Var. <i>Smithii</i>	Dicot	-	-	+	+
Amaranthaceae	<i>Alternanthera sessalis</i> L.	Dicot	Sessile joy weed	+	+	1
	<i>Amaranthus hybridus</i> L	Dicot	-	1	1	1
	<i>Amaranthus spinosus</i> L	Dicot	Spiny amaranth	1	1	+
Apiaceae	<i>Centella asiatica</i> (L.) Urb.	Dicot	Pennywort	+	+	+
Apocynaceae	<i>Catharathus roseus</i>	Dicot	Periwinkle	-	-	1
Araceae	<i>Colocasia esculentus</i> L	Dicot	Cocoyam	+	+	+
Arecaceae	<i>Raffia farinifera</i> Gaertn. (L)	Monocot	Raffia palm	1	+	2
Asteraceae	<i>Ageratum cornyzoides</i> . L	Dicot	King grass	1	1	1
	<i>Tithonia diversifolia</i> Hemsl.	Dicot	Sun flower	1	2	-
	<i>Vernonia amygdalina</i> Del	Dicot	Bitter leaves	1	1	+
	<i>Vernonia hymenolepis</i> A. Rich	Dicot	Sweet bitter leaves	1	1	-
	<i>Vernonia gigantea</i> (Walter) Trel.	Dicot	Wild large leaf	-	-	+
	<i>Spilanthes filicaulis</i> (Schum. & Thonn.) C. D. Adams	Dicot	Eye for fowl"	1	-	+
	<i>Synedrella nodiflora</i> Cabi.	Dicot	Node weed	-	-	+
Athyraceae	<i>Diplazium zammati</i> (Khnn) C. Chr.	Dicot	Single branch fern	-	-	+
Casiapinaceae	<i>Cassia alata</i> Ls	Dicot	Leave like that of quava	-	+	-
Commelinaceae	<i>Commelina beghalensis</i> L	Dicot	-	3	2	1
	<i>Commelina diffusa</i> (Burm) F	Dicot	Tropical sidewort	1	1	1
Convolvulaceae	<i>Ipomoes aquatic</i> Forsk	Dicot	-	1	1	1
	<i>Ipomoea batatas</i> L	Dicot	Sweet potatoes	+	+	+
Curcubitaceae	<i>Zshneria scarbra</i> (L.f.) Sond.	Dicot	Curcumber	-	+	-
Cyperaceae	<i>Cyperus haspen</i>	Monocot	-	-	-	1
	<i>Cyperus distans</i>	Monocot	-	2	1	1
	<i>Mariscus alternifolius</i> (Sensu Hepper)	Monocot	-	-	-	1
	<i>Rhynchospora corymbosa</i> (L.) Britton.	Monocot	-	-	-	1
Dryopteridaceae	<i>Dryopteris felix-mas</i> (L) Schoot	Dicot	Fern plant	+	+	1
Fabaceae	<i>Desmodium salicifolium</i> (Poir.) DC	Dicot	-	-	1	+
	<i>Centrosoma pubescens</i> (D.C.) Benth	Dicot	-	-	+	1
Malvaceae	<i>Urena lobata</i> L.	Dicot	-	1	-	1
Maranthaceae	<i>Marantchloa purpurea</i> (Ridl.) Milne-Redh	Dicot	-	+	+	+
Mimosaceae	<i>Mimosa pudica</i>	Dicot	-	-	+	-
Nymphaeaceae	<i>Nymphaea alba</i> (H)	Dicot	Water lily	+	-	-
Onagraceae	<i>Ludwigia abysisnica</i> A. Rich	Dicot	Water primerose	1	1	2
Piperaceae	<i>Piper umberlatum</i> (L)	Dicot	-	-	-	+
Poaceae	<i>Anzonopus compressus</i> (Sw.) P. Beauv.	Monocot	Fat leaf carpet grass	+	+	-
	<i>Coix lachrymal-jobi</i> (L)	Monocot	-	1	-	2
	<i>Cyndon dactylon</i> (Linn)	Monocot	Bermuda grass	2	1	+

