Agroforestry Parkland Species Diversity:

Uses and Management in Semi-Arid West Africa (Burkina Faso)

Albert Nikiema

Promotoren: Prof. Dr.Ir. L.J.G. van der Maesen
Hoogleraar Plantentaxonomie
Wageningen Universiteit

Co-promotor Dr. J.B. Hall
Senior Lecturer, School of Agricultural and Forest Sciences, University of Wales, Bangor, UK

Promotiecommissie: Prof. Dr. P. Baas
Universiteit Leiden
Prof.dr. A.M. Cleef
Wageningen Universiteit
Prof. Dr. K. E. Giller
Wageningen Universiteit
Prof. Dr. J. Lejoly
Université Libre de Bruxelles

Dit onderzoek is uitgevoerd binnen de onderzoekschool Biodiversiteit

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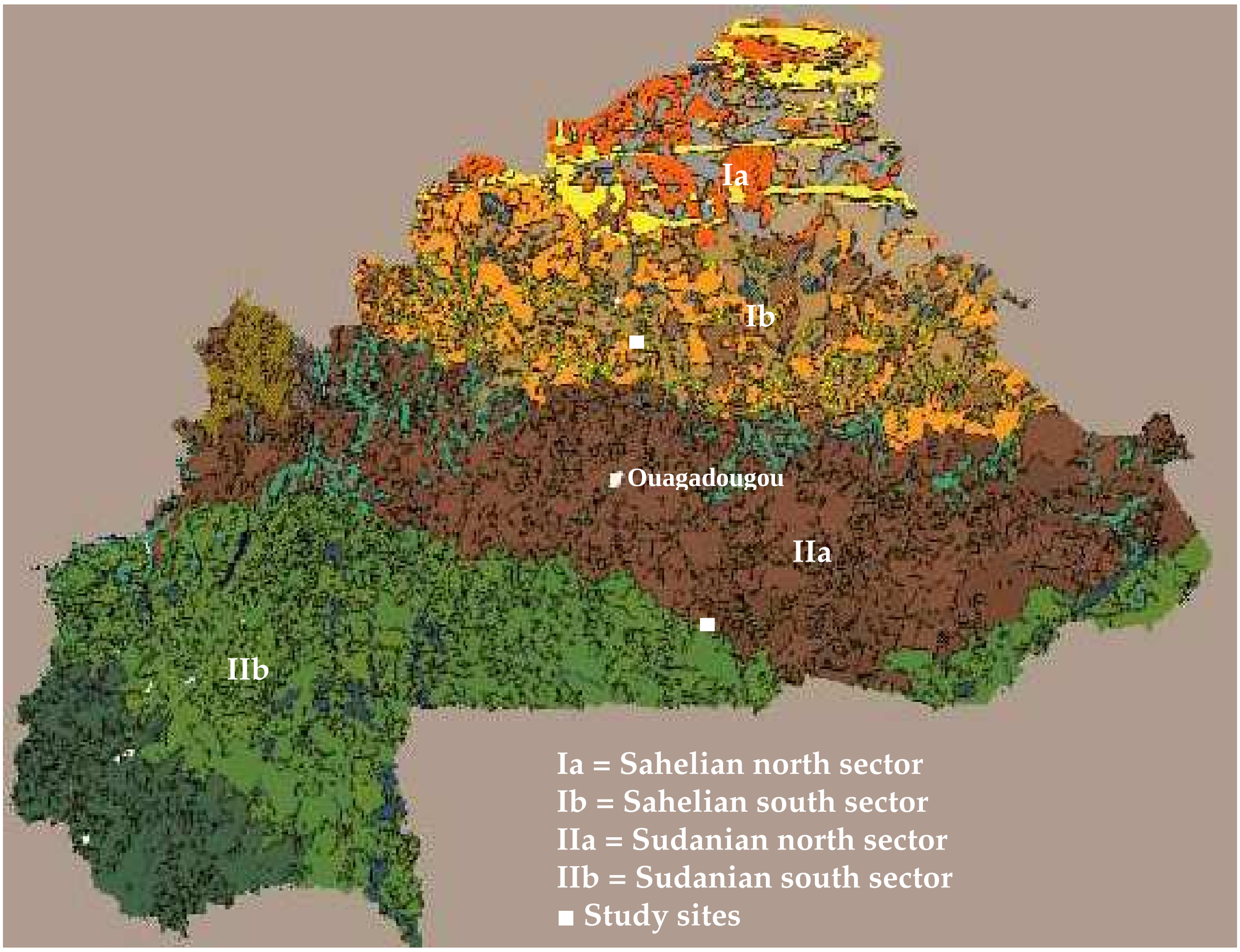
Proefschrift
ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit
Prof. Dr. Ir. L. Speelman
in het openbaar te verdedigen
op dinsdag 8 maart 2005
des namiddags te 13.30 uur in de Aula

Nikiema, A.
Agroforestry Parkland Species Diversity:
Uses and Management in Semi-Arid West Africa (Burkina Faso)

PhD thesis Wageningen University, Wageningen
ISBN 90-8504-168-6

Key words: Species diversity, agroforestry parkland, diversity indices, NWFPs, Bush fire, Semi-arid West Africa, fodder trees
This study was carried out at the CNSF, Centre National des Semences Forestières, Ouagadougou, Burkina Faso, and at NHN-Wageningen, Biosystematics Group,
(Generaal Foulkesweg 37, 6700 ED Wageningen), Department of Plant Sciences, Wageningen University, the Netherlands.

To my wife Blandine and
my children Brice, Sylviane, Nadège and José



Vegetation map of Burkina Faso (Fontes & Guinko 1995)

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Samenvatting

Soortsdiversiteit in het agroforestry parklandschap: gebruik en beheer in semi-aride West Afrika (Burkina Faso)

Het agroforestry parkland in semi-aride West Afrika is een landgebruiksysteem, dat landbouwers in de gelegenheid stelt eenjarige gewassen te telen in combinatie met nuttige bomen. Naast graansoorten worden van bomen afkomstige producten verkregen, zoals groenten, vruchten, plantaardige olie, brandhout en medicijnen. De meervoudige functie van het parklandsysteem kan alleen standhouden als de soortsdiversiteit op adequate manier wordt beheerd.

Dit proefschrift richt zich op het vaststellen van de diversiteit van houtige soorten in het parkland, het belang van hun gebruik en de ernst van de bedreigingen verbonden met deze soorten, en de mogelijkheden geboden door de lokale en stedelijke markten opdat boeren kunnen investeren in beter beheer van de soortenrijkdom in het agroforestry parkland .

De soortensamenstelling van houtige planten laat zien dat het parklandschap in zuid-centraal Burkina Faso, in de Sudan ecozone, minder soorten herbergt dan het beschermde bos, terwijl het tegendeel is vastgesteld in de Sahel ecozone in noord-centraal Burkina. Algemene dominante soorten in het parkland zijn *Vitellaria paradoxa, Balanites aegyptiaca, Sclerocarya birrea, Bombax costatum, Lannea microcarpa, Sterculia setigera,* en *Parkia biglobosa*.

De situatie van de parklanden is momenteel nogal alarmerend omdat regeneratie uitblijft, vanwege de verkorting of het afschaffen van een braakperiode. Deze verandering in het landgebruikssysteem in de loop van de tijd zal waarschijnlijk voortduren met de groeiende druk van de bevolking op landbouwgronden, en heeft daarom urgente aandacht nodig. Behoud en beheer van het parkland hebben daarom een nieuwe aanpak nodig opdat de bedreigingen worden afgewend en in mogelijkheden worden omgezet.

