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Diversity and Dynamics of Plant Communities in Niger River Valley (W Regional Park)

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1. Introduction

The "W" Regional Park covers an area adjacent to the border of Benin, Burkina Faso and Niger (Fig. 1). The park hosts diverse flora and fauna. The large part of plant communities of this area remain poorly understood and only few reports on this subject are available (Garba, 1985; Boudouresque, 1995 and Couteron et al. 1992).

The objective of this work was to characterize plant communities along the Niger River bank during the flooding period and the dry season. These two periods play important roles in the ecosystem dynamics.

2. Materials and methods

The "W" Regional Park is located in the West African north-sudanian zone (Fig. 1; White, 1983) and covers an area of 1.024.280 ha. The average annual rainfall is 704.7 ± 180 mm with an average temperature of 37 ° C (Fig. 2). This park includes several Precambrian geological structures. In the river valley, the soil is of clayey gley/pseudo-gley type. The banks of this river host a "special vegetation" called "bourgou" by the local population in reference to "bourgoutiere" commonly used in the literature for this type of vegetation (Dulieu, 1989). The phytosociological investigation was conducted in several sites located in this area from 2002 to 2003 during the flooding period and the dry season. Each releve included the complete list of species with their abundance-dominance coefficients (Braun Blanquet, 1932).

Data analysis was performed with Canoco software (ter Braak and Smilauer. 1998). For the different plant communities that were studied, the specific diversity indices of Shannon and Weaver (1949 in Legendre and Legendre, 1998) and Pielou equitability index were calculated.

