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ANALYSIS OF THE HERBACEOUS UNDERGROWTH OF THE WOODY SAVANNA IN THE FATHALA RESERVE, DELTA DU SALOUM NATIONAL PARK (SENEGAL)

Pavla NEŽERKOVÁ-HEJCMANOVÁ[1,*], Michal HEJCMAN[1], Abdoul Aziz CAMARA[2], Markéta ANTONÍNOVÁ[1], Vilém PAVLŮ[3], Tomáš ČERNÝ[4] and Amadou Tidian BÂ[2]

[1] Czech University of Agriculture, Kamýcká 129, Prague 6-Suchdol, 16521, Czech Republic
[2] Cheikh Anta Diop University in Dakar, Faculty of Sciences and Techniques, Department of Vegetal Biology, Dakar, Senegal
[3] Research Institute of Crop Production, Prague-Ruzyně, Grassland Research Station, Rolnická 6, 460 01 Liberec, Czech Republic
[4] Institute of Botany, Academy of Sciences of the Czech Republic, Zámek 1, 252 43 Průhonice, Czech Republic
(* Author for correspondence ; email : hejcmanova@its.czu.cz)

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ABSTRACT. — We investigated the herbaceous layer in the Fathala Reserve, a fenced area in the Delta du Saloum National Park in Senegal, in order to determine the role of the undergrowth vegetation in woody savanna. We recorded 53 plant species from 19 families in 30 herb layer relevés of 5 × 5 m. Fabaceae (22 %), Convolvulaceae (13 %), and Poaceae (11 %) were the most frequent families. On the basis of a Detrended Correspondence Analysis and a cluster analysis we distinguished 4 vegetation units in the herbaceous layer. *Andropogon gayanus* var. *bisquamulatus*, *Schizachyrium sanguineum*, and *Andropogon gayanus* (beardless, non-tufty type) were dominant in units 1, 3, and 4, respectively. Unit 2 was composed of the most ubiquitous species. In a Canonical Correspondence Analysis, habitat type (well-drained sites, moist depressions, and seasonally inundated sites) only explained 15.9% of the undergrowth vegetation variability. We concluded that only woody plants and dominant grasses represent the forming element of woodland savanna. Herbaceous plants recorded in the Fathala Reserve do not manifest any specific requirements to environmental, and particularly soil, conditions.

KEY WORDS. — *Andropogon gayanus* var. *bisquamulatus*, *Schizachyrium sanguineum*, forest herb layer, vegetation analysis, woody savanna.

Nomenclature : BERHAUT 1971-1988, VANDEN BERGHEN 1988-1991, LEBRUN & STORK 1992-1997.

INTRODUCTION

The Delta du Saloum National Park (DSNP) in central-west Senegal, created in 1976 and covering an area of 76,000 ha, is the second largest and the most recently designated national park in Senegal. The most valuable ecosystems include savannas, salines with mangroves and halophytic vegetation on islands and peninsulas. Together with adjacent areas, the national park was declared

a World Heritage Site and Biosphere Reserve in 1981, and was accepted as a RAMSAR wetland site in 1984 because of its relatively well-preserved natural ecosystems and possible restoration of degraded ones.

The Fathala Forest represents the *terra firme* of the DSNP. In spite of DSNP's high biodiversity and the early activity of naturalists in Senegal in colonial times (e.g., ADANSON 1757, BRUNNER 1840a, 1840b, CHEVALIER 1920, 1933), the Fathala Forest has paradoxically received relatively more attention only recently. A first study of the vegetation of the Fathala Forest was carried out by TROCHAIN (1940) as part of the vegetation description in Senegal, followed by SANOKHO (1977) and DUPUY & VERSCHUREN (1982). FREDERIKSEN & LAWESSON (1992) and LAWESSON (1995) described the Fathala Forest in their ecological and phytogeographical study of the woody vegetation in Senegal. NIANG (2001) studied annual dynamics and the regeneration of 5 selected important woody species. However, the most complex study of the vegetation in the Fathala Forest was conducted by Lykke and her collaborators. She studied the structure and floristic composition of different vegetation types (LYKKE 1994, LYKKE & SAMBOU 1998), described the remnant gallery forest in the area (LYKKE 1996, LYKKE & GOUDIABY 1999), perceived changes in the vegetation (LYKKE 1998) and identified priorities in the conservation of the area's vegetation (LYKKE 2000). Regarding the predominant role of trees and shrubs in the ecosystem, botanical investigation has so far been focused mostly on the tree and shrub layers.