De wisselwerking tussen parkland en veehouderij via mestonderzoek liet zien dat bepaalde soorten als voeder de voorkeur hebben van koeien en/of schapen en geiten. Daarom wordt aangeraden boomsoorten met goede voederkwaliteit aan te planten in de parklanden. Bosproducten anders dan hout (Non-wood forest products) worden verkocht in lokale zowel als in stedelijke markten van Ouagadougou en dit geeft aan dat beheer van parklanden het stimuleren van inkomsten-leverende boomsoorten moet inhouden op het niveau van de landbouwers.

Het afbranden van gebieden in landelijke gebieden is onderzocht om de geschikte periode vast te stellen het branden te beginnen, en om de tegen brand minder resistente boomsoorten te identificeren, welke speciale aandacht behoeven. In het afsluitende hoofdstuk geeft een tabel aan, hoe belangrijk in het parkland sommige soorten zijn, de bedreigingen die er zijn en hoe het beheer van de belangrijke soorten aangepakt zou moeten worden.

Summary

Agroforestry parkland species diversity: uses and management in semi-arid West Africa (Burkina Faso)

Agroforestry parkland in semi-arid West Africa is a rural land use system, which allows farmers to grow annual crops in combination with useful trees. In addition to cereals, tree products such as vegetables, fruits, vegetable oil, firewood, fodder, and medicines are obtained from the parklands. However the multiple function of the parkland system can only be fulfilled if parkland species diversity is adequately managed.

This thesis is focused on assessing the woody species diversity in the parklands, the important uses and threats linked to these species and the opportunities that rural and urban markets offer to justify farmers' investment in better agroforestry parkland diversity management.

Results on woody species composition showed that the parkland system in south-central Burkina, in the Sudanian eco-zone, has fewer species than the protected forest, while the opposite figure is observed in the Sahelian eco-zone of north-central Burkina. Common dominant species recorded in the parklands are *Vitellaria paradoxa, Balanites aegyptiaca, Sclerocarya birrea, Bombax costatum, Lannea microcarpa, Sterculia setigera,* and *Parkia biglobosa*.

The physiognomy of the parklands is at present quite alarming because of lack of regeneration, which is explained by the shortening or suppression of the fallow period. This change in the land use system over time is likely to persist along with a growing population pressure on agricultural land, and therefore requires urgent attention. Conservation and management of the parklands therefore needs a new approach which can turn some of the threats into sustainable management opportunities.

The investigation on livestock parkland interaction showed that some species are preferred fodder for cows and/or sheep and goats. It is therefore proposed that quality fodder species are planted in the parklands. Non Wood Forest Products (NWFFs) are sold in local and urban markets and the result of the survey conducted in Zoundweogo local markets and urban markets in Ouagadougou suggest that management of parklands should integrate the promotion of income generating species at farmer’s level as well as at rural landscape level.

Bush fire as a management tool used in the rural areas was studied to identify the suitable period for the fires to be lighted and identify the vulnerable species, which need special attention.

As an example it is finally proposed in a synthesis table, how each species should be evaluated for subsequent management actions in the parklands.

Albert Nikiema,
Wageningen 2005

Résumé

La diversité des espèces de Parc Agroforestier: Utilisations et Gestion en Afrique de l'Ouest Semi-aride

Les Parcs Agroforestiers en zone semi-aride d'Afrique de l'Ouest, constituent un système d'utilisation des terres rurales qui permet aux paysans de produire des cultures annuelles en combinaison avec des arbres utilitaires. Ainsi, en plus des céréales, ils obtiennent des parcs agroforestiers des produits d'arbres tels que les légumes, les fruits, les huiles végétales, le bois de feu et les médicaments. Cependant, la fonction multiple du parc agroforestier ne peut être remplie que si la diversité des espèces est gérée adéquatement.

Cette thèse s'est focalisée à évaluer la diversité des espèces ligneuses dans les parcs, leurs utilisations, les menaces qui pèsent sur ces espèces et les opportunités que les marchés ruraux et urbains offrent, et qui peuvent justifier les investissements des paysans dans une meilleure gestion des parcs agroforestiers.

Les résultats relatifs à la composition des espèces ligneuses montrent que dans la zone écologique Soudanienne au Centre – Sud du Burkina, le system parc, a moins d'espèces que dans la forêt protégée, alors que le schéma inverse est observé dans l'éco-zone Sahélienne au Centre Nord du Burkina ou il y'a moins d'espèces ligneuses dans la forêt que dans le parc agroforestier. Les espèces dominantes couramment recensées dans les parcs agroforestiers sont *Vitellaria paradoxa, Balanites aegyptiaca, Sclerocarya birrea, Bombax costatum, Lannea microcarpa, Sterculia setigera*, et *Parkia biglobosa*.

La physionomie des parcs agroforestiers est assez alarmante actuellement à cause du manque de régénération due à des jachères de plus en courtes ou simplement inexistantes. Il est à craindre que, dans le contexte actuel d'accélération de la pression démographique sur les terres agricoles, cette évolution dans le système d'utilisation des terres persiste, d'où la nécessite d'une attention urgente sur les parcs agroforestiers. La conservation et la gestion des parcs agroforestiers ont donc besoin d'une approche nouvelle qui puisse convertir certaines menaces en opportunités de gestion durable.

Les études sur l'interaction entre le bétail et le parc agroforestier montrent que certaines espèces constituent un fourrage préféré pour les bœufs et /ou le petit ruminant (moutons et chèvres). Il est donc proposé que les espèces fourragères de qualité soient plantées dans les parcs agroforestiers. Les Produits Forestiers Non Ligneux (PFNL) sont vendus dans les marchés ruraux et urbains et représente un secteur économique non négligeable au Burkina Faso, il est donc recommandé que, la promotion des espèces génératrices de revenues au niveau paysan soit intégré dans la gestion des parcs agroforestiers en particulier et dans celle des terroirs villageois en général.

L'étude des feux de brousse en tant qu'outil de gestion de l'espace rural a permis d'identifier les périodes favorables aux mis à feux et les espèces vulnérables qui ont besoin d'une attention particulière.
A titre d'exemple, il est finalement proposé dans un tableau de synthèse, comment chaque espèce doit être évaluée en vue d'actions conséquentes dans les parcs agroforestiers.

Albert Nikiema,
Wageningen 2005

Chapter 1

General introduction: Managing woody species diversity in agroforestry parklands.

Fig. 1: *Faidherbia albida* heavily pruned to feed livestock in Fakara village (Niger).

Chapter 2

Woody species composition of Sudan savanna parklands in relation to rural land use gradients in Burkina Faso

Submitted to "Agroforestry Systems"

Chapter 2

Woody species composition of Sudan savanna parklands in relation to rural land use gradients in Burkina Faso

Nikiema A.[1 2 *], van der Maesen L.J.G.[2] and Hall John B.[3]

[1] *Centre National de Semences Forestières, 01 BP 2682 Ouagadougou, Burkina Faso.*
[2] *Biosystematics Group, Wageningen University, Generaal Foulkesweg 37, 6703 BL Wageningen, the Netherlands.*
[3] *School of Agricultural and Forest Sciences, University of Wales Bangor, Gwynedd LL57 2UW, UK.*

Abstract

The agroforestry parkland system in the semi-arid West Africa, which has supported farmers' life for centuries because of the diversity of plant resources it provides, is under serious threat due to the increasing population pressure on the agricultural lands. The system that used to be described as sustainable shows signs of decline at present.

The results of the study proved that species richness as well as diversity indices is significantly lower in the agricultural land than in the contiguous protected forest in the Sudanian eco-zone, in south-central Burkina. Shannon diversity index (H') was respectively 2.39 in the protected forest, 1.49 in the fallow land and 1.05 in the cultivated areas. The dominant species population structures indicate lack of regeneration in the agricultural land. The overall figure of species occurrence in the different land use type indicate that 35% of the woody species recorded in the region is absent in the agricultural land.

