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The vascular plant diversity of Burkina Faso (West Africa) – a quantitative analysis and implications for conservation

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Abstract

ZIZKA, A., A. THIOMBIANO, S. DRESSLER, B. M. I. NACOULMA, A. OUÉDRAOGO, I. OUÉDRAOGO, O. OUÉDRAOGO, G. ZIZKA, K. HAHN & M. SCHMIDT (2015). The vascular plant diversity of Burkina Faso (West Africa) – a quantitative analysis and implications for conservation. *Candollea* 70: 9-20 In English, English and French abstracts. DOI: http://dx.doi.org/10.15553/c2015v701a2

Based on a species inventory and the related distribution dataset, the authors present a quantitative analysis of the vascular plant diversity of Burkina Faso (BFA) and its four phytogeographic zones. We analyzed species richness, higher taxon diversity, life forms, chorological types, introduced species, habitat preferences and the number of rare species. The flora of BFA comprises 1972 non-cultivated vascular plant species in 752 genera and 145 families. Species richness and plant family richness are highest in the South Sudanian zone in the South of the country. *Fabaceae, Poaceae* and *Cyperaceae* are the most species rich plant families. Only one species (*Isoetes jaegeri* Pitot) is endemic to the country, whereas the vast majority occurs throughout Africa. The flora is dominated by therophytes and phanerophytes. Our results show a good representation of the West African flora in BFA. The flora and vegetation of the four phytogeographic zones within BFA is determined by the latitudinal climatic gradient of the region. The relative number of phanerophytes and forest species decrease along the gradient, while the relative number of therophytes increase. Based on the specimen record we classified 38% of the plant species as "rare" to BFA. The analyses show that the south-west of BFA is a center of national biodiversity and a potential "hotspot" for conservation. In addition to its high species richness this area harbors the highest number of rare species (409 species, 29%) including the endemic species.

Résumé

ZIZKA, A., A. THIOMBIANO, S. DRESSLER, B. M. I. NACOULMA, A. OUÉDRAOGO, I. OUÉDRAOGO, O. OUÉDRAOGO, G. ZIZKA, K. HAHN & M. SCHMIDT (2015). La diversité des plantes vasculaires du Burkina Faso (Afrique de l'Ouest) – une analyse quantitative et implications pour la conservation. *Candollea* 70: 9-20. En anglais, résumés anglais et français. DOI: http://dx.doi.org/10.15553/c2015v701a2

Les auteurs présentent la première analyse quantitative des plantes vasculaires du Burkina Faso (BFA) et de ses quatre zones phytogéographiques basée sur un inventaire des espèces ainsi qu'un set de données de leurs distributions relatives. Nous avons analysé la richesse spécifique, la diversité des rangs taxonomiques supérieurs, les types biologiques et chorologiques, les plantes introduites et le nombre d'espèces rares. La flore du BFA comprend 1972 espèces de plantes vasculaires non cultivées, regroupées en 752 genres

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et 145 familles. La richesse spécifique comme celle des familles sont les plus élevées dans la zone Soudanienne au sud du pays. Les familles les plus riches en espèce sont les *Fabaceae,* les *Poaceae* et les *Cyperaceae*. Une seule espèce (*Isoetes jaegeri* Pitot) est endémique du pays, alors que la majorité des autres espèces sont répertoriées dans toute l'Afrique. La flore est dominée par les thérophytes et les phanérophytes. Nos résultats montrent que la flore du BFA est représentative de la flore de l'Afrique de l'Ouest. La flore des quatre secteurs phytogéographiques du BFA est déterminée par le gradient climatique latitudinal de la région. Le nombre relatif de phanérophytes et d'espèces forestières décroit le long de ce gradient pendant que le nombre relatif de thérophytes augmente. En se basant sur le nombre de collection, nous avons classifié 38% des espèces comme «rares» pour le BFA. Les analyses montrent que le sud-ouest du BFA est le centre de la biodiversité pour ce pays et un «hotspot» potentiel pour la conservation. En plus de sa richesse spécifique, cette région abrite le nombre le plus élevé d'espèces rares (409 espèces, 29%) incluant l'espèce endémique.

Keywords

Chorological types – Neophytes – Phytogeography – Plant conservation – Rare species – Sahel – Sudanian zone

Introduction

Burkina Faso (BFA) is a landlocked country in West Africa. It covers about 274,000 km² and spans between 9-15°N and 6°W-3°E. BFA has an even topography and is situated on a plain at between 300-400 m above sea level. The most prominent elevations are two minor mountain chains: The Gobnangou Mountains (about 340 m) in the East close to the border with Benin and the massif of Mt. Tenakourou (749 m) in the West close to the border with Mali. The hydrology of BFA is dominated by the Volta basin and comprises five big perennial or semi-perennial rivers. BFA counts 18 million inhabitants, most of them in rural communities (13.2 millions; Central Intelligence Agency, 2014). Average population density is 52.2 inhabitants per square kilometer, but ranges from 11 inh/km² (Kompienga) to 616 inh/km² (Kadiogo) in the different provinces (Ministère de L'Economie et des Finances Burkina Faso, 2008). BFA comprises three national parks, one UNESCO biosphere reserve, 15 sites protected under the Ramsar Convention on Wetlands, 12 nature reserves and multiple local conservation areas adding up to a total protected area of 42,000 km² (corrected after Belemsobgo et al., 2012; Ramsar, 2013).