In spite of its protection, the Fathala Forest is still being exploited by local people, especially for the harvest of wild fruits, honey, leaves and bark, and for illegal exploitation of timber that represents an important source of energy and construction material. The Fathala Forest also faces problems with fires, especially with respect to the regeneration of woody species (NIANG 2001). Every year the National Park administration sets prescribed, so called "early fires", as soon as possible after the rainy season, e.g., in November. Finally, overgrazing by livestock has a strong impact on the environment. This causes degradation of the ecosystem (LYKKE 1996) and a poor fauna remains (DUPUY & VERSCHUREN 1982). To regenerate the original vegetation and to reconstitute game populations, the National Park administration permitted fencing of the forest in 2000.

With respect to the change in management of the fenced forest and the introduction of game, we considered it important to fill the existing gap in knowledge regarding the undergrowth vegetation of Fathala Forest. The aim of our study was, therefore, to describe the herbaceous layer in the reserve.

MATERIAL AND METHODS

STUDY AREA

The Fathala Forest Reserve is a fenced part (2000 ha) of the Fathala Forest in the Delta du Saloum National Park in western Senegal (13°39' N and 16°27' W). The area belongs to the transition zone between phytochoria of the Sudanian regional centre of endemism and the Guinea-Congolian/Sudanian transition zone (WHITE 1983). Mean annual precipitation is 839 mm (Banjul meteorological station, LYKKE 1996). The major dry season lasts from November to May, while the major rainy season spans from July to October. Mean day temperature is 31.2°C in May and 26°C in January (Kaolack meteorological station, NIANG 2001). Soils are tropical ferric luvisols and nitosols on plateaus, and weakly developed gleysols in the lower valley (FAO-UNESCO 1977).

The reserve was fenced in 2000. There is some native game as bushbuck (*Tragelaphus scriptus*), warthog (*Phacochoerus africanus*), patas monkey *(Erythrocebus patas*) ; and several introduced game species, such as 28 individuals of roan antelope (*Hippotragus equinuus*), 2 giraffes (*Giraffa camelopardalis* ; sub-adult male and female), 10 common elands (*Taurotragus oryx*), and a couple of white rhinoceroses (*Ceratotherium simum*). More animals are planned to be introduced in the near future. The area is relatively flat with dry plateaus, passing into shallow humid valleys, such as "Mare of the Dragon". The principal aspects of the vegetation are wooded grassland, woodland, and transitional woodland on the plateaus, with *Combretum nigricans-Prosopis africana* woodland, *Bombax costatum-Pterocarpus erinaceus* woodland, *Piliostigma thonningii-Dichrostachys cinerea* thicket, in humid valleys turning into *Erythrophleum suaveolens-Dialium guineense* gallery forests (LAWESSON 1995).

Data collection

The present study was carried out in November 2003, at the end of the rainy season, before bush fires were set. Collection of vegetation data was focused on forbs and grasses, because trees and shrubs have already been widely studied in the area (Lykke 1996, Lykke & Sambou 1998, Lykke & Goudiaby 1999, Niang 2001). We used a simple random sampling over the fenced area (2000 ha) and collected 30 phytosociological relevés of 5 × 5 m (25 m^2). In each plot we recorded all plant species in the herb layer, the coverage of individual species, and the habitat type. We distinguished between three types of habitat : well-drained habitat (WD) that was already dry, moist depressions (MD) where moisture remained in the soil longer after the wet season, and seasonally inundated habitats (SI), which were part of the "Mare du Dragon" valley and where stagnant water was present for a part of the year (Fig. 1).