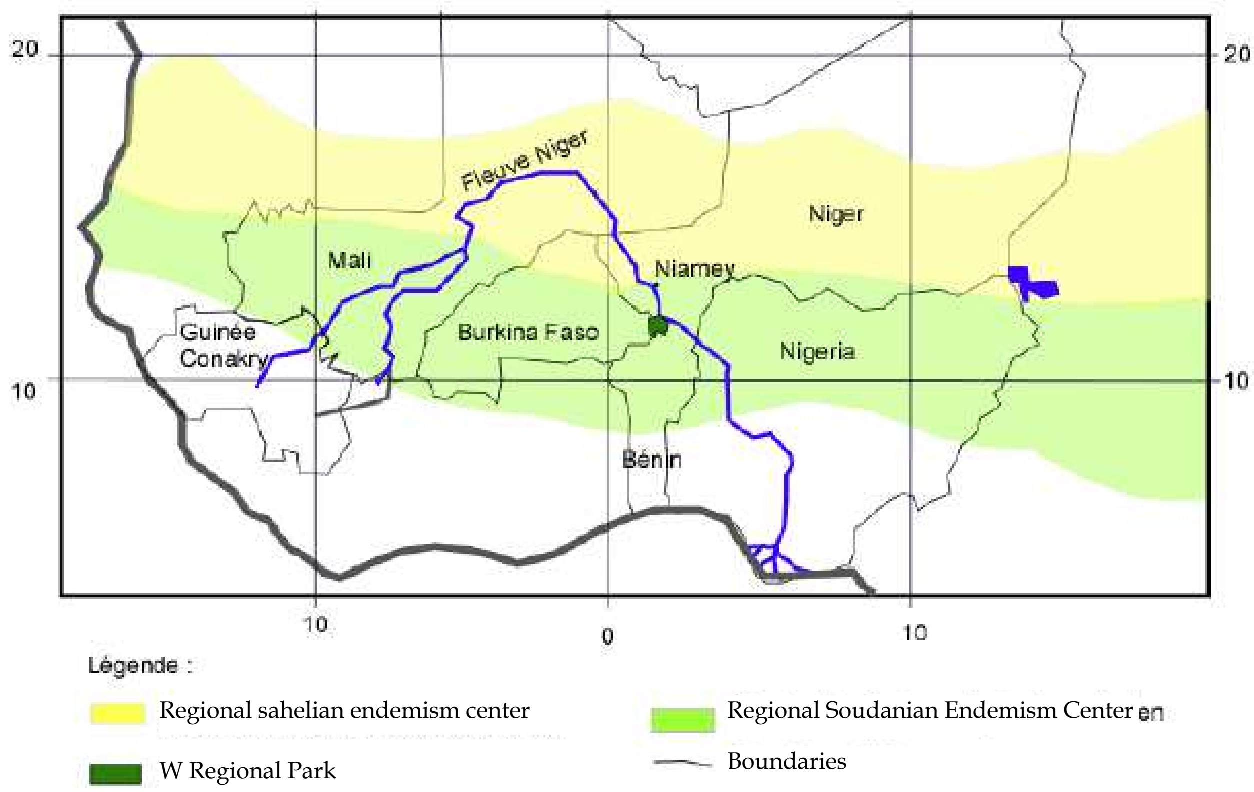

Fig. 1. "W" national park in West Africa

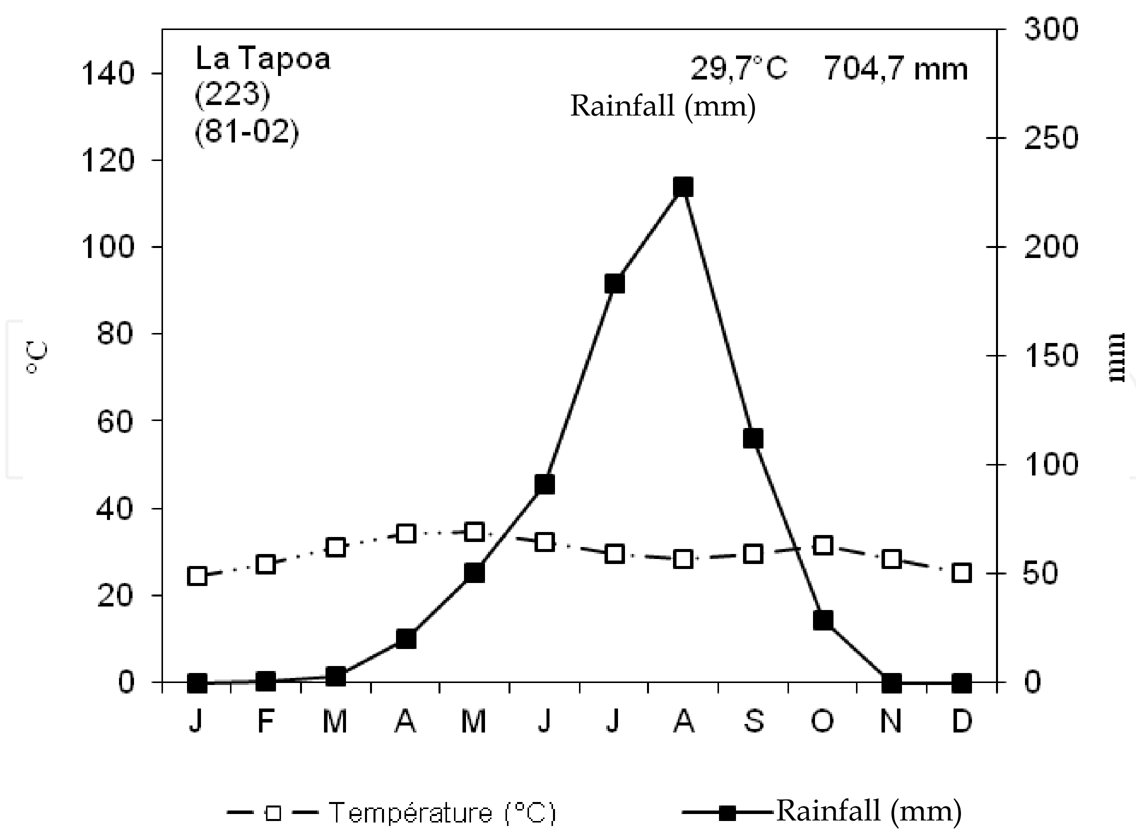

Fig. 2. Ombrothermic curve of Tapoa station (Niger)

The nomenclature after identification of species is referred to in Lebrun and Storck (1991-1997). The reported species were represented by *herbarium specimens* available in the herbaria of the UAM and ULB (BRLU).

3. Results

Detrended Correspondance Analysis was performed on a matrix of 42 relevés and 116 species. The first Axis reflected a gradient of water depth (Fig. 3). Near the origin of this axis were located the groups of plants adapted to deep water conditions occurring during flooding period while the dry season plant groups were positioned on its positive side.

The syntaxons described were:

- *Polygono senegalensis Echinochloetum colonae ass. nova,*
- *Eichhornietum crassipedis Vanderlyst* 1931,
- *Leptochloo coerulescentis Stachytarphetetum angustifoliae ass. nova,*
- *Cyperetum maculati* Mandango 1982.

