American-Eurasian Journal of Sustainable Agriculture, 6(4): 333-343, 2012
ISSN 1995-0748

ORIGINAL ARTICLE

Ecological Characterization Of Plant Groupings Of The Herbaceous Stratum In the Djoudj National Park of Birds in Senegal

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ABSTRACT

The Djoudj Birds National Park (DBNP) is facing a threatening environmental problem. These include mainly the proliferation of invasive plants (especially herbaceous) that affect the functioning of the DBNP aquatic ecosystems which and disrupts circulation in the plan of water. Besides, an anthropic pressure increases the degradation of these areas. Facing the difficulty and the necessity to solve it, we undertook this study. At first, we used the phytosociological releves method of Braun-Blanquet to identify the various groupings of plants of the herbaceous stratum through six sites. Secondly, soil samples were taken and analyzed to determine main physical and chemical parameters influencing the development of the plant grouping. The phytosociological releves method has enabled us to identify 12 herbaceous plants grouping. Through the physical and the chemical soil components and the different ecologic factors, the herbaceous plants groupings have been characterized, showing thus the link between plants and environmental factors. Therefore, the spread of weeds that disrupt the plan of water depends partly on physical and chemical conditions of the substratum.

Key words: Djoudj Birds National Park - Plants groupings - Herbaceous stratum - Aquatic ecosystem - Plans of water - Ecological characterization.

Introduction

The Djoudj Birds National Park, located in Senegal River delta between latitude 16° 30' North and longitude 16° 10' West (Bâ *et al*., 2000), is a wetland of international interest, site of Ramsar (Scott, 1980) and a world humanity heritage of for UNESCO (Treca *et al*., 1992).

Created in 1971 and covering a surface of 16,000 ha, the DBNP gives many opportunities like many wet areas: surroundings cleansing waste water (Clough *et al*., 1983; Harbinson, 1986; Conley *et al*., 1991), source of income and subsistence (Khattabi, 1999), ecotourism due to the attractive landscape and the existence of at least 3,000 000 birds from 336 different species (Treca *et al*., 1992). Since the park was set up, the floodgate and the closing of the Diama dam in 1986 have stopped the flow of salt water coming from the stretch of the Senegal River, Djoudj, into the park. Those two achievements led to the proliferation of weeds in the water flow (*Typha domingensis* Pers., *Pistia stratiotes* L. and more recently *Salvinia molesta* D. S. Mitchell) of which the most harmful outcomes are the usual decreasing of the sunlight and the dry-up of the usual flooded areas. Numerous technical methods have been used to control the spread of weeds, among others the weeding and the biological policy. But, even though the effects of the given results are immediately efficient, they don’t seem to be obvious in the long term. In fact, these plants spread and grow whenever the favourable edaphic conditions combined as showed by researches submitted by Trochain (1940), Mitchell & Tur (1975).

We have tried through this study to show the determinism and characterization of the different groupings of plants in the herbaceous stratum of DBNP.. This study could therefore contribute to the revitalisation and the conservation process of the endangered areas as already done by some authors like Mitchell & Tur (1975), Toure *et al.* (2001), Thonnerieux (2002).

Material And Methods

Sites’ Characteristics:

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This study has been performed in six sites located in the DBNP (fig. 1). They are: the pond of Djoudj (N: 16.24.34.4 and W: 016.18.09.4), the breeding cage of pelicans (N: 16.25.02.0 and W: 016.16.04.0), the pond of Khar (N: 16.22.29.9 and W: 016.14.45.6), the pond of Gainth (N: 16.23.57.0 and W: 016.15.36.8), the pond of Debi (N: 16.29.35.2 and W: 016.16.23.1), the Grand baobab (N: 16.21.17.3 and W: 016.13.02.4). The choice of those sites was based on the gradient of humidity, one of the most determinant factors in humid area ecosystem. The pond of Djoudj and the breeding cage of pelicans are sites which are flooded all over the year whereas the ponds of Khar, of Debi and of Gainth are sites which are temporarily flooded. The Grand baobab is a dry site.

The site of study is characterized by a flat area where there are the swelling of the Senegal River which flood lakes and ponds. Concerning the climate, the northern position of Djoudj is a Sahelian domain more precisely the Sahelo-Saharian sector (Bâ *et al.*, 2000). In this area where the temperature of the year is 25°C (triplet *et al.*, 1995), we notice three seasons (figure 2):

- A humid season or rainy season (from June to October)
- A dry and cold season from (October to February)
- A dry and hot season (from February to June)

The relative humidity is inferior to 40% during the dry season and rises up to 70% during the rainy season. The potential evaporation increases from 2,200 mm for the humid part and to 560 mm for the dry part (Drijver & Marchand, 1995). It outnumbers by far the prevision of rainfalls since they are 500 mm per year (Triplet *et al.*, 1995).

