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The applicability of Relative Floristic Resemblance to evaluate the conservation value of protected areas

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Aims – It is important to know the contribution of a protected area to global conservation. A new method called 'Relative Floristic Resemblance' that uses databased and georeferenced herbarium specimens, is introduced. Its usefulness and applicability to assess the conservation value of protected areas is addressed.
Method – This is tested using the collection database of the National Herbarium of The Netherlands (NHN) and species checklists of Gabon and of five national parks in Gabon and the Central African Republic.
Results – The method proved to be a valuable instrument for revealing this conservation value, and can even, though with caution, be used for areas where a species list is still incomplete. We conclude that the four Gabonese parks are well chosen and each clearly conserve a different and comparatively unique flora. The Dzanga-Sangha Reserve captures a flora that ranges across a considerable part of the Congo Basin.

Key words – Conservation, protected areas, Relative Floristic Resemblance, biodiversity, flora, collection database, Gabon, Central African Republic, Dzanga-Sangha.

INTRODUCTION

Previously, national parks and other protected areas in Africa were generally created to conserve the fauna in these places, or to put it more bluntly, only large mammals mattered. The last decade, however, has shown a growing importance of the botanical composition and floral values when new protected areas are being created or existing ones are evaluated or extended. In many cases (e.g. Jansen et al. 1983, Jongkind 2010) simple species lists are being produced, and the interesting species discussed, in order to 'evaluate' conservation importance of the flora. In other studies a combination of criteria, such as number of endemics or rare species and different habitat types, is used to evaluate and/or select sites for conservation (e.g. Doumenge et al. 2003, Sosef et al. 2004).

However, it is also necessary to evaluate the value of a protected area by addressing its contribution to regional or global conservation (Gardner et al. 2007). To do this, one not only needs to know which species occur within such an area, but also where else these species occur. This is because we want to know how unique the species composition is on a regional or even global scale. A species that is endemic to a national park can only be conserved *in situ* in that park, and thus it gives the park a much higher status than a species with a broad distribution. For this reason some biodiversity assessment studies (e.g. Wieringa & Poorter 2004, Küper et al. 2004) weigh rarity. So, an area with a flora (and/or fauna) that is comparatively unique, hence does not occur in other places, should receive high conservation priority.

Another element that may play a role when prioritizing areas for conservation is to what extent a protected area can vouch for other, unprotected areas. If a non-protected area has a flora that is also present in a protected area, the need to protect this area as well is reduced (at least from the botanical species-level viewpoint; of course there are plenty of other reasons to conserve such areas), and conservation efforts can better be focussed on areas who's flora is not yet secured.

These additional considerations for conservation planning cause a major problem for most conservationists, at least when they are not solely interested in well-known groups like large mammals or birds. For plants, for example, they might have performed inventories and have an idea about what occurs in the areas they want to assess, but they will generally not have information about where else these plant species occur and hence what the global importance of these areas is. In areas like tropical Africa, where the amount of available data on plant distributions is usually quite limited, such problems seem even more acute.

'Relative Floristic Resemblance', a method that uses databased herbarium records, may fill in this gap. This method has been tested using four recently established national parks in Gabon and one in the Central African Republic. These are: Batéké Plateaux N.P., Crystal Mountains N.P., Loango N.P. and Minkébé N.P. in Gabon (see fig. 1) and the Dzanga-Sangha Reserve in the Central African Republic. These five parks were chosen because their flora is reasonably well known; the availability of a fairly complete species list is a prerequisite for this method. Moreover, the four Gabonese parks were only created in 2002, they have previously not been assessed for their floristic conservation value, and they are situated in four different corners of Gabon. Finally, we expected at least one of the four Gabonese parks (Crystal Mountains) to have a comparatively unique flora (based on the concept of rain forest refuges, see Sosef 1996), another two (Loango and Batéké Plateau) to harbour important savannah vegetations, while the fourth (Minkébé) together with the one in the Central African Republic (Dzanga-Sangha Reserve) are expected to contain more widespread species. Hence, we hoped these examples would be suitable to show various aspects of this new method. As a further demonstration of the method and aid to interpret the results, the analysis was also performed using the species list of the country Gabon as a whole.

