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REGULAR PAPER

Diversity and conservation value of Gabon's savanna and inselberg open vegetation: an initial gap analysis

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Background and aims – Eighty per cent of Gabon's territory is covered by forest with most species inventory work focused on these areas. However, herbaceous open vegetation types are abundant in this country and can be found in savannas on the coast, in the centre and in the south, and on inselbergs. The species diversity patterns of these habitats remain largely unexplored yet are targeted for both conservation and development. Here, we evaluate the floristic diversity of savannas in Gabon, their affinities with the inselberg open vegetation, and their contribution to the national park system in Gabon, which is currently undergoing a gap analysis. We then use a case study from the Batéké Plateaux to demonstrate species rarity in a single savanna.
Materials and methods – Species presence in the grassy formations of the savannas in Loango, Lopé, Pongara, and Plateaux Batéké national parks and in Kum inselberg is compared using ordination and clustering based on a similarity matrix (Sørensen index). For the Batéké Plateaux savannas, the species rarity and distributions are assessed using Star ratings.
Key results – The species in the open herbaceous vegetation in Gabon account for at least 11% of the total flora of the country (508 species out of 4,710). Except for the coastal savannas, all sites are highly dissimilar in floristic composition (Sørensen index 0.065–0.26) and no dominant savanna type occurs within the dataset. The inselberg site is the most dissimilar and constitutes a separate vegetation unit. Most savanna species of the Batéké Plateaux area are widely distributed, but not weedy. A few are extremely rare and are linked with moist habitats, substrate, and fire occurrence. Our results show the diversity and the conservation value of open, herbaceous habitats. Currently, the Gabonese National Park network is partly protecting the savanna and inselberg vegetation. However, several areas remain un-assessed and merit further exploration.

Keywords – Conservation, diversity, floristics, inselberg, protected area, savanna.

INTRODUCTION

The flora of Gabon is estimated to comprise as many as 7,000 species (Sosef et al. 2006) with most of the country being covered by forest (estimated at 80%). The highest species diversity and number of endemics are thought to be found in the forested montane areas (Sosef 1994) and along the coastal plane of Gabon (Ikabanga 2010, Ngagnia Ndjabounda 2010). While several studies have focused on forest diversity patterns (Hardy & Senterre 2007, Parmentier et al. 2007), few have considered open areas such as savannas. Collections from these areas continue to be of low density, and specialists working on the Central African flora are surprised that common herbaceous savanna species have not yet been recorded in Gabon (pers. comm.: S. Phillips, Kew Gardens, Richmond, UK and J. van der Maesen, Wageningen University, the Netherlands). Indeed, grassy formations in Central Africa are perceived to contain only widespread species, which has led botanists to devote less time to inventories of savannas, sometimes only spending a single day in the field and using the literature to supplement their collec-

tions (e.g. Cable & Cheek 1998). However, given a lack of time spent collecting in this habitat, the 'wide-spread species' assumption may not be correct. Furthermore, the existing information has only marginally been used for comparative studies exploring the diversity patterns and suggesting conservation measures. As such, it is difficult to understand the conservation value of Gabon's open, herbaceous vegetation, and whether it is sufficiently conserved in the protected area system. This is an important concept to understand as there are currently efforts both to conserve (through creating new protected areas) and to transform (through planting oil palm) savanna areas in Gabon.

Currently, Gabon's protected area system is undergoing a gap analysis to justify current areas and identify new ones that would complement Gabon's protected area network to ensure that it provides adequate coverage of the country's habitat and species diversity (e.g. Margules & Pressey 2000). These studies include work on bird, mammal, reptile, endemic plants, and a habitat analysis. This paper contributes to the open habitat analysis.

Development is also planned for some savanna areas of Gabon: in the form of oil palm plantations. Despite oil palm having been an active industry in Central Africa since the colonial period (e.g. Coquery-Vidrovitch 1987, Lynn 1989), an increase in production in foreseen in Gabon. In the coming years, some 200,000 ha of Gabon will be planted, with a focus on the southern savanna areas of Mouila, Ngounie, Nyanga and Tchibanga (Présidence de la République Gabonaise 2010). The question then is, why conserve or develop these open, herbaceous areas?

Koechlin (1962) described Gabon's savannas according to species composition and dominance of graminoid and woody species and then classified them into three categories: coastal, enclosed interior and vast interior savannas. White (1983) deemed these grasslands to be mostly 'secondary' but also containing some small, edaphic savannas. He indicated that the secondary grasslands fringing the Guineo-Congolian forest "show considerable local variation in floristic composition, but most of their constituent species are widespread and occur both north and south of the equator". His species list included tree and grass species, but provided no list of forbs. A full assessment of the floristic diversity of these savannas, including forbs, has never been conducted, though it has been proposed by others (Dauby 2007, Harris et al. in press). In recent years, several protected areas in Gabon encompassing savannas representative of the three types recognized in Koechlin's classification have been inventoried, including: Loango and Pongara National Parks on the coast; La Lopé National Park's large enclosed savanna in the interior; and the Plateaux Batéké's vast continental interior savannas.

The most similar open natural habitat to savannas in Gabon are those found on inselbergs (a German term for ''islands hills''). Inselbergs are rocky outcrops standing out from encircling plains as isolated hills or groups of hills. Many inselbergs embedded in the rain forest are partially covered with open vegetation including natural grassland and herbaceous fringes (Parmentier et al. 2005). Several studies on inselberg vegetation in Gabon, Equatorial Guinea and Cameroon have been conducted in the last decade (Reitsma et al. 1992, Ngok Banak 2005, Parmentier & Müller 2006, Parmentier et al. 2006a, 2006b).