Family	Species Name	Abundance				
		Class	Common name	MF	AN	MB
	<i>Digitaria sanguinalis</i> (L)	Monocot	Crabgrass	-	1	1
	<i>Echinochloa crus-pavonis</i> (Kunth) Schult	Monocot	-	1	1	-
	<i>Echinochloa paramidelis</i> (Lam.) Hitchc.	Monocot	-	2	1	2
	<i>Eragrostis spp. Michx.</i>	Monocot	-	1	1	-
	<i>Imperata cylindrica</i>	Monocot	Spear grass	1	1	-
	<i>Leersia hexandra</i> Sw.	Monocot	-	2	2	2
	<i>Panicum maximum</i> Jacq. Var	Monocot	Guinea grass	1	1	-
	<i>Paspalum conjugatum</i> P. J. Bergius	Monocot	Sour grass	1	-	1
	<i>Pennisetum purpureum</i> (Schumach)	Monocot	Elephant grass	1	2	+
	<i>Saccharum officinarum</i> (L)	Monocot	Sugar cane	-	1	-
	<i>Sacilepis Africana</i>	Monocot	-	-	-	1
Polygonaceae	<i>Rumex nepalensis</i> L.	Dicot	-	-	-	+
Pteridiaceae	<i>Pteridium equilinum</i>	Dicot	Braken fern	+	+	+
Polygonaceae	<i>Polygonum limbatum</i> Meisn.	Dicot	-	2	1	1
Portulacaceae	<i>Portulaca oleraceae</i> L	Dicot	-	+	+	-
Rubiaceae	<i>Spermacoce latifolia</i> Aubl.	Dicot	-	1	1	1
Sellaginellaceae	<i>Sellaginella Kraussiana</i> (Kunze)A.Braun	Dicot	-	+	-	1
Smilacaceae	<i>Smilax Krausiana</i> Meisn		-	-	-	1
Solanaceae	<i>Physalis angulate</i> L. var.		-	-	-	+
Tiliaceae	<i>Triumfetta cordifolia</i> A. Rich.		-	1	1	1
Zingiberaceae	<i>Aframomum officinalis</i> Schum	Monocot	Ginger	+	-	1
Total	30	50		34	34	39

Macrophytes constituted an important part of the wetland. From the quadrat studies, 50 plant (macrophytes) species distributed in 28 families were identified in the wetlands (Figure 3). The species observed were mainly emergent herbaceous plants (grasses) with only few shrubs and trees. The *Poaceae* (26%) occurred as the most represented family, followed by *Asteraceae* (12%), *Cyperaceae* (8%), *Acanthaceae* (6%), *Amaranthaceae* (6%) with other species less represented (Figure 10). The marsh land from visual observation was dominated by *Leersia hexandra* growing in open water and covering large areas.

The control site at Mbelewa was represented by 39 species. Here, the dominant species ranked in abundance were as follows *Raphia farinifera* > *Ludwigia hexandra* > *Coix spp.* > *Leersia hexandra* > *Echinochloa paramidelis*.

The Mile 4 to Below Foncha segment (Peri urban) was represented by 40 species. Here, the dominant species were ranked in abundance as *Commelina bengalensis* > *Leersia hexandra* > *Cyperus distance* > *Echinochloa pyramidalis*. At the Ayaba to Ngomegham segment Urban segment), *Pennisetum purpureum* > *Echinochloa pyramidalis* > *Tithonia diversifolia* > *Leersia hexandra* were the abundant species. *Pennisetum purpureum*, *Echinochloa pyramidalis* and *Tithonia diversifolia* lined the main river course.

From the study, the Simpson indices of diversity were 0.94 each at Mulang (Table 3), and at Mile Four (Table 4), both the urban and peri-urban sites, lower than the 0.96 value recorded at Mbelewa, the control site (Table 5).

Table 3: Simpson index of diversity from vegetation sample at Mulang of the Bamenda wetland gardens