Data analysis

Detrended Correspondence Analysis (DCA) was used to evaluate the multivariate vegetation data in view of the fact that the data set was relatively heterogeneous with a long gradient length (Lepš & Šmilauer 2003). Canonical Correspondence Analysis (CCA) together with a Monte Carlo permutation test (n = 999) was used to evaluate the relationship between vegetation data and habitat types. All these analyses were performed in the canoco package and visualised in ordination diagrams (ter Braak & Šmilauer 2002).

In addition to the ordination methods, relevés were subjected to a cluster analysis (syn-tax 2000 software, Podani 2001). Chord distance and ß-flexible clustering method (with ß = -0.25, which is close to Ward's method, see Sneath & Sokal 1973) was used. Species abundance data were transformed to an ordinal scale prior to analysis. This transformation made the results of the clustering algorithm more robust, since contributions of dominants were attenuated relatively to those of rare species. On the basis of this analysis, vegetation relevés were pooled into a synoptic table in the juice software (Tichý 2002). We used the *Phi*-coefficient as a measure of species fidelity to distinguish diagnostic species in the respective groups (Chytrý *et al*. 2002). The threshold-value of the *Phi*-coefficient was set to 30.

RESULTS AND DISCUSSION

We identified 53 herbaceous species from 19 families. The most frequent families were Fabaceae (22%), Convolvulaceae (13%), and Poaceae (11%). The DCA and cluster analyses differentiated the herbaceous cover in the Fathala Reserve in four distinct vegetation units labelled Groups 1 to 4 (Fig. 2 and Fig. 3). The synoptic table based on fidelity values shows distinguished vegetation units with their diagnostic species (see Appendix 1). Group 1 represents the vegetation unit with the dominant, more than 2 metres tall grass *Andropogon gayanus* var. *bisquamulatus*, present in all sampled plots. Its vigorous culms and robust tufts provided appropriate support for voluble species, especially from the genus *Ipomoea*. Other dominants in the group were *Tephrosia bracteolata* and *T. linearis*. Group 2 consists of many species that occur in small numbers without any particular dominants. Therefore, this group is rather negatively differentiated from other units : it has no species with sufficient diagnostic power (i.e., species in categories of constancy IV and V, which correspond to species frequencies of 60-80% and 80-100%). On the other hand, Group 2 has a higher number of unique, rare species. The only exception is *Hyptis suaveolens*, but regardless of its high frequency it is also more often present in two other groups. Therefore, this species is considered to be a transgressive one, with no specific diagnostic value. Group 3 consists of species with a more variable occurrence in the plots : *Corchorus olitorius, Cyperus* sp., *Euphorbia hirta, Ipomoea nil, I. pes-tigridis, Vernonia galamensis* strictly occurred in one to three plots, while other species (e.g., *Alternanthera nodiflora, Cassia obtusifolia, Celosia trigyna, Corchorus aestuans,* and *Pandiaka angustifolia*) were more widespread. Nevertheless, all species of Group 3 were associated with the dominant, 1.5 m tall grass *Schizachyrium sanguineum,* with conspicuous preference to seasonally inundated habitats, especially in the 'Mare du Dragon' valley. Group 4 only included 3 relevés, represented by the dominant *Andropogon gayanus* (beardless, non-tufty type) and accompanied by *Alysicarpus ovalifolius, Cassia mimosoides, Crotalaria glaucoides,* and *C. goreensis.*

The CCA analysis revealed a significant but weak relation between the vegetation units and

FIG. 1. — Three representative habitat types in Fathala Reserve : (from top to bottom) well-drained habitat (WD), moist depression habitat (MD), and seasonally inundated habitat (SI).