The creation of protected areas in Gabon began during the colonial era but was formalised under the Gabonese administration starting in the early 1960s with the recognition of a series of hunting reserves (Wilks 1990). Wilks (1990) proposed new areas for protection, including the savanna areas of Ozouri (coastal lakes area) and the Batéké Plateaux around Lékoni. He also mentioned two savanna areas in south-western Gabon that were then classified as 'Réserves Naturelles' but that have since been declassified, viz. Kouri and Ndende. Prior to the establishment of thirteen new national parks (NPs) in Gabon in 2002, gap analyses indicated that the protected area system was not representative of the country's biodiversity and habitats; the forest-savanna mosaic was considered to be under-represented and of ecological importance for conservation (Doumenge et al. 2001, 2003b). Other sites have since been proposed, including two for the forest-savanna mosaic at Okandja (northern Batéké Plateaux) and Fouari (southern Tchibanga forest-savanna mosaic) (Doumenge et al. 2003a). The current protected area network of Gabon includes thirteen national parks and several protected areas, of which eight that contain areas of savanna: Batéké Plateaux NP, La Lopé NP, Pongara NP, Loango NP, Mayumba NP, Moukalaba-Doudou NP, Arboretum de Raponda Walker, and the Wonga Wongue Presidential Hunting Reserve. Only one contains inselbergs (Minkébé NP).

Botanists continue to place national floras within a global context by citing numbers of species and rates of endemism (e.g. Davis et al. 2009). Such comparisons help the scientific and conservation communities to identify diverse areas and gaps in their knowledge, thereby orienting future collecting and conservation efforts (Sosef et al. 2006). However, these accounts usually do not take into consideration the global distribution of taxa. The use of Star ratings makes it possible to evaluate taxa (and the communities in which they occur) based on their distribution range, and has been used in Cameroon (Cable & Cheek 1998, Tchouto et al. 2006), Gabon (Sosef et al. 2004), Ghana (Hawthorne & Abu Juam 1995) and Central America (Gordon et al. 2004). Nearly every previously published approach using this system has, however, focused on forest communities; this paper presents its first proper publication for herbaceous vegetation.

Both savannas and inselbergs contain herbaceous vegetation, however, the similarity between the inselberg and the savanna floras has not been formally tested and their relative contribution to species and habitat conservation in Gabon has not been analysed. We present here the first floristic comparison of the open herbaceous vegetation of Gabon, asking five questions: (1) what is the overall contribution of these species to Gabon's floristic diversity, (2) how does species composition differ amongst geographic areas, (3) are inselbergs grassland savanna islands? (4), do some savannas contain globally rare species? and (5) what is the contribution of these floras to Gabon's national park system?

Table 1 – Summary of study site characteristics.

Site	GPS coordinates	Rainfall (mm per year)	Altitude (m)	Species in each grassy, open formation	Total number of collections (specimens from all habitats)	References
Batéké Plateaux NP	2°07'S 14°03'E	2,000–2,890	400–700	175	~ 1,725	Bout 2006, Walters 2010
Kum inselberg	1°50'N 11°38'E	1,843	740	68	347	Parmentier et al. 2006a, 2006b, Parmentier & Müller 2006
Loango NP	1°50'S 9°20'E	2,000–2,363	0–100	136	~ 1,954	Harris et al. in press
Lopé NP	00°12'S 11°36'E	1,500	100–700	217	> 2,500	Korte 2007, Leal 2004, McPherson et al. (unpubl. res., Missouri Botanical Garden, St. Louis, USA)
Pongara NP	00°16'N 9°19'E	2,000–3,100	0–40	85	586	Dauby et al. 2008

STUDY SITES

The savannas of four National Parks and the grassy formation in one inselberg in Gabon were chosen for this analysis: savannas of Loango and Pongara on the coast, La Lopé and the Kum inselberg in the centre and north, and the Batéké Plateaux in the south-east (fig. 1). Gabon is located on the Equator and has one long dry season (June–September) during which anthropogenic and sometimes natural fire is prevalent in the savannas; there is a long rainy season (October–May), punctuated by one to two small dry seasons (December–March). In these mesic savannas, there is a mixture of trees (reproducing via post-fire re-sprouting rather than from seed), herbs, and C_4 grasses (eg. Ratnam et al. 2011). The study sites receive 1,500–3,100 mm of rainfall per year and are located between elevations of 0–740 m (table 1). On the inselberg, due to shallow soils, environmental conditions vary from very dry, with high temperatures and high levels of evapotranspiration, to very humid where water flows and accumulate (Parmentier & Müller 2006). Given that there are no existing estimates of the size of the study areas and that there is no accurate vegetation map reliable for all study areas in order to use a GIS to calculate these areas, we include the 'total number of collections' as a measure of collection effort of each of the study areas and so an estimation of size and completeness of the floristic lists compared.