Most of the surface of Gabon (80%) is covered by lowland tropical rain forest, the remainder being mostly savannah. Its highest mountains reach just over 1000 m. It is a centre of high biodiversity for African rainforest vegetation (Breteler 1990, Küper et al. 2004, Sosef et al. 2006) where many groups of forest taxa reach their highest species richness (e.g. Wieringa 1999, Versteegh & Sosef 2007, Breteler & Nguema Miyono 2008, Breteler & Wieringa 2008, Breteler 2010, 2011), rendering an analysis of Gabonese parks both urgent and interesting.

METHOD

To create species lists for four national parks in Gabon and the whole of Gabon the current Gabon-database (Sosef et al. 2006) was used. This is a subset of the collection database of the National Herbarium of The Netherlands (NCB Naturalis, section NHN) stored in the software package Brahms (Filer 2010) and can be consulted on the internet (http://dps.plants.ox.ac.uk/bol/Gabon). The NHN database now encompasses over 1.1 million collections records, of which about 340,000 relate to African specimens and 83% of these are geo-referenced. Of the over 74,000 Gabon records 98% are geo-referenced. Figure 1 shows the current collection density in Gabon as registered in the database. The species lists of all four parks are based on all geo-referenced specimens of vascular plants present in the database that are identified at least to species level and where the coordinates fall within the park or within a 10 km wide buffer zone around the park (table 1). Specimen selection was performed using ArcView GIS 3.3. For the Dzanga-Sangha Reserve in the Central African Republic a species list was provided in 2009 by David Harris (an update of Harris 2002). All analyses are conducted at species level. To achieve this, all six species lists (five parks plus Gabon) were extended to include all subspecific taxa, except those that are linked as synonyms to other names in the database. The extension was performed using the "Extend tags to all related infra taxa" tool in Brahms, subsequently all tags of synonym taxa were removed again.