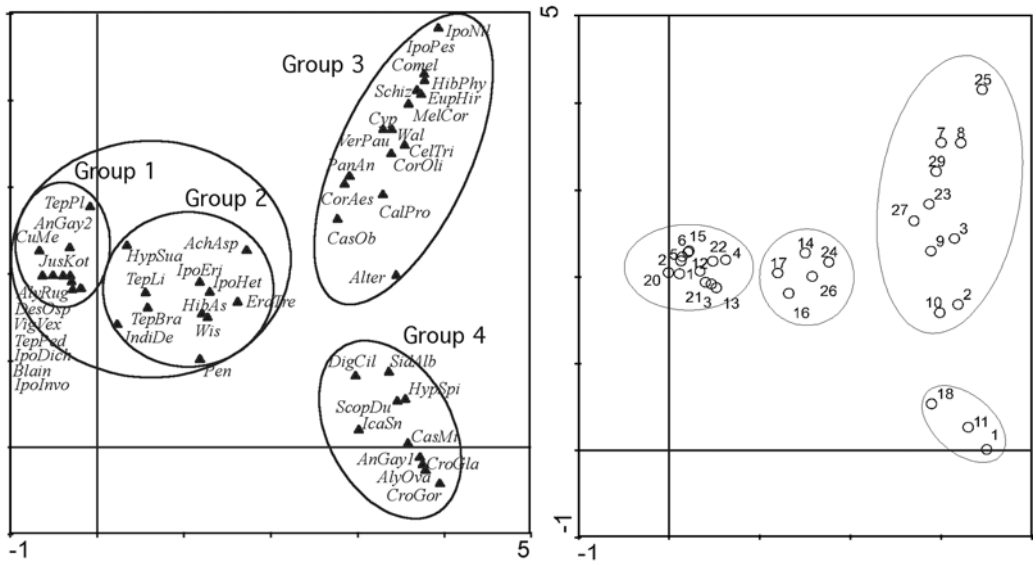

FIG. 2. — Ordination diagrams showing the results of DCA analysis. Species and plots are presented separately. Abbreviations : AchAsp - *Achyranthes aspera*, Alter - *Alternanthera nodiflora*, AlyOva - *Alysicarpus ovalifolius*, AlyRug - *A. rugosus*, AnGay1 - *Andropogon gayanus*, AnGay2 - *A. gayanus* var. *bisquamulatus*, Blain - *Blainvillea gayana*, CasMi - *Cassia mimosoides*, CasOb - *C. obtusifolia*, CelTri - *Celosia trigyna*, Comel - *Commelina* spp., CorAes - *Corchorus aestuans*, CorOli - *C. olitorius*, CroGla - *Crotalaria glaucoides*, CroGor - *C. goreensis*, CuMe - *Cucumis melo* var. *agrestis*, Cyp - *Cyperus* sp., DesOsp - *Desmodium ospriostreblum*, DigCil - *Digitaria ciliaris*, EraTre - *Eragrostis tremula*, EupHir - *Euphorbia hirta*, HibAs - *Hibiscus asper*, HibPhy - *H. physaloides*, HypSpi - *Hyptis spicigera*, HypSua - *H. suaveolens*, IcaSn - *Icacina oliviformis*, IndiDe - *Indigofera dendroides*, IpoDich - *Ipomoea dichroa*, IpoEri - *I. eriocarpa*, IpoInvo - *I. involucrata*, IpoNil - *I. nil*, IpoPes - *I. pes-tigridis*, IpoHet - *I. heterotricha*, JusKot - *Justicia ladanoides*, MelCor - *Melochia corcholifolia*, MonCil - *Monechma ciliatum*, PanAn - *Pandiaka angustifolia*, Pen - *Pennisetum* sp., Schiz - *Schizachyrium sanguineum*, ScopDu - *Scoparia dulcis*, SidAlb - *Sida alba*, TepBra - *Tephrosia bracteolata*, TepLi - *T. linearis*, TepPed - *T. pedicillata*, TepPl - *T. platycarpa*, VerPau - *Vernonia galamensis*, VigVex - *Vigna vexillata*, Wal - *Waltheria indica*, Wis - *Wissadula amplissima*. Numbers in the scatter plot denote relevés numbers.

habitat type, because it only explained 15.9% of variability ($F = 2.56$, $P = 0.002$). Vegetation units 1 and 2 displayed heterogeneity in terms of habitat preference, whereas vegetation units 3 and 4 were bound to seasonally inundated and well-drained habitats, respectively. The *Andropogon gayanus* (beardless, non-tufty type)-dominated vegetation unit grew on well-drained (gravel) soils where no evident soil moisture remained after the rainy season, while the *Andropogon gayanus* var. *bisquamulatus* and *Schizachyrium sanguineum*-dominated swards (units 1 and 3) occupied moist habitats. Seasonally inundated areas covered by *Schizachyrium sanguineum*, which occurred in the "Mare de Dragon" valley, were dominated also by a low sward of forbs and often bare areas. Vegetation unit 2 comprised species without any particular preference to neither well-drained nor moist habitats, and, in this sense, was ubiquitous and widespread.