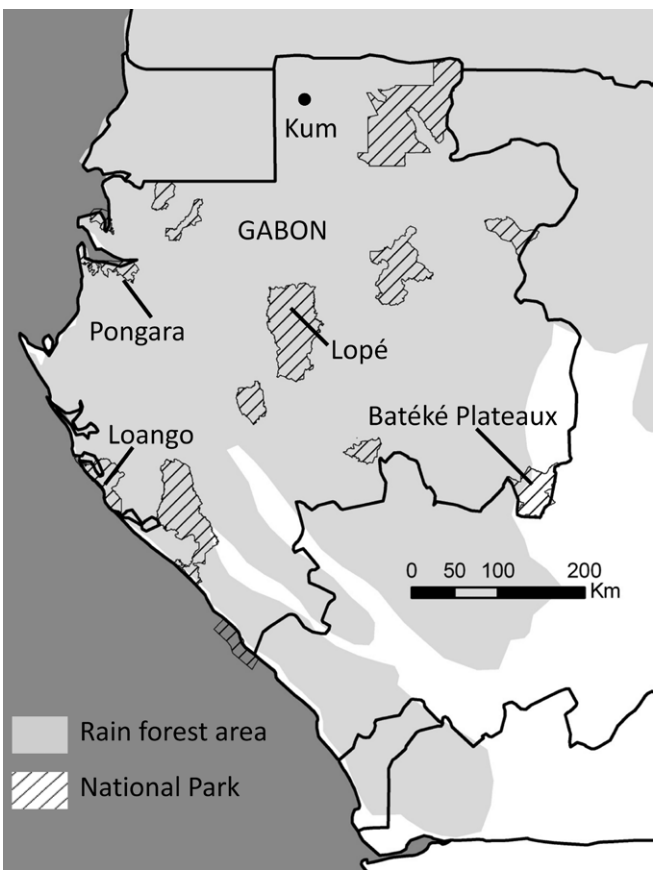

Figure 1 – Location of the 5 study sites in Gabon (West Central Africa): four savanna areas and one inselberg (Koum).

Despite the debate over the use of the word 'savanna' to describe African herbaceous formations which seeks to categorise them according to the percentage of woody cover (see Lowry et al. 1997, White 1983), these formations in Gabon vary in cover and height of vegetation within short distances making the utilisation of this classification difficult without good woody cover estimations or precise collection notes using the same system (see Walters 2010). For those following White's classification, the herbaceous formations described in this paper correspond to shrubland, grassland, wooded grassland, transition woodland, herbaceous freshwater swamp and aquatic vegetation types (as described in Lowry et al. 1997, White 1983). Here we use the word savanna for all of these categories where (1) graminoid species are continuous, interrupted by trees and shrubs, (2) fires occur, and (3) growth is closely associated with alternating wet and dry seasons (Bourliere & Hadley 1983). We do not consider roadside vegetation or saline herbaceous formations in this work. All of the savannas under study here have been

Table 2 – Star ratings detailed by range of distribution (Hawthorne 1996).

Star	Estimated range in no. degree squares in Africa	Notes
Black	1.6 ± 0.5	Rare globally and rare in Gabon. Urgent conservation attention required.
Gold	7.8 ± 3.8	Rather rare globally and locally. Conservation attention required.
Blue	24.5 ± 12.6	Widespread globally but rare in Gabon; or widespread in Gabon but rare globally. Some conservation attention from Gabon required.
Green	69.2 ± 49.8	No conservation concern.

formed under previous climatic conditions which favoured the expansion of savannas (Delègue et al. 2001, Maley 2001). Many of these savannas are part of the country's cultural heritage, containing sites of archaeological and anthropological value (Oslisy 2001, Dupré & Pinçon 1997, Walters 2010). As a prime example, La Lopé NP is classified as a mixed biological and cultural UNESCO World Heritage site.

METHODS

Fieldwork and dataset composition

The analyses in this paper are the result of data obtained from fieldwork by GW in the Batéké Plateaux conducted between 2000 and 2009, by GW in Loango National Park in 2005 and by IP in the Kum Inselberg area in 1999 and 2002. For other sites, we used data from the checklists of Pongara (Dauby et al. 2008) and La Lopé (McPherson & White 1995). Specimen identifications were made at BR, K, LBV, MO, and WAG.

The taxa from the open habitats of each site were extracted from the species lists, and names were standardized according to the Gabon Checklist (Sosef et al. 2006). The data from the different sites were pooled into a global list of 508 taxa that was used to calculate the proportion of the species in the Gabon Checklist that are present in the savanna and in the inselberg sites included in our study.

Floristic similarity of all sites

A cluster analysis was conducted on the species lists of each of the five sites (Group average, Sørensen similarity index) using *Primer6*© (Clarke et al. 2006). Species similarity between site pairs, *i* and *j*, was estimated using the Sørensen similarity index C_{ij} (Sørensen 1948) because it is regarded as one of the most effective for comparing presence/absence data between samples (Southwood & Henderson 2000). The index was calculated as follows:

$$C_{ij} = \frac{2a}{2a + b + c}$$

where *a* is the total number of species present in both samples, *b* the number of species present only in sample *i* and *c* the number of species present only in sample *j*. Clustering was made using the group average method (Clarke 1993). An ordination analysis of the five sites was then completed using Non-metric Multi-Dimensional Scaling (NMDS) using *Primer6*© based on the Sørensen similarity matrix. Options used for NMDS were: Kruskal stress formula = 1; minimum stress = 0.01; number of restarts = 100. The hierarchical classification obtained by Clustering was represented on the ordination diagram using the 10 and 20% similarity cut. The geographical distance between pairs of sites was calculated. Correlation was then used to infer the relationship between the Sørensen similarity index and inter-site distance.

Evaluation of species distribution and rarity in the Batéké Plateaux

The distribution for each species of the Batéké Plateaux list was obtained from botanical references such as national or regional floras (e.g. the *Flore du Gabon*) and on occasion from the original species description. Only species that were fully identified were used thus removing fourteen species from the list. Using the Star rating system and the same degree-square assignments proposed in Hawthorne & Abu-Juam (1995), these distributions were then categorised. The four main Stars in the Star rating are summarized in table 2.

RESULTS

Floristic similarity of all sites

The species of the five study sites represent 10.8% of the currently known flora of Gabon (508 of 4,710 species), with savanna species alone representing 9.6% (453 species) of the flora. The floristic composition is highly different among all sites, with Sørensen similarity indices ranging between 0.065 and 0.26. Only one species (*Sauvagesia erecta* L.) is shared among the five sites, and just eighteen species have been recorded at four sites. The inselberg site has the most distinct species composition and the two coastal savannas are the most similar to one another, although even these still exhibit a high level of dissimilarity (fig. 2).