The drying up of flooded zones takes place from December to mid-January when there are short falls of swelling of the river and from late March to early April later after the significant swelling of the river.

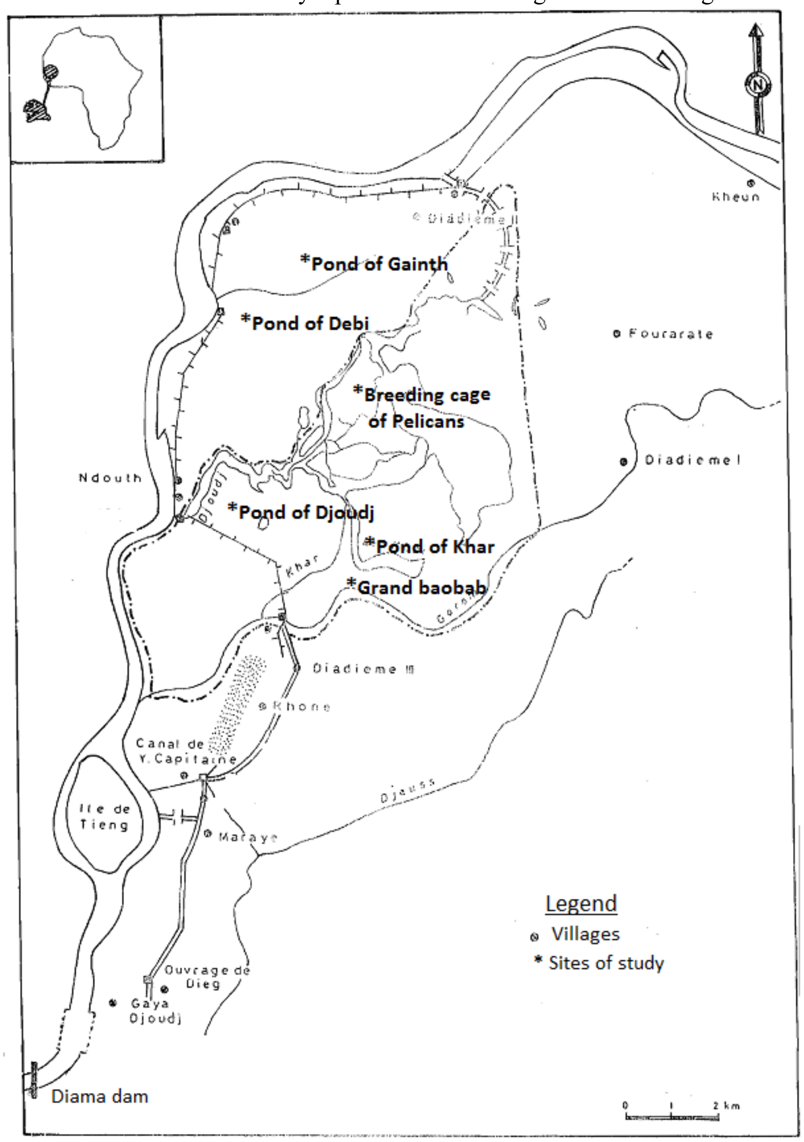

Fig. 1: Localisation of the six sites for the study

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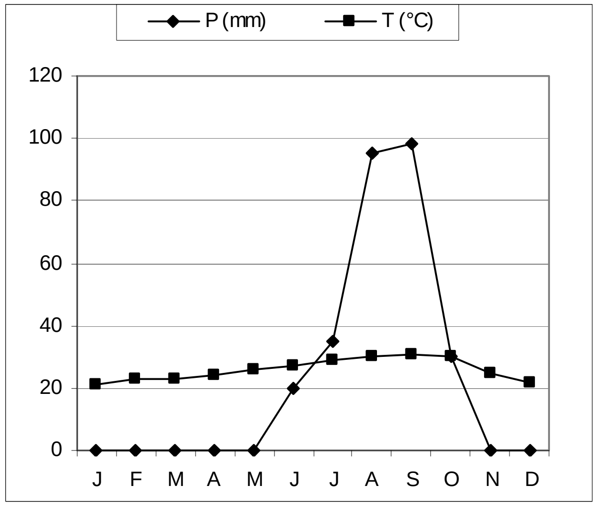

Fig. 2: Ombrothermic diagram of Saint-Louis's region from the averages over 30 years from 1961 to 1990
P = Precipitation; T = average Temperature

Data collection:

Physical and chemical data:

Soil was sampled at the first 20 cm and water was taken at surface in flooded zones. A composite soil or water of three samples was taken in each site. The analysis was carried out in the pedological laboratory in Ross-Bethio where we have explored four physical and chemical factors; soil texture, pH, salinity and Soil Absorption Ratio (SAR) was calculated to evaluate the degree of salinity. The SAR is a chemical quantity which is the mathematical expression based on the concentration of ions Na+, Ca2+ and Mg2+. Higer is the SAR; more soils contain sodium ions, which make the ground hard when it is dry and slow water absorption by plants (Clangor and Fillet, 1999).

