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Ecological and floristic characterization of inselberg habitats in Burkina Faso

Caractérisation écologique et floristique des habitats des inselbergs du Burkina Faso

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Résumé : Les inselbergs se caractérisent par la diversité de leurs habitats et la précarité de leur sol. La sauvegarde de la diversité floristique des inselbergs passe par la connaissance de leurs habitats. L'objectif de cette étude est de recenser les habitats des inselbergs du Burkina Faso et de décrire leur flore et leur écologie. Les données ont été collectées suivant un échantillonnage stratifié et aléatoire dans des placettes de 0,25 m² à 900 m² en fonction de la taille de l'habitat. Onze habitats ont été recensés. Trois cent cinquante-quatre espèces végétales réparties dans 209 genres et 81 familles ont été recensées. Les savanes arbustives et les savanes herbeuses sont les habitats les plus riches en espèces. Les habitats les plus pauvres en espèces sont les grottes et les dalles rocheuses. Il ressort de cette étude, une dissimilitude floristique entre la majorité des habitas des inselbergs. Les familles dominantes sont les Poaceae, les Fabaceae-Faboideae, les Cyperaceae et les Rubiaceae. Les Thérophytes, les Hémicriptophytes et les Phanérophytes sont les types biologiques dominants. Les types phytogéographiques dominants sont les Soudano-zambéziens et Pantropicales. La profondeur et l'humidité du sol sont les facteurs écologiques qui distinguent les différents habitats des inselbergs.

Mots clés: inselbergs, habitats, écologie, composition floristique, Burkina Faso

Abstract : Inselbergs are characterized by the diversity and specificity of their habitats due to the precariousness of their soil. Safeguarding the floristic diversity of inselbergs requires knowledge of their habitats. The objective of this study is to identify the habitats of inselbergs in Burkina Faso and describ their flora and ecology. Data were collected according to stratified and random sampling in plots from 0,25 m^2 to 900 m^2 depending on the size of habitat. A total of eleven habitats has been identified, comprising 354 plant species, 209 genera and 81 families. Shrub savannas and grass savannas are the habitats which are richest in species. In contrast, caves and Cryptogamic crusts are the habitat types which are poorest in species. This study highlights a floristic dissimilarity between the majority of habitats on inselbergs. Poaceae, Fabaceae-Faboideae, Cyperaceae and Rubiaceae are dominant families. Therophyte, Hemicryptophyte and Phanerophyte dominate among the biological growth forms. Phytogeographically, the Soudano-zambesian and pantropical type prevail. Soil depth and moisture are the ecological key factors that distinguish between different habitats within inselbergs.

Key words: inselbergs, habitats, ecology, floristic composition, Burkina Faso

INTRODUCTION

Fragmentation and destruction of habitats resulting from human activities are considered as the main cause for the erosion of biodiversity (Bergès *et al.* 2010). Safeguarding and sustainable management of the biodiversity of an ecosystem therefore requires profound knowledge as well as protection of the habitats of which it is composed. It's in this perspective that the habitats of several ecosystems have been the subject of many studies since the 19th century in Burkina Faso (Mbayngone *et al.* 2008). Even though habitats of several ecosystems have been studied, there are still some other for which ecological and floristical investigations are missing in Burkina Faso. Likewise, this is the case of inselbergs.

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Inselbergs are tropical rock outcrops, mainly consisting of precambrian granite and gneiss with a geomorphological age of more than 70 million years (Barthlott *et al.* 1993). In terms of edaphic, microclimatic and floristic aspects, inselbergs are isolated "islands" from the surrounding landscape (Sarthou *et al.* 2017). The lack of soil and water, exposure to UV-radiation, high temperatures and constant winds clearly distinguish inselbergs from the surrounding area (De Paula *et al.* 2017). Seen from a distance, inselbergs appear to form homogenous landscape features that consist mainly of large areas of bare, dark coloured rock. However, more attentive and close observations reveal that they are ecosystems with a variety of clearly distinguishable habitat types (Porembski *et al.* 2000). Therefore, a set of plant communities related to habitat types occur on rock outcrops. So far, habitats of inselbergs have been described floristically and ecologically for West Africa. Oumorou & Lejoly (2003) have characterized the vegetation types of the inselberg Sobakperou in Benin. Barthlott *et al.* (1993) have described the habitat types of inselbergs in Ivory Coast and Guinea. As aforementioned, habitats of inselbergs in Burkina Faso have not been an target of ecological and floristical characterisation so far.

The following questions can therefore be asked: (i) which different habitat types occur on inselbergs in Burkina Faso?; (ii) what are the specific ecological and floristical characteristics of each habitat? In order to answer these questions, this study aims at capturing the different habitat types of inselbergs in Burkina Faso and to characterise their ecology and flora.

MATERIALS AND METHODS

Study area

Burkina Faso is located in the heart of West Africa between latitudes 9°02' and 15°05' north and 02°02' east and 05°03' west (Fig. 1). It is subdivided into two phytogeographical domains and four phytogeographical sectors on the basis of climate, plant formations and flora (Fontès & Guinko 1995). Inselbergs are found from the North Sahelian sector to South Sudanian sector. The North Sahelian sector and the South Sudanian sector are richer in inselbergs. In the different phytogeographic sectors, inselbergs are granite and/or sandstone. The present study was conducted in the four phytogeographical sectors of Burkina Faso. Data was collected in the different phytogeographic sectors (Fig. 1).

