Plant species associated with different levels of species richness and of vegetation cover as indicators of desertification in Burkina Faso (West Africa)

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Summary: Desertification is a major problem in Sudano-sahelian West Africa, including the loss of biodiversity and vegetation cover. The loss of related ecosystem services is having a severe impact on human wellbeing. To facilitate assessments of these aspects of desertification, we decided to find plant species suitable as indicators. Based on a large database of vegetation plot data for Burkina Faso, we identified species associated with high or low levels of species richness and vegetation cover by calculating average values of these measures from vegetation plots on which they occur. To account for the differences between the dry Sahel and the more humid Sudan, we separated the plots of our study area in three vegetation zones (Sahel, North Sudan, South Sudan). Furthermore, herbs and woody plants were analysed separately, as they were usually represented in different plot sizes in the primary data. For each combination of species richness or vegetation cover, vegetation zone and growth form we identified ten species indicating low and another ten species indicating high values and assigned indicator values based on the average values of these species in the relevés.

Key words: degradation, desertification, indicator species, species richness, vegetation cover

1 Introduction

Desertification is defined as land degradation in drylands and is a major ecological and economical problem at global level. The United Nations Convention to Combat Desertification (UNCCD 1994) specifically mentions the loss of biological
productivity and long-term loss of natural vegetation, which have direct effects on various ecosystem services ranging from regulating services such as soil protection and water retention to provisioning services such as fodder, food and traditional medicine. The Sudano-Sahelian savanna belt at the southern edge of the Sahara desert is one of the areas especially vulnerable to desertification (Niaissé et al. 2004) and Burkina Faso, situated directly in the centre of this region and very typical for the region with its natural vegetation and land use is a perfect study area for a case study identifying indicator species for key aspects of desertification. Based on a large database of vegetation data for West Africa (Janssen et al. 2011, Schmidt et al. 2012, http://westafricanvegetation.senckenberg.de) we identified plant species associated with high and low levels of vegetation cover and species richness. These two factors representing biological aspects of the definition of desertification proved to be effective in its documentation (Gonzalez 2001, Gonzalez et al. 2012) and may be further connected with desertification not only as an effect, but also as a causing factor (Charney et al. 1977).

2 Methods

For the identification of indicator species, we used phytosociological data from the West African Vegetation Database including digitized data from Ataholo (2001), Böhmi (1998), Denschlag (1998), Guinko (1984), Kéré (1996), Kirchmair (2008), Kirchmair et al. 2012, Kromer (2004), Küppers (1996), Schmidt (2006) and Zwarg (2008), which in part have been published in Ataholo & Wittig (2011), Böhmi (2001), Müller (2004), Müller & Wittig (2002, 2004), Wittig et al. (2003, 2011), Zwarg et al. (2012). Synonyms have been resolved following Thombiano et al. (2012). As relevés have usually been done separately and on different plot sizes for herbs and woody species, we divided the pool of relevé records accordingly. Only plots of similar size (usually 100 m² for herb plots and 900 or 1000 m² for woody plants) have been considered, as species richness is known to increase with plot size. Using precipitation data from WorldClim (Hijmans et al. 2005), we further separated relevés from the Sahel, the North and South Sudanian Zone. Only relevés from narrow, well-sampled precipitation ranges of 300 - 450 mm (Sahel, 771 relevés), 750 - 900 mm (N-Sudan, 788 relevés) and 1100 - 1250 mm (S-Sudan, 654 relevés) have been used. For each relevé, the number of occurring species has been counted and the sum of the species coverages (in percent) has been calculated. Conversion from Braun-Blanquet classes into percent has been done according to Haeupler (1982), the sum of coverages may exceed 100% due to overlaps and conversion. We have excluded species with less than 5 spatially unique occurrence points and calculated for all remaining species the average species richness and the average total vegetation cover of the relevés in which it occurs. These values have been used as indicator values for the species.

3 Results

For all combinations of measure (species richness / vegetation cover), growth form (herbaceous or woody) and vegetation zone (Sahel, N-Sudan, S-Sudan), the 10 highest and lowest ranking species with their respective indicator values are shown in Tables 1-4.