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{1}{2}([Ca^{2+}]+[Mg^{2+}])}}$$

Floristic data:

The phytosociological releves were done to determine the different plants groupings in the areas. A total of 93 releves were set up in the six sites: 14 releves in the pond of Djoudj, 11 in the breeding cage of pelicans, 16 in the pond of Khar, 14 in the pond of Gainth, 14 in the pond of Debi,, 24 in the Grand baobab.

The Braun-Blanquet method based on the choice of areas that are floristically homogenous (Lacoste & Salanon, 1969; Ozenda, 1964) were used and the plots was at least equal to the minimal fixed area between 16 and 45 m^2 for different tropical formations according to Poissonet & Cesar (1972), Grouzis (1988), Akpo *et al.* (2003).

For each releve, the list of species were established followed by their index of abundance/dominance, of sociability according to the scale of Braun-Blanquet, their phenology and their recovery on the scale of 0 to 100 %.

The taxa were determined using *"Flora of Senegal"* (Berhaut, 1967). The synonyms have been updated and normalized (Lebrun and Stork, 1991, 1992, 1995 and 1997).

Statistical analysis

To determine the plants groupings from floristic data, a Factorial Correspondence Analysis (FCA) was performed with the software XLSTAT. For that, rare species were eliminated like many authors among them Baruch (1984), Belsky (1983), Brzeziecki (1987), Burke (2001), Cooper (1984), Hall & Swaine (1976), Hermy & Stieperaere (1981), Newbery (1991).

Concerning the analysis of the relationship between the different plants groupings and the edaphic factors, the PCA (Principal Components Analysis) were executed using the software ADE4.

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Results:

Determination and location of plants groupings:

Eighty nine herbaceous species plants were listed and divided into 33 families (table I). The FCA on the 93 achieved releves across that zone enabled us to reveal 12 groupings of plants (figures 3 to 5).

In the pond of Khar (figure 3), two groupings were opposed following the horizontal axis F1; it was the grouping of *Bolboschoenus maritimus* (L.) Palla and *Fimbristylis ferruginea* Hook. & Arn. in positive abscissas and a grouping of *Sporobolus robustus* Kunth in negative ones.

In the site of Gainth (figure 3), the grouping of *Azolla africana* Desv was in contrast with the grouping of *Sesbania rostrata* Brem & Obermfollowing the horizontal axis F1. Those two groupings were in contrast with the grouping of *Salsola baryosma* (Schult.) Dandy following the vertical axis F2 which might be a gradient of humidity.

In the site of the breeding cage of Pelicans (figure 4), besides the grouping of *Azolla africana* already indicated in the site of Gainth, we had the groupings of *Sphenoclea zeylanica* Gaertn., of *Pistia stratiotes* and of *Nymphaea lotus* L. which were all aquatic.

The site of Debi (figure 4) was a zone of *Nymphaea* with a grouping of *Nymphaea lotus* and another one of *Nymphaea micrantha* Guill. & Perr. The presence of the grouping of *Echinochloa colona* (L.) Link. were also noticed in the site.

In the site of the Grand baobab, particularly in the dry zone (figure 5), we had an important grouping of *Portulaca foliosa* Ker-Gawl. where we also found vegetal species of dry zone such as: *Enteropogon prieurii* (Kunth) Clayton (E6), *Dactyloctenium aegyptium* (L.) Willd. (E8), *Eragrostis tenella* (L.) Roem. & Schult (E28), *Cenchrus biflorus* Roxb. (E30), *Arthrocnemum indicum* (Willd.) Moq. (E43). On the edge of the lake of Gorom located in the extreme East of the Grand baobab site, we noticed the group of *Typha domingensis* Pers. that were also found in the site of the pond of Djoudj.

Characterization of the plants groupings

The PCA on the chart groupings/edaphic factors (figure 6) enabled us to highlight the relationship between herbaceous vegetation and the substratum of DBNP. Then, the figure 6 showed the correlation between some groupings and some edaphic factors of the area. The groupings of *Bolboschoenus maritimus* and *Fimbristylis ferruginea* (G2), of *Pistia stratiotes* (G4), of *Sphenoclea zeylanica* (G7), of *Echinochloa colona* (G8) and of *Salsola baryosma* (G11) were correlated to high SAR because the PCA associated the variable groupings to high values.