There is only a weak correlation of floristic similarity with inter-site distance when all sites are considered (r^2 = 0.08). However, when Kum inselberg is excluded (leaving only savanna sites), the correlation value slightly increases (r^2 = 0.28).

Evaluation of species distribution and rarity in the Batéké Plateaux

A total of 183 herbaceous and woody species have been recorded from the savannas of the Batéké Plateaux. Forty-seven of these species (26%) are rare in Gabon, known only from Haut Ogooué Province, although all of them have distributions extending beyond the borders of the country. When considering the global rarity of these species, 89% correspond to the Green Star category, i.e. they are widely distributed; 6% were classified as blue species, 1% were as-

Table 3 – Batéké Plateaux globally rare species.

Family	Species	Star	Factors apparently limiting distribution
Apocynaceae	*Asclepias occidentalis* Goyder	Gold	Post-fire emergence; Kalahari Sands Specialist (Goyder 2009)
Cyperaceae	*Scleria baroni-clarkei* De Wild	Gold	Unknown (Piérart 1953)
Eriocaulaceae	*Syngonanthus ngoweensis* Lecomte	Black	Moist Savanna (Kimpouni 1992)
Eriocaulaceae	*Syngonanthus schlechteri* Ruhl.	Gold	Moist Savanna (Kimpouni 1992)
Fabaceae	*Eriosema batekense* van der Maesen & G.M.Walters	Black	Kalahari Sands Specialist (van der Maesen & Walters 2011)
Verbenaceae	New species	Gold	Kalahari Sands Specialist (P. Bamps, Meise, Belgium, pers. comm.)

signed a Gold star, and another 1% a Black Star. The distribution of these rare Black and Gold species appears to be limited by edaphic conditions (related to the presence of the Kalahari Sands substrate), periodic inundation, or burning (table 3). All star ratings and the data matrix can be found in the online supplement (electronic appendix).

DISCUSSION

This analysis suggests that despite the fact that open herbaceous vegetation is present on inselbergs (grasslands and herbaceous fringes, Parmentier & Müller 2006), the flora of these inselberg micro-habitats is very different from the savanna flora. Open inselbergs and savanna floras clearly represent separate vegetation units.

Inselberg are not savanna islands in the rain forest

Very low floristic similarity between savannas and the open herbaceous inselberg vegetation of the Kum inselberg reinforces the results of earlier studies in which inselberg vegetation in Gabon, Equatorial Guinea and Cameroon was described in detail (Parmentier & Müller 2006, Parmentier et al. 2006b). The flora of the inselberg grasslands and herbaceous fringes is a different mix of species from the rain forest, ruderal and secondary forest elements, strictly saxicolous taxa and species restricted to the inselberg habitat (e.g. *Epistemma rupestre* H.Huber, *Euphorbia letestui* J.Raynal, *Plectranthus inselbergi* B.J.Pollard & A.J.Paton, *Tricarpelema africanum* Faden). Inselbergs surrounded by rain forest show insular properties, with species similarity between sites declining with distance (Parmentier et al. 2005). At a local scale, species composition is best explained by the edaphic conditions along the forest-inselberg ecotone, corresponding to an array of ecological niches (Parmentier 2003), but at the regional scale, theses ecological niches are occupied by different species. These sub-regional species pools probably result from the history of past vegetation changes due to climatic fluctuations (Parmentier & Hardy 2009). The inclusion of floristic data from other inselberg sites in Gabon (of which there are many) would therefore certainly contribute additional species to the overall list of taxa from open grassy vegetation in Gabon.

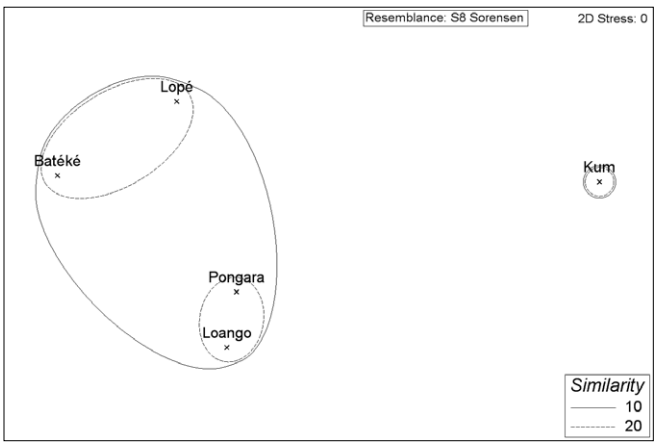

Figure 2 – Ordination of the five sites using Non-metric Multi-Dimensional Scaling obtained from a Sørensen similarity matrix. Lines delineate groups obtained by clustering and applying a cut of 10 and 20% of similarity.

Floristic similarity among savannas

This analysis shows that, as indicated by White (1983), the savanna floras of Guineo-Congolia are floristically varied, even when the forb component is considered. The dissimilarity in composition of the sites studied here is probably related to a variety of factors including substrate age and type, savanna age, phytogeography, and inter-site distance. Since our sample size is not sufficient to elucidate cause, we will just note some observations for further investigation.

Both edaphic and climatic factors have shaped savanna floras in Gabon (Droissart 2009, Delègue et al. 2001, Maley 2001, Delire et al. 2008). Limited seed dispersal may also explain species dissimilarity between sites, as it did for inselbergs. While the correlation for similarity of species among the four savanna sites was linked to inter-site distance, it was weak; this relationship might become strengthened with the addition of more study sites.