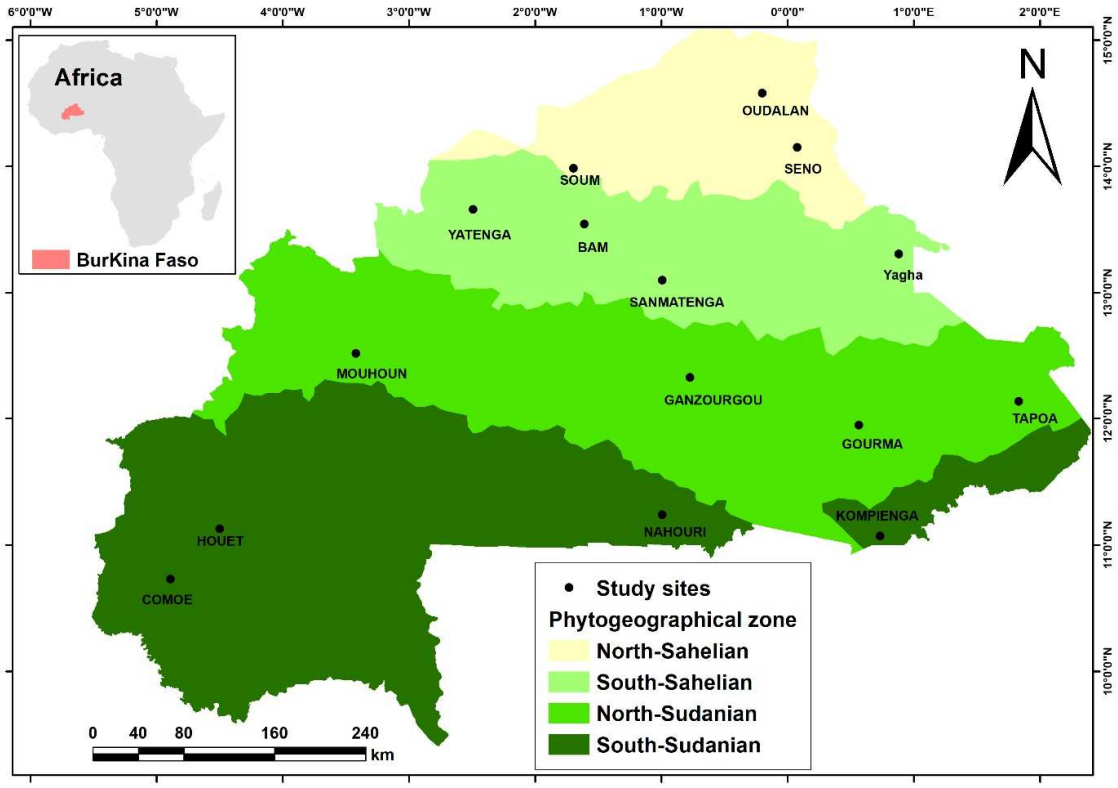

Figure 1. Localisation of study sites (Sources: BNDT/IGB. GPS Surveys)

Data collection

The data were collected during the months of June, July, August, September and October according to stratified and random sampling. The selected period made it possible to inventory the majority of plant species evolving in the different habitats. The different habitat types present on each inselberg were recorded. For each habitat, a list of all plant species was compiled as well as the abundance-dominance using Braun-Blanquet (1932) scale. The data were collected on plots size about 0,25 m2 to 900 m2 depending on the size of the habitat (Porembski 1996; Büdel *et al*. 1997). The ecological characteristics of each habitat were registred. The data were gathered from 52 inselbergs within the four phytogeographical sectors in Burkina Faso.

Data analysis

Plant species were determined from the specimens collected and identified by means of field guides (Hutchinson et Datziel 1963; Akoegninou *et al.* 2006). The adopted nomenclature in this article is the same like in the catalogue of vascular plants of Burkina Faso (Thiombiano *et al.* 2012).
For the comparison of floristic diversity of habitats, some diversity parameters have been evaluated. These are:
- mean number of species $Nm = \frac{Rt}{Nr}$; **Nr**: number of plots per habitat, **Rt**: total number of species inventoried in each habitat;
- maximum diversity index, $Hmax = lnS$; **S**: total number of species in the population;
- Shannon's diversity index, $H = -\sum_{i=1}^{s} PilnPi$, P_i (relative abundance of i^{th} species in a plot) = (ni/N); ni: number of individuals/species; N: total number of individuals per plot;
- Equitability index, $E = \frac{H}{lnS}$;
Sørensen's similarity index, $Cs = \frac{2c}{2c+b+a}$ with **c:** number of common species; **a**: number of species found in habitat A; **b**: number of species found in habitat B.
The utilized biological types are defined by Raunkiaer (1934).
The utilized phytogeographical types originate the chorological subdivisions of White (1986). The raw spectra were developed to show the abundance of each biological and phytogeographic type (Kouassi *et al.* 2009; Tindano *et al.* 2015).
A Kruskal-Wallis non-parametric comparison ANOVA was used to compare the different diversity parameters studied.

RESULTS

Habitat types on inselbergs

Cryptogamic crusts

The surface of granitic and sandstone rock formations is characterized by the absence of soil (Photo 1). However, it is covered by lichens and cyanobacteria which are most frequently responsible for rock surface coloration. Regarding the lichens, the genus *Peltula* is the most common, whereas *Stigonema* and *Scytonema* are the most common cyanobacteria group in this habitat.

Photo 1. Cryptogamic crusts, Houet province (Koro). Photo E. Tindano (2019).

Caves

The main characteristics of caves are their almost inexistent soil cover, their shadow and their humidity which predominates during rain season and partly in dry season (Photo 2). Caves occur on both granitic and sandstone inselbergs. Plant index species for caves are *Begonia rostrata* Welw. Ex Hook.f. and *Batopedina tenuis* (A. Chev. ex Hutch. & Dalziel) Verdc (Appendix Table). Cyperaceae is the most dominant family, followed by Begoniaceae and Rubiaceae.

Photo 2. Cave, Comoé province (Takalédougou). Photo E. Tindano (2012).

Crevices

Crevices are fissures in rocks (Photo 3) that are present on granitic and sandstone inselbergs. They can be characterized by soil deposits whose thickness varies with the size of crevice. The soil confers certain humidity within crevices and permits establishment of herbs, mainly Poaceae. Woody species are often found, especially in the larger cracks where soil is thicker. Twenty-eight (28) plant species have been inventoried within these habitats. They split up into 23 genera and 12 families. The mean number of species is 4,60 ± 2,41. Shannon's diversity index is 1,49 ± 0,43 and equitability index is 1 ± 0,00 (Tab. 1). The index species for crevices are *Andropogon gayanus* Kunth, *Striga gesnerioides* (Willd.) Vatke and *Tephrosia linearis* (Willd.) Pers (Appendix Table). The most dominant families in crevices are Poaceae (21,43 %), Fabaceae-Faboideae (17,86 %), Cyperaceae (14,29 %) and Rubiaceae (14,29 %) (Tab. 2). Therophytes (46,43 %), Phanerophytes (25,00 %) and Hemicryptophytes (21,43 %) are the dominant life forms (Tab. 3). The most abundant phytogeographical types belong to Sudano-Zambesian (28.57 %), Afro-Tropical (25,00 %), Pantropicals (14,29 %) and Sudanians (14,29 %) (Tab. 4).