The groupings of *Sesbania rostrata* (G5) and of *Sporobolus robustus* (G10) were correlated to salinity rate, pH and percentage of high unrefined silt.

The groupings of *Typha domingensis* (G1) and of *Ipomoea aquatica* Forssk. (G9) were correlated to fine sand, where as the *Nymphaea* grouping would be favoured by muddy or even clayey substratum.

The groupings of *Azolla africana* (G3) and of *Portulaca foliosa* (G12) were not correlated with any edaphic factors. In fact, *Azolla africana* is floating species and it has no direct contact with soil in flooded areas whereas *Portulaca foliosa* is the characteristic species related to *Poaceae* in very cosmopolitan sahalian zones.

Table I: Recorded species and their codes

Species	Family	Codes
Bolboschenus maritimus (L.) Palla	*Cyperaceae*	E1
Sphenoclea zeylanica Gaertn.	*Campanulaceae*	E2
Salsola baryosma (Schult.) Dandy	*Chenopodiaceae*	E3
Typha domingensis Pers.	*Typhaceae*	E5
Enteropogon prieurii (Kunth) Clayton	*Poaceae*	E6
Ludwigia stolonifera (Guill. & Perr.) P.H. Raven	*Onagraceae*	E7
Dactyloctenium aegyptium (L.) Willd.	*Poaceae*	E8
Echinochloa colona (L.) Link.	*Poaceae*	E9
Azolla africana Desv.	*Azollaceae*	E10
Portulaca foliosa Ker-Gawl.	*Portulacaceae*	E11
Pistia stratiotes L.	*Araceae*	E12
Nymphaea micrantha Guill. & Perr.	*Nymphaeaceae*	E13
Fimbristylis ferruginea Hook. & Arn.	*Cyperaceae*	E14
Aeschynomene sensitiva P. Beauv.	*Fabaceae*	E15
Diplachne fusca (L.) Roem. & Schult.	*Poaceae*	E16
Sesbania rostrata Bremek. & Oberm.	*Leguminosae*	E17
Sporobolus robustus Kunth.	*Poaceae*	E18
Phragmites australis (Cav.) Steud.	*Poaceae*	E19
Ipomoea aquatica Forssk.	*Convolvulaceae*	E20
Suaeda fruticosa Forssk. ex J. F. Gmel.	*Chenopodiaceae*	E21
Nymphaea lotus L.	*Nymphaeaceae*	E22
Cressa cretica L.	*Convolvulaceae*	E23

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Nymphoïdes indica (L.) Kuntze	*Menyanthaceae*	E24
Pentatropis nivalis (J. F. Gmel.) D.V. Field & J. R. I. Wood	*Asclepiadaceae*	E25
Utricularia sp.	*Lentibulariaceae*	E26
Aristida adscensionis L.	*Poaceae*	E27
Eragrostis tenella (L.) Roem. & Schult.	*Poaceae*	E28
Limnophyton obtusifolium Miq.	*Alismataceae*	E29
Cenchrus biflorus Roxb.	*Poaceae*	E30
Lemna aequinoctialis Welwitsch	*Lemnaceae*	E31
Sesbania leptocarpa DC.	*Leguminosae*	E32
Cyperus articulatus L.	*Cyperaceae*	E35
Centrostachys aquatica (R. Br.) Wall.	*Amaranthaceae*	E36
Vossia cuspidata Griff.	*Poaceae*	E37
Sacciolepis africana C. E. Hubb. & Snowden.	*Poaceae*	E38
Eragrostis tremula (Lam) Hochst. ex Steud.	*Poaceae*	E39
Alternanthera sessilis (L.) DC.	*Amaranthaceae*	E40
Cyperus rotundus L.	*Cyperaceae*	E41
Arthrocnemum indicum (Willd.) Moq.	*Chenopodiaceae*	E43
Pycreus macrostachyos (Lam.) J. Reynal	*Cyperaceae*	E45
Heliotropium ovalifolium Forssk.	*Boraginaceae*	E46
Tephrosia sp.	*Fabaceae*	E47
Amaranthus graecizans L.	*Amaranthaceae*	E48
Oryza sp.	*Poaceae*	E49
Ipomoea coptica (L.) Roth.	*Convolvulaceae*	E50