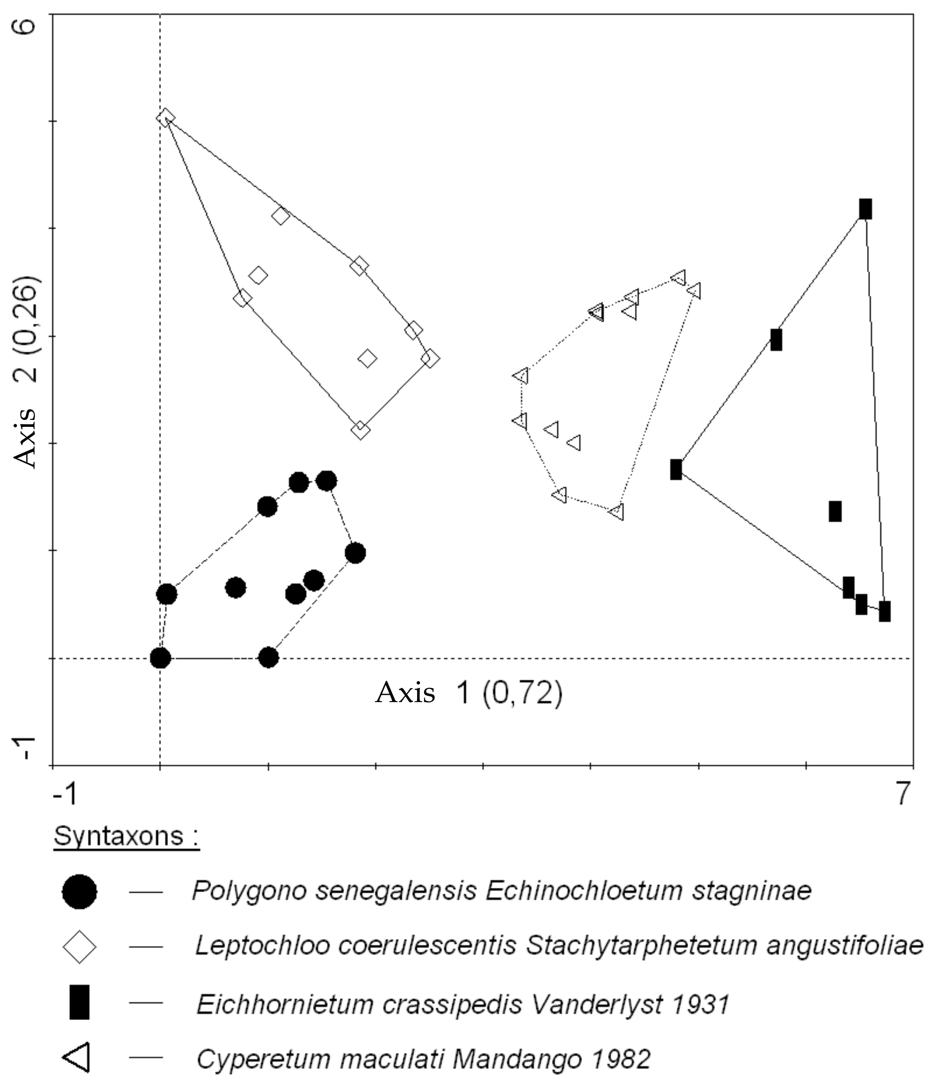

Fig. 3. Plant communities' classification in the banks of Niger River valley

3.1 *Polygono senegalensis Echinochloetum stagninae* ass. nova

Polygono Echinochloetum stagninae was defined by 13 releves and 22 species of which four were specific to this association: *Echinochloa stagnina, Polygonum senegalensis*, *Lemnapaucicostata* and *Azolla pinnata* (Table 1). Water depth may exceed 2 m. The pH was neutral and close to 7. The distribution of the biological types showed the predominance of therophytes (33.3%) followed by hydrophytes (28.6%) and phanerophytes (28.6%). Regarding the phytogeographical units, results showed the dominance of species with paleotropical distribution (33.33%) followed by pantropical species (28.57% and Sudan-Zambezian species (23.81%). The number of species per releve varied from 2 to 17 with an average of 4.19 ± 1.86. The Shannon diversity index was 2.69 and the maximum diversity index up to 4.64 while the Pielou equitability was 0.57.