Photo 3. Crevices, Sanmatenga province (Dondolé). Photo E. Tindano (2013)

"Permanent" runoff habitat

These habitats are characterized by a runoff of water during the whole wet season and parts of the dry season (Photo 4). The physiognomy of the vegetation close to the running water is eponymous for the rupicolous formations on inselbergs. The essential characteristic of these habitats represent mats of algae underneath the running water. Permanent runoff habitats are found exclusively on sandstone inselbergs in Burkina Faso.
The floristic richness is within 31 species in 26 genera and 16 families. The mean number of species, Shannon's diversity index and equitability index are 15,00 ± 7,07; 2,65 ± 0,49 and 1 ± 0,00, respectively (Tab. 1).
Index species are *Justicia tenella* (Nees) T Anderson. and *Rhamphicarpa fistulosa* (Hochst.) Benth (Appendix Table 1). The most dominant families are Poaceae (22,58 %), Cyperaceae (12,90 %) and Fabaceae-Faboideae (12,90 %) (Tab. 2). Therophytes (41,94 %), Hemicryptophytes (22,58 %) and Geophytes (12,90 %) are the dominant life forms in order of importance (Tab. 3). The most abundant phytogeographical types belong to Afro-Tropicals (38,71 %), Pantropicals (22,58 %) and Sudanians (16,13 %) (Tab. 4).

Photo 4. "Permanent" runoff habitats, Houet province (Koro). Photo E. Tindano (2012).

Rock pools

As their name suggests, pools on rocks are small reservoirs of water on inselbergs. They can be distinguished from other micro-habitats due to their submerged soil for several weeks after rains (Photo 5). They occur both on granitic and sandstone inselbergs. The floristic richness is 35 species within 28 genera and 14 families. The mean number of species is 3,21 ± 1,67, Shannon's diversity index is 1,01 ± 0,62 and equitability index is 0,79 ± 0,43 (Tab. 1). Species that are subject to this habitat are *Cyperus podocarpus* Boeckeler, *Cyperus reduncus* Hochst. ex Boeckeler and *Dopatrium longidens* Skan (Appendix Table 1). The most dominant families are Cyperaceae (38,10 %), Poaceae (19,05 %) and Fabaceae-Faboideae (9,52 %) (Tab. 2). The dominant life forms in order of importance are Therophytes (60,61 %), Helophytes (15,15 %) and Hemicryptophytes (12,12 %) (Tab. 3). Afro-Tropicals (33,33 %), Pantropicals (27,27 %) and Sudano-Zambesians (12,12 %) are the most abundant phytogeographical types in order of importance (Tab. 4).

Wet slabs

With a skeletal soil of 3,67 ± 3,33 cm, wet slabs are characterized by a runoff for a few hours or even days after the rains (Photo 6). They are both present on granitic and sandstone inselbergs. Thirty-seven (37) plant species, distributed in 32 genera and 20 families, have been listed on wet slabs. The mean species number is 10,00 ± 2,65. Shannon's diversity index and equitability index are 0,60 ± 0,47 and 0,67 ± 0,49, respectively (Tab. 1). Index species of this habitat are *Bulbostylis densa* (Wall.) Hand.-Mazz. and *Lepidagathis anobrya* Nee (Appendix Table 1). The most dominant families are Poaceae (13,89 %), Cyperaceae (11,11 %) and Fabaceae-Faboideae (11,11 %) (Tab. 2). Therophytes (51,43 %), Geophytes (17,14 %), Chamephytes (11,43 %) and Hemicryptophytes (11,43 %) are the dominant life forms (Tab. 3). The most abundant phytogeographical types of this habitat are Afro-Tropicals (44,12 %), Pantropicals (20,59 %) and African Multiregional (14,71 %) (Tab. 4).

Photo 5. Rock pools, Comoé province (Takalédougou). Photo E. Tindano (2012).

Photo 6. Wet slabs, Houet province (Kotédougou). Photo E. Tindano (2012).

Monocotyledonous mats, Afrotrilepis pilosa mats

The main characteristic species of this habitat is *Afrotrilepis pilosa.* With the help of its roots, this species colonizes bare rock surfaces and traps the soil. As time goes by, soil can attain an average depth of 7,60 ± 0,70 cm (Photo 7). Mats of *Afrotrilepis pilosa* occur in Burkinqa Faso on sandstone inselbergs. The flora richness is 48 species distributed in 39 genera and 19 families. The mean species number is 8,71 ± 4,48, Shannon's diversity index and equitability index are 1,90 ± 0,88 and 0,86 ± 0,36, respectively (Tab. 1). Other characterictic specie of this habitat is *Kyllingia tenuifolia* Steud (Appendix Table 1). The Poaceae family (24 %) dominates this habitat, followed by Cyperaceae (22 %) and Fabaceae-Faboideae (10 %) (Tab. 2). Therophytes (52 %), Hemicryptophytes (16 %) and Geophytes (12 %) are the dominant life forms (Tab. 3). The most abundant phytogeographical types are Afro-Tropicals (38 %), Sudano-Zambesians (16 %) and Pantropicals (14 %) (Tab. 4).

Photo 7. *Afrotrilepis pilosa* mats, Houet province (Koro). Photo E. Tindano (2012).

Monocotyledonous mats, dry grassland with shallow soil

Dry grasslands with shallow soils are, as their name suggests, characterized by an average soil depth of 4,08 ± 2,27 cm (Photo 8). Periodically, they are dampened by runoff water during wet season. They are found on both granitic and sandstone formations. These habitats comprise 58 plant species distributed in 45 genera and 21 families. Mean species number is 10,00 ± 2,65. Shannon's diversity index and Pielou's equitability index are 0,60 ± 0,47 and 0,67 ± 0,49 (Tab. 1). Index species of dry grasslands are *Cyperus buchholzii* Boeck. and *Synedrella nodiflora* Gaertn (Appendix Table). The most dominant families are Poaceae (25,86 %), Cyperaceae (24,14 %) and Fabaceae-Faboideae (10,35 %) (Tab. 2). Dominant life forms in dry grasslands are Therophytes (57,89 %), Hemicryptophytes (15,79 %), followed by Geophytes and Phanerophytes (8,77 % each) (Tab. 3). Afro-tropicals (36,21 %), Pantropicals (13,33 %) and Paleotropicals (13,33 %) are the most abundant phytogeographical types (Tab. 4).