Species	Family	Codes
Abutilon pannosum (G. Forst.) Webb	*Malvaceae*	E51
Corchorus tridens L.	*Tiliaceae*	E52
Sesuvium sesuvoides (Fenzl.) Verdc.	*Aizoaceae*	E53
Oxystelma bornouense R. Br.	*Asclepiadaceae*	E54
Portulaca oleracea L.	*Portulacaceae*	E55
Salicornia europaea L.	*Chenopodiaceae*	E57
Physalis angulata L.	*Solanaceae*	E58
Ammania sp.	*Lythraceae*	E61
Ipomoea kotschyana Hochst. ex Choisy	*Convolvulaceae*	E62
Leptadenia hastata Decne.	*Asclepiadaceae*	E63
Boerhavia sp.	*Nyctaginaceae*	E64
Nymphaea sp.	*Nymphaeaceae*	E65
Ludwigia erecta (L.) H. Hara	*Onagraceae*	E66
Achyranthes aspera L.	*Amaranthaceae*	E67
Eragrostis ciliaris ciliaris (L.) R. Br.	*Poaceae*	E68
Aerva javanica Juss.	*Amaranthaceae*	E70
Cleome sp.	*Capparidaceae*	E71
Leptadenia pyrotechnica Decne.	*Asclepiadaceae*	E72
Mollugo nudicaulis Lam.	*Molluginaceae*	E73
Neptunia oleracea Lour.	*Leguminosae*	E74
Paspalidium geminatum (Forssk.) Stapf.	*Poaceae*	E75
Melochia corchorifolia L.	*Sterculiaceae*	E76
Blutaparon vermiculare (L.) Mears	*Amaranthaceae*	E77
Sesuvium portulacastrum L.	*Aizoaceae*	E78
Corchorus olitorius L.	*Tiliaceae*	E80
Ipomoea sp.	*Convolvulaceae*	E81
Brachiaria sp.	*Poaceae*	E82
Panicum laetum Kunth.	*Poaceae*	E83
Schoenefeldia gracilis Kunth.	*Poaceae*	E84
Pergularia daemia (Forssk.) Chiov.	*Asclepiadaceae*	E85
Cistanche phelypaea (L.) Cout.	*Orobanchaceae*	E86
Eclipta prostrata L.	*Asteraceae*	E87
Cadaba farinosa Forssk.	*Capparaceae*	E88

Scoparia dulcis L.	*Scrophulariaceae*	E91
Blumea aurita DC.	*Asteraceae*	E92
Digitaria sp.	*Poaceae*	E94
Merremia hederacea Hallier F.	*Convolvulaceae*	E95
Hygrophila auriculata (Schumach.) Heine.	*Acanthaceae*	E96
Trianthema portulacastrum L.	*Aizoaceae*	E97
Euphorbia glaucophylla Poir.	*Euphorbiaceae*	E98
Tephrosia pedicellata Baker	*Leguminosae*	E99
Tribulus terrestris L.	*Zygophyllaceae*	E101
Mukia maderaspatana (L.) M. J. Roem.	*Cucurbitaceae*	E102
Echinochloa stagnina P. Beauv.	*Poaceae*	E103