Given the floristic dissimilarity, it should also be noted that the woody dominants and edge colonisers in each savanna are also different thus requiring locally adapted management approaches (Mouandza-Membo & Walters 2007, Jeffery et al. 2011). Recent studies suggest that the savannas in each of these areas are being encroached by forest (Delègue

et al. 2001, Leal et al. 2007, Nana 2005), a common occurrence also in Cameroon (Mitchard et al. 2009), and the Republic of Congo (Dowsett & Dowsett-Lemaire 1991, Favier et al. 2004, Schwartz et al. 1996). This phenomenon is particularly relevant to protected areas established to preserve savanna, as in the case of La Lopé (Palla 2011, Walters 2010).

Evaluation of species distribution and rarity in the Batéké Plateaux

Vegetation work in the Batéké Plateaux savannas began in earnest in the 1970s (e.g. Makany 1972, 1976). However these studies were conducted prior to the discovery or description of most of the area's endemic species, many descriptions of which included historic and new collections (eg. Goyder 2009, van der Maesen & Walters 2011, Kimpouni 1992). This study takes into account these recent discoveries. The results presented here indicate that savanna vegetation contains six globally rare species which are classified as Black or Gold Stars. Moreover, the six globally rare species in the Batéké Plateaux are those restricted to either the Kalahari sands substrate or moist savannas, or among those subjected to fire; these species can be added to the list of those that are endemic to the southern Kalahari sands (e.g. Walters et al. 2006).

The rarity of some species in the Batéké Plateaux savannas suggests that more collection effort should be made in these habitats. This result is similar to observations for the coastal, wet savannas in Equatorial Guinea (Phillips 2000), for both the Niari and Plateaux Batéké savannas in Gabon (Descoings 1975), and for the Loango savannas (Harris et al. in press). The discovery of these species comes through collection and identification efforts in savanna areas by specialists in herbaceous floras; indeed, recently more than thirty new records for the flora of Gabon have come from savannas, including the discovery of rare species (Harris et al. in press, Walters et al. 2011).

Star Ratings were not available for all species in all sites in this study meaning that the associated Genetic Heat Index could not be calculated. Future work in using the Star Rating system to generate Genetic Heat Indices will be helpful in assessing the relative value of areas for conservation (e.g. Tchouto et al 2006). It is suggested that future work focus on assigning Star rating for the species in these and other areas.

Current protection of savanna and inselberg sites

Representation of a nation's biological diversity is one reason for which protected areas are created (Margules & Pressey 2000). Many assessments of Gabon's protected area system have focused only on evaluating the species diversity of forests; however, savannas and inselbergs also deserve conservation attention. Recent work on assessing the floristic similarity of both forest and savanna taxa from four national parks (Minkébé, Monts de Cristal, Loango, and Batéké Plateaux) in Gabon has found that the floras of these parks are extremely different (Wieringa & Sosef 2011). Our study produced similar results for the open, herbaceous vegetation in the five sites in this study; indeed, with the present level of analysis, it is impossible to identify any dominant savanna types in Gabon, if they exist. These studies suggest that the savanna and forest floras currently protected are different and contribute to representing Gabon's flora; as such, their protection is justified. However sufficient data to analyse all savannas and inselbergs in Gabon are lacking as a result of low collection density in other sites (Sosef 2010). While the savannas studied here have been well prospected, three key savanna areas in Gabon need further collections in order to be assessed: Tchibanga, Franceville-Boumango, and Wonga Wongue. This includes some of those savannas currently proposed for oil palm plantations.

Most of the country's inselbergs are found in the continental forest that extends east of the Monts de Cristal towards Minkébé NP. Only a group of inselbergs in Minkébé NP are currently protected, while the site examined in this study remains unprotected. With the exception of a single study (Ngok Banak 2005), almost nothing has been published about the inselberg flora of the Medouneu area, which harbours hundreds of inselbergs, as indicated by an aerial survey conducted in 2001. The conservation value of the inselbergs in this area was recognized by USAID's Central African Regional Program for the Environment when defining the Monte Alén and Monts de Cristal inselbergs Landscape. However, most of these sites are located in logging concessions and lack any conservation status. We therefore suggest that inselbergs should be a priority in management plans submitted by forest companies to the Gabonese government.

The open, herbaceous areas of Gabon are variously being conserved or developed; however, our results indicate diversity and potential rarity of some species in these areas. This underscores the importance of study before action. However, until better specimen coverage is made available through additional inventory work across all sites, the data for analysing aspects of the flora, including the geographic distribution of herbaceous and woody floristic diversity, will remain limited.

SUPPLEMENTARY DATA

Supplementary data are available at *Plant Ecology and Evolution*, Supplementary Data Site (http://www.ingentaconnect.com/content/botbel/plecevo/supp-data), and consist of a list of star ratings and a species matrix used for ordination analysis (pdf format).

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REFERENCES

Bourliere F., Hadley M. (1983) Present-day savannas: an overview. In: Bourliere F. (ed.) Ecosystems of the world 13: tropical savannas: 1–17. Amsterdam, Elsevier Scientific Publishing Company.

Bout N. (2006) Suivi écologique des grands mammifères et de l'impact humain: Rapport Final. Wildlife Conservation Society-Gabon. Projet Plateaux Batéké.

Cable S., Cheek M. (1998) The plants of Mt Cameroon: a conservation checklist. Kew, Royal Botanic Gardens.

Clarke K.R. (1993) Non-parametric multivariate analysis of changes in community structure. Australian Journal of Ecology 18:117–143. http://dx.doi.org/10.1111/j.1442-9993.1993.tb00438.x

Clarke K.R., Gorley R.N. (2006) PRIMER v6: User Manual/Tutorial. Plymouth, PRIMER-E.

Coquery-Vidrovitch C. (1987) Rébellions et révolutions au Zaire. Tome 1. Paris, Editions L'Harmattan.

Dauby G. (2007) Etude floristique et biogeographique du Parc National de la Pongara. MSc thesis, Université Libre de Bruxelles, Brussels, Belgium.