Key words: Agroforestry parkland, plant diversity, rural land use, woody species, Sudan savanna

Introduction

Land use in the semi-arid region of West Africa is predominantly characterised by non-intensive levels of agricultural activities such as cereal cultivation and cattle grazing. Many useful indigenous plant species are kept within the crop fields and form a striking component of the farmland. This land use system, commonly known as the agroforestry parkland systems, has been successively described as farmed parkland by Pullan (1974) then as one of the many agroforestry systems observed all over the world (Nair 1985). The process of parklands establishment relies on traditional agricultural practices which include selective clearing of natural vegetation leaving only desired woody species on the land when establishing crop fields. These valued species which generally have multipurpose uses, form an integral part of the farmers' land use system in most semi-arid areas of West Africa.

The agroforestry parkland systems have been described as good examples of traditional land use systems and biodiversity management practices (Boffa 1999, Schreckenberg 1999, Lovett 2000). However, at present the sustainability of the parkland systems is under serious threat of degradation because of accelerated changes in agricultural practices, as a consequence of increased demand for arable land. Shortening of the fallow period combined with an increasing duration of continuous tilling of the same land have led to the ageing of the parkland trees as well as insufficient and/or lack of tree regeneration (Nikiema 1993, Gijsberg et al. 1994, Boffa 1999, Schreckenberg 1999). Nikiema (1993) reported that one of the reasons that *Parkia biglobosa* populations are not renewed for many years is due to the destruction of "regeneration beds", represented by the understorey of low and thick shrubs, which occurs in the fallow, but is cut in the cultivated fields. Schreckenberg (1999) concluded from her work in north Benin that regeneration of the parklands is likely to be limited since fallow periods have been reduced to only 2-4 years.

The major functions of parkland trees have been widely documented and cover a range of the local population needs: food, medicine, cooking oil, firewood, shelter, tools, forage etc. (Bosch et al. 2002, Bonkoungou et al 2002, Booth & Wikens 1988). Parkland trees are also a significant source of income for the rural population. Species such as *Acacia senegal*, *Parkia biglobosa* and *Vitellaria paradoxa* are reported to be a reliable source of income for farmers (Ouedraogo 1995, Hall et al. 1997, Seif El Din & Zarroug 1996).

Despite the important role of parkland trees, there is very little quantitative information regarding species composition and the relative representation of major species throughout the parklands which could help in identifying proper management actions to sustain the agroforestry parkland system. Furthermore, as a predominant land use system in semi-arid regions (Boffa 1999), monitoring the dynamic of the different species is a prerequisite to sound management policies.

The objective of this paper is to assess parkland woody species diversity and describe relative representation and structure of the major parkland tree species in South-Central Burkina.

Material and Methods

Study area

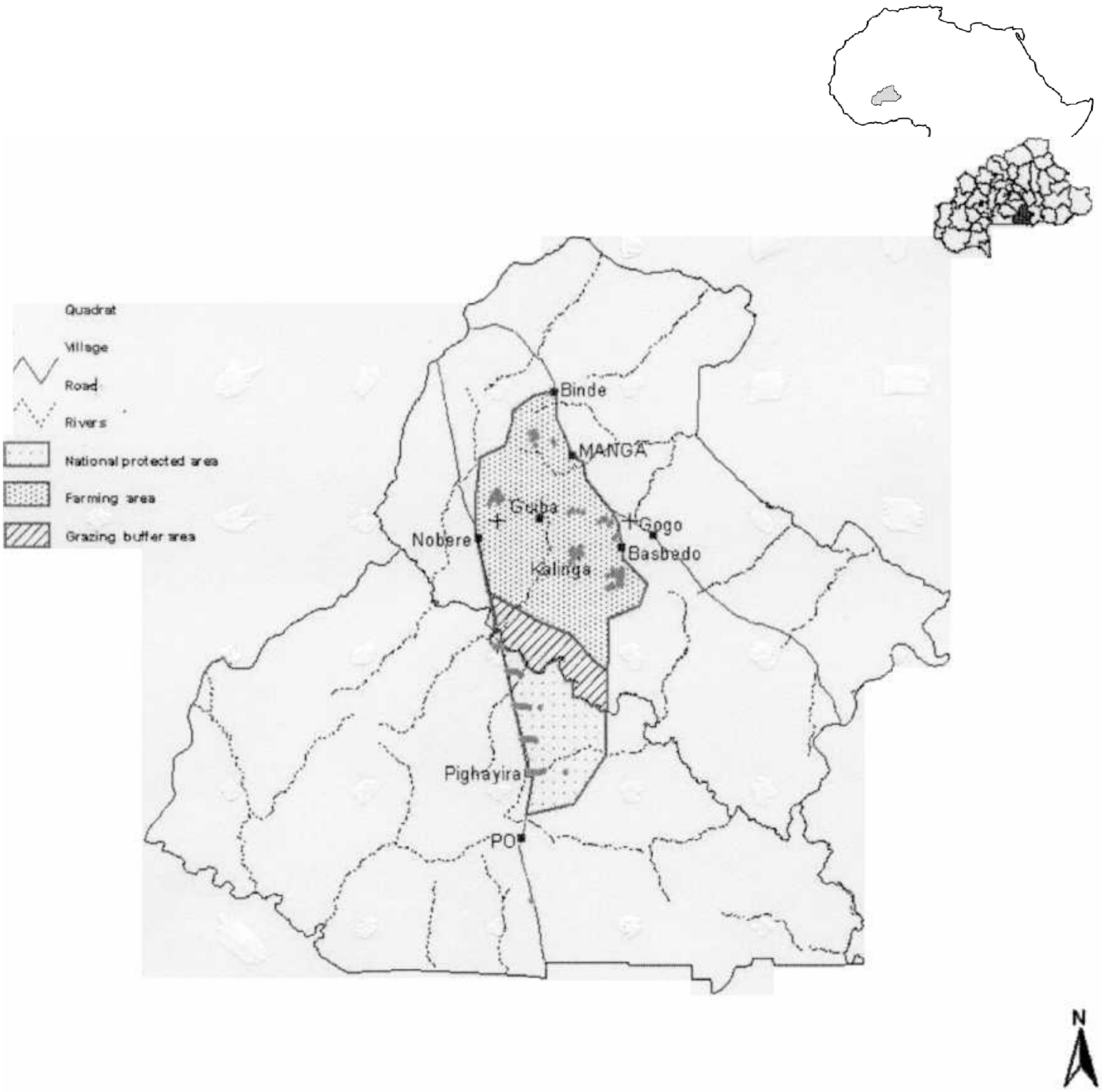


Fig. 2.1. Map of the study area with the location of the sample quadrats (•) and the delimitation of the main land uses in South-Central Burkina Faso.

The study was carried out in the provinces of Zoundweogo and Nahouri, in the south-central part of Burkina Faso. This area offers suitable land use gradients that include well-defined farmed lands, and a state-protected national park as well as grazing land.

The area lies between 11° 42′ to 11°14′ North and 00°58′ to 01°11′ West. It covers a surface of about 1000 km^2 of which 20% is a part of the National Park of Pô, gazetted by law in 1973 and looked after by foresters, 70% is agricultural land mixed with village settlements, as is usually the case in the area, and 10% is a buffer zone between the protected area and the farmland and devoted to grazing only (fig. 2.1). These different contiguous land use types offer study conditions under limited ecological variations.

The climate is of Sudanian type with a rainy season lasting for 4 to 5 months (May – September) and annual rainfall varying between 800 and 1000 mm, the dry season lasts from October to April.