The dominant species recorded in our study, *Schizachyrium sanguineum* and both varieties of *Andropogon gayanus* are common grasses of woody savannas in West Africa. *Andropogon gayanus* var. *bisquamulatus* is considered a significant grass that plays a dual role in plant succession. It is a prominent fore-runner in plant succession with other tall grasses of developing primary woodland and forest, but it is also abundant in a variety of secondary sites on disturbed, sandy soils including roads, footpaths and old fallow lands (INNES 1977). This description corresponds

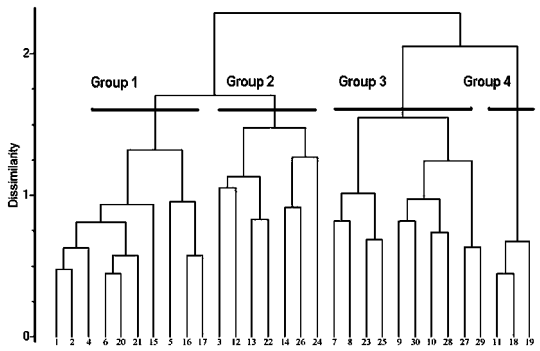

FIG. 3. — Dendrogram based on cluster analysis. Numerals denote relevé numbers.

to the habitats of the Fathala Forest. We were not able to determine the other type of *Andropogon gayanus*, which is beardless on the culms and does not form tufts, because there were no spikelets, the main character distinguishing the varieties of this species at the time of the relevés. Plants of the beardless, non-tufty type were already dried up, evidently more than var. *bisquamulatus*. *Andropogon gayanus* was also described as being one of the most abundant dominant species in Niokolo Koba National Park (SARR 1997). In general, it is abundant in woody savannas, on fallow lands, and on sandy and silty, temporarily inundated soils, and has a wide distribution range (VANDEN BERGHEN 1991). *Schizachyrium sanguineum* is a variable, coarse, erect, reddish-purple perennial bunchgrass that can reach up to 3 m in height. It is widely distributed in a great variety of habitats, ranging from dry rocky mountain soils to deep, seasonally water–logged, marshy alluvium, and is usually a member of the fire pro-climax grass and tree savanna communities (INNES 1977). Its ability to occupy a wide range of habitats was also mentioned by VANDEN BERGHEN (1991). SARR (1997), in his study of grasses, identified an individual group dominated by *Schizachyrium sanguineum*, especially on plateaus with gravel soils in the Niokolo Koba National Park. This species is also an accompanying species in many other plant communities (SARR 1997). In the Fathala Reserve, it occurred in seasonally inundated areas, and was the dominant grass in the 'Mare du Dragon' valley. All these dominant grasses are highly palatable not only to cattle (INNES 1977), but also to wildlife (AL OGOUMRABE 2002). The area is from this point of view appropriate and perspective for wildlife ranching activities.

To date, authors studying the area have focused mostly on woody vegetation. For instance, TROCHAIN (1940) listed 29 plant species in Fathala, almost all of which were trees or shrubs. SANOKHO (1977) published a list of 205 plant species from 6 different sites in the Fathala Forest ; one site was situated in the area of the present Fathala Reserve, where he recorded 122 woody and herbaceous species. Sanokho's study did not include ecological factors, although the author shortly commented on the anthropogenic factor. LYKKE (1994) provided the most recent and extensive study of the vegetation in the Fathala Forest, including the herb layer. She already recorded 34 of the 53 species identified in our study and mentioned the same families (Poaceae, Fabaceae, Convolvulaceae) as dominating in the area. She described the herbaceous stratum in relation to topography and human impact. Her results, showing preferential species defined according to topography, do not correspond with our results.