Family	Species	Class	Common name	Count (n)	n-1	n(n-1)
Acanthaceae	<i>Brilantasia nitens</i> Lindau	Dicot	-	3	2	6
	<i>Decliptera laxata</i> C. B. Clarke	Dicot	-	12	11	132
	<i>Justicia obliquifolia</i> Standl.	Dicot	Blood medicine	2	1	2
	<i>Nesonia canescens</i> Var. <i>Smithii</i>	Dicot	-	5	4	20
Amaranthaceae	<i>Alternanthera sessalis</i> L.	Dicot	Sessile joy weed	4	3	12
	<i>Amaranthus hybridus</i> L	Dicot	-	15	14	210
	<i>Amaranthus spinosus</i> L	Dicot	Spiny amaranth	12	11	132
Apiaceae	<i>Centella asiatica</i> (L.) Urb.	Dicot	Penny wort	5	4	20
Araceae	<i>Colocasia esculentus</i> L	Dicot	Cocoyam	3	2	6
Arecaceae	<i>Raffia fanivera</i> Gaertn(L)	Monocot	Raffia palm	3	2	6
Asteraceae	<i>Ageratum cornyzoides</i> . L	Dicot	King grass	12	11	132
	<i>Tithonia diversifolia</i> Hemsl.	Dicot	Sun flower	35	34	1190
	<i>Vernonia amygdalina</i> Del	Dicot	Bitter leaf	9	8	72
	<i>Vernonia hymenolepis</i> A. Rich	Dicot	Sweet bitter leaf	4	3	12
Casiapinaceae	<i>Cassia alata</i> L.	Dicot	Leaves like that of guava	2	1	2
Commelinaceae	<i>Commelina beghalensis</i> L	Dicot	-	43	42	1806
	<i>Commelina diffusa</i> (Burn) F	Dicot	Tropical sidewort	10	9	90
Convolvulaceae	<i>Ipomoea aquatic</i> Forsk	Dicot	-	9	8	72
	<i>Ipomea batatas</i> L	Dicot	Sweet potatoes	5	4	20
Curcubitaceae	<i>Zsheria scarbra</i> (L.F.) Sond.	Dicot	Curcumber	4	3	12
Cyperaceae	<i>Cyperus distans</i>	Monocot	-	15	14	210
Dryopteridaceae	<i>Dryopteris felix-mas</i> (L) Schoot	Dicot	Fern plant	2	1	2
	<i>Centrosoma pubescens</i> (D.C.) Benth	Dicot	-	3	2	6
	<i>Desmodium salicifolium</i> (Poir.) DC	Dicot	-	11	10	110
Maranthaceae	<i>Marantchloa purpurea</i> (Ridl.) Milne-Redh	Dicot	-	1	0	0
Mimosaceae	<i>Mimosa pudica</i>	Dicot	-	2	1	2
Onagraceae	<i>Ludwigia abysisnica</i> A. Rich	Dicot	Water primerose	12	11	132
Poaceae	<i>Anzonopus compressus</i> (Sw.) P. Beauv.	Monocot	Flat leaf carpet grass	7	6	42
	<i>Cyndon dactylon</i> (Linn)	Monocot	Bermuda grass	16	15	240
	<i>Digitaria sanguinalis</i> (L)	Monocot	Crab grass	14	13	182
	<i>Echinochloa crus-pavonis</i> (Kunth) Schult	Monocot	-	17	16	272
	<i>Echinochloa paramidelis</i> (Lam.) Hitchc	Monocot	-	13	12	156
	<i>Eragrostis spp.</i> Michx.	Monocot	-	10	9	90
	<i>Imperata cylindrica</i>	Monocot	Spear grass	15	14	210
	<i>Leersia hexandra</i> Sw.	Monocot	-	67	66	4422
	<i>Panicum maximum</i> Jacq. Var	Monocot	Guinea grass	10	9	90
	<i>Pennisetum purpureum</i> (Schumach)	Monocot	Elephant grass	54	53	2862
	<i>Saccharum officinarium</i> (L)	Monocot	sugar cane	10	9	90
	<i>Pteridium equilinum</i>	Dicot	Braken fern	4	3	12
	<i>Polygonium limbatum</i> Meisn	Dicot	-	12	11	132
Portulacaceae	<i>Portulaca oleraceae</i> L	Dicot	-	3	2	6
Rubiaceae	<i>Spermacoce latifolia</i> Aubl.	Dicot	-	10	9	90
Total	42			505		13312

D = 0.052302

Simpson index = 0.94

Table 4: Simpson index of diversity from vegetation samples at Mile Four.

Family	Species	Class	Common name	count (n)	n-1	n(n-1)
Acanthaceae	<i>Brilantasia nitens</i> Lindau	Dicot		20	19	380
	<i>Decliptera laxata</i> C. B. Clarke	Dicot	-	22	21	462
	<i>Justicia obliquifolia</i> Standl.	Dicot	Blood medicine	7	6	42
Amaranthaceae	<i>Alternanthera sessalis</i> L.	Dicot	Sessile joy weed	3	2	6
	<i>Amaranthus hybridus</i> L	Dicot	-	11	10	110
	<i>Amaranthus spinosus</i> L	Dicot	Spiny amaranth	13	12	156
Apiaceae	<i>Centella asiatica</i> (L.) Urb.	Dicot	Penny wort	5	4	20
Araceae	<i>Colocasia esculentus</i> L	Dicot	Cocoyam	8	7	56
Arecaceae	<i>Raffia fanivera</i> Gaertn(L)	Monocot	Raffia palm	19	18	342
Asteraceae	<i>Ageratum cornyzoides</i> . L	Dicot	King grass	22	21	462
	<i>Tithonia diversifolia</i> Hemsl.	Dicot	Sun flower	21	20	420
	<i>Vernonia amygdalina</i> Del	Dicot	Bitter leaves	16	15	240
	<i>Vernonia hymenolepis</i> A. Rich	Dicot	Sweet bitter leaves	14	13	182
	<i>Spilanthes filicaulis</i> (Schum. & Thonn.) C. D. Adams	Dicot	Eye for fowl	18	17	306
Commelinaceae	<i>Commelina beghalensis</i> L	Dicot	-	119	118	14042
	<i>Commelina diffusa</i> (Burn) F	Dicot	Tropical sidewort	16	15	240
Convolvulaceae	<i>Ipomoea aquatic</i> Forsk	Dicot	-	14	13	182
	<i>Ipomea batatas</i> L	Dicot	Sweet potatoes	5	4	20
Cyperaceae	<i>Cyperus distans</i>	Monocot	-	63	62	3906
Dryopteridaceae	<i>Dryopteris felix-mas</i> (L) Schoot	Dicot	Fern plant	9	8	72
Malvaceae	<i>Urena lobata</i> L	Dicot	-	21	20	420
Maranthaceae	<i>Marantchloa purpurea</i> (Ridl.) Milne-Redh	Dicot	-	6	5	30
Nymphaeaceae	<i>Nymphaea alba</i> (H)	Dicot	Water lily	8	7	56
Onagraceae	<i>Ludwigia abyssinica</i> A. Rich	Dicot	Water primerose	17	16	272
Poaceae	<i>Anzonopus compressus</i> (Sw.) P. Beauv.	Monocot	Flat leaf carpet grass	5	4	20
	<i>Coix lachrymal-jobi</i> (L)	Monocot	-	13	12	156
	<i>Cyndon dactylon</i> (Linn)	Monocot	Bermuda grass	103	102	10506
	<i>Echinochloa crus-pavonis</i> (Kunth) Schult	Monocot	-	20	19	380
	<i>Echinochloa paramidelis</i> (Lam.) Hitchc	Monocot	-	43	42	1806
	<i>Eragrostis</i> spp. Michx.	Monocot	-	18	17	306
	<i>Imperata cylindrica</i>	Monocot	Spear grass	10	9	90
	<i>Leersia hexandra</i> Sw.	Monocot	-	68	67	4556
	<i>Panicum maximum</i> Jacq. Var	Monocot	Guinea grass	19	18	342
	<i>Paspalum conjugatum</i> P. J. Bergius	Monocot	Sour grass	21	20	420
	<i>Pennisetum purpureum</i> (Schumach)	Monocot	Elephant grass	21	20	420
Pteridiaceae	<i>Pteridium equilinum</i>	Dicot	Braken fern	7	6	42
Polygonaceae	<i>Polygonum limbatum</i> Meisn.	Dicot	-	47	46	2162
Portulacaceae	<i>Portulaca oleraceae</i> L	Dicot	-	4	3	12
Rubiaceae	<i>Spermacocelatifolia</i> Aubl	Dicot	-	11	10	110
Sellaginellaceae	<i>Sellaginella Kraussiana</i> (Kunze)A.Braun	Dicot	-	2	1	2
Total	40			889		43754