The landscape is characterised by a flat plateau interrupted by a few rocky hills and inselbergs, and situated at 200 - 400 m above sea level. The seasonal river Nakanbe (White Volta River) crosses the area from north to south (Kessler & Geerling 1991).

The soil type is ferruginous leached, overlaying clayey-sandy to sandy-clayey material. The human population density is among the highest in the country, 50 – 60 inhabitants per km^2 and demand for agricultural land is increasing (Doumbia, 1993; INSD, 1996). The natural vegetation is a Sudanian savanna woodland characterised by species such as *Detarium microcarpum*, *Pteleopsis suberosa*, *Terminalia avicennioides* and *Burkea africana* (Fontes & Guinko 1995) and is represented by the National Park Kaboré Tambi (NPKT).

The farmlands are basically composed of two entities: crop fields, and fallows of 2 to 5 years old. The main activity of the inhabitants is the cultivation of pearl millet and sorghum using a traditional hoe to plough the land and "farm fire" to clear the fields of undesired vegetation (Guinko 1985). The use of animal traction was introduced but its' adoption remains limited due to the costs involved.

Useful trees are selected while clearing the land and kept in the farmland leading to the establishment of agroforestry parklands. Common tree species selected by farmers are *Vitellaria paradoxa, Parkia biglobosa, Lannea microcarpa, Sclerocarya birrea,* and *Tamarindus indica.* A shrub layer is observed in the young crop fields as well as in the fallows, consisting of re-growth of *Vitellaria paradoxa, Diospyros mespiliformis* and many Combretaceae species.

The area of the National Park used to be traditional hunting forest for some of the surrounding villages (e.g. Nobéré, Tewaka, Doncin, and Guiba). Bush fire used to be one of the common local hunting tools and still occurs annually in the region for various reasons.

Sampling

Sampling focused on assessing woody species diversity which is expected to be affected by land use type. Stratified sampling was adopted distinguishing two land use types (the agricultural lands and the forest reserve) and targeted only the plateau topographic feature that is commonly used for agriculture. Rocky hills and riversides were excluded since they are not commonly occupied by agriculture and therefore will not be represented in the two land use types. We finally considered the following land use categories:

- Protected forest vegetation represented by the National Park of Pô named "*Kabore Tambi*".
- Farmland composed of crop fields and patches of fallow land.

Species were recorded following transect lines along which regular quadrats are positioned. The first transect was set perpendicular to the road and the others parallel to the first by use of a compass. A distance of 100 meters separated the road from the first quadrat to avoid roadside effect. The distance between consecutive transects was 5 km and between quadrats 250 meters. Transect length was set at 2500 meters but modified to exclude non-targeted habitats (e.g. rivers, rocky hills, farmers compounds). Quadrats falling in topographic features other than the plateau were therefore not considered in the present study. Quadrat sizes were 20 x 20 m for forest vegetation and fallow lands and 50x100 m in the crop fields, because of the low density of trees in those areas.

All woody species found in the plots with stem diameter ≥ 2 cm at 20 cm above ground, were recorded. Instead of DBH, stem diameters at 20 cm above ground (D_{20cm}) were measured because many useful woody species that remain small in the savanna vegetation would have been excluded otherwise. Data collected concerned species presence and stem diameter.

A total of 8 transect lines were used for the inventory in the agricultural areas. Along the transect lines 32 plots were laid in the cultivated lands and an equal number in the fallow vegetation an estimate of the proportions of fallow and cultivated land is shown in Table 2.1. In the protected forest there were 39 quadrats along 4 transects lines. The geographical positions of quadrats were recorded with a GPS allowing their precise location (fig 2.1).

Table 2.1: Estimates of the proportions of cultivated and fallow areas using line transects

Line Transects	Cultivated areas (%)	Fallow areas (%)
1	54	46
2	70.24	29.76
3	73	27
4	46.87	53.13
5	51.01	49.07
6	78.24	21.76
7	59.14	40.86
8	93.10	06.90
Average	**66**	**34**

Data analysis

The species area curves, type III, following Scheiner's (2003) classification were plotted to ensure that most species in the different land use types were sampled (fig 2.2).

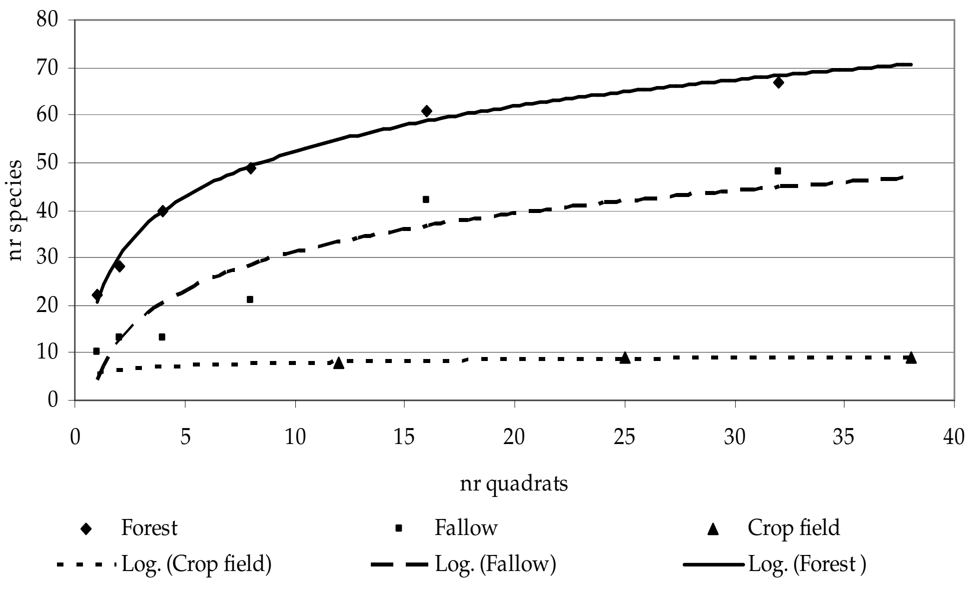


Fig. 2.2. Semi-log species area curves of the plateau topographical features in the forest reserve (♦), the farmland under fallow (■) and the crop fields (▲)

Species diversity and land use

Woody species diversity and equitability (evenness) were estimated per quadrat, using the Shannon-Wiener index *H′* and the Pielou index *J* respectively (Magurran, 1988). These estimators provide information on species richness, frequencies and dominance in the areas (Kent & Coker 1999).

H' and J are calculated using the following formulas:

Diversity: $H' = -\sum_{i=1}^{s} Pi \ln Pi$

Equitability: $J = \frac{H'}{H\max} = \frac{\sum_{i=1}^{s} Pi \ln Pi}{\ln s}$

where s = number of species

Pi = Proportion of individuals or abundance of the i^{th} species expressed as a proportion of the total cover.

ln = log base n

Analysis of variance was performed to compare the woody species diversity of the different land use types. Species number, Shannon diversity index, Pielou equitability index, species density and basal area were determined.

The woody biomass was calculated as the total basal area (BA) per hectare.

BA [m^2ha^{-1}] = $\pi(D_{20cm}$ in cm /200$)^2$ x 10 000/quadrat size in m^2

Dominant species structure and land use

Six diameter classes were used to build frequency tables of the species in each land use type.

Data on population size were plotted against land use type to visualise their possible impact on species dynamics.

Results

Species inventory

Table 2.2 presents the results of the species inventory for the different land use types. Species richness and abundance per land use type are given. In total 86 different woody species were recorded, 69 species were found in the protected forest, 48 in the fallow lands and 41 in the cultivated lands.