Dauby G., Leal M., Stévart T. (2008) Vascular plant checklist of the Pongara National Park. Systematics and Geography of Plants 78: 155–216.

Davis A., Govaerts R., Bridson D.M., Ruhsam M., Moat J., Brummit N.A. (2009) A global assessment of distribution, diversity, endemism, and taxonomic effort in Rubiaceae. Annals of the Missouri Botanical Garden 96: 68–78. http://dx.doi.org/10.3417/2006205

Delègue M.-A., Fuhr M., Schwartz D., Marriotti A., Nasi R. (2001) Recent origin of a large part of the forest cover in the Gabon coastal area based on stable carbon isotope data. Oecologia 129: 106–113.

Delire C., Ngomanda A., Jolly D. (2008) Possible impacts of 21st century climate on vegetation in Central and West Africa. Global and Planetary Change 64: 3–15. http://dx.doi.org/10.1016/j.gloplacha.2008.01.008

Descoings B. (1975) Les grandes régions naturelles du Congo. Candollea 30: 91–120.

Doumenge C., Yuste J.-E.G., Gartlan S., Langrand O., Ndinga A. (2001) Conservation de la biodiversité forestière en Afrique Centrale Atlantique: le réseau d'aires protégées est-il adéquat? Bois et Forêts des Tropiques 268: 5–27.

Doumenge C., Ndinga A., Nembot T.F., Tchanou Z., Ondo V.M., Nze N.O., Bourobou-Bourobou H., Ngoye A. (2003a) Conservation de la biodiversité en Afrique centrale atlantique II. Identification d'un réseau de sites critiques. Bois et Forêts des Tropiques 276: 43–58.

Doumenge C., Nembot T.F., Tchanou Z., Ondo V.M., Nze N.O., Bourobou-Bourobou H., Ngoye A. (2003b) Conservation de la biodiversité forestière en Afrique centrale atlantique III. Gestion et priorités d'investissement dans les sites critiques. Bois et Forêts des Tropiques 277: 53–67.

Dowsett R.J., Dowsett-Lemaire F. (1991) Flore et faune du Bassin du Kouilou (Congo) et leur exploitation. Liège, Tauraco Press.

Droissart V. (2009) Etude taxonomique et biogéographique des plantes endémiques d'Afrique centrale atlantique: le cas des Orchidaceae. PhD. Thesis, Université Libre de Bruxelles, Brussels, Belgium.

Dupré M.-C., Pinçon B. (1997) Métallurgie et politique en Afrique Centrale: deux milles ans de vestiges sur les Plateaux Batéké Gabon, Congo, Zaire. Paris, Editions Kathala.

Favier C., de Namur C., Dubois M.-A. (2004) Forest progression modes in littoral Congo, Central Atlantic Africa. Journal of Biogeography 31: 1445–1461. http://dx.doi.org/10.1111/j.1365-2699.2004.01094.x

Gordon J.E., Hawthorne W.D., Reyes-García A., Sandoval G., Barrance A.J. (2004) Assessing landscapes: a case study of tree and shrub diversity in the seasonally dry tropical forests of Oaxaca, Mexico and southern Honduras. Biological Conservation 117: 429–442. http://dx.doi.org/10.1016/j.biocon.2003.08.011

Goyder D. (2009) A synopsis of Asclepias (Apocynaceae: Asclepiadoideae) in tropical Africa. Kew Bulletin 64: 369–399. http://dx.doi.org/10.1007/s12225-009-9133-3

Hardy O., Senterre B. (2007) Characterizing the phylogenetic structure of communities by an additive partitioning of phylogenetic diversity. Journal of Ecology 95: 493–506. http://dx.doi.org/10.1111/j.1365-2745.2007.01222.x

Harris D.J., Armstrong K., Walters G., Wilks C., Mouandza-Mbembo J.C., Niangadouma R., Weiringa J.J., Breteler F.(in press) Phytogeographical analysis and checklist of the vascular plants of Loango National Park, Gabon. Plant Ecology and Evolution.

Hawthorne W.D., Abu-Juam M. (1995) Forest protection in Ghana. Gland, Switzerland, IUCN.

Hawthorne W.D. (1996) Holes and sums of parts in Ghanaian forest: regeneration scale and sustainable use. Proceedings of the Royal Society of Edinburgh (B) 104: 75–176.

Ikabanga D.U. (2010) Analyse de l'endémisme des plantes vasculaires du Gabon. M.S. 1 thesis, Université des Sciences et Techniques de Masuku, Franceville, Gabon.

Jeffery K.J., Palla F., Walters G., Mendoza I., Abernethy K.A., White L.J.T. (2011) Fire management in a changing landscape: a case study from Lopé National Park, Gabon. Proceedings 5th International Wildland Fire Conference, Sun City, South Africa. Available at: ftp://ftp2.fs.fed.us/incoming/wo_fam/Wildfire2011%20Conference.SouthAfrica/Wildfire2011%20e-programme/Programme%20contents/Wildfire2011%20Conference%20Papers/Wildfire2011%20Conference%20Papers/Conference%20Papers/Florence%20Palla_Jeffery.pdf [accessed 25 Nov. 2011]

Kimpouni V. (1992) Les *Eriocaulaceae* du Congo. Fragmenta Floristica et Geobotanica Polonica 37(1): 127–145.

Koechlin J. (1962) Graminées. Flore du Gabon 5.

Korte L.M. (2007) The spatial and social organisation of forest buffalo (Syncerus caffer nanus) at Lopé National Park, Gabon. Ph.D. thesis, Michigan State University, East Lansing, USA.

Leal M., Nguema D., Mounoumoulossi E., Bissiemou P. (2007) The biodiversity of Bai Djobo. Libreville, Missouri Botanical Garden report to the Rufford Foundation.