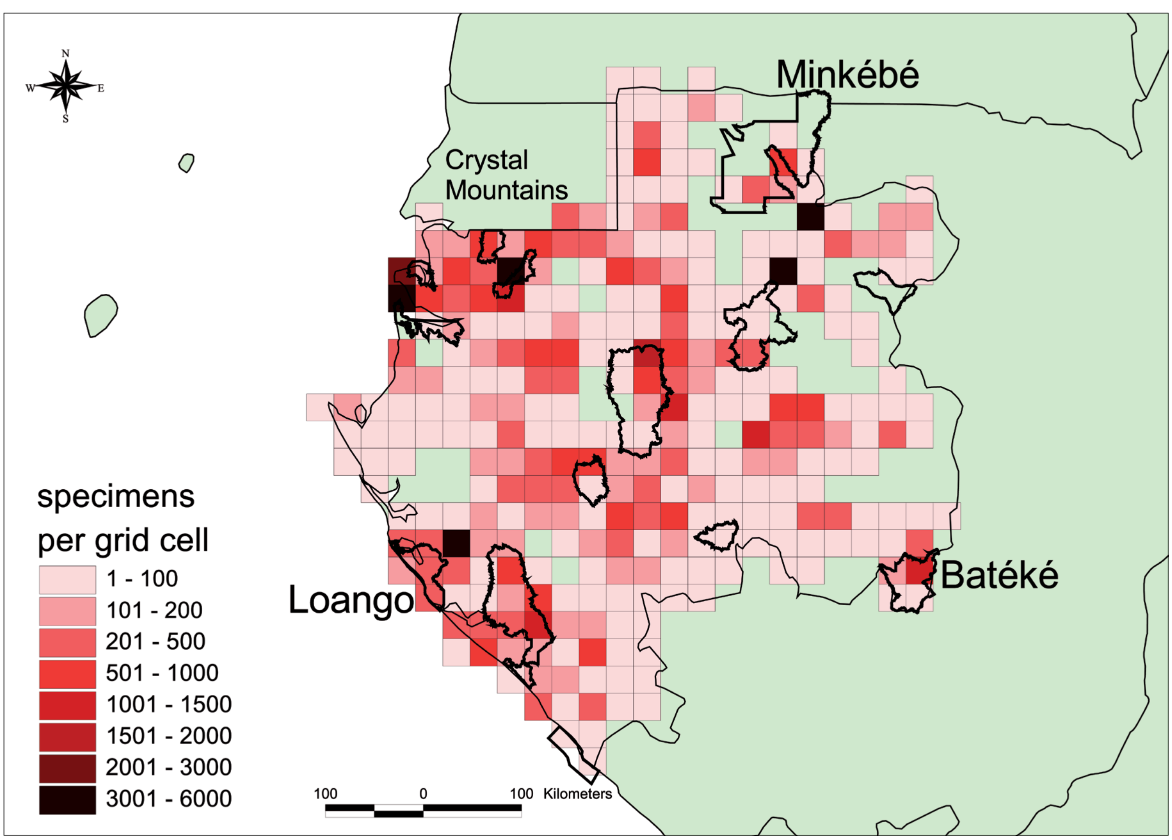

Figure 1 – Collection density in Gabon per 15° × 15° grid cell. The boundaries of the national parks are shown by black lines. The four parks used in the analysis are provided with their short name. Crystal Mountains N.P. consists of two separate areas.

Table 1 – Number of collections and resulting species number for each National Park and for Gabon.
Collections are only considered if identified to at least species level and from within a 10 km radius of the Park. For the Gabon list all identified records from Gabon have been used.

locality	collections	species
Batéké	861	473
Crystal Mountains	4223	1351
Loanga	1418	782
Minkébé	1099	609
Dzanga-Sangha	c. 5600	1012
Gabon	57713	5197

Using all geo-referenced and fully identified records of vascular plants present in the NHN collection database, a grid cell table covering the whole world containing the number of species in each cell was obtained. Similar tables were prepared counting only the species present in the six species lists. These tables were prepared with Brahms 6.7 (Filer 2010) using the DistDiv procedure on species × grid cell with options "exclude cultivated botanical records", "always use accepted name" and "exclude vague name" on. The species only present in the six species lists were counted for each grid cell by first extracting all collection records of species from these lists (including synonyms) and then running the DistDiv procedure using the option "extracted botanical records only".

We have defined the 'Relative Floristic Resemblance' (RFR) of a cell to a specific area (e.g. National Park or country) as the proportion (expressed as a percentage) of species present in a cell that also figure in the species list of that area. Thus, to obtain the RFR of each grid cell to each park and to Gabon the number of species in each cell that are present in the reference area list was divided by the total number of species for that cell, and expressed as a percentage. Grid cells that are completely covered by the reference area of course always result in a RFR of 100% (see e.g. fig. 2). To evaluate the extent of national park floras over Africa, the grid cells size was set to 1 × 1°. For a more detailed analysis within the Lower Guinean floristic region, cells of 15 × 15' (c. 28 × 28 km) were used.

Only cells with more than ten known species are considered in this analysis. The results are visualized in grid cell maps. But, since not all grid cells in Africa reach this number, and some zones are quite empty because of lack of data in the NHN database (e.g. Sahara, Botswana), the image is sometimes too scattered to be read easily. Therefore, interpolated maps have also been created. Interpolation was performed in ArcView using interpolating method IDW, twelve neighbours, second power, and no barriers.

RESULTS AND DISCUSSION

The wetter zones of tropical Africa are roughly divided into four phytogeographical regions, three are part of the Guineo-Congolian regional centre of endemism: Upper Guinea (Liberia to Togo), Lower Guinea (southern Nigeria to northern Angola) and Congolia (most of the Republic of Congo and D.R.Congo), where the fourth is formed by some isolated forest patches in the Zanzibar-Inhambane regional mosaic (White 1979, 1983). The RFR maps of Gabon (fig. 2) show a high resemblance of the flora of both Lower Guinea and Congolia to that of Gabon, much stronger than to that of Upper Guinea. In the latter area the highest resemblance is found in the SE corner of Liberia which is the wettest part of West Africa. The more detailed 15 × 15' grid cell map shows that the vegetation in the whole of Equatorial Guinea and southern Cameroon resembles the Gabonese flora to a very high degree, except in the mountainous areas of West Cameroon and Bioko which harbour a mountain flora not present in Gabon. This also shows how to read the maps: the resemblance of a grid cell to the 'source area' only shows which proportion of the species in that cell also occurs in the checklist area (in this case Gabon). It does not show how many Gabonese species are not found in that grid cell, nor if this grid cell is relatively rich or poor in species. So, it only tells you what percentage of the flora of the grid cell is 'covered' by the flora of Gabon; hence what proportion of its species are conserved if the whole of Gabon was a protected area.