Due to the absence of mountains as atmospheric barriers, the climate of BFA is determined by the South to North rainfall and temperature gradient typical for West Africa (Falk & Szarzynski, 2012). This gradient manifests itself in a latitudinal decrease in rainfall and an increase in rainfall seasonality. BFA spans this gradient from about 1400 mm mean annual precipitation (MAP) and 4-6 dry months in the South to 400 mm MAP and 7 to 8 dry months in the north of the country (Guinko, 1984a; Falk & Szarzynski, 2012). Additionally, the mean annual temperature and temperature seasonality increase from South to North. The dominating vegetation form of BFA is savanna. Following the climate gradient it ranges from woodlands and open dry forests in the South to thorn bush savannas and tiger bush in the North (Guinko, 1984a). The transition between these savanna ecosystems is continuous with a general decrease of woody cover from South to North and a decrease in plant size in the tree and grass layers (Schmidt et al., 2011, 2013). BFA is part of the Sudanian zone and the Sahel according to the vegetation map of Africa (White, 1983). Moreover, Guinko (1984a) recognized four different vegetation sectors from the South to the North of BFA (Fig. 1): the South Sudanian zone (MAP: 1000-1400 mm, 4-6 dry months), the North Sudanian zone (MAP: 750-1000 mm, 6-7 dry months), the Subsahel (MAP: 600-700 mm, 7-8 dry months) and the Sahel (MAP: <600 mm, 7-8 dry months) (hereafter called phytogeographic zones, PGZs). Important azonal vegetation formations are gallery forest along rivers (Sambaré et al., 2011) and the distinct vegetation on isolated rocky outcrops and small mountains (inselbergs; Müller, 2008).

Modern botanical research in West Africa started in the mid of the 19th century with the publication of the Flora of tropical Africa (Oliver, 1868). Since then few scientific publications have marked milestones in the description of the flora and vegetation of the area that today is BFA (e.g. Chevalier, 1933; Aubréville, 1936; Hutchinson & Dalziel, 1954-1972; Guinko, 1984a; Lebrun et al., 1991). In the last 20 years, enforced research effort has yielded insights in distribution patterns and ecology of specific plant groups such as grasses (Schmidt et al., 2011), *Combretaceae* (Bognounou et al., 2010; Thiombiano et al., 2006) and woody plants (Couteron & Kokou, 1997; Schmidt et al., 2013) as well as the flora and vegetation of specific areas such as the faunal reserve of Pama (Mbayngone et al., 2008), the Sahel reserve (Schmidt et al., 2008) and the Arly National Park (Ouédraogo et al., 2011). However, a comprehensive analysis of the flora of BFA was not available until now. In this study we present a comprehensive quantitative analysis of the flora of BFA, based on the recently published national checklist (Thiombiano et al., 2012) and extensive distribution data. We analyzed species richness, life forms, chorological types, habitat preferences and introduced species in BFA and its four phytogeographic zones. Additionally, we analyzed plant diversity and rare species occurrence on a province level. This study together with the checklist provides ecologists, botanists and biogeographers as well as conservationists and decision makers with up to date reference numbers. Due to the dominant influence of the climatic gradient the flora of BFA is also of interest as a model case for neighboring West African countries.

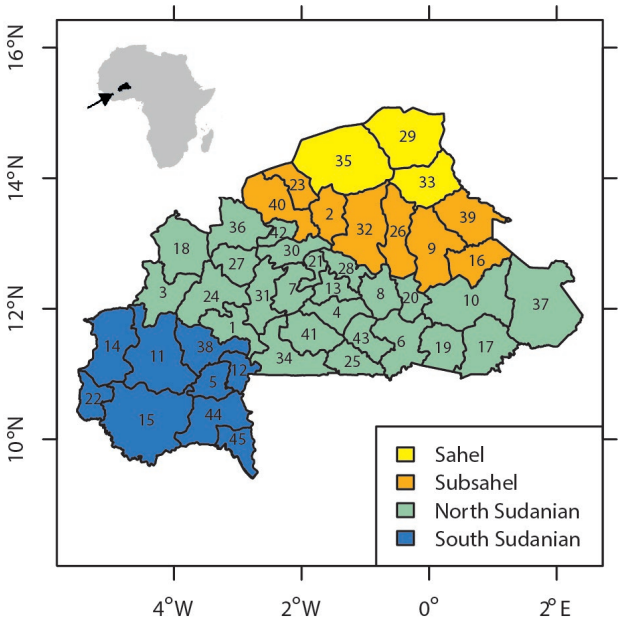

Fig. 1. – The provinces of Burkina Faso and their assignment to the phytogeographic zones used in this study. The classification of provinces to the PGZs is modified after White (1983) and Guinko (1984a).
[1: Les Balé; 2: Bam; 3: Banwa; 4: Bazègua. 5: Bougouriba; 6: Boulgou; 7: Boulkiemdé; 8: Ganzourgou; 9: Gnagna; 10: Gourma; 11: Houet; 12: Ioba; 13: Kadiogo; 14: Kénédougou; 15: Comoé; 16: Komandjari; 17: Kompienga; 18: Kossi; 19: Koulpélogo; 20: Kouritenga; 21: Kourwéogo; 22: Léraba; 23: Loroum; 24: Mouhoun; 25: Nahouri; 26: Namentenga; 27: Nayala; 28: Oubritenga; 29: Oudalan; 30: Passoré; 31: Sanguié; 32: Sanmatenga; 33: Séno; 34: Sissili; 35: Soum; 36: Sourou; 37: Tapoa; 38: Tuy; 39: Yagha; 40: Yatenga; 41: Ziro; 42: Zondoma; 43: Zoundwéogo; 44: Poni; 45: Noumbiel]

Material and Methods

All analyses were based on the database of the checklist of Burkina Faso (BFA) by Thiombiano et al. (2012). The species list of this checklist is fully digitized in a relational database (MS Access) with standardized and free-text fields for the different categories of synonymy, ecology and plant use. The database includes information on distribution, life form, traditional use, habitat for each species known in the country, and additional information on ecology and phytosociology where available. Geographic ranges are documented from a total of 17,914 herbarium specimen as detailed locality information, referenced to province level. The African plant database (Klopper et al., 2007; African Plant Database, 2015) was used as taxonomic standard for species names and synonyms for the database. The analyses were performed in two steps:

1. The analyses for BFA on the national scale were based on the spontaneous flora recorded in the checklist. Therefore we excluded the 95 cultivated species of BFA. That is, 1972 out of the 2067 species mentioned in the checklist were considered in the analyses. Cultivated species are treated in a separate paragraph in the text.
2. The analyses concerning the phytogeographic zones (PGZs) and the provinces were based on the geographic information of the herbarium specimens cited in the checklist and documented in our databases. For these analyses 10 species were excluded because their location could not be identified unambiguously. That is, 1962 species and a total of 17,914 specimens were included in the analyses on PGZ- and province-level. The province borders used in this study are based on corrected information from the GADM database of Global Administrative Areas (Hijmans et al., 2013). We assigned the provinces of BFA to four phytogeographic zones following White (1983) and Guinko (1984a) (Fig. 1). We used the number of specimens per species as surrogate for species abundance, and classified species with less than three recorded specimens in BFA as "rare species". We assume that this approach allows for the first time a (rough) evaluation of the fraction of rare species per PGZ and province. Note, however, that these estimates can be biased by sampling effort (especially for species that are difficult to collect) and must be interpreted carefully (Schmidt et al., 2010). Additionally, the unevenly distributed specimen record (Schmidt et al., 2005) and the lack of specimens for some provinces revealed in this study are severe challenges for a well-founded analysis on a province level. To avoid this dilemma we only include provinces with more than 350 recorded specimens in the province level analyses. We assume that this approach reduces the sampling bias and allows pointing out major tendencies.

Results

General flora composition

The flora of Burkina Faso (BFA) comprised 1972 non-cultivated higher plant (including ferns) species in 752 genera and 145 families (Table 1). As shown in Table 1, species richness decreases from South to North along the regional climate gradient. We found the South Sudanian zone to be the phytogeographic zone (PGZs) with the highest biodiversity. It comprised the highest recorded species richness (1410 species), the highest number of species per area, the highest absolute and relative number of exclusive species (species only occurring in one of the PGZs) and the highest absolute and relative number of rare species (Table 1). Additionally it comprised the highest number of genera (614) and families (131). Although only 22% of the area of BFA was assigned to the South Sudanian zone (Fig. 1) it comprised 71% of all species, 82% of the genera and 90% of the families occurring in BFA (Table 1). Concerning the diversity of the other PGZs the values of the Subsahel and Sahel were noteworthy. Only nine species (4%) were exclusive to the Subsahel whereas it shared 224 species (90%) of its flora with the North Sudanian zone and 152 species (61%) with the Sahel (Table 2). Table 2 shows

Table 1. – The flora of Burkina Faso and its four phytogeographic zones.
[Exclusive species: species only occurring in this zone; Rare species: species with <3 recorded specimen in Burkina Faso; Specimens: number of specimens per zone available for this study]

Zone	Area [km²]	Families	Genera	Species	Species/ 10000 km²	Exclusive species	Rare species	Specimens
Burkina Faso	274,500	145	752	1972	72	1	741	17,909
South Sudan	59,952	131	614	1410	235	535	409	5321
North Sudan	128,721	121	554	1279	99	309	285	9841
Subsahel	50,395	56	161	254	50	9	24	374
Sahel	28,882	73	265	518	179	102	85	2378

Table 2. – Shared plant species between the four phytogeographic zones.
[The numbers in the brackets indicate the percentage of the flora of a specific row]

	South Sudanian	North Sudanian	Subsahel	Sahel
South Sudanian	X	848 (= 60%)	179 (= 13%)	309 (= 22%)
North Sudanian	848 (= 66%)	X	229 (= 18%)	384 (= 30%)
Subsahel	179 (= 70%)	229 (= 90%)	X	152 (= 60%)
Sahel	309 (= 60%)	384 (= 74%)	152 (= 29%)	X

that the South Sudanian shares 60% of its flora with the North Sudanian, 13% with the Subsahel and 22% with the Sahel. The recorded species number per reference area was higher in the Sahel than in the North Sudanian (Table 1), contradicting the expectations of decreasing species number along the climatic gradient. Detailed information on distribution, habitat and life form for each species as well as summaries for each PGZ can be obtained from the authors on request.

Fabaceae, Poaceae and *Cyperaceae* were the most species rich plant families in BFA (Fig. 2). *Cyperaceae* and to a lesser extent *Convolvulaceae* and *Vitaceae* showed high species richness in a relatively low number of genera. *Indigofera* L., *Cyperus* L. and *Crotalaria* L. were the most species-rich genera. Of the 12 most common genera 6 belonged to the two most species rich families. The distribution of the important genera *Acacia* Mill. and *Ficus* L. in the PGZs illustrated the change in habitat from South to North. While the number of species in the savanna-associated genus *Acacia* increased from the South Sudanian zone to the Sahel, the number of species of the forest-associated genus *Ficus* declines along the climate gradient. The genus *Cyperus* had a high relative species richness in the Sahel which could be explained by sufficient humid to wet azonal habitats (temporary ponds and watercourses, e.g. Mare d'Oursi).