	A															B											
N°	1	2	3	4	5	6	7	8	9	10	11	12	13			14	15	16	17	18	19	20	21	22	23		
N° Author	577	474	562	563	565	566	567	390	392	26	27	28	29			479	557	476	558	30	31	571	439	576	551		
Surface (m²)	10	15	15	20	20	20	10	10	15	15	15	10	10			10	20	10	10	15	10	10	10	10	10		
Land cover (%)	15	24	78	42	7	77	68	86	44	53	9	77	74	ALC	CP	30	10	63	59	57	54	36	30	47	23	ALC	CP
Polygono Echinochloetum stagninae ass. nova.																											
Polygonum senegalense	-	-	3	1	+	+	2	2	+	3	+	4	-	14,3	III	-	-	-	-	-	+	+	+	+	-	1,2	III
Echinochloa stagnina	+	+	3	3	1	4	3	4	3	2	+	+	4	29,3	V	-	-	-	-	-	2	-	-	-	-	1,5	I
Azolla pinnata	-	-	-	-	-	-	-	-	-	-	-	+	-	0,2	I	-	-	-	-	-	-	-	-	-	-		
Lemna paucicostata	-	-	-	-	-	-	-	-	-	-	-	-	+	0,2	I	-	-	-	-	-	-	-	-	-	-		
Oryza sativa L.	-	-	-	-	-	-	-	-	-	-	+	-	-	0,2	I	-	-	-	-	-	-	-	-	-	-		
***Eichhornietum crassipedis* Vanderlyst 1931**																											
Eichhornia crassipes (Mart.) Solms Laub.	+	2	+	+	+	+	2	+	-	-	-	-	-	3,7	III	+	+	3	+	1	2	2	+	+	2	9,9	V
Oryza longistaminata	-	-	-	-	-	-	-	-	-	-	-	-	+	0,2	I	-	-	-	-	3	-	2	+	-	-	5,6	II
Cyperus dilatatus Schum. & Thonn.	-	+	-	-	-	-	-	-	-	-	-	-	-	0,2	I	+	+	+	+	-	-	-	-	-	-	1,2	III
Ceratopteris cornuta	-	-	-	-	-	-	-	-	-	-	-	-	-			+	+	+	-	-	-	-	-	-	-	0,9	II
Saciolepis africana	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	+	+	-	-	-	-	0,6	II
Echinochloa crus - pavonis	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	+	-	+	-	0,6	II
Ludwidgia adscendens	-	-	-	-	-	-	-	-	+	-	-	-	-	0,2	I	-	-	-	-	-	+	-	-	-	-	0,3	I
Saciolepis ciliocincta	-	+	-	-	-	-	-	-	-	-	-	-	-	0,2	I	-	-	-	-	-	-	-	+	-	-	0,3	I
Echinochloa obtusifolia	-	-	-	-	-	-	-	-	-	-	-	-	-			2	-	-	-	-	-	-	-	-	-	1,5	I
Nymphaea lotus	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	2	-	-	-	-	1,5	I

	A															B											
Other species																											
Pterocarpus santalinoides DC.	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	+	-	-	-	-	-	-	-	0,3	I
Acacacia ataxacantha	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	3	-	-	-	-	-	-	3,8	I
Albizia zygia	-	-	-	-	-	-	-	-	-	-	-	-	-			+	-	-	-	-	-	-	-	-	-	0,3	I
Sesbania sesban	-	-	-	-	-	-	-	-	-	-	-	+	-	0,2	I	-	-	-	-	-	-	-	-	-	-		
Mitragyna inermis	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	+	-	-	-	-	-	-	-	0,3	I
Dichrostachys cinerea	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	+	-	-	0,3	I
Ipomomoea rubens	+	-	-	-	-	-	-	-	-	-	-	-	-	0,2	I	-	1	+	+	+	-	-	+	-	1	1,4	IV
Mimosa pigra	+	-	-	-	-	-	-	-	-	-	-	-	-	0,2	I	-	-	1	-	-	-	-	+	3	+	4,5	III
Paspalum scrobicularum	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	+	-	-	-	-	-	-	-	0,3	I
Phaseolus lunatus	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	+	-	-	-	-	-	+	0,6	II
Luffa cylindrica	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	+	-	-	0,3	I
Vetiveria nigritana	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	+	-	-	-	-	-	0,3	I
Phyllanthus reticulathus	+	-	-	-	-	-	-	-	-	-	-	-	-	0,2	I	-	-	+	-	-	-	-	-	-	-	0,3	I
Taccazea apiculata	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	+	-	-	-	-	-	0,3	I
Cynodon dactylon (L.) Pers.	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	+	-	-	-	-	-	1	0,4	II
Merremia hederacea	-	-	-	-	-	-	-	-	-	-	-	-	-			+	-	-	-	-	-	-	+	-	-	0,6	II
Ipomoea blepharophylla	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	+	-	-	-	-	-	-	0,3	I
Dorstenia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	+	-	-	-	-	-	-	0,3	I
Cerathophyllum demersum	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	+	-	-	0,3	I
Utricularia stellaris L.f.	-	-	-	-	-	+	-	-	-	-	-	-	-	0,2	I	-	-	-	-	-	-	-	-	-	-		
Ipomoea aquatica	-	-	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	+	-	-	-	-	-	0,3	I

ALC: Average Land Cover, PC: Presence Coefficient

Table 1. *Polygono Echinochloetum stagninae* ass. nov. & *Eichhornietum crassipedis*.