The species lists for the five national parks (table 1) show an enormous difference in species numbers. Crystal Mountains is by far the richest park with 1351 species, followed

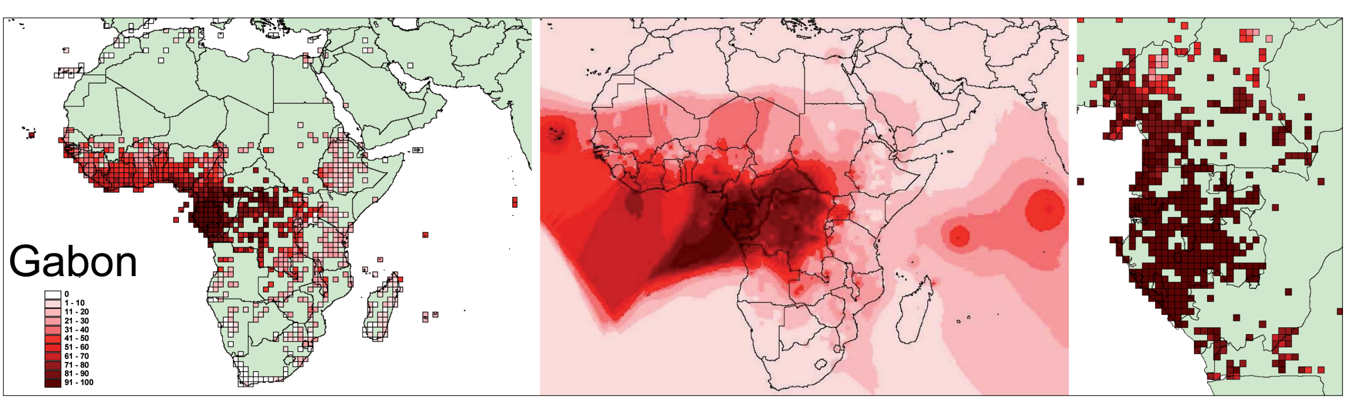

Figure 2 – Relative Floristic Resemblance map for the flora of Gabon, on the left using grid cells of 1° × 1° (only showing grid cells with more than ten known species), in the centre the interpolated map for 1° × 1°, and at the right a map zooming in on Lower Guinea using grid cells of 15' × 15'. The national parks are indicated by their boundaries.

by Dzanga-Sangha (1012), Loango (782) and Minkébé (609). Batéké Plateau has the lowest species number with only 473 species. Both Batéké Plateau and Minkébé are presumably richer than is shown by these numbers because for both parks some botanical collections have not yet been included in the NHN database and in both only a very limited part has been explored botanically. A provisional species list for Batéké Plateau (Walters 2007) that includes many non-vouchered records already shows slightly more names (522, but only 461 identified to species level) while there have been many new identifications since. The species lists for Batéké Plateau and Minkébé can thus be used in this study to evaluate the effect of incomplete species lists.

The maps showing the results of the RFR analyses for the five parks (fig. 3) show quite different pictures. Some parks like Loango and Batéké Plateau have a flora that apparently is quite unique and hardly extends outside of these parks. Other parks like Crystal Mountains and Dzanga-Sangha have a high resemblance over vast areas of central Africa. Strikingly enough, these last two parks do not show a lot of overlap in resemblance area; they are quite complementary to one another. Although it does not have the largest species number, the Dzanga-Sangha reserve does show the largest area with a high resemblance in Africa. We may thus conclude that thanks to the protection of the Dzanga-Sangha reserve, a fair portion of the flora of the entire Congo Basin has been secured, at least at species level. In the 1° grid cell analysis the cells of the Minkébé N.P. show a fairly high resemblance to Dzanga-Sangha. However, in the more detailed analysis the RFR's are not that high, and although Minkébé shares a lot of species with Dzanga-Sangha, Minkébé apparently also has a set of locally more common species (represented in several 15' cells) that it does not share. Since we know that the Minkébé inventory has a strong emphasis on woody plants, especially large trees, this may well be the cause of this effect. This is corroborated by the result that the more western grid cell in the park, where the sampled flora is based on the last part of the A-transect (van Valkenburg et al. 1998) and hence consists solely of large trees, has a lower resemblance to Dzanga-Sangha than the two cells along the Nsing River, where general collecting also took place. This apparent effect, that large trees show more local diversity patterns than plant species in general, should be analysed in further studies.