Leal M. (2004) The African rain forest during the Last Glacial Maximum, an archipelago of forests in a sea of grass. Ph.D thesis, Wageningen University, Wageningen, The Netherlands.

Lowry P.P., Schatz G., Phillipson P. (1997) The classification of natural and anthropogenic vegetation in Madagascar. In: Goodman S., Patterson B.D. (eds) Natural change and human impacts in Madagascar): 93–123. Washington, D.C., Smithsonian Institution Press.

Lynn M. (1989) From sail to steam: The impact of the steamship services on the British palm oil trade with West Africa, 1850–1890. Journal of African History 30: 227–245. http://dx.doi.org/10.1017/S0021853700024117

Makany L. (1972) Une tourbière tropicale à sphaignes sur les contreforts des Plateaux Batéké (Congo). Annales de l'Université de Brazzaville 8C: 93–104.

Makany L (1976) Végétation des Plateaux Teke (Congo). Ph.D. thesis, Université de Brazzaville, Brazzaville, Republic of Congo.

Maley J. (2001) La destruction catastrophique des forêts d'Afrique centrale survenue il y a environ 2500 ans exerce encore une influence majeure sur la répartition actuelle des formations végétales. Systematics and Geography of Plants 71: 777–796.

Margules C.R., Pressey R.L. (2000) Systematic conservation planning. Nature 405: 243–253. http://dx.doi.org/10.1038/35012251

McPherson G., White L.J.T. (1995) Checklist of Lopé-Okanda Reserve, Gabon, Africa [online]. Available at http://www.mobot.org/mobot/research/Lopé_int.shtml [accessed 29 Oct. 2010].

Mitchard E.T.A., Saatchi S.S., Gerard F.F., Lewis S.L., Meir P. (2009) Measuring woody encroachment along a forest-savanna boundary in Central Africa. Earth Interactions 13: 1–29. http://dx.doi.org/10.1175/2009EI278.1

Mouandza-Mbembo J.C., Walters G. (2007) Etude ecologique sur Chrysobalanus icaco L. subsp. icaco et Chrysobalanus icaco L. subsp. atacoriensis dans la partie nord du Parc National de Loango, Gabon.In: XVIIIth AETFAT Congress, 26 February–2 March 2007, Yaoundé, Cameroon: 153. Yaoundé, Herbier National du Cameroun.

Nana A. (2005) Apport de la télédétection et du SIG pour le suivi de la dynamique forêt/savane ? Cas au Gabon du parc national de la Lopé (1982–1996). DESS thesis, Ecole Nationale des Eaux et Forêts, Cap Esterias, Gabon.

Ngagnia Ndjabounda E.C. (2010) Analyse descriptive des plantes endémiques du Gabon. M.S.1 thesis, Université des Sciences et Techniques de Masuku, Franceville, Gabon.

Ngok Banak L. (2005) Diversité végétale des inselbergs et des dalles rocheuses du nord Gabon. Ph.D. thesis, Université Libre de Bruxelles, Brussels, Belgium.

Oslisy R. (2001) The history of human settlement in the Middle OgoouéValley (Gabon): Implications for the environment. In: Weber B., White L.J.T, Vedder A., Naughton-Trevis L. (eds) African Rain Forest Ecology and Conservation: an interdisciplinary perspective: 101–118. New Haven, Yale University Press.

Palla F., Picard N., Abernethy K., Ukizintambara T., White E.C., Riéra B., Rudant J.-P., White L. (2011) Structural and floristic typology of the forests in the forest-savanna mosaic of the Lopé National Park, Gabon. Plant Ecology and Evolution. 144: 255–266. http://dx.doi.org/10.5091/plecevo.2011.478

Parmentier I. (2003) Study of the vegetation composition in three inselbergs from Continental Equatorial Guinea (Western central Africa): effects of site, soil factors and position relative to the lower or upper forest fringe. Belgian Journal of Botany 136:63–72.

Parmentier I., Stévart T., Hardy O. (2005) The inselberg flora of Atlantic Central Africa. I. Determinants of species assemblages. Journal of Biogeography 32: 685–696. http://dx.doi.org/10.1111/j.1365-2699.2004.01243.x

Parmentier I., Müller J.V. (2006) Grasslands and herbaceous fringes on inselbergs in Atlantic central Africa. Phytocoenologia 36: 565–597. http://dx.doi.org/10.1127/0340-269X/2006/0036-0565

Parmentier I., Oumorou M., Pauwels L., Lejoly J. (2006a) Comparison of the ecology and distribution of the Poaceae flora on inselbergs embbeded in savannah (Benin) or in rain forests (western central Africa). Belgian Journal of Botany 1398: 65–77.

Parmentier I., Oumorou M., Porembski S., Lejoly J., Decocq G. (2006b) Ecology, distribution, and classification of xeric monocotyledonous mats on inselbergs in West Africa and Atlantic central Africa. Phytocoenologia 36: 547–564. http://dx.doi.org/10.1127/0340-269X/2006/0036-0547

Parmentier I., Senterre B., Whittaker R. J., A.T.D.N., Alonso A., Balinga M.P., Bakayoko A., Bongers F., Chatelain C., Comiskey J., Cortay R., Djuikouo Kamden M.-N., Doucet J., Gautier L., Hawthorne W.D., Issembe Y.A., Kouamé F.N., Kouka L.A., Leal M., Lejoly J., Lewis S.L., Nusbaumer L., Parren M.P.E., Peh K.S. H., Phillips O.L., Sheil D., Sonké B., Sosef M.S.M., Sunderland T.C.H., Stropp J., ter Steege H., Swaine M. D., Tchouto M.G.P., van Gemerden B.S., van Valkenburg J.L.C.H., Wöll H. (2007) The odd man out? Might climate explain the lower tree α-diversity of African rain forests relative to Amazonian rain forests? Journal of Ecology 95: 1058–1071. http://dx.doi.org/10.1111/j.1365-2745.2007.01273.x

Parmentier I., Hardy O.J. (2009) The impact of ecological differentiation and dispersal limitation on species turnover and phylogenetic structure of inselberg's plant communities. Ecography 32: 613–622. http://dx.doi.org/10.1111/j.1600-0587.2008.05697.x

Phillips S. (2000) Two more new species of Eriocaulon from West Africa. Kew Bulletin 55: 195–202. http://dx.doi.org/10.2307/4117776

Piérart P. (1953) Les espèces du genre Scleria Berg. du Congo Belge et du. Ruanda-Urundi. Lejeunia, Mém. 13: 5–68.