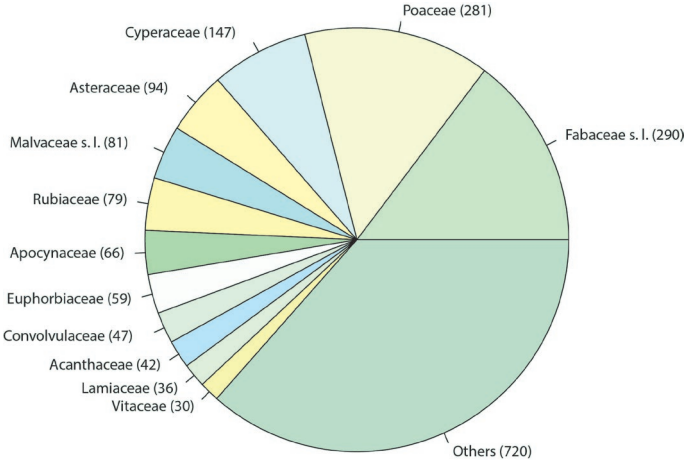

Fig. 2. – The twelve most species-rich plant families in Burkina Faso.

Based on the specimen record, 741 (38%) of all species in BFA were classified as rare (Table 1). Furthermore on average 38% of the species in the 12 most common families could be classified as rare in BFA. *Fabaceae* and *Poaceae* had the highest total number of rare species, but a below average fraction of rare species. In contrast *Cyperaceae, Asteraceae, Euphorbiaceae* and *Convolvulaceae* comprised an above average fraction of rare species.

Table 3. – Geographic range of plant species occurring in Burkina Faso and its four phytogeographic zones.

Geographic range	Burkina Faso	South Sudanian	North Sudanien	Subsahel	Sahel
Burkina Faso	1	1	0	0	0
West Africa	272	203	141	24	23
Africa	958	731	619	118	199
Old World	376	224	255	72	174
Cosmopolite	348	241	257	40	120
Unknown	15	8	7	0	2

Biogeography

Table 3 shows the distribution range of species occurring in BFA. Most of the species range across Africa. There was only one species (*Isoetes jaegeri* Pitot) endemic to BFA, recorded exclusively from the South Sudanian zone. *Pandanus brevifrugalis* Huynh which has been considered another endemic to BFA has been included into *P. senegalensis* Huynh recently (Beentje & Callmander, 2014). The great majority of species (958/49%) had a wide distribution range throughout Africa (Table 3). 116 species (6%) recorded for BFA were found to be introduced. Their great majority originated in the Americas (Fig. 3), next important source was Asia, and comparatively few species had been introduced from Madagascar and Maurice. The North Sudanian zone had the highest absolute and relative number of introduced species recorded. Most of the introduced species occurred as weeds in pastures and agricultural areas and have obviously been introduced unintentionally. For very few members of the flora an intentional introduction and subsequent escape from cultivation could be assumed, e.g. *Azadirachta indica* A. Juss. and *Bixa orellana* L.

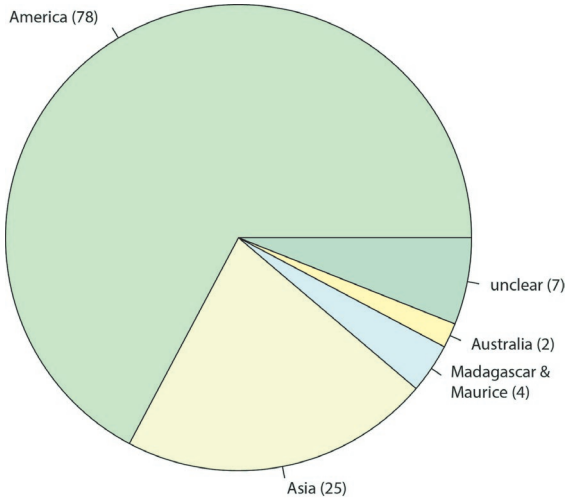

Fig. 3. – Origin of introduced plant species in Burkina Faso. The majority of introduced species originates in the Americas.

Habitat and life-forms

Savannas were the most species rich habitat in BFA and all its PGZs (data not shown). Furthermore the savanna biome was also home to most habitat specialists (species only occurring in one habitat). In the South Sudanian zone, species occurring in forests and forest specialists were relatively and absolutely more common than in the other PGZs. As expected from the climate gradient, the relative importance of forest species and forest specialists dropped significantly from the South Sudanian zone to the Sahel. This was also true for species occurring in gallery forests and gallery forest specialists. The change in habitat was also reflected in the occurrence of different life form types. Therophytes and phanerophytes were the most common life forms in BFA (Fig. 4A-D). In Fig. 4, the proportion of therophytes increases from South to North while at the same time the number of hemicryptophytes and phanerophytes decreases. While phanerophytes were the most common life form in the high rainfall South Sudanian zone (489/35%; Fig. 4A), their relative importance decreased with decreasing rainfall to the Sahel (106/20%; Fig. 4D). At the same time the relative importance of therophytes increased from 32% in the South Sudanian zone to 53% in the Sahel. Hemicryptophytes and chamaephytes were mostly restricted to the North- and South Sudanian zones and were essentially less common in the Subsahel and Sahel. The relative importance of geophytes (165 spp./8%) was rather constant from South to North (between 6 and 8%), apart from a drop to 3% in the Subsahel. Helophytes (39 spp.) and Hydrophytes (49 spp.) also formed a well-represented group. Nine of the 26 ferns and fern allies from BFA feature these life forms. Epiphytes were astonishingly rare. Among the nine epiphytic species, five are parasites from the family *Loranthaceae* (*Agelanthus dodoneifolius* (DC.) Polhill & Wiens, *Englerina lecardii* (Engl.) Balle, *Tapinanthus bangwensis* (Engl. & K. Krause) Danser, *T. globiferus* (A. Rich.) Tiegh., *T. ophiodes* (Sprague) Danser). The remaining four are true epiphytes, comprising three orchids (*Calyptrochilum christyanum* (Rchb. f.) Summerh., *C. emarginatum* (Sw.) Schltr., *Polystachya golungensis* Rchb. f.) and one fern (*Nephrolepis biserrata* (Sw.) Schott; *N. undulata* (Sw.) J. Sm. is regarded as a facultative epiphyte). The 24 species of *Ficus* were recorded as phanerophytes here, although at least some of them are hemi-epiphytes, growing epiphytic in the juvenile phase.