Table 2.2: Total number of individuals for each recorded wood species and their abundance in forest land, in fallow land and in cultivated land in Zoundweogo and Nahouri provinces, south-central Burkina Faso. Sa= Total sample area and pi= relative abundance.

		Land Use					
No	Species	Forest		Fallow		Cultiv.	
		Sa = 1.56 ha	Pi	Sa = 1.32 ha	Pi	Sa = 13.5 ha	Pi
1	Vitellaria paradoxa	226	0.0736	118	0.18	184	0.335
2	Terminalia avicennioides	217	0.0707	0	0	0	0
3	Combretum collinum	208	0.0678	4	0.006	0	0
4	Pteleopsis suberosa	208	0.0678	0	0	0	0
5	Acacia dudgeoni	163	0.0531	11	0.017	1	0.002
6	Detarium microcarpum	150	0.0489	3	0.005	2	0.004
7	Grewia cissoides	148	0.0482	0	0	0	0
8	Strychnos spinosa	126	0.041	0	0	0	0
9	Acacia gourmaensis	117	0.0381	8	0.012	20	0.036
10	Piliostigma thonningii	109	0.0355	16	0.024	30	0.055
11	Combretum glutinosum	91	0.0296	158	0.241	62	0.113
12	Pterocarpus erinaceus	88	0.0287	1	0.002	2	0.004
13	Stereospermum kunthianum	87	0.0283	6	0.009	11	0.02
14	Pseudocedrela kotschyi	78	0.0254	32	0.049	23	0.042
15	Combretum molle	74	0.0241	0	0	1	0.002
16	Terminalia laxiflora	70	0.0228	29	0.044	7	0.013
17	Annona senegalensis	67	0.0218	55	0.084	27	0.049
18	Maytenus senegalensis	67	0.0218	3	0.005	0	0
19	Tinnea barteri	65	0.0212	0	0	0	0
20	Anogeissus leiocarpa	63	0.0205	5	0.008	0	0
21	Cochlospermum tinctorium	62	0.0202	0	0	0	0
22	Gardenia ternifolia	61	0.0199	10	0.015	4	0.007
23	Feretia apodanthera	45	0.0147	12	0.018	9	0.016
24	Dichrostachys cinerea	38	0.0124	3	0.005	4	0.007
25	Entada africana	38	0.0124	2	0.003	0	0
26	Crossopteryx febrifuga	38	0.0124	0	0	0	0
27	Securinega virosa	35	0.0114	24	0.037	21	0.038
28	Burkea africana	31	0.0101	0	0	1	0.002
29	Gardenia triacantha	26	0.0085	0	0	0	0
30	Gardenia erubescens	24	0.0078	8	0.012	5	0.009
31	Afrormosia laxiflora	22	0.0072	0	0	0	0
32	Combretum ghasalense	21	0.0068	0	0	0	0
33	Lannea acida	20	0.0065	6	0.009	2	0.004
34	Combretum fragrans	17	0.0055	3	0.005	0	0
35	Prosopis africana	17	0.0055	1	0.002	0	0
36	Acacia hookii	13	0.0042	0	0	0	0
37	Bombax costatum	11	0.0036	0	0	5	0.009
38	Diospyros mespiliformis	10	0.0033	20	0.03	6	0.011
39	Securidaca longipedunculata	10	0.0033	0	0	0	0
40	Lannea velutina	9	0.0029	0	0	0	0
41	Zizyphus mucronata	8	0.0026	1	0.002	1	0.002
42	Piliostigma reticulata	7	0.0023	2	0.003	1	0.002
43	Bridelia ferruginea	6	0.002	4	0.006	1	0.002
44	Gewia mollis	6	0.002	0	0	0	0
45	Nauclea latifolia	6	0.002	0	0	0	0
46	Ximenia americana	5	0.0016	0	0	1	0.002

47	Ampelocissus africanus	5	0.0016	0	0	0	0
48	Combretum sericium	5	0.0016	0	0	0	0
49	Sapium grahamii	5	0.0016	0	0	0	0
50	Tamarindus indica	5	0.0016	0	0	0	0
51	Telosma africana	5	0.0016	0	0	0	0
52	Lannea microcarpa	3	0.001	25	0.038	27	0.049
53	Sclerocarya birrea	3	0.001	9	0.014	14	0.025
54	Grewia bicolor	3	0.001	4	0.006	0	0
55	Cissus populnea	3	0.001	1	0.002	0	0
56	Guiera senegalensis	3	0.001	0	0	0	0
57	Strychnos innocua	3	0.001	0	0	0	0
58	Trichelia emetica	3	0.001	0	0	0	0
59	Balanites aegyptiaca	2	0.0007	8	0.012	10	0.018
60	Parkia biglobosa	2	0.0007	7	0.011	10	0.018
61	Mitragyna inermis	2	0.0007	1	0.002	0	0
62	Lonchocarpus laxiflorus	2	0.0007	0	0	0	0
63	Xeroderris stuhlmannii	2	0.0007	0	0	0	0
64	Sterculia setigera	1	0.0003	2	0.003	5	0.009
65	Fadogia agrestis	1	0.0003	0	0	0	0
66	Lippia chevalieri	1	0.0003	0	0	0	0
67	Maerua angolensis	1	0.0003	0	0	0	0
68	Opilia celtidifolia	1	0.0003	0	0	0	0
69	Vitex simplicifolia	1	0.0003	0	0	0	0
70	Acacia seyal	0	0	26	0.04	34	0.062
71	Acacia sieberiana	0	0	6	0.009	5	0.009
72	Senna singueana	0	0	5	0.008	1	0.002
73	Ozoroa insignis	0	0	5	0.008	0	0
74	Ficus ingens	0	0	0	0	4	0.007
75	Faidherbia albida	0	0	2	0.003	1	0.002
76	Vitex doniana	0	0	2	0.003	1	0.002
77	Adansonia digitata	0	0	0	0	2	0.004
78	Azadirachta indica	0	0	0	0	2	0.004
79	Daniellia oliveri	0	0	1	0.002	1	0.002
80	Ficus sycomorus	0	0	1	0.002	1	0.002
81	Zizyphus mauritiana	0	0	2	0.003	0	0
82	Eucalyptus camaldulensis	0	0	0	0	1	0.002
83	Combretum paniculatum	0	0	1	0.002	0	0
84	Erythrina senegalensis	0	0	1	0.002	0	0
85	Ficus capensis	0	0	1	0.002	0	0
86	Khaya senegalensis	0	0	1	0.002	0	0
	Total plants	**3070**	**1**	**656**	**1**	**550**	**1**
	Total number of species	**69**		**48**		**41**	

The Venn diagram in fig. 2.3 summarises the state of species richness in the three different land use types and their overlaps. It shows that 26 species are ubiquitous, occurring in all land use types, while 30 species are present exclusively in the forest reserve. Species found only in parklands (cultivated and fallow areas) amount to 17 and in small number for most of them (see table 2.2).