Minimum and maximum values of species richness associated with the indicator species (Tables 1-2) are increasing with the rainfall gradient from the Sahel to the South Sudan, both for herbaceous and woody species. This is not the case for vegetation cover (Tables 3-4), where the Sudan in general has species associated with higher covers than the Sahel, but with a maximum in the North Sudan.

Only few species are indicators in more than one category, e.g. Echinochloa stagnina indicating high vegetation cover and low species richness in the Sahel. An exception is in the Sahelian woody plants (Tables 2, 4) where several species are indicating high (or low) values of both, vegetation cover and species richness.

4 Discussion

Species richness (4.1) and vegetation cover (4.2) are key measures to characterize the vegetation-specific aspects of desertification and the resulting impoverishment in ecosystem services in drylands. It is however important to keep in mind that different habitat types may have naturally lower levels of plant diversity and cover, independent from detrimental impacts of human activities or climate change. It is also important to consider, that these aspects are independent from each other and species associated with low species richness may well be associated with high vegetation cover (e.g. Echinochloa stagnina).

4.1 Species richness

Among the high diversity indicators in the Sahel we find species like the perennial grass Andropogon gayanus which has once covered large areas of the region, now almost disappeared with increasing grazing pressure (Bremen & Cissi 1977, Rietkerk et al. 1996), but also tree species typical of intact tiger bush areas such as the Grewia spp. (Müller 2013) and trees highly valued for fodder, like Pterocarpus lucens. Within the low diversity indicators are species often occurring in nearly monospecific patches such as the Echinochloa spp. of riparian floodplains, but also two of the most frequent trees of the Sahel, Acacia tortilis and Balanites aegyptiaca which are among the few tree species remaining in the most highly degraded areas and have been identified by Wezel & Lykke (2006) to be increasing in the course of the Sahelian vegetation changes of the last decades.

A number of tall savanna grasses like Hyparrhenia smithiana and Andropogon tectorum are among the high diversity indicators for the North Sudan, also species typical for termite mounds such as Combretum aculeatum and Grewia bicolor (Erpenbach et al. 2013), which may be explained by increased habitat diversity. Among the low diversity indicators, a number of species occurring on bowé (Zwarg et al. 2012), e.g. Loudetiopsis kerstingii, can be found, but also water-bound species such as Oryza longistaminata or Sarcoccephalus latifolius.
In the South Sudan, among the high diversity indicators we find species of savanna (e.g. *Psorospermum febrifugum*, *Ziziphus abyssinica*) and gallery forest (e.g. *Ficus sur*; Thömbano et al. 2012). Some trees of the low diversity indicators are from gravelly or shallow soils.

### 4.2 Vegetation cover

Herbs indicating high vegetation cover in the Sahel include interestingly a number of C4 dicots (*Portulaca oleracea*, *Boerhavia repens*, *Trianthema portulacastrum*), but also *Echinochloa stagnina*, often forming dense lawns of low diversity in temporarily inundated sites. Among the trees are several species of the tiger bush (which has been shown to be a highly diverse habitat of the Sahel region by Schmidt et al. 2008) but also species of denser riparian forest. Low vegetation cover indicators are often species of dunes like *Leptadenia pyrotechnica* or of degraded glacis.

Among the North Sudanian species indicating high vegetation cover are species of high grass savanna like *Psorospermum smithiana* and *Andropogon tectorum*, open forests and termitaria thickets (e.g. *Combretum aculeatum*). Herbs indicating low vegetation cover are often from shallow soil areas (*Polypogon corymbosa*, *Cenntium elegans*). Interestingly, the indicator values for the North Sudanian vegetation cover indicators are often species of dunes like *Leptadenia pyrotechnica* or of degraded glacis.