3.2 *Eichhornietum crassipedis* Vanderlyst 1931

Eichhornietum crassipedis Vanderlyst 1931 was distributed along the linear fringe of the Niger River bank. Water depth was quite similar as for *Polygono senegalensis Echinochloetum stagninae*, since they colonized the same stations.

The distribution of biological types revealed the predominance of hydrophytes (40%), followed by therophytes (20%) and microphanerophytes (20%). The helophytes represented only 10%. Regarding the phytogeographical distribution results showed the dominance of cosmopolitan species. The *Eichhornietum crassipedis* association consisted of 10 releves and 17 species. The average number of species per releve was 4. The Shannon diversity index was 2.34 and Pielou equitability 0.57. These values indicated a very small number of dominant species within the plant community.

3.3 *Leptochloo Stachytarphetetum angustifoliae* ass. nova association

Leptochloo coerulescentis Stachytarphetetum angustifoliae developed in the late dry season and beginning of the rainy season on the banks of the river that were sufficiently dewatered to allow the development of an herbaceous layer. It corresponded to a more or less continuous linear strip along the banks that were battered by the waves.

This syntaxon was defined by 10 releves and 34 species of those three were specific to the association: *Stachytarpheta angustifolia*, *Leptochloa coerulescens*, *Cardiospermum halicacabum* (Table 2). The raw distribution of biological types showed that helophytes were dominant (58% -73%), followed by therophytes (25%) and hydrophytes (22%) in the pondered distribution. Species of Sudanian distribution represented only 8% of the spectrum. As for the weighted spectrum, it was largely dominated by the species of Sudanese-Zambezian distribution (59.4%), species of Sudanian (9%) and Afrotropical species distribution (8.79%). The number of species per survey varied from 3 to 13 with an average of 7.6 ± 3.2. The Shannon diversity index was 3.6 and the maximum diversity index 4.9. The equitability index of Pielou was 0.74. These results suggest an equal distribution and overlap between species.

3.4 *Cyperetum maculati* Mandango 1982 association

Cyperetum maculati grows in the dry season on the sandbanks of the river's main channel. *Cyperus maculatus* form clumps of variable size. It is a rhizomatous species which is completely submerged during flooding periods. During this period of prolonged immersion, the plants were represented by perennial rhizomes. The floristic association has many annuals germinating on wet sand (Table 2). The association was defined by 10 releves and 39 species of which seven were specific to this association: *Cyperus maculatus, Cleome viscosa, Glinus lotoides, Glinus oppositifolius, Cassia occidentalis, Trianthema portulacastrum and Bergia suffruticosa.*

Cyperetum maculati Mandago 1982 was represented by open herbaceous vegetation in dense clumps. The biological types distribution was dominated by therophytes and hydrophytes respectively 43.8% and 28.1%. The weighted distribution was represented by therophytes and phanerophytes with respectively 37.8% and 36.3% followed by hydrophytes (24.8%). The raw phytogeographical units distrbution was dominated by paleotropical species (30.3%), followed by species of Sudanese-Zambezian distribution (27.27%) and pantropical species (24.24%). Other types showed low phytogeographic values. For this group, the number of species per survey varied from 5 to 18 with an average of 7.3 ± 4.42. The Shannon diversity index was 3.14 with a maximum diversity index of 5.24. Pielou equitability index value was 0.64. These results support the conclusion that recovery is evenly distributed between species.