D = 0.055425

Simpson = 0.94

Table 5: Simpson index of diversity from vegetation samples at Mbelewa.

Family	Species	Class	Common name	n	n-1	n(n-1)
Acanthaceae	<i>Brilantasia nitens</i> Lindau	Dicot	-	22	21	462
	<i>Decliptera laxata</i> C. B. Clarke	Dicot	-	10	9	90
	<i>Justicia obliquifolia</i> Standl.	Dicot	Blood medicine	5	4	20
	<i>Justicia flava</i> (Forssk.) Vahl	Dicot	Blood medicine	17	16	272
	<i>Nesonia canescens</i> Var. <i>Smithii</i>	Dicot		7	6	42
Amaranthaceae	<i>Alternanthera sessalis</i> L.	Dicot	Sessile joy weed	19	18	342
	<i>Amaranthus hybridus</i> L	Dicot	-	20	19	380
	<i>Amaranthus spinosus</i> L	Dicot	Spiny amaranth	6	5	30
Apiaceae	<i>Centella asiatica</i> (L.) Urb.	Dicot	Penny wort	5	4	20
Apocynaceae	<i>Catharatus roseus</i>	Dicot	Periwinkle	20	19	380
Araceae	<i>Colocasia esculentus</i> L	Dicot	Cocoyam	4	3	12
Arecaceae	<i>Raffia fanivera</i> Gaertn(L)	Monocot	Raffia palm	27	26	702
Asteraceae	<i>Ageratum conyzoides</i> L	Dicot	King grass	24	23	552
	<i>Vernonia amygdalina</i> Del	Dicot	Bitter leaf	4	3	12
	<i>Vernonia gigantea</i> (Walter) Trel.	Dicot	Wild large-leaf bitter leaf	2	1	2
	<i>Spilanthes filicaulis</i> (Schum. & Thonn.) C. D. Adams	Dicot	Eye for fowl	5	4	20
	<i>Synedrella nodiflora</i> Cabi.	Dicot	Node weed	3	2	6
Athyraceae	<i>Diplazium zammati</i> (Khnn) C. Chr.	Dicot	Single branch fern in fold	2	1	2
Commelinaceae	<i>Commelina beghalensis</i> L	Dicot	-	19	18	342
	<i>Commelina diffusa</i> (Burn) F	Dicot	Tropical sidewort	10	9	90
Convolvulaceae	<i>Ipomoea aquatic</i> Forsk	Dicot	-	17	16	272
	<i>Ipomea batatas</i> L	Dicot	Sweet potatoes	7	6	42
Cyperaceae	<i>Cyperus haspen</i>	Monocot	-	21	20	420
	<i>Cyperus distans</i>	Monocot	-	16	15	240
	<i>Mariscus alternifolius</i> (Sensus hepper)	Monocot	-	14	13	182
	<i>Rhynchospora corymbosa</i> (L.) Britton.	Monocot	-	12	11	132
Dryopteridaceae	<i>Dryopteris felix-mas</i> (L) Schoot	Dicot	Fern plant	22	21	462
Fabaceae	<i>Centrosoma Pubescens</i> (Ridl.) Milne-Redh	Dicot	-	19	18	342
	<i>Desmodium salicifolium</i> (Poir.) DC	Dicot	-	5	4	20
Malvaceae	<i>Urena lobata</i> L	Dicot	-	20	19	380
Maranthaceae	<i>Marantchloa purpurea</i> (Ridl.) Milne-Redh	Dicot	-	6	5	30
Onagraceae	<i>Ludwigia abysisnica</i> A. Rich	Dicot	Water primrose	47	46	2162
Piperaceae	<i>Piper umberlatum</i> (L)	Dicot	-	4	3	12
Poaceae	<i>Coix lachrymal-jobi</i> (L)	Monocot	-	70	69	4830
	<i>Cyndon dactylon</i> (Linn)	Monocot	Bermuda grass	9	8	72
	<i>Digitaria sanguinalis</i> (L)	Monocot	Crab grass	16	15	240
	<i>Echinochloa paramidelis</i> (Lam.) Hitchc	Monocot	-	97	96	9312
	<i>Leersia hexandra</i> Sw.	Monocot	-	63	62	3906
	<i>Paspalum conjugatum</i> P. J. Bergius	Monocot	Sour grass	12	11	132
	<i>Pennisetum purpureum</i> (Schumach)	Monocot	Elephant grass	3	2	6
	<i>Sacilepis Africana</i>	Monocot	-	20	19	380
Polygonaceae	<i>Rumex nepalensis</i> L	Dicot	-	8	7	56
	<i>Polygonum Limbatum</i> Meisn.	Dicot	-	12	11	132