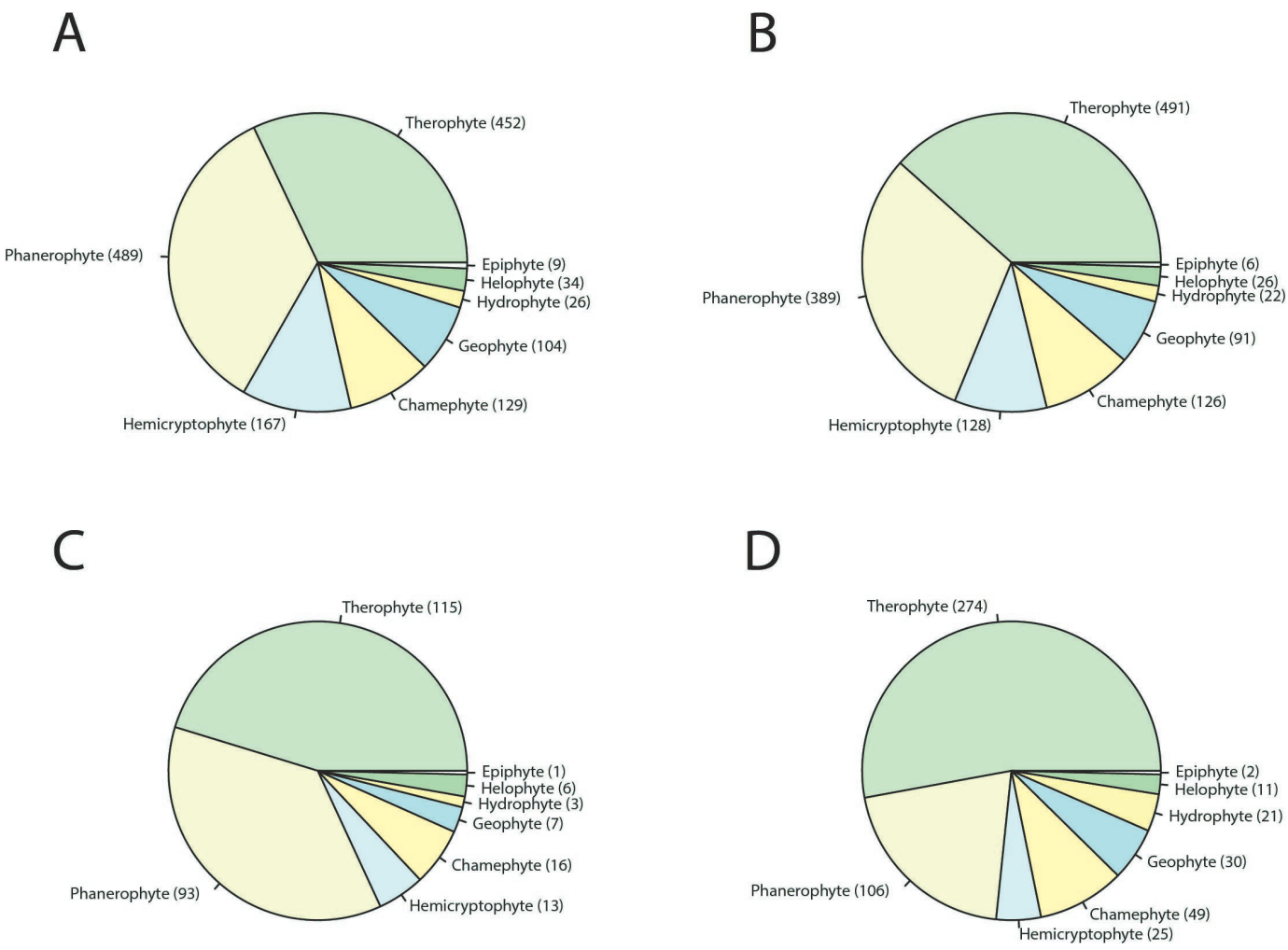

Fig. 4. – Proportion of life forms in the different phytogeographic zones of Burkina Faso. [**A.** South Sudanian; **B.** North Sudanian; **C.** Subsahel; **D.** Sahel]

Province-level analysis

The specimen record was unevenly distributed among the provinces of BFA (Fig. 5A). From the provinces with a good specimen record (>350 specimens), Comoé and Houet in the South-West of BFA (South Sudanian zone) and Tapoa and Gourma in the South-East (North Sudanian zone) stood out as the most species rich provinces (Fig. 5B). The distribution of rare species stressed the importance of the South-West of BFA for national biodiversity, as the number of rare species was highest in Comoé and Houet (Fig. 5C). Furthermore Comoé, Houet and Kénédougou showed the highest fraction of rare species with 22%, 17% and 17% respectively (Fig. 5D). Figure 5 shows that the South-West and the South-East of BFA are "hotspots" of species richness and rare species occurrence. Figure 6 illustrates species richness per province dependent on province area (Fig. 6A), protected area (Fig. 6B), population density (Fig. 6C) and latitude (Fig. 6D). However, these results have to be interpreted carefully due to the expected effect of sampling intensity (Fig 5A).

Cultivated species

Cultivated species were not included in the analyses presented above, except when occurring spontaneously outside the areas of cultivation. In addition to the 1972 spontaneously occurring species, 95 (4.5%) cultivated species were recorded for BFA. Of these 95 species 75 (79%) were known to be introduced. Thus, including cultivated species, a total of 191 (9.7%) species were known to be introduced and 37.5% of these were cultivated.