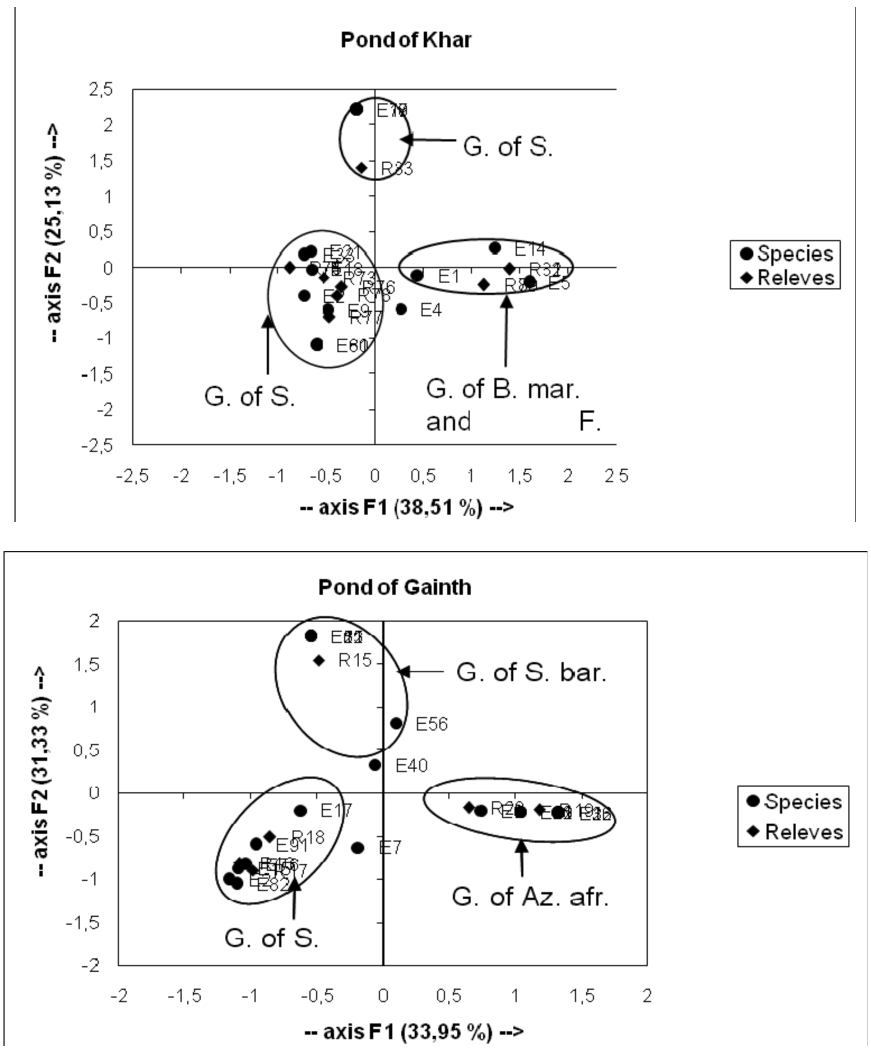

Fig. 3: FCA: diagram of releves*species in the sites of the ponds of Khar and Gainth.

Abbreviations : S. port. = *Sesuvium portulacastrum* ; B. mar. = *Bolboschoenus maritimus* ; F. fer. = *Fimbristylis ferruginea* ; S. rob. = *Sporobolus robustus* ; S. bar. = *Salsola baryosma* ; Az. afr. = *Azolla africana* ; S. ros. = *Sesbania rostrata*.

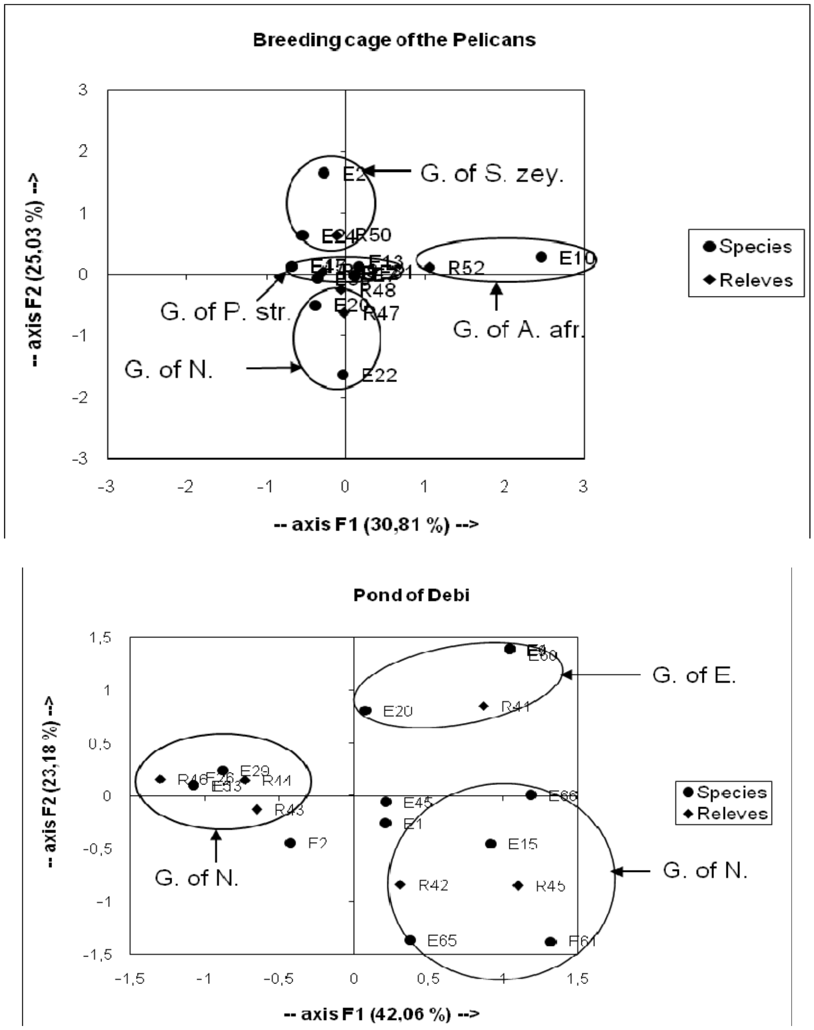

Fig. 4: FCA: diagram of releves*species in the sites of the breeding cage of Pelicans and the pond of Debi.