Family	Species	Class	Common name	n	n-1	n(n-1)
Pteridiaceae	<i>Pteridium equilinum</i>	Dicot	Braken fern	3	2	6
Rubiaceae	<i>Spermacoce latifolia</i> Aubl.	Dicot	-	15	14	210
Sellaginellaceae	<i>Sellaginella Kraussiana</i> (Kunze)A.Braun	Dicot	-	16	15	240
Smilacaceae	<i>Smilax Krausiana</i> Meisn	Dicot	-	18	17	306
Solanaceae	<i>Physalis angulate</i> L. var.	Dicot	Fejoo	2	1	2
Tilaceae	<i>Triumfetta cordifolia</i> A. Rich.	Dicot	-	18	17	306
Zingiberaceae	<i>Aframomum officinalis</i> Schum	Monocot	-	10	9	90
Total	50			833		28700

D = 0.041411

Simpson Index= 0.96

Variability of Surface Soil Properties in the Wetlands of Bamenda Municipality and the relationship with macrophyte diversity

Table 6 shows the mean physico-chemical properties of surface soils in the three major sites assessed. The soils were slightly acidic with a lower pH (1:2.5) water value of 5.35 recorded at the Mulang site (that receives drains from the urban zone) than that of 6.04 pH value recorded at the Mbelewa site (the control site). The soils of the Mulang site had the lowest pH and the least diversity of plants. The soils of the urban wetland site (Mulang) site registered the highest EC of 309 uS/cm while the lowest EC value (120 uS/cm) was obtained at the Peri-urban site of Mile four. Soil organic carbon was in the order of 14.38 % > 13.88 % > 13.30 % for the Mulang, Mbelewa and Mile Four site, respectively. Organic carbon however showed moderate variation at the control and peri-urban site but was highly variable at the urban site with a lower diversity of species. Just like the SOM the soils of the urban zone had the best C/N ratio of 14.9. The sum of the exchangeable bases across the study sites were similar (0.97, 1.09, 1.00 for the Mbelewa site, Mile Four site and Mulang site, respectively). Exchangeable acidity stood in the order of 0.378>0.300>0.223 for the control site, peri urban and urban site respectively. The concentration of exchangeable Al³⁺ was highest at the urban site.

These soils were evaluated for their variability using the coefficient of variation (CV %). CV values ranging from 0-15% are considered slightly variable, 15-35% moderately variable, while > 35% they are considered highly variable (Tabi *et al.*, 2012; Asongwe *et al.*, 2016). From the data, (Table 7) Sand, pH-H₂O, pH-KCl, Na were consistently least variable across the three sites. Mg²⁺, ΣBases, were moderately variable across the three zones. C/N, and Exch. Acidity, were highly variable.

Table 6: Physico-chemical properties of surface soil properties at the Mile Four, Foncha and Mulang sites of the Bamenda Municipality.

Site	Sand Silt Clay ____%____			pH (1:2.5) H2O	KCl	EC uS/cm	OM Tot N ____%____	C/N	Av. P mg/Kg	Ca ²⁺ ΣBases	Mg ²⁺	K ⁺	Na ⁺	Exch. Acid. Al ³⁺ H ⁺ ____cmol(+)/Kg			
														____cmol(+)/Kg			
Mbelewa site	57	23	20	6.04	5.41	230	13.88	0.55	16.8	18	0.30	0.50	0.04	0.1305	0.97	0.378	0.0
Mile Four	63	22	15	5.73	4.63	120	13.30	0.50	19.1	16	0.41	0.52	0.04	0.1265	1.09	0.300	0.1
Mulang site	72	14	14	5.35	4.87	309	14.38	0.58	14.9	27	0.33	0.51	0.04	0.1239	1.00	0.223	0.1

Table 7: Variability classes of soil properties for the different sites in Bamenda municipality.