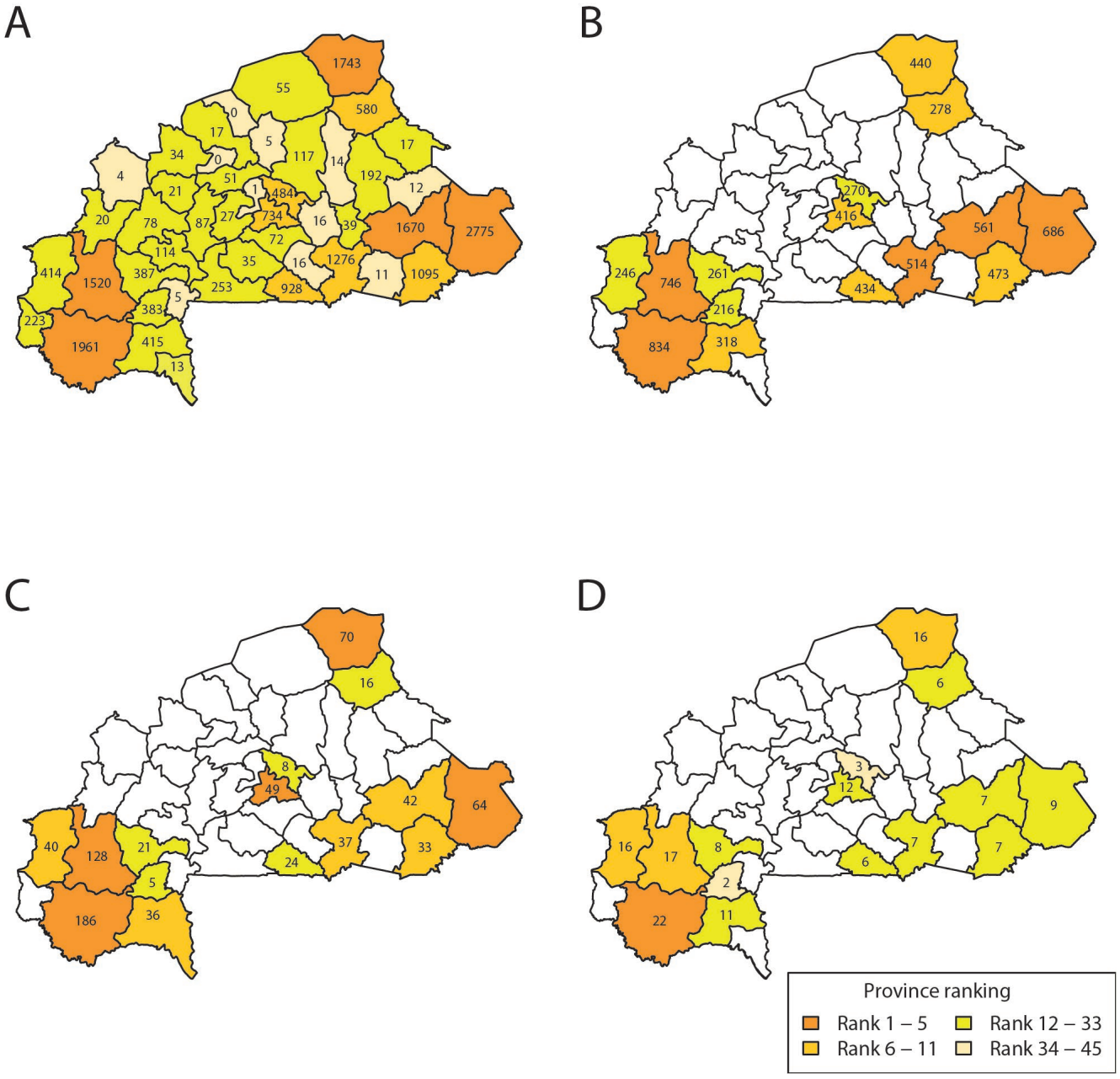

Fig. 5. – Species richness in Burkina Faso on a province level.
[**A.** The number of plant specimens available for this study; **B.** The number of species recorded; **C.** The number of "rare species" (<than 3 specimens in BFA); **D.** The percentage of "rare species". The colors illustrate the position within a ranking of all provinces. For B-D only data for provinces with more than 350 recorded specimens is shown. See figure 1 for province names]