Photo 8. Dry grassland, Sissili province (Bozo). Photo E. Tindano (2012).

Ephemeral flush vegetation

Ephemeral flush vegetation differ from dry grasslands in that they have deeper soils (7,38 ± 3,34 cm) saturated with water (Photo 9) and that they occur on both granitic and sandstone formations. Seventy-five (75) plant species distributed in 52 genera and 26 families have been listed in this habitat. The mean species number, Shannon's diversity index and equitability index are 5,50 ± 2,47; 1,75 ± 0,31 and 1 ± 0,00, respectively (Tab. 1). Index species are *Bacopa floribunda* (R.Br.) Wettst., *Drosera indica* L., *Lindernia schweinfurthii* (Engl.) Dandy. and *Ludwigia abyssinica* A.Rich (Appendix Table 1). The dominant families are Poaceae (26,67 %), Cyperaceae (24,00 %), Rubiaceae and Fabaceae-Faboideae (5,33 % each) (Tab. 2). Therophytes (56,00 %), Hemicryptophytes (18,67 %) and Geophytes (8 %) are the most dominant life forms (Tab. 3). The most abundant phytogeographical types are Afro-Tropicals (32,43 %), Pantropicals (24,32 %) and African Multiregional (16,22 %) (Tab. 4).

Photo 9. Ephemeral flush vegetation, Houet province (Koro). Photo E. Tindano (2012).

Grass savannas on shallow soils

Grass savannas on superficial soils are plant formations of granitic and sandstone inselbergs that are characterized by a rarely discontinuous herbaceous mat and comprised mainly of annual species (Photo 10). Soil depth is 16,89 ± 2,30 cm. This habitat encompasses 245 plant species in 159 genera and 48 families. The mean species number per plot is 21,47 ± 5,44. Shannon's diversity index and equitability index are 3,04 ± 0,25 and 1,00 ± 0,00 (Tab. 1). Index species are *Aspilia rudis* Oliv. & Hiern, *Boswellia dalzielii* Hutch., *Grewia villosa* Willd., *Sida acuta* Burm.f., *Vigna reticulata* Hook.f., (Appendix Table 1). The most dominant families are Poaceae (16,10 %), Fabaceae-Faboideae (9,76 %) and Malvaceae (9,76 %) (Tab. 2). Therophytes (51,02 %), Phanerophytes (36,33 %) and Chamaephytes (7,76 %) are the dominant life forms of grass savannas (Tab. 3). The most abundant phytogeographical types are Sudano-Zambesians (25,71 %), Pantropicals (22,86 %) and Afro-Tropicals (20,41 %) (Tab. 4).

Shrub savannas

These habitats of granitic and sandstone inselbergs are characterized by a denser woody stratum than of grassy savannahs and a discontinuous herbaceous stratum (Photo 11). Median soil depth is 27,94 ± 5,01 cm. Of all habitats on inselbergs, this is the richest in species diversity. Therefore, the flora comprises 341 species distributed in 214 genera and 62 families. The median species number per plot is 26,33 ± 7,65. Shannon's diversity index is 3,21 ± 0,33 and equitability index is 1,00 ± 0,00 (Tab. 1). Index species are *Acacia hockii* De Wild., *Andropogon fastigiatus* Sw., *Baissea multiflora* A. DC., *Biophytum umbraculum* Welw., *Bridelia ferruginea* Benth., *Euclasta condylotricha* (Hochst. ex Steud.) Stapf, *Gardenia ternifolia* Schumach. et Thonn., *Lannea velutina* A. Rich., *Ozoroa obovata* (Oliv.) R.Fern. & A.Fern., *Tephrosia linearis* (Willd.) Pers., *Tephrosia nana* Schweinf. and *Vigna radiata* (L.) R.Wilczek [cult.], (Appendix Table 1). The most dominant families are Fabaceae-Faboideae (14,08 %), Poaceae (14,08 %), Malvaceae (5,87 %) and Rubiaceae (5,87 %)

(Tab. 2). The dominant life forms are Phanerophytes (41,40 %), Therophytes (37,03 %) and Hemicryptophytes (7,58 %) (Tab. 3). Sudano-Zambesians (28,15 %), Afro-Tropicals (23,17 %) and Pantropicals (16,42 %) are the most abundant phytogeographical types (Tab. 4).

Photo 10. Grass savannah, Oudalan province (Kollel). Photo E. Tindano (2011).

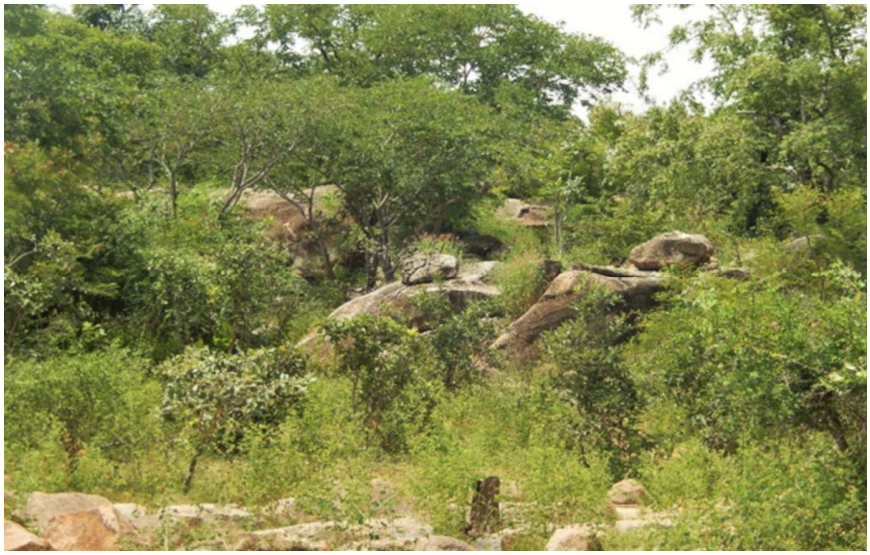

Photo 11. Shrub savannah, Ganzourgou province (Wayen). Photo E. Tindano (2019).