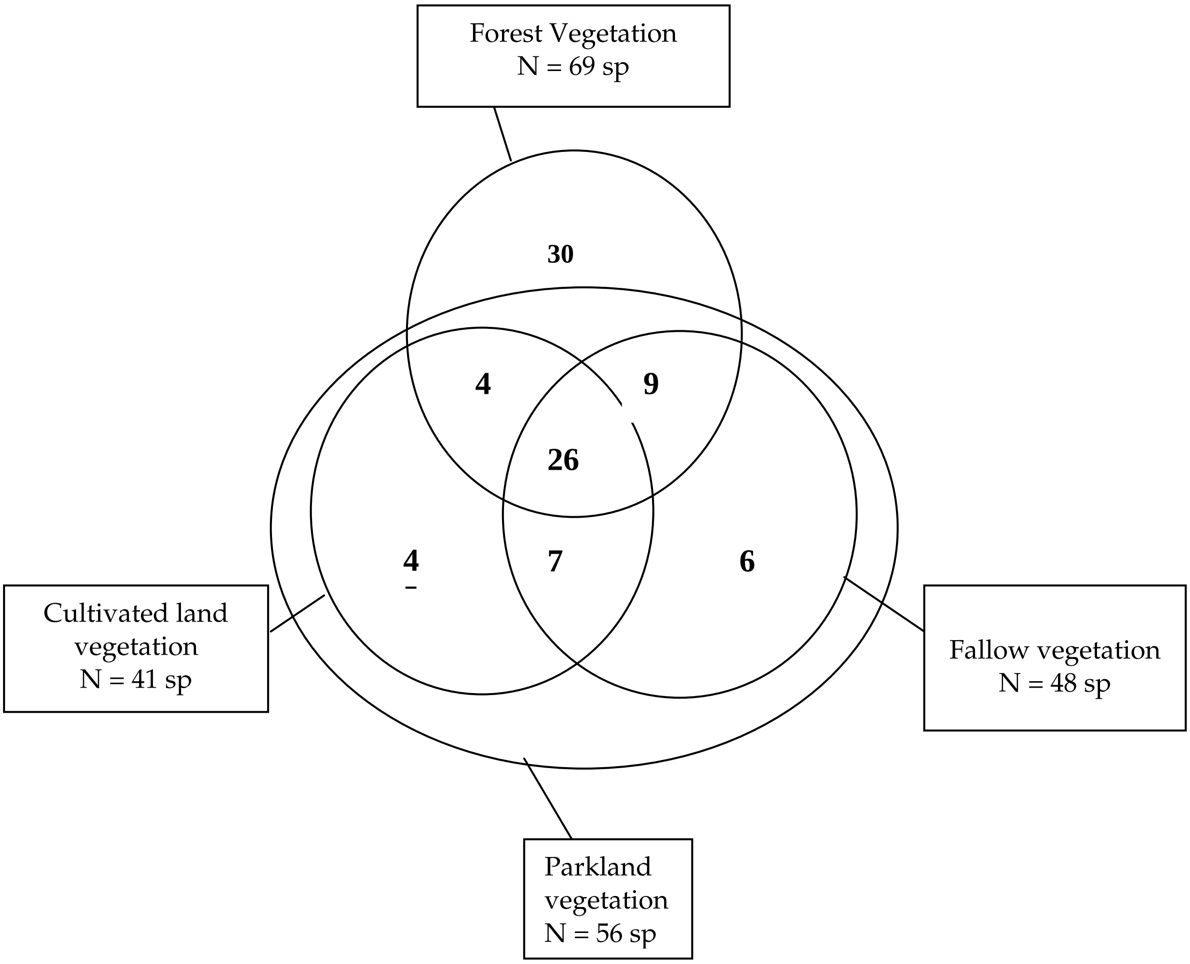


Fig. 2.3. The Venn diagram presents the species richness pattern under different land use in South-Central Burkina.

As it appears from table 2.2, dominant ubiquitous species are *Vitellaria paradoxa, Acacia gourmaensis, Piliostigma thonningii, Combretum glutinosum, Pseudocedrela kotschyi, Annona senegalensis, Securinega virosa, Diospyros mespiliformis*. Dominant species exclusive to the protected forest are *Terminalia avicennioides, Pteleopsis suberosa, Grewia cissoides,* and *Strychnos spinosa* while noticeable species exclusive to the parkland are *Acacia seyal, Acacia sieberiana,* and *Senna singueana.*

Land use and species diversity

The diversity indicators used to compare the land use types showed significant difference between them (Table 2.3). The Shannon diversity index (H′) showed that the protected forest has the highest mean index with H′=

2.39 and the cultivated land the lowest with H'= 1.49. Other important variables such as number of species, density basal area and Pielou equitability index showed the same trend (Table 2.3).

The analysis of variance indicates significant differences (F-probality <0.05) between land use for all variables except the Pielou equitability index. Basal area differences were only significant between cultivated area and forest with respective mean value of 1.102 m^2/ha and 4.26 m^2/ha.

Table 2.3: Biodiversity indicators and basal areas in protected forest, fallow lands and cultivated areas

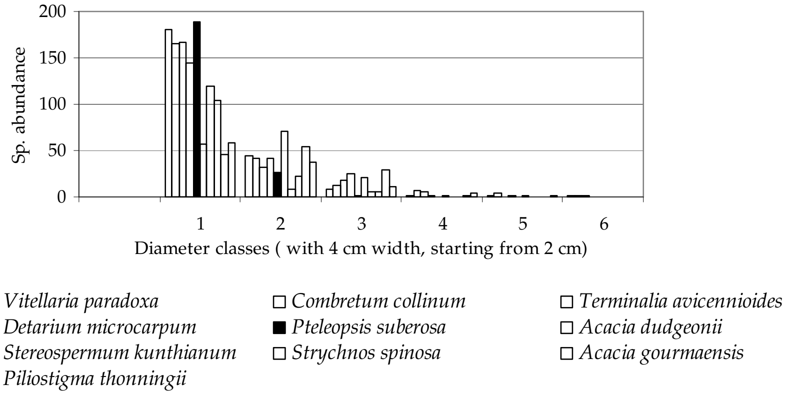
Land use type	Quadrat size	Number of quadrats	Mean No of species per quadrat	Mean Density (per ha)	Mean Shannon (H')	Mean Pielou (J)	Mean Basal area (m^2/ha)
Forest reserve (PNKT)	400 m^2	39	18.23 ^{a}	1967.9 ^{a}	2.39 ^{a}	0.82 ^{a}	4.26 ^{a}
Fallow land	400 m^2	33	7.48 ^{b}	681.1 ^{b}	1.49 ^{b}	0.80 ^{a}	3.31 $_a$
Cultivated land	5000 m^2	27	4.05*	29.70 ^{c}	1.05 ^{c}	0.78 ^{a}	1.102 ^{b}

Different superscript letters within columns, indicate significant differences between means (Fisher LSD, P=0.05).
* Comparison excludes value of cultivated land here because of difference in quadrat size.

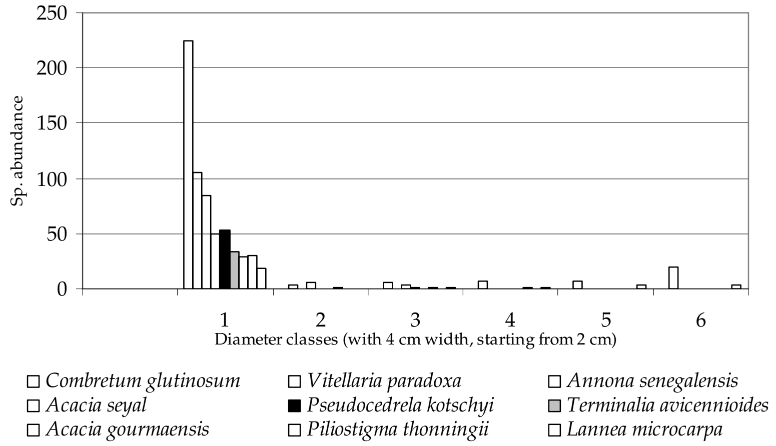
Population structure of important species related to land use

Population structures for important species were summarised by diameter class and according to land use (Fig. 2.4). The results show lack of regeneration of these important species on cultivated land. Old trees, represented by the largest diameter classes, dominate the parkland (Fig. 2.4.c). Diameter class distribution in the protected forest (Fig. 2.4a)clearly shows a tendency for most species to remain within the small diameter classes very few will reach maturity. Species such as *Vitellaria paradoxa, Terminalia avicennioides, Stereospermum kunthianum, Detarium microcarpum,* and *Acacia dudgeonii* grow into taller trees in the cultivated land. In the forest land, plants are much more often subject to bush fire and to competition for nutrients than in the agricultural land. These factors obviously reduce the growth rate of the trees in the savanna dry forest. In the fallow it appears also that many species have a larger population in the smaller diameter classes than in the larger classes, which is an indication of potential regeneration. When farmers come back after the fallow period, they leave the tallest individuals to grow to maturity.