Site	Least variable (CV< 15%)	Moderatly Vaiable (15 < CV≤ 35%)	Highly Variable CV> 35%)
Mbelewa site	Sand, silt, clay pH _{H2O} , pHKCl, EC, Na ⁺ , Al ³⁺ , CECsoil, ECEC	OM, Tot.N, Ca ²⁺ , Mg ²⁺ , K ⁺ , ΣBases, BSECEC.	C/N, Av. P, Exch.acidity, H ⁺ , CECclay.
Mile Four	Sand, pH _{H2O} , pHKCl, K ⁺ , Na ⁺ , CECsoil, ECEC.	Silt, clay, EC, OM, Av.P, Mg ²⁺ , ΣBases, BSECEC.	Tot. N, C/N, Ca ²⁺ , Exch. Acidity, ECECclay
Mulang site	Sand, pH _{H2O} , pHKCl, Na ⁺	Silt, Clay, Tot. N, Ca ²⁺ , Mg ²⁺ , K ⁺ , Na ⁺ , ΣBases, Al ³⁺ , CEC sol, B	EC, OM, C/N, Av.P, Exch. Acidity, H ⁺ , CECclay, BSCEC

Clustering of the variables

Table 8 and figure 4 respectively shows the agglomeration table and the hierarchical dendrograms for classification of the chemical variables for the surface soils from the wetlands. Two significant clusters were formed. Amongst the two major clusters, one cluster combined rural environment (control site, site 21) and the peri-urban site where urbanization inputs are minimal. The other cluster represented the urban environment with varying human activities. In the urban

zone. *Alternanthera sessilis* was widespread in this cluster. The Mann-Whitney U test, revealed a significant lower ($P < 0.05$) concentration of the chemical constituents of the control site and the urban sites indicating contamination, warranting monitoring.

Table 8: Agglomeratin schedule for different clusters obtained from soil analyses in the fresh water wetlands of Bamenda Municipality

Agglomeration Schedule						
Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	14	18	.002	0	0	4
2	23	24	.010	0	0	12
3	17	19	.015	0	0	5
4	14	15	.081	1	0	7
5	12	17	.338	0	3	7
6	9	13	.561	0	0	9
7	12	14	.840	5	4	9
8	20	22	1.192	0	0	19
9	9	12	1.681	6	7	11
10	4	5	1.820	0	0	12
11	9	16	7.061	9	0	14
12	4	23	30.756	10	2	14
13	2	3	112.000	0	0	17
14	4	9	129.863	12	11	18
15	7	8	399.432	0	0	16
16	7	10	849.348	15	0	17
17	2	7	908.425	13	16	18
18	2	4	2340.274	17	14	20
19	11	20	5437.587	0	8	20
20	2	11	9244.048	18	19	22
21	1	21	26015.207	0	0	22
22	1	2	41940.680	21	20	23
23	1	6	732950.182	22	0	0

Discussions

From the floristic study, semi aquatic and marshland plant species in the wetlands were mainly herbaceous and shrubby and showed discoloration in patches throughout the wetland. According to Tsala et al., (1993) and Halabowski *et al.*, (2020), the presence of metal pollutants in wastewater and other anthropogenic influences constitute a stress factor for plants through their toxic effects on the photosynthetic process and membrane function. The decolouration of vegetation in this wetland could therefore be allied to excessive chemical elements from anthropogenic activities.

The study sites did not differ considerably from the rest as they clustered together as a community, probably due to high similarity in species composition that are affected by similar levels of environmental disturbances. Human activities involving cutting, of raffias and woody species resulted to an open vegetation with shrubs scattered all over the wetlands. Hyde and Wursten (2007) and Zelnik et al., (2021) have noted similar vegetation composition in the mining-impacted sites in wetlands along Lake Victoria in East Africa and Slovenian watercourses, respectively. This could be indicative that, the areas have suffered some degree of disturbance either from cultivation or other human activities with the exception of the control site, with a relatively higher number of trees.

Macrophytes constituted an important part of the wetland. According to Lindholm et al., (2020), macrophytes play a key role in the remediation of macro and micronutrients because they have the capacity to grow vigorously in nutrient rich environments especially emergent and floating species. The plants could absorb and sequester pollutants; or reduce erosion by damping wave actions and as such should be considered for proper management in order to contribute significantly to the wellbeing of other components of the dynamic aquatic system.