Of the four assessed Gabonese parks only Crystal Mountains has an enormous species count and the conservation effect extents over a large area. However, all eleven other terrestrial national park grid cells show only between 25 and 67% resemblance to this park, meaning all these parks still harbour quite a lot of species not present in Crystal Mountains N.P. and hence none of these parks becomes superfluous. The same is true for the other three Gabonese parks that were assessed: none of the other parks show a lot of resemblance to any of these three parks, and it thus seems the park areas have been very well chosen. The parks that have a flora with a very limited extent (Loango and Batéké) not only show very low resemblance from other parts of Gabon, but these parks likewise show less resemblance to other parks (like Crystal Mountains). This combination points to the unique flora these two national parks harbour. Although both parks have a large savannah component, their floras do not resemble each other either. This conclusion is corroborated by the study of Walters et al. (submitted); the flora of Loango is discussed in more detail by Harris et al. (submitted). For Batéké Plateau it is striking that it has a much higher correlation with some parts of Congo-Kinshasa than with nearby Gabonese cells. Since most of the park soil consists of Kalahari sands, Walters et al. (2005) expected a relative high correlation with other areas with Kalahari sands like eastern Angola. But since no grid cells in eastern Angola reach eleven species, we do not have any data points to corroborate that hypothesis.

As stated above, the species lists for Batéké Plateau and Minkébé are relatively incomplete. Incomplete species lists will have the effect that a grid cell may have some species that will be scored as "not occurring in the reference area", while in fact they do occur there. This results in lower resemblance values. However, one may expect the effect to be equal for all cells; for example if 32% of the real number of species in a park is not yet on its species list, the RFR values will also, on average, be 32% lower. So, in theory, the map for that park will show a paler image than if a complete list were available. Indeed fig. 3 shows us that the maps for these two parks are in general paler than the other maps. However, the image that starts emerging for e.g. Minkébé is as was expected for this park: high affinities with south-eastern Cameroon, northern Congo-Brazzaville and parts of the Congo Basin. That the overall image does appear (though paler) proves that the method can be used for parks with a partially incomplete species list. But, judgements regarding the uniqueness of their flora should be made with extreme caution. A second effect, however, will be that this error will introduce its own variation by chance, on top of the variation introduced by the subset of known species for a grid cell, resulting in 'spotty' maps. Both types of variation will be smaller if the number of known species of a grid cell is larger. The interpolated maps for Batéké Plateau and Minkébé indeed show a spotty image, especially in the Congo Basin, an area where in our database the number of collections per grid cell is usually quite low. On the other hand this does not yet disturb the overall impression obtained about the resemblance patterns for these parks. If the increased variation is judged to be too disturbing, it is possible to set the minimum number of species in a grid cell to fifteen or twenty instead of eleven as was used here. Where to place this cut-off value will always be a compromise between getting results from more grid cells against possibly getting some grid cells with extreme results caused by random variation in cells with few data. Therefore, the 'ideal' cut-off point will tend to be higher for analyses of parks with incomplete species lists.

An interesting effect that can be observed in the resemblance maps of Gabon is that some low altitude, isolated oceanic islands like the Seychelles, the Maldives and Cape Verde show a higher resemblance than other areas at the same distance (best shown in the interpolation where the sea is coloured to show what would have been expected if it were land). These low oceanic islands usually have a relatively poor flora with few endemics and comparatively high numbers of pan-tropical weeds and beach species. So, due to this their flora concurs for a fair part with the Gabonese flora. Most national park analyses do not show this effect, pointing to a low number of pan-tropical weeds collected in these