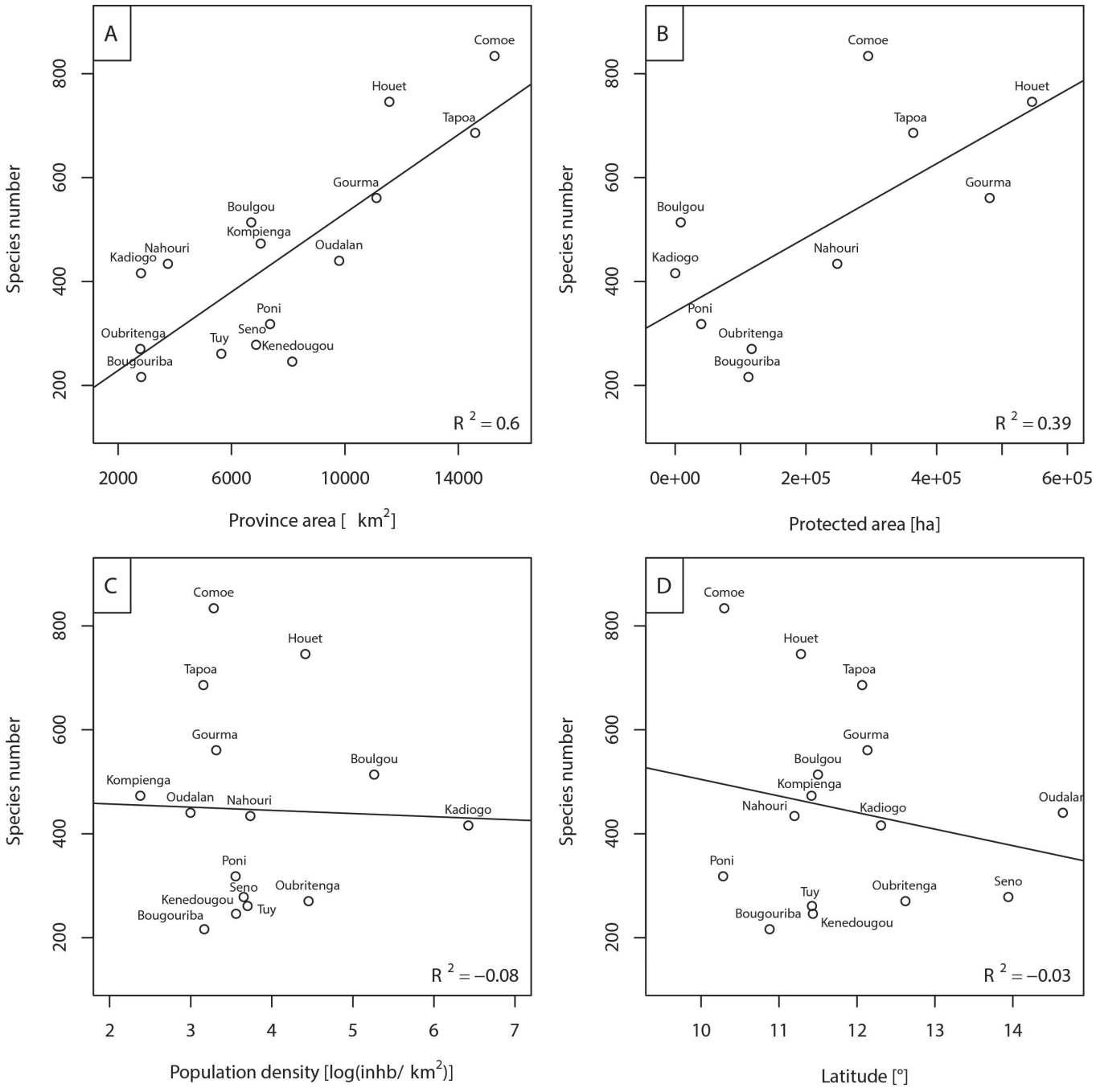

Fig. 6. – Province species richness in relation to province characteristics. Species richness per province is shown dependent on 4 factors. [**A.** Province area; **B.** Protected area (without the "Réserve sylvo-pastoral et partielle de faune du Sahel" in the Oudalan province, due to the unclear conservation status); **C.** Population density (logarithmic transformation); **D.** Latitude. The lines show a linear regression. Only provinces with more 350 recorded specimens are shown]

Discussion

Based on a recently published checklist (Thiombiano et al., 2012) we present a comprehensive analysis of the flora of Burkina Faso (BFA) on a national scale. The results can be grouped to four major pinpoints: **(1)** There are clear similarities between the flora of BFA and the regional flora of West-Africa. **(2)** The floral composition of the four phytogeographic zones within BFA is determined by the latitudinal climate gradient of the region. Species richness is highest in the South Sudanian. The Subsahel is of particular interest for future research and collecting activity. **(3)** Our analyses point to the South-West of BFA as a center of national biodiversity and stress it as region for future conservation efforts. **(4)** The existing conservation areas in the South-East of the country comprise a representative proportion of the flora of the country. In the next paragraphs we will discuss these results in detail.

The 1972 spontaneous species from 145 families recorded for BFA comprise 28% of the species and 92% of the families Hepper (1972) recorded for entire West Africa. The high percentage of West African families present in BFA might be due to its wide coverage of the regional climatic gradient. The 12 most common plant families in BFA are a good representation of the most common West-African families (Da, 2010). Exceptions to this pattern are the *Orchidaceae* and *Moraceae* which are underrepresented in BFA and the *Malvaceae* s.l. that are overrepresented (Fig. 2). This pattern might be due to habitat preferences of the mentioned taxa. At least some groups of *Orchidaceae* (e.g. epiphytes) and *Moraceae* (e.g. *Ficus*) are related to forest habitats which are relatively rare in BFA compared to southern West-Africa. Looking at the most diverse families in the neighboring countries, Ivory Coast (322,000 km^2) and Benin (112,600 km^2) display a higher overall plant diversity and a different pattern as far as the families are concerned. For Cote d´Ivoire, Aké Assi (2001, 2002) lists 3853 species of vascular plants. While the species numbers for *Fabaceae, Poaceae, Cyperaceae* and *Asteraceae* are only moderately to slightly higher compared to BFA, *Rubiaceae* (316 vs. 79 spp.) and *Orchidaceae* (237 vs. 23 spp.) stand out with a much higher diversity. Interestingly, the numbers for Benin (with of course smaller country area) are closer to those of BFA (*Rubiaceae:* 139 spp.; *Orchidaceae:* 48 spp.). The differences, especially in the orchid family, can be easily interpreted by the lack of humid (Guinean) forests in BFA and also Benin. This is also underlined when looking at the flora of Mali (Boudet & Lebrun, 1986; 1,240,000 km^2, 1739 spp. in total), which comprises only 14 spp. of *Orchidaceae* and 68 spp. of *Rubiaceae*. When comparing the analysis of the flora of West Tropical Africa (Hepper, 1965, 1972) with that of BFA, *Orchidaceae* and *Rubiaceae* also stand out as families clearly underrepresented.