Habitat diversity parameters

Floristic richness and specific diversity

Altogether, a total of 354 plant species distributed in 209 genera and 81 families have been listed for habitats on inselbergs in Burkina Faso. Shrub savannas are the habitat which is richest in species (341 species), followed by grass savannas (245 species). Cryptogamic crusts and caves (3 species) are the habitats which are poorest in species (Tab. 1). The diversity parameters Nm, H and E vary significantly from one habitat to another. However, the p-values are all low at 0,001 ($p<0,001$). Habitats with more diverse flora are, in order of importance, shrub savannas, grass savannas, dry grassland and permanent runoff zones with indices of Shannon's diversity more close to the maximum diversity index (Tab .1). The flora of remaining habitats is diversified to a lesser extent. Wet slabs and rock pools are habitats with an index of equitability within the interval of [0; 0,8]. However, there is a dominance of species in both habitats. For the remaining habitats, equitability index lies within the interval [0,8; 1], indicating the absence of a dominance of species in these habitats (Tab. 1).

Table 1. Diversity parameters of habitats on inselbergs.

	Famillies	Genera	Species	Nm	Hmax	H	E
Cry cru	2	3	2	-	0,69	-	-
Cav	3	3	3	-	1,10	-	-
Cre	12	23	28	4,60 ± 2,41	3,33	1,49 ± 0,43	1 ± 0,00
Run hab	16	26	31	15,00 ± 7,07	3,43	2,65 ± 0,49	1±0,00
Roc poo	14	28	35	3,21 ± 1,67	3,56	1,01 ± 0,62	0,79 ± 0,43
Wet sla	20	32	37	10,00 ± 2,65	3,61	0,60 ± 0,47	0,67 ± 0,49
***A. pi* mat**	19	39	48	8,71 ± 4,48	3,87	1,90±0,88	086±0,36
Dry gra	21	45	58	10,18 ± 3,63	4,06	2,28±0,29	1±0,00
E. fl veg	26	52	75	5,50 ± 2,47	4,32	1,75 ± 0,31	1 ± 0,00
Gra sav	48	159	245	21,47 ± 5,44	5,50	3,04±0,25	1,00±0,00
Shr sav	62	214	341	26,33 ± 7,65	5,83	3,21±0,33	1,00±0,00

Cry cru: Cryptogamic crusts; **Cav**: caves; **Cre**: Crevices; **Run hab**: runoff habitat; **Roc poo**: Rock pools; **Wet sla**: Wet slabs; ***A.pi* mat**: *Afrotrilepis pilosa* mats; **Dry gra**: dry grassland; **E. fl veg**: Ephemeral flush vegetation; **Gra sav**: Grass savannas; **Shr sav**: Shrub savannas.

The habitats on inselbergs throughout Burkina Faso comprise 81 families and among them Poaceae, Fabaceae-Faboideae, Cyperaceae and Rubiaceae are the most frequent and dominant. The family of Commelinaceae, although less abundant, is encountered in all habitats except for bare rock (Tab. 2). In contrast, certain families occur exclusively in one single habitat. These include Aloeaceae, Begoniaceae, Caryophyllaceae and Chrysobalanaceae.

Table 2. Crude spectra (%) of families of habitats.

	Cry cru	**Cav**	**Cre**	**Run hab**	**Roc poo**	**Wet sla**	***A.pi* mat**	**Dry gra**	**E.fl veg**	**Gra sav**	**Shr sav**
Acanthaceae	-	-	-	6,45	4,76	8,33	-	-	2,67	0,98	0,88
Adiantaceae	-	-	-	-	-	-	-	-	2,67	-	-
Aloeaceae	-	-	-	-	-	-	-	-	1,33	-	-
Amaranthaceae	-	-	-	-	-	-	-	1,72		0,98	1,17
Amaryllidaceae	-	-	-	3,23	-	2,78	2	1,72	1,33	0,49	0,59
Anacardiaceae	-	-	-	-	-	-	-	-	-	1,46	2,35
Annonaceae	-	-	3,57	-	-	-	-	-	-	0,49	0,88
Apocynaceae	-	-	-	3,23	-	-	-	-	-	2,93	2,93
Araceae	-	-	-	3,23	2,38	-	2,00	1,72	-	-	0,88
Arecaceae	-	-	-	-	-	-	-	-	-	-	0,88
Asparagaceae	-	-	-	3,23	-	2,78	2,00	1,72	-	-	-
Asteraceae	-	-	-	3,23	-	8,33	4	3,45	-	3,41	2,35