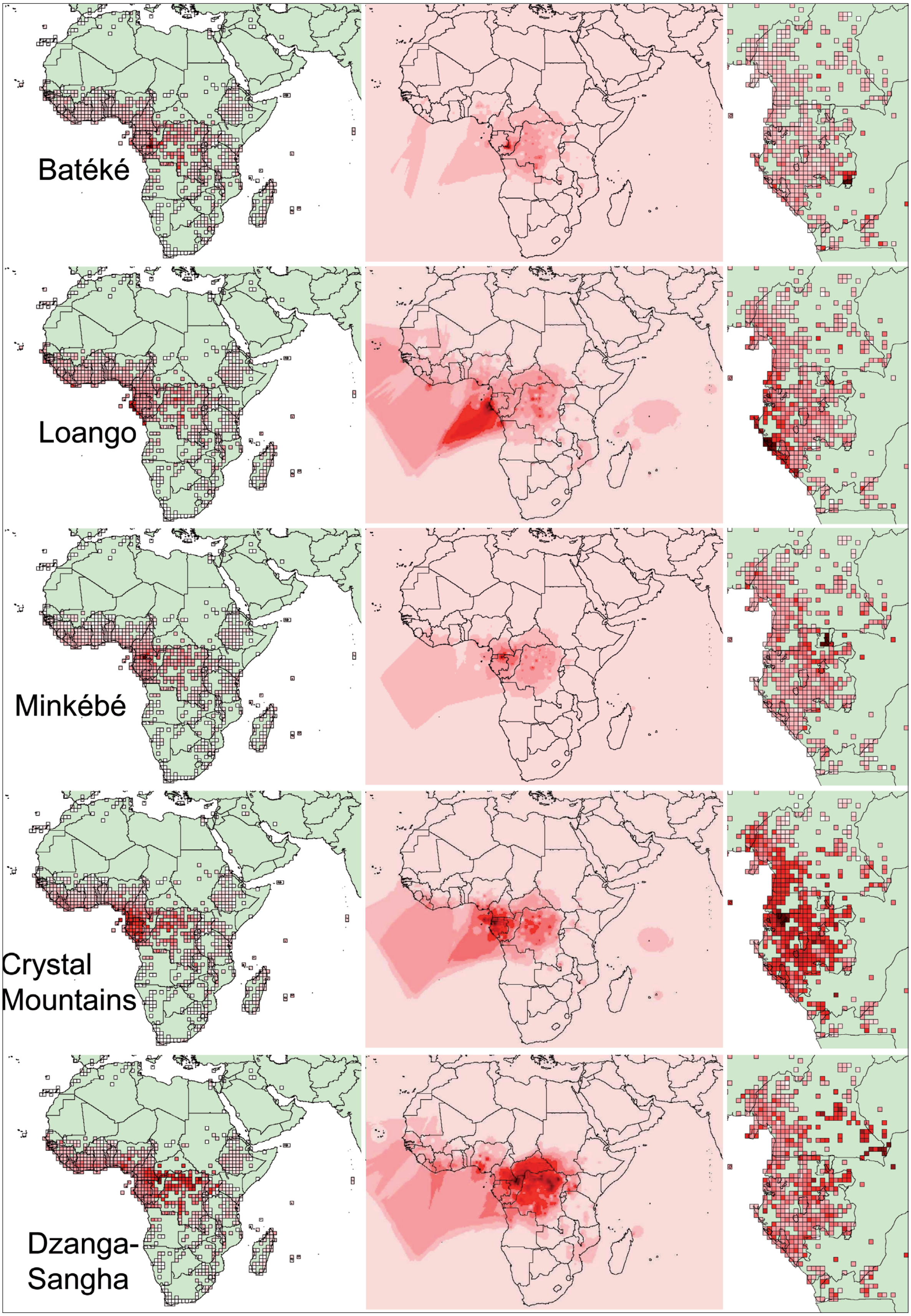

Figure 3 – Relative Floristic Resemblance maps for the protected areas Batéké Plateau, Loango, Minkébé, Crystal Mountains and Dzanga-Sangha. From left to right as in fig. 2.

parks. The only exception is the coastal park Loango that does show elevated values in all these islands. Upon closer examination, the common elements indeed prove to be some weeds and pan-tropical grasses.

Relative Floristic Resemblance can also be used to evaluate which parts of a region or country have a flora that is not yet protected by the present park system. If Gabon were to have such areas, they should be considered for conservation. However, such an analysis, where we can assess which part of the Gabonese flora has not been covered for by the present park system, can only be performed if fairly complete species lists are available for all of the present parks, and this is not yet the case. At the moment there is even one park (Mwagne) where not a single plant species is known from within its borders, and quite a number of parks where very few collections are known (e.g. Birougou) or only a small part of the park has been visited by botanists (Minkébé, Batéké Plateau, Pongara and Ivindo). Although such a combined analysis would be most welcome, at present it cannot be properly performed and more inventory work in the above mentioned parks, as well as to yet uncollected areas in Gabon, is needed.