Quadrat studies revealed 50 plant (macrophytes) species (mainly emergent herbaceous plants: grasses) distributed in 28 families. Ahmad et al., (2009) reported that grasses which are represented by 10.000 species and about 610 genera are the most widespread family of flowering plants of the world. Just as

any aquatic ecosystem, these grasses were dominated by monocots. In some ponded areas close to the main river course, floating macrophytes were observed. Tita et al., (2012) did not identify such plants in the urban segment of the Mezam River system nor made mention of them in ponded areas proximal to it. The latter reported that in 2007, the Nkoup River system was characterized by eutrophic species such as *Potamogeton spp* and *Ceratophyllum demersum* in the upstream segments considerably impacted by agriculture whereas the downstream and urban segments were dominated by floating and emergent species all of which accumulate and bio-concentrate significant amounts of metal pollutants. The fact that these plants were not reported in the agricultural wetlands in the Bamenda Municipality is an indication that this wetland is under stress activities and, thus continually degrading. Diverse urban amenities with some having considerably noxious activities have come to existence within the environs of this agricultural wetland of the municipality. These activities either impinge directly through physical alteration and development and/or indirectly through widespread diverse chemical inputs on the agricultural soils. Aho-Chi (1998) had commented on this alteration.

In the wetlands of Bamenda Municipality, *Poaceae* (26%) occurred as the most represented family, followed by *Asteraceae* (12%), *Cyperaceae* (8%), *Acanthaceae* (6%), *Amaranthaceae* (6%) with other species less represented. The marsh land from visual observation was dominated by *Leersia hexandra* growing in open water and covering large areas. In the area *Pennisetum purpureum* and or *Tithonia diversifolia* lined the main river course with dotted spots of *Sacharum sp.*, *Coix sp*, *Ludwigia sp*, and *Nesonia sp*.

From the flora distribution, the control site at Mbelewa showed the greatest level of species diversity. Species biodiversity is used to indicate the 'biological health' of a particular habitat and is higher in less polluted areas. The control site at Mbelewa was represented by 39 species. Here, the dominant species ranked in abundance were as follows *Raphia farinifera* > *Ludwigia hexandra* > *Coix spp.* > *Leersia hexandra* > *Echinochloa pyramidalis*.

The peri-urban site (Mile 4 to Below Foncha segment) which was represented by 40 species had the dominant species ranked in abundance as *Commelina bengalensis* > *Leersia hexandra* > *Cyperus distans* > *Echinochloa pyramidalis*. The dominance of *Commelina bengalensis* generally occurring in extensive uniform stands along the edge of the channel and in ponded and pond-like areas was similarly reported by Tita et al., (2012). These plants thrive well in seasonally flooded environments and as such their abundance and diversity is proof of their high tolerance for fluctuating water levels and anthropogenic disturbances in the area (Grosshans and Kenkel, 1997, Lindholm et al., 2020).

At the Ayaba to Ngomesham segment (at Mulang), *Pennisetum purpureum* > *Echinochloa pyramidalis* > *Tithonia diversifolia* > *Leersia hexandra* were the abundant species. *Pennisetum purpureum*, *Echinochloa pyramidalis* and *Tithonia diversifolia* lined the main river course. Amongst the plants found in the area, *Coix sp*, *Poligonium sp*, *Ludwigia sp*, *Nesonia sp*, *Leersia sp*, *Echinochloa sp*, *Portulaca oleraceae* are obligate wetland species and thus rarely occur on dry land, while *Penicum sp* and *Pennisetum purpureum* have the same likelihood of occurring in wetlands as on dry land. *Portulaca oleraceae* is a weed in cultivated fields and waste moist marshy places. It is also used as a vegetable and medicinal herb (Sher et al., 2011; Marwat et al., 2011). *Pennisetum purpureum* amongst others is very effective in waste water treatment (Greenway, 2003; and Tita et al., 2012). *Alternanthera sessilis* is a common species, very widespread in waste and cultivated grounds, especially in damp or wet conditions (Townsend, 1974). It is an agricultural weed that invades disturbed wet areas in tropical and subtropical areas. Overall, *A. sessilis* has a low significant ecological impact (Tomaino, 2006) and thus a good indicator species. Just as, *A. sessilis*, *Rumex dentatus L.*, apart from its allelopathic activity (producing substances that inhibit the growth of other plants near it), it also grows in disturbed habitats, often in moist areas.

Lower Simpson indices of diversity (0.94) recorded at the urban and peri-urban indicates that species diversity at the control site is higher than that at the urban and peri-urban sites that show no differences. The urban site had lower species abundances in certain areas, indicating worse environmental conditions such as from toxic chemical inputs from the urban catchment. Similar findings due to worse environmental conditions have been reported by Germ et al., (2021) in a study to assess the diversity of macrophytes and environment of the Ljubljana River (Slovenia).