	C												D										
N°	24	25	26	27	28	29	30	31	32	33			34	35	36	37	38	39	40	41	42		
N° auteurs	306	307	308	312	274	275	345	346	337	342			343	344	329	332	333	318	328	340	322		
Area (m²)	10	10	10	10	10	10	10	10	10	10			10	10	10	10	10	10	10	10	10		
Land cover (%)	27	89	56	41	100	77	65	24	83	25	ALC	CP	100	27	100	100	100	100	19	59,5	42	ALC	CP
***Cyperetum maculati* Mandango 1982**																							
Cyperus maculatus Böck.	-	+	+	3	4	3	-	-	-	+	15	IV	-	-	-	-	-	-	-	-	+	0,3	I
Glinus lotoides L.	+	+	-	-	+	-	+	+	-	1	2	IV	-	-	-	-	-	-	1	-	2	1,8	II
Mollugo nudicaulis	+	4	3	+	-	-	-	-	-	-	11	III	-	-	-	-	-	-	-	-	-		
Glinus oppositifolius (L.) A. DC.	+	-	-	-	-	-	+	+	-	+	1	III	-	-	-	-	-	-	-	-	+	0,3	I
Cleome viscosa L.	2	2	2	-	-	-	-	-	-	-	5	II	-	-	-	-	-	-	-	-	-		
Trianthema portulacastrum (L.) L.	-	-	-	-	+	-	-	-	+	-	1	II	-	-	-	-	-	-	-	-	-		
Bergia suffruticosa (Del.) Fenzl.	+	-	-	-	+	-	-	-	+	-	1	II	-	-	-	-	-	-	-	-	-		
Cassia occidentalis L.	-	-	-	-	+	-	-	-	4	-	7	II	-	-	-	-	-	-	-	-	-		
Heliotropium indicum L.	-	-	-	-	-	-	+	+	-	+	1	II	-	-	-	-	-	+	-	-	+	0,7	II
Leptochloo Stachytarphetetum angustifoliae ass. nova																							
Stachytarpheta angustifolia Mold.	-	-	-	-	-	-	-	-	-	-			3	+	3	3	3	2	-	1	-	19	IV
Leptochloa coerulescens Steud.	-	-	-	-	-	-	-	-	+	+	1	II	-	-	3	3	3	+	-	3	-	17	III
Albizia zygia (DC.) J. F. Mocer.	-	-	-	-	-	-	-	-	-	-			+	2	-	-	+	2	-	-	-	4	III
Cardio spermum halicacabum L.	-	-	-	-	-	-	-	-	-	-			-	-	-	2	-	3	-	-	-	5,8	II
Coldenia procumbens L.	-	-	-	-	+	-	-	-	-	-		I	3	-	-	-	-	-	-	-	-	4,2	I
Hyparrhenia involucrata Stapf. var involucrata	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	-	+	0,3	I
Eragrostis atrovirens (Desf.) Steud.	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	-	+	0,3	I

	C												D										
Other species																							
Morelia senegalensis A. Rich.	-	-	-	-	-	-	-	-	-	-			-	+	3	3	3	2	-	-	-	15	III
Pterocarpus santalinoides DC.	-	-	-	-	-	-	-	-	-	-			-	-	-	3	-	-	-	-	-	4,2	I
Vitex chrysocarpa Planch. ex Benth.	-	-	-	-	-	-	+	-	-	-		I	-	-	+	+	-	-	-	-	-	0,7	II
Flueggea virosa (Rxb. ex. Willd.) Voigt	-	-	-	-	-	-	-	-	-	-			-	-	+	-	-	-	-	-	-	0,3	I
Cola laurifolia Mast.	-	-	-	-	-	-	+	-	-	-		I	-	-	-	+	-	-	-	-	-	0,3	I
Taccazea apiculata Oliv.	-	-	-	-	-	+	-	-	-	-		I	-	-	+	+	-	+	-	-	-	1	II
Acacia ataxacantha DC.	-	-	-	-	-	-	-	-	-	-			+	-	2	+	+	+	-	-	+	3,3	IV
Merremia hederacea Burm. f.	-	-	-	-	+	-	-	-	-	-		I	-	-	-	+	-	-	-	-	-	0,3	I
Diospyros mespiliformis Hochst. ex. A. DC.	-	-	-	-	-	-	-	-	-	-			+	+	-	-	-	+	-	-	-	1	II
Celtis toka (Forssk.) Hepper et Wood.	-	-	-	-	-	-	-	-	-	-			+	-	-	-	-	-	-	-	-	0,3	I
Hyptis spicigera Lam.	-	-	-	-	-	-	+	-	-	-		I	-	-	-	-	-	-	-	-	+	0,3	I
Corchorus tridens L.	-	-	-	-	+	-	-	-	+	-	1	II	-	-	-	-	-	-	-	-	-		
Tamarindus indica L	-	-	-	-	-	-	-	-	-	-			-	+	-	-	-	-	-	-	-	0,3	I
Mitragyna inermis	-	-	-	-	-	-	-	-	-	-			3	-	2	-	-	-	-	-	-	5,8	II
Ipomomoea rubens	-	-	-	-	-	-	-	+	-	-		I	-	-	-	-	-	-	-	+	-	0,3	I
Mimosa pigra	-	-	-	-	-	-	+	+	-	-	1	II	-	-	-	+	3	+	-	-	-	4,8	II
Cynodon dactylon (L.) Pers.	-	-	-	-	-	+	-	+	-	+	1	II	-	-	2	+	-	-	2	2	+	5,7	III
Polygonum senegalense	-	-	-	-	-	2	+	+	-	-	2	II	-	-	-	-	-	-	+	+	+	1	II
Eichhornia crassipes (Mart.) Solms Laub.	-	-	-	-	-	+	-	-	-	-		I	-	-	-	-	-	-	-	-	-		