Begoniaceae	-	+	-	-	-	-	-	-	-	-	-
Bignoniaceae	-	-	-	-	-	-	-	-	-	0,49	0,59
Bixaceae	-	-	-	3,23	-	-	2	1,72	-	0,98	0,59
Burseraceae	-	-	-	-	-	-	-	-	-	0,98	0,29
Capparaceae	-	-	-	-	-	-	-	-	-	4,39	2,35
Caryophyllaceae	-	-	-	-	-	-	-	-	-	-	0,29
Chrysobalanaceae	-	-	-	-	-	-	-	-	-	-	0,59
Combretaceae	-	-	3,57	3,23	-	-	2	3,45	-	5,85	4,11
Commelinaceae	-	+	3,57	3,23	2,38	2,78	4	1,72	2,67	0,98	0,59
Convolvulaceae	-	-	-	3,23	-	2,78	-	-	-	1,46	2,35
Costaceae	-	-	-	-	-	-	-	-	-	-	0,29
Cucurbitaceae	-	-	-	-	-	-	-	-	-	0,98	0,59
Cyperaceae	-	-	14,29	12,90	38,1	11,11	22	24,14	24	2,44	2,64
Dioscoreaceae	-	-	-	-	-	-	-	-	-	-	0,29
Dipterocarpaceae	-	-	-	-	-	-	-	-	-	-	0,29
Droseraceae	-	-	-	-	-	-	2,00	1,72	1,33	-	-
Ebenaceae	-	-	-	-	-	-	-	-	-	0,49	0,29
Eriocaulaceae	-	-	-	-	-	2,78	-	-	2,67	-	-
Euphorbiaceae	-	-	3,57	-	-	-	-	-	1,33	2,44	2,93
Fabaceae-Caesalpinioideae	-	-	3,57	-	-	-	-	-	-	5,85	4,11
Fabaceae-Faboideae	-	-	17,86	12,9	9,52	11,11	10	10,34	5,33	9,76	14,08
Fabaceae-Mimosoideae	-	-	-	-	2,38	-	2	1,72	1,33	7,8	5,57
Fabaceae-Mimosoideae	-	-	-	-	-	-	-	-	-	-	-
Gentianaceae	-	-	-	-	-	2,78	-	-	1,33	-	-
Hypoxidaceae	-	-	-	-	-	-	-	-	1,33	-	-
Hyppocrateaceae	-	-	-	-	-	-	-	-	-	-	0,29
Iridaceae	-	-	-	-	-	2,78	-	-	-	-	-
Isoetaceae	-	-	-	-	-	2,78	-	-	1,33	-	-
Lamiaceae	-	-	7,14	-	-	-	-	1,72	-	0,98	2,05
Lentibulariaceae	-	-	-	-	4,76	-	-	-	1,33	-	-
Linderniaceae	-	-	-	-	-	-	-	-	1,33	-	0,29
Loganiaceae	-	-	-	-	-	-	-	-	-	0,98	0,59
Lythraceae	-	-	-	-	-	5,56	-	-	1,33	0,49	0,29
Malvaceae	-	-	-	-	2,38	-	2,00	3,45	2,67	9,76	5,87
Marsileaceae	-	-	-	-	2,38	-	-	-	1,33	-	-
Meliaceae	-	-	-	-	-	-	-	-	-	-	0,59
Menispermaceae	-	-	-	-	-	-	-	-	-	0,49	-
Molluginaceae	-	-	-	-	-	-	-	-	-	0,49	0,59
Moraceae	-	-	3,57	-	-	-	-	-	-	0,98	1,76
Nyctaginaceae	-	-	-	-	-	-	-	-	-	0,49	0,29
Ochnaceae	-	-	-	-	-	-	-	-	-	-	0,29
Oleandraceae	-	-	-	-	-	2,78	-	-	-	-	-
Onagraceae	-	-	-	-	-	-	2,00	1,72	1,33	-	-
Ophioglossaceae	-	-	-	3,23	2,38	2,78	4,00	1,72	2,67	-	-
Opiliaceae	-	-	-	-	-	-	-	-	-	-	0,29
Orchidaceae	-	-	-	-	-	2,78	-	-	-	-	-
Orobanchaceae	+	-	3,57	3,23	2,38	-	2	1,72	-	-	0,88
Oxalidaceae	-	-	-	-	-	-	-	-	-	-	0,29
Passifloraceae	-	-	-	-	-	2,78	-	-	-	-	0,29
Pedaliaceae	-	-	-	-	-	-	-	-	-	0,49	0,29
Phyllanthaceae	-	-	-	-	-	-	-	-	-	2,93	1,76
Plantaginaceae	-	-	-	-	2,38	-	4	1,72	2,67	-	-

Poaceae	-	-	21,43	22,58	19,05	13,89	24	25,86	26,67	16,1	14,08
Polygalaceae	-	-	-	-	-	-	-	-	-	0,98	0,88
Rhamnaceae	-	-	-	-	-	-	-	-	-	-	0,88
Rubiaceae	-	+	14,29	9,68	4,76	2,78	6	5,17	5,33	3,9	0,29
Rutaceae	-	-	-	-	-	-	-	-	-	-	0,29
Salicaceae	-	-	-	-	-	-	-	-	-	-	0,59
Sapindaceae	-	-	-	-	-	-	-	-	-	0,49	0,29
Sapotaceae	-	-	-	-	-	-	-	-	-	0,49	1,17
Simaroubaceae	-	-	-	-	-	-	-	-	-	-	0,29
Smilacaceae	-	-	-	-	-	-	-	-	-	-	0,29
Solanaceae	-	-	-	-	-	-	-	-	-	0,49	-
Taccaceae	-	-	-	-	-	-	-	-	-	-	0,29
Verbenaceae	-	-	-	-	-	-	-	-	-	-	0,29
Vitaceae	-	-	-	-	-	-	-	-	-	0,98	0,88
Ximeniaceae	-	-	-	-	-	-	-	-	-	0,49	0,29
Zingiberaceae	-	-	-	-	-	5,56	2	1,72	1,33	-	0,29
Zygophyllaceae	-	-	-	-	-	-	-	-	-	0,98	0,59

Cry cru: Cryptogamic crusts; **Cav**: caves; **Cre**: Crevices; **Run hab**: runoff habitat; **Roc poo**: Rock pools; **Wet sla**: Wet slabs; ***A.pi* mat**: *Afrotrilepis pilosa* mats; **Dry gra**: dry grassland; **E. fl veg**: Ephemeral flush vegetation; **Gra sav**: Grass savannas; **Shr sav**: Shrub savannas.

Floristic similarity of habitats

Sørensen's similarity index is calculated for different habitats of inselbergs that are recorded in Tab. 3. A strong floristic similarity is recorded for habitats having at least a rate of 0,5. Those habitats harboring community species, including a strong floristic similarity, are dry grassland and *Afrotrilepis pilosa* mats, dry grassland and permanent runoff zones, Ephemeral flush vegetation and *Afrotrilepis pilosa* mats, shrub savannas and grass savannas, *Afrotrilepis pilosa* mats and permanent runoff zones, Ephemeral flush vegetation and dry grassland, in order of importance. Caves reveal a strong floristic dissimilarity in comparison with other habitats. Likewise, a distinct floristic dissimilarity is evident between wet slabs, grass and shrub savannas; permanent runoff zones and grass savannas.