Variability of Surface Soil Properties in the Wetlands of Bamenda Municipality and the relationship with macrophyte diversity

The soils were slightly acidic with a lower pH (1:2.5) water value of 5.35 recorded at the urban site at Mulang (that receives drains from the urban zone) than that of 6.04 pH value recorded at the Mbelewa site (the control site). Soil pH plays a primordial role in nutrient availability to plants and therefore their growth, development and diversity. Low pH reduces the mineralization of soil organic matter and other nutrient reserves, inhibiting root growth and consequently, adsorption of nutrients. The soils of the Mulang site had the lowest pH and the least diversity of plants. The acidic nature of the soil at this site can also be attributed to various anthropogenic factors. The soils of the urban wetland site (Mulang) site registered the highest EC of 309 $\mu\text{S}/\text{cm}$ while the lowest EC value (120 $\mu\text{S}/\text{cm}$) was obtained at the Peri-urban site of Mile four. The highest pH recorded in the urban site could be associated to additional inputs ions from industrial urban activities. Soil organic carbon was in the order of 14.38% > 13.88% > 13.30% for the Mulang, Mbelewa and Mile Four site, respectively. Soil organic matter is a good indicator of soil fertility and one of the most important soil components, along with stabilization soil structure and improving infiltration rate. Nowadays, soil organic matter stabilization is perceived as a mechanism for organic carbon storage in the soil. Organic matter supplies energy and cell building constituents for most microorganisms and is a critical factor in soil fertility. Organic carbon however showed moderate variation at the control and peri-urban site but was highly variable at the urban site with a lower diversity of species. Just like the SOM the soils of the urban zone had the best C/N ratio of 14.9. This means that the mineralisation rate of the SOM is good. The sum of the exchangeable bases across the study sites were similar (0.97, 1.09, 1.00 for the Mbelewa site, Mile Four site and Mulang site, respectively). Exchangeable acidity stood in the order of 0.378 > 0.300 > 0.223 for the control site, peri urban and urban site respectively. However, the concentration of exchangeable Al^{3+} was highest at the urban site, and a probable indication of inputs from industrial inputs from the urban site.

From the results, Sand, $\text{pH-H}_2\text{O}$, pH-KCl , Na were consistently least variable across the three sites. Tabi and Ogunkunle (2007) had similarly reported least variability of soil pH for vertisols under rice cultivation in the Logone flood plain of Northern Cameroon. A very important parameter that influences many physico-chemical properties of soils including the availability of nutrients, plants richness and diversity is soil pH. In this study, though the pH variability reported is small, minor changes in pH units have significant effects on nutrient availability. Moderately variable Mg^{2+} and ΣBases were observed across the

three zones of the study area which could be attributed to variation in levels of alluvial materials received. Also, variation in chrono sequences of materials that have been subjected to different intensities of weathering could have a significant effect on these physical parameters. All these factors have significant implications on nutrient availability to plants of the wetlands. The moderate variability of these bases implies that, for proper management of the wetlands, a unique policy for the area is insufficient to conserve the wetlands. C/N, and Exch. Acidity, were highly variable. These parameters owe a lot of their origin to organic materials, urban swept off, and farm inputs that could have also influenced the vegetation diversity across the zones.

Clustering of the variables

From the hierarchical dendrograms for the classification of the chemical variables of the surface soils from the wetlands, two significant clusters were formed. The clusters correspond to the geographical location of the sampling sites and possible sources defining the soil quality like agricultural activity, industrial impact and fertilizing, which influences the diversity of macroflora in the area. Amongst the two major clusters, one cluster combined rural environment (control site), and the peri-urban site where urbanization inputs are minimal. The other cluster represented the urban environment with varying human activities. In the urban zone, *Alternanthera sessilis* which was widespread in this cluster is a common species, very extensive in waste and cultivated grounds, especially in damp or wet conditions (Townsend, 1974). According to Lazzaro et al. (2020), it impacts native plant species. The cluster on the lower part of the dendrogram represents dominantly rural and peri-urban areas with natural origins. Here, the dominant species were ranked in abundance as *Commelina benghalensis* > *Leersia hexandra* > *Cyperus distance* > *Ehchinocloa pyramidalis*. The dominance of *Commelina benghalensis* generally occurred in extensive uniform stands. The Mann-Whitney U test, revealed a significant lower ($P < 0.05$) concentration of the chemical constituents of the control site and the urban sites indicating contamination, warranting monitoring.

Conclusions

The wetlands of the Bamenda municipality have a total documented number of 50 macrophytes species distributed in 28 families. The species observed were mainly emergent herbaceous plants (grasses) with only few shrubs and trees. The Simpson indices of diversity stood at 0.94 and 0.96 for the urban and control sites, respectively. The soils were slightly acidic. Sand, pH-H₂O, pH-KCl, Na were consistently least variable across the three sites. Two significant clusters representing a combination of urban and peri urban/rural were formed from the hierarchical dendrograms for classification of the chemical variables for the surface soils wetlands with associations to plants species. The Mann-Whitney U test, revealed a significant lower ($P < 0.05$) concentration of the chemical constituents of the control site and the urban sites indicating contamination, warranting monitoring.

Declarations

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Authors' contribution

This work was carried out in collaboration between all authors. Author AGA, IBB, and AST, designed the study and the data collection instruments, collected the data, performed the statistical analyses and co-wrote the draft with the assistance of Author AEO, VAT, and KPB. All read and approved the final manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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Figures

Figure 3

Percent distribution of riverine wetland flora families in Bamenda Municipality

Figure 4

Dendrogram obtained from soil analyses in the fresh water wetlands of Bamenda Municipality