Average Land Cover, CP: Coefficient de présence

Table 2. *Cyperetum maculati Mandango* 1982 & *Leptochloo- Stachytarphetetum angustifoliae ass. nov*

3.5 Synsystematique

class	Order	Alliance	Associations
Phragmitetea Tüxen & Preising 1942,	*Papyretalia* Lebrun 1947	*Echinochloion crusis-pavonis* Léonard 1950	*Leptochloo-Stachytarphetetosum angustifoliae* ass. nov.
		Jussieuion Léonard 1950	*Polygono senegalense Echinochloetum stagninea* ass. nov.
Potametea pectinati Tüxen & Preising 1942	*Nymphaeetalia loti* Lebrun 1947	*Nymphaeion micranthae* E. Boud. 1995	*Eichhornietum crassipedis* Vanderlyst 1931
Ruderali-manihotetea (Léonard in Taton 1949) Schmitz 1988	*Amarantho-Ecliptetalia* Schmitz 1971	*Ecliption albae* Lebrun 1947	*Cyperetum maculati* Mandango 1982

4. Discussion

The initial phase of the bourgoutiere included Leptochloa coerulescens, Echinochloa stagnina, Echinochloa pyramidalis, Cyperus cylindrostachyus, Saciolepis africana and Stachytarpheta angustifolia. These plant species were progressively established in the late dry season and early rainy season. Leptochloa coerulescens bear fruits during this period. This phase corresponded to the ecological amplitude of Leptochloo-Stachytarphetetum angustifoliae. With the increase in water level, Polygonum senegalense and Echinochloa stagnina actively developed by vegetative propagation.

The optimal phase or aquatic prairie of bourgoutiere corresponded to Polygono *Echinochloetum stagninae*. The group covered a broad variable on the shores of the river. During the dry season, *Echinochloa stagnina* as *Polygonum senegalense* fall on the dewatered river banks. At that time, both species have spread their seeds. In the riverbed, Cypretum maculata Mandango 1982 was subject to strong variations in relation to alternating periods of flood and dry period. During the dry period characterized with a low water flow in the river, the species happened to complete its cycle. The start of this cycle, as and when the water recedes, is characterized by buds on the stolons. The flooding period was characterized by a progressive invasion by water hyacinth and resulted in the formation of *Eichhornietum crassipedis*. This determined syntaxon pollution of aquatic stressed environments (Brendonck et al. (2003)).

These stations were characterized by variability of plant communities determined by the river water regime (Duvigneaud, 1946). Indeed, this group was not identified by Atta and DanJimo (2003) in the same river valley during the dry season. Gradually, as the water level dropped, hydrophytes population declined and progressively replaced by therophytes. This resulted in a decrease of the number of species.

5. Conclusion

Bougoutières vegetation plays an important role in the ecosystem of the W regional park. Apart from *Eichhornietum crassipedis*, the different syntaxons provide forage and habitat for wildlife. These syntaxons were characterized by low diversity indices in relation to dominance effects between species and disturbance (fire bank, harvested biomass) related to human activities.

6. Acknowledgments

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7. List of species

Species	Family
Abrus precatorius L.	Fabaceae
Acacia ataxacantha DC.	Mimosaceae
Albizia zygia (DC.) J.F. Macbr.	Mimosaceae
Azolla pinnata R. Brown var *pinnata*	Azollaceae
Bergia suffruticosa (Del.) Fenzl	Elatinaceae
Caperonia fistulosa Beille	Euphorbiaceae
Cardiospermum halicacabum L.	Sapindaceae
Cassia occidentalis L.	Caesalpiniaceae
Celtis toka| (Forssk.) Hepper & Wood	Ulmaceae
Ceratophyllum demersum L.	Ceratophyllaceae
Ceratopteris cornuta	Adianthaceae
Cleome viscosa L.	Capparaceae
Cola laurifolia Mast.	Sterculiaceae
Coldenia procumbens L.	Boraginaceae
Commelina benghalensis L.	Commelinaceae
Corchorus tridens L.	Tiliaceae
Cynodon dactylon (L.) Pers.	Poaceae
Cyperus dilatatus Schum. & Thonn.	Cyperaceae
Cyperus maculatus Boeck.	Cyperaceae