The importance of topographic, edaphic and rainfall gradients in the classification of vegetation units in Senegal has been widely reported (e.g., TROCHAIN 1940, RAYNAL 1963, CORNET & POUPON 1977, THIAM 1986-1987, DE WOLF 1998). However, at the small scale of a 2000 ha area we did not record any strong effect of environmental conditions. Moreover, most studies focused on woody vegetation and the herbaceous layer is, because of its patchiness and short growing season, often omitted, not only in the Fathala region (e.g., LYKKE 1998, LYKKE & SAMBOU 1998, NIANG 2001), but also in other parts of Senegal (e.g., LAWESSON 1995, MADSEN *et al.* 1996, GOUDIABY *et al.* 2001).

We can conclude that only woody plants and dominant grasses represent the forming element of the woodland savanna ecosystem, whereas the herb layer does not play any particular role. Herbaceous plants recorded in the Fathala

Reserve do not manifest any specific requirements regarding soil conditions. Hence, the undergrowth vegetation in the reserve can hardly be used for a detailed classification of woody savanna.

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APPENDIX 1

Synoptic table of 30 phytosociological relevés in Fathala Reserve (in percentages). Diagnostic species in the respective groups are those with a phi-coefficient of fidelity higher than 30 (CHYTRÝ *et al*. 2002). Abbreviations : transgr. = species concentrated in the respective group, but with a probable optimum in another vegetation type, not sampled here

Group number	1	2	3	4
Number of relevés	10	7	10	3
Group 1				
Andropogon gayanus var. *bisquamulatus*	100	43	10	.
Tephrosia bracteolata	90	57	10	33
Tephrosia linearis	70	14	10	33
Indigofera dendroides	50	14	10	33
Group 1 + 2				
Ipomaea eriocarpa	80	100	40	33
Group 1 + 4				
Hibiscus asper	80	14	30	100
Ipomaea heterotricha (transgr.)	90	57	30	67
Group 2				
Ipomaea dichroa	.	29	.	.
Achyranthes aspera	.	57	30	.
Commelina sp.	.	29	10	.
Justitia ladanoides	.	14	.	.
Ipomaea nil	.	14	.	.
Desmodium ospriostreblum	.	14	.	.
Ipomaea pestigridis	.	14	.	.
Blainvillea guyana	.	14	.	.
Hyptis suaveolens (transgr.)	40	71	40	.
Group 3				
Schizachyrium sanguineum	.	.	80	.
Celosia trigyna	.	.	60	.
Alternanthera nodiflora	.	14	50	.
Walteria indica	.	.	30	.
Sida alba	10	14	50	.
Corchorus aestuans	.	29	50	.
Cassia obtusifolia (transgr.)	50	29	80	.
Corchorus olitorius	.	.	20	.
Group 3 + 4				
Andropogon gayanus	.	14	50	100
Group 4				
Alysicarpus ovalifolius	.	.	.	100
Crotalaria glaucoides	.	.	.	33
Crotalaria goreensis	.	.	.	33
Cassia mimosoides	.	14	10	67
Icacina oliviformis	20	.	.	67

Common species				
Pennisetum sp.	80	57	40	100
Digitaria ciliaris	10	14	10	33
Pandiaka angustifolia	80	43	50	67
Wissadula amplissima	60	71	50	33
Accompanying (rare) species				
Tephrosia platycarpa	30	.	10	.
Vigna vexillata	30	14	.	.
Ipomoea involucrata	10	14	.	.
Alysicarpus rugosus	10	.	.	.
Cucumis melo var. *agrostis*	10	.	.	.
Tephrosia pedicillata	20	14	.	.
Cyperus sp.	.	.	10	.
Vernonia galamensis	.	.	10	.
Euphorbia hirta	.	.	10	.
Hyptis spicigera	.	.	10	.
Eragrostis tremula	.	.	10	.
Scoparia dulcis	.	.	10	.
Melochia corcholifolia	10	.	20	.
Hibiscus physaloides	.	14	10	.

Legend
Group 1 : relevés F1, F2, F4-F6, F15-17, F20-21.
Group 2 : relevés F3, F12-14, F22, F24, F26.
Group 3 : relevés F7-10, F23, F25, F27-30.
Group 4 : relevés F11, F18-19.