Life forms and phytogeography

Therophytes, Hemicryptophytes and Phanerophytes are the most dominant and frequent life forms for the most part of habitats on inselbergs. Although Chamephytes are not so abundant, they occur in the majority of habitat types. The least common life forms are Liane-phanerophytes which occur exclusively in grass and shrub savannas. Helophytes and Hydrophytes are found in seasonal puddles, swampy meadows and wet slabs as their preferred habitat (Tab. 4).

Sudano-Zambesians and Pantropicals are present in all inselberg habitats with the exception of caves and wet slabs. These two phytogeographical types have high raw spectra in different habitats (Tab. 5). The phytogeographical types present at most in two habitats are Afro-Americans, Afro-Asiatic, Sudano-Guinean and Sahelo-Saharan. Those species showing a large distribution (Cosmopolitan, Paleotropicals, Pantropicals and Afro-Americans) are fewer in number (28,30 %) in different habitats than other species (71,70 %) (Tab. 4).

Table 3. Rate of floristic similarity between the habitats of inselbergs.

	Cre	**Roc poo**	**Cav**	**E.fl veg**	**Dry gra**	**Run hab**	**Shr sav**	**Gra sav**	**Wet sla**
Roc poo	0,39								
Cav	0,09	0,07							
E.fl veg	0,31	0,54	0,04						
Dry gra	0,31	0,39	0,04	0,64					
Run hab	0,38	0,38	0,07	0,47	0,72				
Shr sav	0,12	0,12	0,01	0,2	0,16	0,12			
Gra sav	0,13	0,13	0,01	0,21	0,15	0,09	0,67		
Wet sla	0,17	0,29	0,11	0,3	0,5	0,48	0,05	0,07	

A.pi mat	0,31	0,5	0,04	0,72	0,93	0,65	0,18	0,16	0,45

Cry cru: Cryptogamic crusts; **Cav**: caves; **Cre**: Crevices; **Run hab**: runoff habitat; **Roc poo**: Rock pools; **Wet sla**: Wet slabs; ***A.pi* mat**: *Afrotrilepis pilosa* mats; **Dry gra**: dry grassland; **E. fl veg**: Ephemeral flush vegetation; **Gra sav**: Grass savannas; **Shr sav**: Shrub savannas.

Table 4. Crude spectra (%) of life forms of habitats.

	Cry cru	**Cav**	**Cre**	**Run hab**	**Roc poo**	**Wet sla**	***A.pi* mat**	**Dry gra**	**E.fl veg**	**Gra sav**	**Shr sav**
Ch	-	-	7,14	9,68	3,03	11,43	6	3,51	4,00	7,76	6,12
Geo	-	-	-	12,90	6,06	17,14	12	8,77	8,00	2,45	3,21
Hem	-	-	21,43	22,58	12,12	11,43	16	15,79	18,67	2,04	7,58
Hel	-	-	-	3,23	15,15	2,86	4	3,51	6,67	-	0,29
Hyd	-	-	-	-	-	5,71	2	1,75	4,00	0,41	-
LnPh	-	-	-	-	-	-	-	-	-	4,37	4,37
Ph	-	-	25	9,68	3,03	-	8	8,77	2,67	36,33	41,40
Th	-	-	46,43	41,94	60,61	51,43	52	57,89	56,00	51,02	37,03

Ch: Chamephyte, **Geo**: Geophyte, **Hem**: Hemicriptophyte, **Hel**: Helophyte, **Hyd**: Hydrophyte, **LnPh**: Liane-phanerophyte, Ph: Phanerophyte, Th: Therophyte.

Table 5. Crude spectra (%) of phytogeographical types of habitats.

	Cry cru	**Cav**	**Cre**	**Run hab**	**Roc poo**	**Wet sla**	***A.pi* mat**	**Dry gra**	**E.fl veg**	**Gra sav**	**Shr sav**
AA	-	-	-	-	-	-	-	-	-	-	0,70
AS	-	-	-	-	-	-	-	-	-	-	0,70
AT	-	-	25	38,71	33,33	44,12	38	40,00	31,11	19,32	24,39
Cos	-	-	-	-	-	-	-	-	-	0,97	0,35
G	-	-	-	3,23	-	2,94	-	-	-	-	0,35
Pal	-	-	7,14	-	12,12	5,88	12	13,33	10,81	7,73	8,36
Pan	-	-	14,29	22,58	27,27	20,59	12	13,33	24,32	14,98	11,15
AM	-	-	10,71	6,45	3,03	14,71	8	8,89	16,22	3,38	6,62
S	-	-	14,29	16,13	12,12	8,82	12	11,11	5,41	13,53	10,10
SG	-	-	-	-	-	-	-	-	-	0,48	1,39
SS	-	-	-	-	-	-	-	-	-	3,86	1,74
SZ	-	-	28,57	12,90	12,12	2,94	16	11,11	10,81	28,99	29,97

AA: Afro-american, **AS**: Afro-Asiatic, **AT**: Afro-Tropical, **Cos**: Cosmopolitan, **G**: Guinean, **Pal**: Paleotropical, **Pan**: Pantropical, **AM**: African Multiregional, **S**: Sudanian, **SG**: Sudano-Guinean, **SS**: Sahelo-Saharan, **SZ**: Sudano-Zambesian

DISCUSSION

The difference in floristic richness among the divers inselberg habitats can be explained by the edaphic conditions. Indeed, those habitats providing more profound and more humid soil also have the richest flora unlike those with less profound and humid soil comprising a poorer flora. Many studies explain that physico-chemical conditions of soil play a crucial role in the spatial distribution as well as the maintenance of species in their environment (Moumouni *et al.* 2017). The values of Sørensen's similarity index indicate that the floristic diversity between habitats is low for habitats with a higher index or equal to 0,5. These habitats reveal similar environmental conditions, particularly edaphic conditions. The floristic diversity among habitats is more pronounced for habitats having an index of Sørensen's similarity smaller than 0,5. The environmental conditions of these habitats determine a "Turn-over" of important species. The flora of inselberg habitats represent 17,13 % of total flora of Burkina Faso which currently comprises 2067 species according to Thiombiano *et al.* (2012). However, inselbergs harbor an important part of national flora. Inselberg habitats are in favor for establishing of a great floristic diversity (Oumorou & Lejoly 2003). Wittig *et al.* (2000) report that the floristic richness of inselbergs reflects the great diversity of its ecological niches. Indeed, inselbergs in Burkina Faso comprise 11

micro-habitats. The dominance of Poaceae, Fabaceae-Faboideae, Rubiaceae and Cyperaceae are consistent with the results obtained for Benin by Oumorou & Léjoly (2003), for Ivory Coast by Kouassi *et al.* (2009), and for Zimbabwe by Seine *et al.* (1998). The dominance of these four families is a characteristic of West African inselbergs.