(A)



(B)



(C)

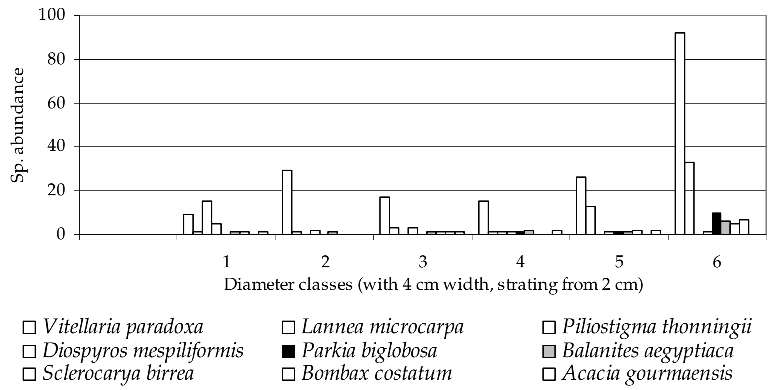


Fig. 2.4. Population structure of dominant species using diameter class distribution in (A) Protected forest, (B) fallow lands and (C) cultivated land.

Discussion and conclusion

Species presence and frequencies in the parkland (cultivated area and fallow land) and in the protected forest suggest that 3 categories of parklands woody species may be distinguished to explain the current state of parkland species diversity:

1. The first category include species selected and protected by farmers in the farmland: these species are able to grow and become adult trees. Examples from this category are: *Bombax costatum, Lannea microcarpa, Parkia biglobosa, Sclerocarya birrea,* and *Vitellaria paradoxa.*

2. The second category includes species not selected nor specially protected but persistent in the parkland. In most cases they have the faculty to regenerate from the remaining rootstock left after the field clearing. Examples of these species are *Combretum glutinosum, Piliostigma thonningii,* and *Diospyros mespiliformis*. These species remain small and shrubby (Fig. 2.4c) in the cultivated land although they can grow to tall trees.

3. The third category concerns species planted by farmers because of their valuable products. In most cases these species are exotic ones. Examples in this study are *Eucalyptus camaldulensis* and *Azadirachta indica*. The latter can also spread spontaneously. In other areas species such as *Mangifera indica* are commonly found in the parklands. In the case of the third category of species dominating, the parkland evolves into a home garden type of agroforestry (Wiersum, 2004).

The result of the survey illustrates the ubiquitous behaviour of species such as *Vitellaria paradoxa* which is ranking high in all land use types (table 2.2). This could be explained by its good regeneration capacity and its resistance to recurrent bush fire effects (Hall et al. 1996, Lovett & Haq 2000) in the region. Other species are confined to one land use type, 30 species to the forest area and 17 to the parklands (Fig. 2.3), suggesting that hostile environmental or anthropogenic factors may prevent those species from growing in all land use types. Species that are sensitive to bush fire could therefore be present in the parkland (*Acacia seyal, Cassia sieberiana)* and absent or rare in the fire prone vegetation of the forest reserve, since parklands are less subject to seasonal fires than forest.

Species diversity management in the rural area is best understood by applying a land use approach since the role of the rural people is central in the use and management of the species. The following Venn diagram provides a scheme with the main land use types which could explain the regional status of species diversity (Fig. 2.5).

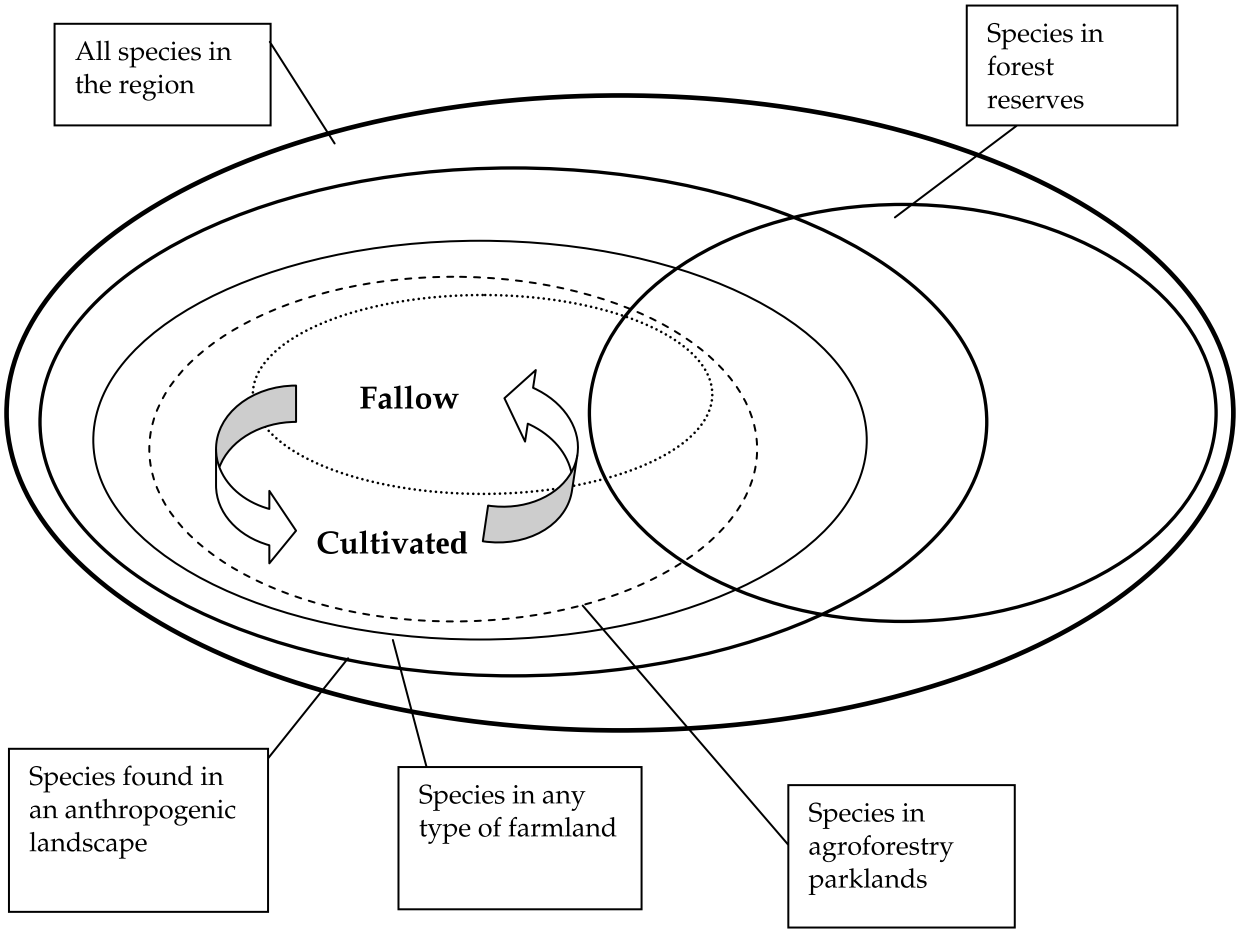


Fig. 2.5. Venn diagram of species diversity in the regional rural landscape, showing cultivated-fallow components within the parkland system

The results of the ANOVA in table 2.3 prove that species diversity as well as tree density and basal area are lower in the parklands (cultivated area or fallow) than in the forest reserve. This clearly indicates loss of species in the parklands of south-central Burkina compared to the nearby protected forest vegetation. A study conducted in north Ghana by Lovett and Haq (2000) showed similar results with species diversity, tree density and basal area being lower on highly intensively farmed land than on the less intensively farmed land. This state of the parkland diversity results from various anthropogenic activities. One explanation is the duration of the fallows in the area which were reported to be short, often less than 5 years. Some farmers explained that because of scarcity of land, they cannot leave the degraded land uncultivated for more than 5 years. Long fallow periods enable species to regenerate and reach an acceptable size for farmers to select them to be maintained during the next cultivation cycle.