Abbreviations: S. zey. = *Sphenoclea zeylanica* ; N. lot. = *Nymphaea lotus*; P. str. = *Pistia stratiotes*; E. col. = *Echinochloa colona* ; N. micr. = *Nymphaea micrantha*.

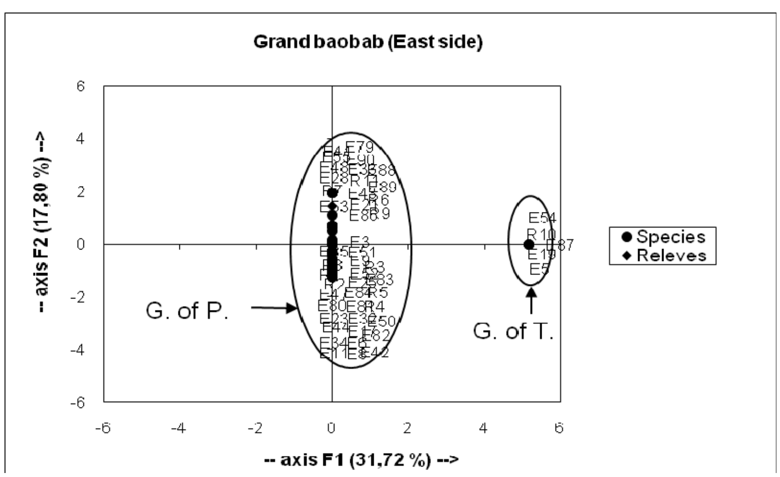

Fig. 5: FCA: diagram of releves*species in the site of the Grand baobab (East side).
Abbreviations: P. fol. = *Portulaca foliosa*.

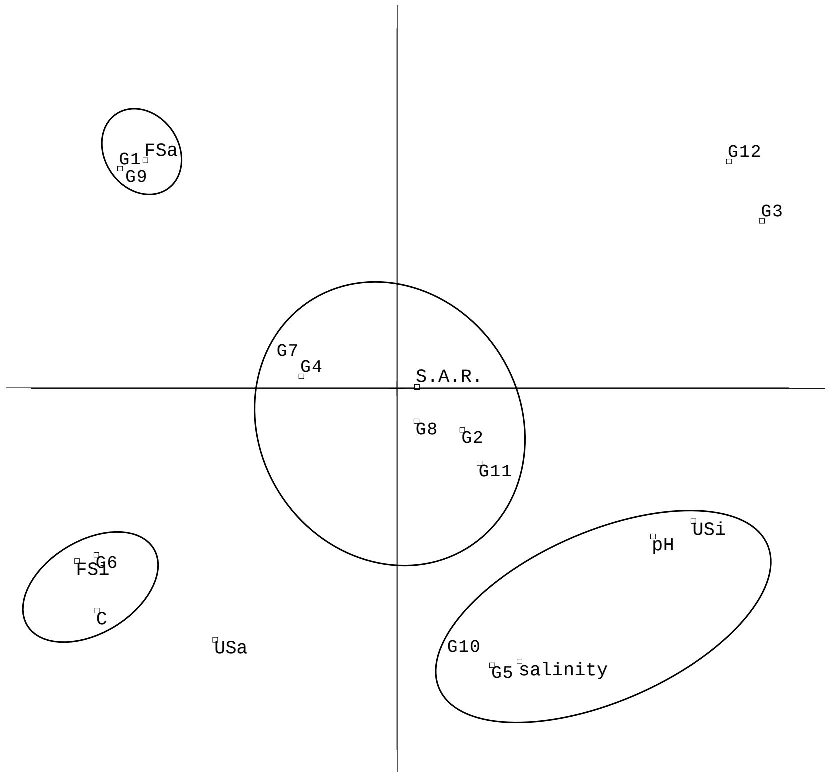

Fig. 6: PCA: Diagram showing the relationships between herbaceous groupings of plants and edaphic factors in the DBNP.

Abbreviations: G1= grouping (g.) of *Typha domingensis* ; G2= g. of *Bolboschoenus maritimus* and *Fimbristylis ferruginea* ; G3= g. of *Azolla africana* ; G4= g. of *Pistia stratiotes* ; G5= g. of *Sesbania rostrata* ; G6= g. of *Nymphaea* ; G7= g. of *Sphenoclea zeylanica* ; G8= g. of *Echinochloa colona* ; G9= g. of *Ipomoea aquatica* ; G10= g. of *Sporobolus robustus* ; G11= g. of *Salsola baryosma* ; g12= g. of *Portulaca foliosa ;* C= clay; FSi= fine silt; USi= unrefined silt; FSa= fine sand; USa= unrefined sand.