| Table 1: Herbaceous species as indicators of species richness (average species richness of all relevés with the respective species is provided in brackets) / Espèces herbacées comme indicatrices de la richesse spécifique (richesse spécifique moyenne de tous les relevés concernant les espèces correspondantes est fournie entre parenthèses). |
| --- |
| **Sahel** | **N-Sudan** | **S-Sudan** |
| **High species richness** | | |
| *Eragrostis ciliaris* (16.57) | *Indigofera kerstingii* (46.8) | *Hausmanniastrium huettneri* (46.63) |
| *Andropogon gayanus* (16.17) | *Cissus flavicans* (42.4) | *Spermaceae chaetocarpa* (44.86) |
| *Cassia nigricans* (16) | *Andropogon tectorum* (42) | *Schizachyrium nodulosum* (44.43) |
| *Cassia mimosoides* (15.93) | *Hyparrhenia smithiana* (41.6) | *Ludwigia erecta* (43.58) |
| *Indigofera pilosa* (15.67) | *Cissus adenocaulis* (40.67) | *Dissotis irvingiana* (43.2) |
| *Evolvulus alsinoides* (15.53) | *Cienfuegosia heteroclada* (39) | *Phyllanthus amarus* (43) |
| *Achyranthes aspera* (15.4) | *Cissus populnea* (38.4) | *Vernonia cinerea* (42.82) |
| *Papalia lappaceae* (15.38) | *Schizachyrium sanguineum* (37.71) | *Sida alba* (42.78) |
| *Hibiscus cannabinus* (15.25) | *Indigofera paniculata* (36.8) | *Vernonia perrotetii* (42.25) |
| *Ipomoea vagans* (15.11) | *Kyllinga pumila* (36.67) | |
| **Low species richness** | | |
| *Setaria pumila* (10.36) | *Eriospurum flagelliforme* (13.83) | *Aspilia angustifolia* (20) |
| *Pancratium triannum* (10.21) | *Cyanotis longifolia* (13.74) | *Pimpinella dichotoma* (19.86) |
| *Clome gynandra* (10) | *Tripogon minimum* (13.62) | *Neurotheca loeseliioides* (19.5) |
| *Cyperus iria* (9.45) | *Abligdaardia abortiva* (13.07) | *Digitaria ciliaris* (19.36) |
| *Microchloa indica* (9.17) | *Loudetia simplex* (13) | *Indigofera polysphaera* (19.17) |
| *Trianthema portulacastrum* (9) | *Setaria barbata* (12.75) | *Urelytrum muricatum* (19.13) |
| *Aeschynomene indica* (8.5) | *Chrysosopogon nigritanus* (12.6) | *Leveria hexandra* (18.5) |
| *Echinocloa colona* (8.42) | *Cenntium elegans* (12.5) | *Melochia corchorifolia* (17.6) |
| *Scilla sudanica* (7.5) | *Loudetiospis kerstingii* (10.19) | *Panicum subabidium* (17.33) |
| *Echinocloa stagnina* (4.14) | *Oryza longistaminata* (7.67) | *Spermaceae paddiss* (17) |

| Table 2: Woody species as indicators of species richness (average species richness of all relevés with the respective species is provided in brackets) / Espèces ligneuses comme indicatrices de la richesse spécifique (richesse spécifique moyenne de tous les relevés concernant les espèces correspondantes est fournie entre parenthèses). |
| --- |
| **Sahel** | **N-Sudan** | **S-Sudan** |
| **High species richness** | | |
| *Dichrostachyys cinerea* (11) | *Exoecaria graminii* (30.8) | *Asparagus africanus* (39.33) |
| *Cadaba glandulosa* (10.83) | *Fadogia agrestis* (30.75) | *Ekebergia senegalensis* (38.67) |
| *Grewia flavescent* (10.46) | *Maernus angolensis* (30.25) | *Agelenthus dodoneifolius* (38.33) |
| *Grewia bicolor* (9.96) | *Grewia cissoides* (26.84) | *Margaritharia discoidae* (33.33) |
| *Acacia ataxacantha* (9.63) | *Grewia bicolor* (26.94) | *Smalax acnes* (33.14) |
| *Boscia angustifolia* (9.31) | *Philenoptera lasiiflora* (25.88) | *Lannea velutina* (31.6) |
| *Acacia erythrocalyx* (9.21) | *Combretum aculeatum* (25.22) | *Psorospermum febrifugum* (31.53) |
| *Dalbergia melanoxylon* (8.43) | *Hymenocardia acida* (22.89) | *Ziziphus abyssinica* (31) |
| *Adansonia digitata* (8.38) | *Vitis madisiensis* (22.09) | *Roura coccinea* (30.67) |
| *Pterocarpus luccis* (8.34) | *Pterocarpus lasiiflora* (21.56) | *Ficus sur* (30.63) |
| **Low species richness** | | |
| *Acacia seyal* (5.25) | *Prospis africana* (12.42) | *Burkea africana* (22.32) |
| *Euphorbia balsamifera* (5.17) | *Parkia biglobosa* (12.11) | *Terminalia mollis* (21.78) |
| *Balantites aegyptiacus* (4.98) | *Ficus platypylla* (11.67) | *Zanha golagensis* (21.67) |
| *Diospyros mespiliformis* (4.92) | *Ziziphus mauritiana* (11.65) | *Combretum adenogonium* (21.5) |
| *Acacia tortilis* (4.86) | *Combretum paniculatum* (11.2) | *Crossopteryx febrifuga* (21.34) |
| *Faidherbia albida* (4.47) | *Combretum adenogonium* (10.52) | *Swartzia madagascariensis* (21) |
| *Acacia nilotica* (4.03) | *Pariari curatelliforme* (10.1) | *Manilkara obovata* (20.83) |
| *Acacia ehrenbergiana* (3.83) | *Acacia seyal* (10.04) | *Marantaceae polyandra* (20.82) |
| *Leptadenia pyrotechnica* (3.37) | *Sarcocephalus latifolius* (8.17) | *Xemaria americana* (20.71) |
| *Mitragyna inermis* (3.09) | *Terminalia macropectora* (6.6) | *Ochna rhizomatosa* (19.33) |
Table 3: Herbaceous species as indicators of vegetation cover [average vegetation cover (sum of single species’ covers in %) of all relevés with the respective species is provided in brackets] / Espèces herbacées comme indicatrices de la couverture végétale [couverture végétale moyenne (somme de la couverture individuelle de toutes les espèces) de tous les relevés contenant les espèces correspondantes est fournie entre parenthèses].