Dactyloctenium aegyptium (L.) P. Beauv.	Poaceae
Dichrostachys cinerea (L.) Wight & Arn.	Mimosaceae
Diospyros mespiliformis Hochst. ex A. DC.	Ebenaceae
Eichhornia crassipes (Mart.) Solms	
Echinochloa crus-pavonis (Kunth) Schult.	Poaceae
Echinochloa obtusiflora Stapf	Poaceae
Echinochloa stagnina (Retz.) P. Beauv.	Poaceae
Eichhornia natans (P. Beauv.) Solms-Laub.	Pontederiaceae
Eleusine indica (L.) Gaertn.	Poaceae
Eragrostis atrovirens (Desf.) Trin. ex Steud.	Poaceae
Eragrostis tremula Hochst. ex Steud.	Poaceae
Fluegga virosa (Roxb. ex Willd.) Voigt	Euphorbiaceae
Glinus lotoides L.	Aizoaceae
Glinus oppositifolius (L.) DC.	Aizoaceae
Heliotropium indicum L.	Boraginaceae
Hyparrhenia involucrata Stapf	Poaceae
Hyptis spicigera Lam.	Lamiaceae
Indigofera hirsuta L.	Fabaceae
Ipomoea aquatica Forssk.	Convolvulaceae
Ipomoea blepharophylla Hall. f.	Convolvulaceae
Ipomoea rubens Choisy	Convolvulaceae
Lemna paucicostata Hegelm. ex Engelm.	Lemnaceae
Leptochloa caerulescens Steud.	Poaceae
Cleome viscosa L.	Capparaceae
Ludwigia octovalvis (Jacq.) Raven	Onagraceae
Luffa cylindrica (L.) M.J. Roem.	Cucurbitaceae
Merremia hederacea (Burm. f.) Hallier f.	Convolvulaceae
Mimosa pigra L.	Mimosaceae
Mitragyna inermis (Willd.) O. Ktze.	Rubiaceae
Mollugo nudicaulis Lam.	Molluginaceae
Morelia senegalensis A. Rich. ex DC.	Rubiaceae
Nymphaea lotus L.	Nympheaceae
Oryza longistaminata A. Chev. & Roehr.	Poaceae
Oryza sativa L.	Poaceae
Paspalum scrobiculatum L.	Poaceae
Phaseolus lunatus L	Fabaceae
Phyllanthus reticulatus Poir.	Euphorbiaceae
Polygonum senegalense Meisn.	Polygonaceae
Pterocarpus santalinoides DC.	Fabaceae
Sacciolepis africana C.E. Hubbard & Snowden	Poaceae
Sacciolepis ciliocincta (Pilger.) Stapf.	Poaceae
Sesbania leptocarpa DC.	Fabaceae
Sesbania sesban (L.) Merr.	Fabaceae

Stachytarpheta angustifolia (Mill.) Vahl	Verbenaceae
Tacazzea apiculata Oliv.	Asclepiadaceae
Tamarindus indica L.	Caesalpiniaceae
Trianthema portulacastrum L.	Aizoaceae
Utricularia stellaris L.f.	Lentibulariaceae
Vetiveria nigritana (Benth.) Stapf	Poaceae

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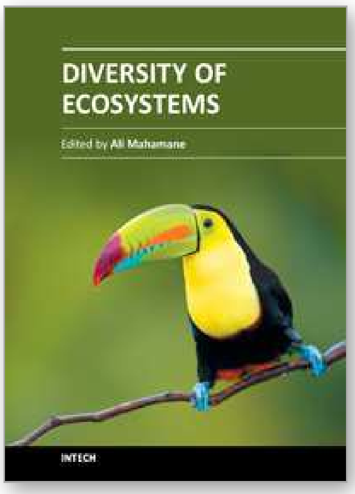

Diversity of Ecosystems
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The ecosystems present a great diversity worldwide and use various functionalities according to ecologic regions. In this new context of variability and climatic changes, these ecosystems undergo notable modifications amplified by domestic uses of which it was subjected to. Indeed the ecosystems render diverse services to humanity from their composition and structure but the tolerable levels are unknown. The preservation of these ecosystemic services needs a clear understanding of their complexity. The role of research is not only to characterise the ecosystems but also to clearly define the tolerable usage levels. Their characterisation proves to be important not only for the local populations that use it but also for the conservation of biodiversity. Hence, the measurement, management and protection of ecosystems need innovative and diverse methods. For all these reasons, the aim of this book is to bring out a general view on the function of ecosystems, modelling, sampling strategies, invading species, the response of organisms to modifications, the carbon dynamics, the mathematical models and theories that can be applied in diverse conditions.