Présidence de la République Gabonaise (2010) Les accords et partenariats stratégiques et structurants: la marche vers l'Emergence. Communiqué de Presse officiel. Libreville, Gabon. Available at: http://www.presidentalibongo.com/presse/communiques/les-accords-et-partenariats-strategiques-et-structurants-la-marche-vers-l-emergen [accessed 2 Nov. 2011]

Ratnam J., Bond W.J., Fensham R.J., Hoffmann W.A., Archibald S., Lehmann C.E.R., Anderson M.T., Higgins S.I., Sankaran M. (2011). When is a 'forest' a savanna, and why does it matter? Global Ecology and Biogeography 20: 653–60. http://dx.doi.org/10.1111/j.1466-8238.2010.00634.x

Reitsma J.M., Louis A.M., Floret J.J. (1992) Flore et végétation des inselbergs et dalles rocheuses: première étude au Gabon. Bulletin du Museum national d'Histoire Naturelle de Paris, 4è sér., section B, Adansonia 14: 73–97.

Schwartz D., de Foresta H., Marriotti A., Balesdent J., Massimba J.P., Girardin C. (1996) Present dynamics of the savanna-forest boundary in the Congolese Mayombe: a pedological, botanical and isotopic (^{13}C and ^{14}C) study. Oecologia 106: 516–524. http://dx.doi.org/10.1007/BF00329710

Sørensen T.A. (1948) A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analyses of the vegetation on Danish commons. Kongelige Danske Videnskabernes Selskabs Biologiske Skrifter 5: 1–34.

Sosef M.S.M. (1994) Refuge begonias: taxonomy, phylogeny and historical biogeography of Begonia sect. Loasibegonia and sect. Scutobegonia in relation to glacial rain forest refuges in Africa. Wageningen Agricultural University Papers 94: 1–306.

Sosef M.S.M., Issembe Y.A., Bourobou-Bourobou H., Koopman W.J.M. (2004) Botanical diversity of the pleistocene forest refuge: Monts Doudou. Memoirs of the California Academy of Sciences 28: 17–91.

Sosef M.S.M., Wieringa J.J., Jongkind C.C.H., Achoundong G., Issembe Y.A., Bedigian D., van der Berg R.G., Breteler F., Cheek M., Degreef J., Faden R., Goldblatt P., van der Maesen L.J.G., Ngok Banak L., Niangadouma R., Nzabi T., Nziengui B., Rogers Z. S., Stévart T., van Valkenburg J.L.C.H., Walters G., de Wilde J.J.F.E. (2006) Check-list des plantes vasculaires du Gabon. Scripta Botanica Belgica 35.

Sosef M.S.M. (2010) Progress on the Flore du Gabon. In: Jeannoda V.H., Razafimandimbison S., De Block P. (eds) XIXth AETFAT Congress, Madagascar, 25–30 April 2010, Abstracts. Scripta Botanica Belgica 46: 465. Meise, National Botanic Garden of Belgium.

Southwood T.R.E., Henderson P.A. (2000) Ecological Methods. 3rd Ed. London, Blackwell Publishing Ltd.

Tchouto M.G.P., Yemefack M., de Boer W.F., de Wilde J.J.F.E., van der Maesen L.J.G., Cleef A.M. (2006) Biodiversity hotspots and conservation priorities in the Campo-Ma'an rain forests, Cameroon. Biodiversity and Conservation 15: 1219–1252. http://dx.doi.org/10.1007/s10531-005-0768-6

van der Maesen L.J.G., Walters G. (2011) Novitates gabonenses 77: A new Eriosema from Gabon and adjacent Congo. Plant Ecology and Evolution 144: 101–105. http://dx.doi.org/10.5091/plecevo.2011.494

Walters G. (2010) The Land Chief's embers: ethnobotany of Batéké fire regimes, savanna vegetation and resource use in Gabon. PhD thesis, University College of London, London, United Kingdom.

Walters G., Dauby G., Stévart T., Niangadouma R., Lachenaud O. (2011) Novitates gabonenses 80: additions and corrections to the Flora of Gabon. Edinburgh Journal of Botany 68: 423–442.

Walters G., Bradley A., Niangadouma R. (2006) Floristics of Gabon's Batéké Plateaux: Guineo-Congolian plants on Kalahari Sands. In: Ghazanfar S.A., Beentje H.J. (eds) Taxonomy and ecology of African plants, their conservation and sustainable use: 259–266. Kew, Royal Botanic Gardens.

Wieringa J., Sosef M.S.M. (2011) The applicability of Relative Floristic Resemblance to evaluate the conservation value of protected areas. Plant Ecology and Evolution 144: 242–248. http://dx.doi.org/10.5091/plecevo.2011.588

White F. (1983) The vegetation of Africa: a descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa. Paris, UNESCO.

Wilks C. (1990) La conservation des écosystemes forestiers du Gabon. Gland, Switzerland, IUCN.

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