| Sahel         | N-Sudan          | S-Sudan          |
|---------------|------------------|------------------|
|               | High vegetation cover |                  |
| Trianaetha portulacastrum (121.86) | Hyparrhenia smithiana (147.9) | Schizachyrium platyphyllum (116.88) |
| Boerhavia repens (120.73) | Cissus adenocalyx (146.75) | Melanthera elliptica (108.89) |
| Portulaca olareace (119.12) | Cissus populnea (142.2) | Anelemia paludosum (104.22) |
| Sida cordifolia (117.78) | Chenhegiosia heteroclada (133.25) | Setaria spachelata (104.01) |
| Cleome gymandra (110.87) | Schizachyrium sanguineum (132.34) | Fimbriylis ferruginea (102.94) |
| Setaria pumila (106.45) | Indigofera kerstingii (130.67) | Rhynchospora eximia (101.4) |
| Digitaria horizontalis (105.8) | Andropogon tectorum (130.6) | Tragia senegalensis (100.83) |
| Ipomoea dichroa (105.56) | Cissus flavicans (127.95) | Aspilia angustifolia (100.58) |
| Echynochloa stagnina (105.13) | Indigofera stenophylla (125.89) | Aspilia paludos (99.87) |
| Sesamum alatum (103.74) | Stylosanthes fruticosa (121) | Fimbriylis dichotoma (98.88) |
|               | Low vegetation cover |                  |
| Polycarpacea linearifolia (45.33) | Cleome viscosa (60) | Taccia leontopetaloides (47.24) |
| Boerhavia coccinea (42.25) | Justicia insularis (58.75) | Pandiakla involucrata (47.17) |
| Cucumis melo (36.94) | Triumfetta rhomboidae (58.22) | Crassocephalum togoense (46.74) |
| Andropogon fastigiatas (35.66) | Cyanotis longfolia (56.28) | Loutedetiposis kerstingii (46.45) |
| Tragus racemous (30.06) | Blepharis madrugapatensis (56.23) | Crotaalia retusa (45.3) |
| Molugo nudicaulis (28.66) | Sporobolus festivus (55.42) | Elionurus elegans (44.42) |
| Schizachyrium exile (26.33) | Polycarpacea corymbosa (55.03) | Cenium villosum (44.39) |
| Cleome scaposa (24.82) | Papalii lappacea (55.03) | Justicia insularis (42.72) |
| Euphorbia forskalii (20.83) | Cleoman elegans (50.53) | Aeolianthus pubescens (37.86) |
| Scilla sudanica (5.98) | Aspilia busei (45.17) | Tragia vogelii (37.54) |