The dominance of Therophytes accounts for, on one hand, the dry edaphic conditions of inselbergs and, on the other, the prevalence of savannas formations to the detriment of forest formations (Mbayngone *et al.* 2008). Indeed, the edaphic conditions of inselbergs are characterised by the absence or shallow depth of soil (Tindano *et al.* 2015). Nevertheless, Therophytes are capable of surviving the drastic edaphic conditions during dry season in the form of seeds. The presence and abundance of Hemicryptophytes and Geophytes on inselbergs reflect the undisturbed nature of inselbergs. Corresponding to Nacoulma *et al.* (2011), the presence and abundance of Hemicryptophytes and Geophytes are indicators for stability of inselbergs.

CONCLUSION

Inselbergs in Burkina Faso feature a highly diversified ecological niche characterised by 11 habitats. The flora of these habitats is rich with 354 plant species distributed in 209 genera and 81 families. The habitats being richest in species are shrub savannahs and grass savannahs. Poorest in species are Ephemeral flush vegetation and caves. Generaly speaking, the habitats of inselbergs in Burkina Faso exhibit a floristic dissimilarity among each other. This floristic dissimilarity can be explained by variation of edaphic parameters, particularly soil depth and humidity, from one habitat to another. The minor proportion of species with a large distribution in relation to other species reveal the stability and best conservation of the original phytodiversity of inselbergs.

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Appendix Table. List of species subservient to certain habitat.

Espèsces	Cry cru	Wet sla	Cr e	Roc poo	Ca v	A.pi mat	E.fl veg	Dry gra	Shr sav	Gra sav	Run hab
Acacia hockii De Wild.	-	-	-	-	-	-	-	-	+*	-	-
Afrotrilepis pilosa (Boeckeler) J. Raynal	-	-	-	-	-	+*	-	-	-	-	-
Andropogon fastigiatus Sw.	-	-	-	-	-	-	-	-	+*	-	-
Andropogon gayanus Kunth	-	-	+	-	-	-	-	-	+	+	-
Aspilia rudis Oliv. & Hiern	-	-	-	-	-	-	-	-	-	+*	-
Bacopa floribunda Wettst.	-	-	-	-	-	-	+	+	-	-	-
Baissea multiflora A. DC.	-	-	-	-	-	-	-	-	+*	-	-
Batopedina tenuis (A.Chev. ex Hutch. & Dalziel) Verdc.	-	-	-	-	+*	-	-	-			-
Begonia rostrata Welw. ex Hook.f.	-	-	-	-	+*	-	-	-	-	-	-
Biophytum umbraculum Welw.	-	-	-	-	-	-	-	-	+*	-	-
Boswellia dalzielii Hutch.	-	-	-	-	-	-	-	-	-	+*	-
Bridelia ferruginea Benth.	-	-	-	-	-	-	-	-	+*	-	-
Bulbostylis densa (Wall.) Hand.-Mazz.	-	+	-	-	-	-	-	+	-	-	-
Cyperus buchholzii Boeckeler	-	-	-	-	-	+	-	+	-	-	+
Cyperus podocarpus Boeckeler	-	-	-	+*	-	-	-	-	-	-	-
Cyperus reduncus Hochst. ex Boeckeler	-	-	-	+*	-	-	-	-	-	-	-
Dopatrium longidens Skan	-	-	-	+*	-	-	-	-	-	-	-
Drosera indica L.	-	-	-	-	-	+	+	+	-	-	-
Euclasta condylotricha Stapf in Prain	-	-	-	-	-	-	-	-	+*	-	-
Gardenia ternifolia Schumach. & Thonn.	-	-	-	-	-	-	-	-	+*	-	-
Grewia villosa Willd.	-	-	-	-	-	-	-	-	-	+*	-
Justicia tenella T. Anderson	-	-	-	-	-	-	-	-	-	-	+*
Kyllinga tenuifolia Steud.	-	-	-	-	-	+	+	-	-	-	-
Lannea velutina A. Rich.	-	-	-	-	-	-	-	-	+*	-	-
Lepidagathis anobrya Nees	-	+	-	-	-	-	-	-	-	-	+
Lindernia schweinfurthii (Engl.) Dandy	-	-	-	-	-	-	+*	-	-	-	-
Ludwigia abyssinica A.Rich.	-	-	-	-	-	+	+	+	-	-	-
Ozoroa obovata (Oliv.) R.Fern. & A.Fern.	-	-	-	-	-	-	-	-	+	+	-

Rhamphicarpa fistulosa Benth.	-	-	-	+	-	-	-	-	-	-	+
Sida acuta Burm.f.		-	-	-	-	-	-	-	-	+*	-
Striga gesnerioides (Willd.) Vatke	-	-	+*	-	-	-	-	-	-	-	-
Synedrella nodiflora (L.) Gaertn.	-	-	-	-	-	+	-	+	-	-	-
Tephrosia linearis (Willd.) Pers.	-	-	+	-	-	-	-	-	+*	+*	-
Tephrosia nana Kotschy ex Schweinf.	-	-	-	-	-	-	-	-	+*	-	-
Vigna radiata (L.) R.Wilczek	-	-	-	-	-	-	-	-	+*	-	-

Cry cru: Cryptogamic crusts; **Cav**: caves; **Cre**: Crevices; **Run hab**: runoff habitat; **Roc poo**: Rock pools; **Wet sla**: Wet slabs; ***A.pi* mat**: *Afrotrilepis pilosa* mats; **Dry gra**: dry grassland; **E.fl veg**: Ephemeral flush vegetation; **Gra sav**: Grass savannas; **Shr sav**: Shrub savannas.
+ = presence; - = absence, * = restricted to habitat