CONCLUSIONS

'Relative Floristic Resemblance' using digitized and georeferenced herbarium specimen data proves a powerful and useful tool to assess the botanical conservation value and extent of protected areas. This method works well if the total plant species content of the protected area is fairly well know. For protected areas where the included species are only partly known, the resulting map is paler (overall lower resemblance) but the general resemblance pattern does appear. Users should be aware that in such cases the image is too pale and compensate for this prior to drawing conclusions. To avoid too much variation for some grid cells due to data artefacts, the user may increase the cut-off value for the minimal number of species per grid cell. This method does not need a lot of data for areas in the rest of the region addressed to work properly. Occurrence data of fifteen to twenty species per grid cell will be enough for analyses of incomplete species lists, while as few as ten may work for complete lists; for many areas often no more data than this is available, and for such areas this method will be the only one available. Grid cell size of an analysis will depend on the research question (local or more general) and the amount of available data.

The conservation value of the Dzanga-Sangha appears to extend well into the Congo Basin; hence, a considerable part of the Congo Basin forest flora is probably under protection thanks to this park.

The four Gabonese parks analysed appear to have very different and unique floras. These parks cannot vouch for any of the other terrestrial Gabonese parks. On the other hand, the flora of some parks is so poorly known that even their resemblance to well-known parks cannot be assessed. These parks urgently need to be inventoried. When all parks have fairly complete species lists, a combined analysis can be performed to assess which part of the Gabonese flora has not been covered by the present park system, and which areas need protection in order to overcome this shortcoming. This will prove very useful advice to governmental agencies, NGO's and conservationists on where to plan or move future parks.

The power of this method may be improved substantially if all data available in collection databases of herbaria around the world is pooled (as is already the case for the Gabon database). Then more detailed 30'or 15' grid cell analyses can be performed over larger areas, and analyses performed for protected areas in countries where single herbaria databases hold insufficient data.

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REFERENCES

Breteler F.J. (1990) Gabon's evergreen forest: the present status and its future. Mitteilungen aus dem Institut für Allgemeine Botanik in Hamburg 23a: 219–224.

Breteler F.J., Nguema Miyono N.S. (2008) Revision of the African species of Crudia (Leguminosae, Caesalpinioideae). Systematics and Geography of Plants 78: 81–110. [available at http://www.ingentaconnect.com/content/nbgb/sgp/2008/00000078/00000001/art00005]

Breteler F.J., Wieringa J.J. (2008) Novitates Gabonenses 63. Illigera cava (Hernandiaceae), a new species from Gabon and Congo (Brazzaville). Blumea 53: 453–457. [available at http://www.ingentaconnect.com/content/nhn/blumea/2008/00000053/00000002/art00019]

Breteler F.J. (2010) Revision of the African genus Anthonotha (Leguminosae, Caesalpinioideae). Plant Ecology and Evolution 143: 70–99. doi:10.5091/plecevo.2010.369

Breteler F.J. (2011) Revision of the African genus Isomacrolobium (Leguminosae, Caesalpinioideae). Plant Ecology and Evolution 144: 64–81. doi:10.5091/plecevo.2011.426

Doumenge C., Nembot T.F., Tchanou Z., Ondo V.M., Nze N.O., Bourobou H., Ngoye A. (2003) 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. [available at http://bft.cirad.fr/cd/BFT_277_53-67.pdf]

Filer D.L. (2010) Botanical Research And Herbarium Management System Version 6.7. Department of Plant Sciences, University of Oxford. Available at http://dps.plants.ox.ac.uk/bol/BRAHMS/ [Accessed 24 Aug. 2011]

Gardner T.A., Caro T., Fitzherbert E.B., Banda T., Lalbhai P. (2007) Conservation value of multiple-use areas in East Africa. Conservation Biology 21: 1516–1525. doi:10.1111/j.1523-1739.2007.00794.x

Harris D.J. (2002) The vascular plants of the Dzanga-Sangha Reserve, Central African Republic. Scripta Botanica Belgica 23: 1–274.

Harris D.J., Armstrong K.E., Walters G.M.,Wilks C.M., Mouandza Mbembo J.-C., Niangadouma R., Wieringa J.J., Breteler F.J. (submitted) Phytogeographical Analysis and Checklist of the Vascular Plants of Loango National Park, Gabon. Plant Ecology and Evolution.