The high fraction of Africa-wide distributed species in the flora of BFA and the shown connection to the American flora (Fig. 3) are also typical for West Africa (Hepper, 1965). Looking at endemism, the number of species unique to BFA is very low: one single species. This might in part be explained by the comparatively low geodiversity of the country. Topography is a major predictor of biodiversity (Kreft & Jetz, 2007) and mountains are known centers of biodiversity and endemism (Hoorn et al., 2013; Barthlott et al., 2005). The absence of forest refugia might also be one factor contributing to the low rate of endemism in BFA. However, low plant endemism seems to be a general feature of the West African savanna belt. Looking at the life form spectrum, the low number of only five truly epiphytic species is surprising and reflects the dry climatic conditions and the generally poor African epiphyte flora. A considerable number of hydro- and helophytes underlines the presence of wet azonal habitats throughout the country (as does *Cyperaceae* diversity, see above)

The species richness of the phytogeographic zones in BFA is highest in the South Sudanian and decreases towards the North Sudanian and the Subsahel (Table 1). A decrease in species richness along the climatic gradient from South to North is expected from findings on a regional scale for West-Africa (Da, 2010) and studies from other areas (Sambaré et al., 2011; Savadogo, 2013). The relative high number of species per area observed for the Sahel in our dataset (Table 1) does not fit with this trend. This is possibly due to increased sampling effort in this zone (Table 1), and edge effects leading to oversampling of species in the Sahel due to their relative rareness in the country. The change in species number correlates with a change of habitat. Our study shows that the observed change from Sudanian woodlands and tall-grass savannas to the Sahelian grasslands and thornbush savannas (Guinko, 1984b) is reflected in life form composition and habitat preferences of the flora (Fig. 4). The relative importance of phanerophytes and forest species decreases from South to North and at the same time the relative importance of therophytes and savanna species increases. The habitat shift is also visible in the change of species richness of a typical forest *(Ficus)* and a typical savanna *(Acacia)* genus, which decrease and increase from South to North respectively. Concordant with Guinko (1984b) our study confirmed the Subsahel as a transition zone including floristic elements from the Sahel and the Sudanian zones (Table 2). This transitional character of the Subsahel is stressed by the finding of only nine exclusive species in the Subsahel. Our data showed a larger similarity in species and life form composition between Subsahel and North Sudanian zone than Subsahel and Sahel (Table 2). In addition, the Subsahel showed by far the lowest diversity on all taxonomic levels (Table 1). However, these results must be interpreted carefully. A detailed spatial analysis of the total specimen record (Fig. 5A) revealed a severe sampling deficit in some regions of the Subsahel as probable explanation for the low diversity patterns. Thus, we recommend the Subsahel as focus for future research and sampling activity, to clarify the floristic identity of this phytogeographic zone.

The comparison of species richness on a province level is of special interest, as it enables the relation of species richness to socio-ecological factors and the number of protected areas. Defining endemism and discussing conservation issues based on political entities like provinces or countries might seem arbitrary. However, these areas are clearly defined, commonly accepted structures and in many cases other subdivisions based on data e.g. landscape structure or vegetation are simply not available. Especially for conservation issues, another argument is most important: conservation assessment and strategies are usually linked to the political entities and the legislation relevant for conservation relies on biodiversity information for exactly these areas. Thus province-level information is important and might allow a better focus of future conservation effort. Within the scope of our analyses we found clear differences in species richness, number of rare species and fraction of rare species between the provinces of BFA (Fig. 5, 6). We found the highest species numbers in Comoé, Houet, Gourma and Tapoa. These four provinces are also within the top six regarding protected areas (Fig. 6B). Our results stress the special relevance of Comoé for biodiversity in BFA, as it comprises the highest species number and the highest number of species rare in BFA (Fig. 5C-D). In addition it exclusively hosts the plant species endemic to the country. This special position is probably related to the location of Comoé within BFA which accounts for high topodiversity and high rainfall and thus different habitat conditions allowing for the occurrence of species for which other parts of BFA are unsuitable. Figure 6 shows the correlation between province area and species richness, as well as protected area and species richness. The proportion of variation in species richness explained by population density (Fig. 6C) and latitude (Fig. 6D) seems low, but were likely masked by the effect of province area and especially sampling intensity (Fig. 5A). Future studies based on datasets with a more complete sampling will hopefully allow quantifying the effect of the different environmental factors in greater detail.

Our analyses stress the importance of the South-West of BFA for conservation on a national scale. This is supported by the analyses of the PGZs (Table 1) as well as the analyses of the provinces (Fig. 5C-D). The high biodiversity in these areas together with the projected high species loss in the South of BFA due to climate and land-use change (Heubes et al., 2013) stresses the importance of enforced conservation efforts in the South-West of BFA. These results are consistent with results from a model-based analysis on a West-African scale that suggests the South-West of BFA as "hotspot" area for future conservation areas (Da, 2010). The comparison of our results with inventories of three existing protected areas in the region (Pama Faunal Reserve, Arly National Park, and the W National Park in the South-East of BFA and the Pendjari National Park in Northern Benin) confirm that these areas represent typical elements of the flora of BFA. As on the national scale, they are dominated by therophytes and phanerophytes, and *Fabaceae* and *Poaceae* are the most species rich families (Mbayngone et al., 2008; Ouédraogo et al., 2011; Assédé et al., 2012; Nacoulma, 2012). With regard to taxon richness, the Pama faunal reserve comprises 50% of the families and 23% of the species of BFA (Mbayngone et al., 2008), the Arly National Park comprises 57% of the families and 25% of the species of the country (Ouédraogo et al., 2011) and the Pendjari Reserve in Benin on the border with BFA, hosts 67% of the plant families and 35% of the plant species in BFA (Assédé et al., 2012). Thus the three national parks represent an important fraction of the flora of BFA and our results stress their importance for the conservation of the flora of the country.

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