Table 4: Woody species as indicators of vegetation cover [average vegetation cover (sum of single species’ covers in %) of all relevés with the respective species is provided in brackets] / Espèces ligneuses comme indicatrices de la couverture végétale [couverture végétale moyenne (somme de la couverture individuelle de toutes les espèces) de tous les relevés contenant les espèces correspondantes est fournie entre parenthèses].

| Sahel         | N-Sudan          | S-Sudan          |
|---------------|------------------|------------------|
|               | High vegetation cover |                  |
| Dichrostachys cinerea (72.04) | Dioscorea dumetorum (134.6) | Paulinina pinnta (79.59) |
| Acacia ataxacantha (70.35) | Dombeya buettnerii (124.2) | Ekebergia senegalensis (76.35) |
| Grewia bicolor (65.28) | Combretum aculeatum (114.16) | Gardenia ternfolia (75.01) |
| Grewia flavesens (64.44) | Hymenocodia acidula (107.34) | Ochna rhizomatosa (75) |
| Diospyros mespiliformis (60.86) | Bombax costatum (94.2) | Margaritaria discoidea (70.07) |
| Feronia apodantha (58.59) | Grewia mollis (88.15) | Ochna schweinfurthiana (69.15) |
| Combretum micranthum (57.56) | Pluegeea virosa (83.02) | Ficus glomosa (68.86) |
| Acacia erythrocalya (54.5) | Ziziphus mursorata (82) | Lannea velutina (66.7) |
| Boscia angustifolia (54.07) | Terminalia laxiflora (80.58) | Diospyros mespiliformis (63.59) |
| Cadaba glandulosa (52.63) | Grewia lasiodiscus (80.5) | Grewia mollis (63.42) |
|               | Low vegetation cover |                  |
| Grewia villosa (31.9) | Acacia seyal (51.12) | Gardenia erubescens (43.99) |
| Acacia seyal (31.69) | Xeroderris stuhlmannii (50.46) | Terminalia schimperiana (43.59) |
| Combretum glutinosum (30.05) | Detarium microrcarpus (49.77) | Bridelia scleroneura (43.26) |
| Balanites argyptica (28.06) | Ficus glomosa (49.28) | Pseudocedrela kotschyi (42.11) |
| Acacia senegal (27.94) | Parinari curatellifolia (49.15) | Combretum adenognon (40.76) |
| Acacia tortilis (27.17) | Commiphora africana (49.01) | Gardenia aquillia (40.32) |
| Cadaba farinosa (24.93) | Ziziphus mauritiana (45.37) | Terminalia laxiflora (38.49) |
| Euphorbia balsamifera (19.44) | Surcoevphalus latifolius (33.37) | Piloseigma honningii (38.06) |
| Faidherbia albida (16.41) | Albizia chevalieri (30.7) | Ximenia americana (36.15) |
| Leptadenia pyrotechnica (13.93) | Terminalia macroptera (12.27) | Cryptolepis oblongifolia (32.76) |

species are higher than for the South Sudanian ones. This may be an effect of large nature reserves of the WAP complex being located in this zone and having large stands of close-to-natural habitats.

The **South Sudanian** high vegetation cover indicators include gallery forest species like *Paulinina pinnta*, low vegetation cover indicators include species of bowé and other shallow soil sites (*Loutedetiposis kerstingii, Cenium villosum*).

Vegatation plot data as used in this study has proven to be a good data source to identify species associated with different levels of vegetation cover or species richness. There are however potential problems with observational data in general that might affect the results: Mere observations without any further documentation of the species are difficult to verify. In this context the practice of depositing voucher specimens in scientific collections (in this case the Herbarium Senckenbergianum) proved very useful and enabled the authors to verify the identity of species.
The indicator species may be used by botanists and non-specialists alike. Indicator values could e.g. be used for spatial studies with distribution data from collection databases or georeferenced photo collections. For field studies, species identification is crucial but this has been facilitated for Burkina Faso in the last decade by new and updated print or online field guides (e.g. ARBONNIER 2009, SACANDÉ et al. 2012, DRESSLER et al. 2014).

Acknowledgements
We thank all contributors to our database and acknowledge funding by the European Commission for the UNDESERT project (243906) and the Hessian Initiative for the development of scientific and economic excellence (LOEWE) for the Biodiversity and Climate Research Centre (BiK-F).

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