Jansen R.Ph., Moussault A.T., Wessels L.J., Wieringa J.J. (1983) Hoofdstuk 4 macrofauna. In: Buhr G.P., Janssen R.P., Langendorff O. (eds) "Het Galgenveld". Een inventarisatieverslag van de Flora en Fauna: 31–52. Uitgave nr. 3, Stichting Biologische Werkgroep 't Gooi.

Jongkind C.C.H. (2010) Report of the botanical work for FFI January–February 2010 in Liberia. Internal report Flora and Fauna International.

Küper W., Sommer J.H., Lovett J.C., Mutke J., Linder H.P., Beentje H.J., Van Rompaey R.S.A.R., Chatelain C., Sosef M.S.M., Barthlott W. (2004) Africa's hotspots of biodiversity redefined. Annals of the Missouri Botanical Garden 91: 525–535. [JSTOR: http://www.jstor.org/stable/3298550]

Sosef M.S.M. (1996) Begonias and African rain forest refuges: general aspects and recent progress. In: van der Maesen, L.J.G., van der Burgt X.M., van Medenbach de Rooy J.M. (eds) The biodiversity of African plants. Proceedings of the XIVth AETFAT Congress, 22–27 August 1994, Wageningen, The Netherlands: 602–611. Dordrecht, Kluwer Academic Publishers.

Sosef M.S.M., Issembé Y., Bourobou H.P., Koopman W.J.M. (2004) Botanical biodiversity of the Pleistocene forest refuge Monts Doudou (Gabon). In: Fisher B.L. (ed.) Monts Doudou, Gabon: A floral and faunal inventory with references to elevational variation. Memoirs of the California Academy of Sciences 28: 17–91. San Francisco, California Academy of Sciences.

Sosef M.S.M., Wieringa J.J., Jongkind C.C.H., Achoundong G., Azizet Issembé Y., Bedigian D., van den Berg R.G., Breteler F.J., Cheek M., Degreef J., Faden R.B., 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 – Checklist of Gabonese vascular plants. Scripta Botanica Belgica 35: 1–438.

van Valkenburg J.L.C.H., Ketner P., Wilks C.M. (1998) A floristic inventory and preliminary vegetation classification of the mixed semi-evergreen rain forest in the Minkébé region, North East Gabon. Adansonia, Sér. 3, 20: 139–162.

Versteegh C.P.C., Sosef M.S.M. (2007) Revision of the African genus Annickia (Annonaceae). Systematics and Geography of Plants 77: 91–118. [available at http://www.ingentaconnect.com/content/nbgb/sgp/2007/00000077/00000001/art00005]

Walters G.M. (2007) Liste provisoire des plantes du Parc National Plateaux Batéké et les environs. Internal report. Saint Louis, Missouri Botanical Garden.

Walters G.M., Bradley A., Niangadouma R. (2005) Floristics of Gabon's Batéké Plateaux: Guineo-Congolian plants on Kalahari Sands. In: Ghazanfar S.A., Beentje H. (eds) African Plants: Biodiversity, Ecology, Phytogeography and Taxonomy: 259–266. Kew, Royal Botanic Gardens.

Walters G.M., Stévart T., Parmentier I. (submitted) Is every savanna the same? Assessing the floristic similarity of Gabon's savannas. Plant Ecology and Evolution.

White F. (1979) The Guineo-Congolian Region and its relationships to other phytochoria. Bulletin du Jardin botanique national de Belgique 49: 11–55. doi:10.2307/3667815

White F. (1983) The vegetation of Africa. A descriptive memoir to accompany the Unesco / AETFAT / UNSO vegetation map of Africa – Natural Resources Research no. 20. Paris, UNESCO.

Wieringa J.J. (1999) Monopetalanthus exit. A systematic study of Aphanocalyx, Bikinia, Icuria, Michelsonia and Tetraberlinia (Leguminosae, Caesalpinioideae). Wageningen Agricultural University Papers 99-4: I–XVI, 1–320.

Wieringa J.J., Poorter L. (2004) Biodiversity hotspots in West Africa; patterns and causes. In: Poorter L., Bongers F.J.J.M., Kouamé F.N., Hawthorne W.D. (eds) Biodiversity of West African Forests. An Ecological Atlas of Woody Plant Species: 61–72. Oxford, United Kingdom, CAB International.

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