Discussion:

The 12 plants groupings found through this study can be split into three sets: a set of aquatic area groupings of plants (groupings of *Azolla africana* Desv., of *Nymphaea*), a set humid or temporarily flooded area groupings of plants (groupings of *Sesbania rostrata* Brem. & Oberm., of *Sporobolus robustus* Kunth.) and a set of dry area group of plants (grouping of *Portulaca foliosa* Ker-Gawl.). This showed that the development of herbaceous plants groupings in the DBNP could be correlated to favourable conditions probably related to edaphological factors.

The grouping of *Typha domingensis* found in the sites of Grand Baobab (East side) and Djoudj has been described by Sarr *et al*. (2001) on the banks of the Lower part of the Ferlo valley. We still come across other species such as *Phragmites australis* (Cav.) Steud. (E19), *Oxystelma bornouense* R. Br. (E54) and *Eclipta prostrata* L. (E87).

In the site of Khar, *Typha domingensis* often die when water become more and more salty, is replaced by *Bolboschoenus maritimus*. The latter, in which *Sporobolus robustus* accompanied by *Blutaparon vermiculare* (L.) Mears (E77), is of a paramount importance in the activities of the site river residents according to Toure *et al.* (2001). Then, the complex of *Sporobolus robustus* constitutes the first units fodders of the park.

The two groupings of the site of Gainth (groupings of *Azolla africana* and *Sesbania rostrata*) make the DBNP a genuine reservation of green fertilizer for rice growing according to Sing (1977), Kulasooriya & Da Silva (1977), Liu chung Chu (1979), Dao *et al.* (1979). Then, the *Azolla-Anabaena* association (nitrogen fixing symbiosis) is a strong fertilizer of rice fields whereas *Sesbanaia rostrata* is known for its great nitrogen fixative capacity (Rinaudo *et al.*, 1983).

The particularity of the site of Debi where rice is grown periphery is the presence of the grouping of *Echinochloa colona* (L.) Link., a characteristic species which is a real competitor with rice (Valverde *et al.*, 2000).

The elevated S.A.R. values noticed in groupings proved that they prefer the areas with sodium. These works were consistent with the foundings of Itoh *et al.* (1994) as well as Valverde *et al.* (2000) which have shown that the characteristic species of these groupings (*Bolboschoenus maritimus*, *Sphenoclea zeylanica*, *Echinochloa colona*) can be halophyte.

The high rate of salinity for the grouping of *Sporobolus robustus* is supported by the works of Vieillefon (1977) while the high pH has been proven by Rinaudo & Moudiongui (1985) for *Sesbania rostrata*.

This study conducted in the DBNP has enabled us to highlight the plant groupings of the herbaceous groundsheet and their main characteristics.

Some of these aquatic plant groupings hinder the functioning of hydrographic network by completely covering mar made lakes then causing their long term dry up. It's about the groupings of *Pistia stratiotes*, of *Typha domingensis*, of *Phragmites australis*, of *Nymphaea*, of *Bolboschoenus maritimus*, of *Fimbristylis ferruginea*. Those intrusive aquatic plant groupings are today a real acute problem (Mitchell, 1985): limitation of the light penetration, the increasing of the evapotranspiration, the drying up of man-made lakes. Thus through this study which has enabled us to characterize those plant groupings hindering the hydrology, it's now possible to make available means to fight against their extension which becoming more and more disturbing in the park. In the contrary, other plant groupings are of capital interest for the DBNP, namely the fodder plant groupings (example the grouping of *Sporobolus robustus*), or the groupings assimilated to green fertilizer reservation (example the grouping of *Azolla africana*). Thus, the characterization of these plant groupings could enable the improvement of their development for the river side residents of the park whose income activities are essentially based on livestock farming and agriculture.

Through this study, 12 different plant groupings have been identified with a high specific diversity. In fact, 103 species can be found in those 12 groupings. This figure is close to that announced by Noba *et al.* (2010) who have catalogued the flora of the NBDP. That's how the DBNP appears to be a site of high biodiversity because of the diversities of zones in a relatively reduced area. This study has also enabled to better understand the fragility of humid zones ecosystems, the vegetation of which is tightly linked to the variation of the physical and chemical conditions in the substratum. In fact, many zones subjected to the artificial system of inundation (closing and opening of the sluice gates, selting up barns) experience vegetation modification through the seasons. This makes more complex the functioning of the DBNP affecting at the same time the lives of all the animals and plants species. This proves that planning actions must be based on liable scientific bases which enable to minimize the damage done on the natural environment and the biodiversity; hence the need to make planning and a study of impact on the environment.

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