If the entire study area were to be devoted to agriculture, all land therefore being either under cultivation or under fallow, the result would be a loss of 30 species or 35% of the species richness in the area. It is therefore necessary to have well-managed forest reserves to act as refuges for sensitive species and as a biodiversity reservoir from which the parklands can be regenerated through seed dissemination. Agricultural practices in this case contribute to the degradation of species diversity. Other studies indicate that species diversity is higher in agricultural lands than protected forest although most of these did not separate herbs from woody species (Eilu et al. 2003).

Although agricultural practices cause a decrease of species diversity in the cultivated lands, other species are confined to/or show better development in the agricultural areas. The examples of *Adansonia digitata, Acacia seyal, Senna singueana*, *Faidherbia albida,* and *Ziziphus mauritiana* indicate that the parkland component in the rural landscape represents a better environment for the development of those species despite the small number of records in the present study. Possible reasons why the above species are confined to the agricultural land in the Sudan savanna of south-central Burkina could be better conditions in terms of fire control, and less competition for nutrients and water as compared to the forest land where species density is high (Table 2.3).

Implications for parkland management

Spatial planning can play a role in the preservation of biodiversity by creating a network of biodiversity conservation patches. The idea of a network of conservation reserves or biodiversity corridors developed by Van Langevelde et al. (2000) could be adopted by farmers in the rural landscape, where agroforestry parkland is the predominant agricultural system.

The identification of species sensitive to recurrent anthropogenic disturbance factors such as bush fire, regular soil tilling, free grazing and plant products harvesting is essential to sound species diversity management in a given regional landscape. Particular actions could be addressed to those species to ensure their regeneration. Direct sowing of desired species in the parkland could be one of the solutions to the insufficient regeneration of species in the parkland, so far this is only carried out on experimental scale.

Chapter 3

Comparing parkland species diversity in two eco-zones on the Central Plateau of Burkina Faso

Chapter 3

Comparing parkland species diversity in two eco-zones on the Central Plateau of Burkina Faso

Nikiema A.[1 2 *], Hall John B.[3] and van der Maesen L.J.G.[2]

[1] *Centre National de Semences Forestières, 01 BP 2682 Ouagadougou, Burkina Faso.*
[2] *Biosystematics Group, Wageningen University, Generaal Foulkesweg 37, 6703 BL Wageningen, the Netherlands.*
[3] *School of Agricultural and Forest Sciences, University of Wales Bangor, Gwynedd LL57 2UW, UK.*

Abstract

Comparing parkland diversity to adjacent forest reserves provide a good evaluation of the biodiversity conservation role attributed to this ancient land use system that is found in the semi arid West Africa. Woody species survey was conducted simultaneously in contiguous parkland and protected forest in two different eco-zones.

The comparison test revealed that species richness, Shannon index and Pielou equitability index were significantly different between land use and eco-zones although with a different order of importance from the Sudanian site to the Sahelian one. In the Sudanian zone, the forest land use has a higher diversity (H'=2.564) than the parkland (H'=1.527), while in the Sahelian zone, the parkland (H'=1.947) shows higher diversity than the protected forest (H'= 1.495). Parkland species composition in both eco-zones presents a lot of similarities with *Vitellaria paradoxa* being a common dominant species. The resulting data on the parkland species composition strongly support the hypothesis that farmers have been the main dissemination agent of dominant species such as *Vitellaria paradoxa*.

Key words: Parkland species, Species richness, Shannon index, Semi-arid tropics, Burkina Faso.

INTRODUCTION

The Sudan savanna woodland, also known as dry forest, has been shaped by a climate with a long dry season (7-9 months) combined with regular bush fire events. Farming systems in this phytogeographical zone have led to fragmentation of the landscape into patches of farmed land and bushes or forest reserves. Agricultural practices have integrated woody species as well as agricultural crops and/or animals resulting in a land-use system described as agroforestry (Ouedraogo 1994, Bonkoungou et al. 2002, Sinclair 1999). The physiognomy of the agroforestry lands differs all over the world due to interactions between bioclimatic conditions and the socio-cultural behaviour of the rural people. Hence many agroforestry systems have been described (e.g. shifting cultivation or the slash and burn system, the homegarden system, the forest garden system, the trees on farmland system, and the parkland system (Wood 1988, Boffa 1999, Bonkoungou et al. 2002, Wiersum 2004, Teklehaimanot 2004, Atta-Krah et al. 2004).

The latter describes traditional agroforestry practices in the Sudanian and Sahelian ecozone where useful trees are left scattered in the crop fields. Species composition is influenced by farmers' expectations from trees because many plant products contribute to the welfare of the rural population (e.g. leafy vegetables, fruits, fire wood, medicines etc.). These products are also valuable sources of income through harvesting, processing and commercialisation activities (Nikiema et al. 2005).

The parkland agroforestry system illustrates how farmers value and manage plant resources in their territory. It contributes to the conservation of plant genetic resources and, therefore, to biodiversity conservation. The wide range of species kept in the crop fields is witness to the efficiency of species diversity conservation.

Species composition in the agroforestry parklands is influenced by ecological and economic factors in a given socio-cultural environment (Sinclair 1999, Boffa 1999; Nikiema et al. 2005, Bonkoungou et al. 2002). Different parkland physiognomies have been described in West Africa, and named after dominant species: e.g. parc à *Vitellaria paradoxa* (Karité), parc à *Faidherbia albida*, parc à *Adansonia digitata* (Baobab) etc. (Bonkoungou et al. 1998).

Agroforestry parklands are subject to degradation because of the increased demand for arable land. In addition to soil degradation commonly noticed in the agricultural lands of the semi-arid areas, the tree component of the agroforestry parklands also shows signs of decline in some areas. The ratio between fallow lands and cultivated areas tends to decrease with time while the tree population structure and species diversity show signs of decline in the Sudan zone of West Africa (Gijsbers et al. 1994, Nikiema 1993, Kelly et al. 2004). Parkland systems tends to evolve with time towards a reduced number of trees species dominated by highly valued useful plants such as *Vitellaria paradoxa, Faidherbia albida, Borrassus aethiopum, Parkia biglobosa,* and *Adansonia digitata*.

Fallowing is the mechanism under which parklands are traditionally regenerated in the West African Sudan zone (Boffa 1999, Somé 1996) and plantation trees have contributed only to a small extent so far. This suggests that natural vegetation should have the capacity of supporting regeneration though seed production and dispersal and/or shoots from the rootstocks of the various species during fallow. Comparing the parkland woody species diversity with adjacent protected natural vegetation provides a means of evaluating the contribution of parklands to the conservation of regional species diversity. Results obtained in the north Sudan area of Burkina Faso showed that on farmed land woody species diversity was much lower than in forest reserves (chapter 2). The question of whether these findings represent a general tendency in agroforestry parkland systems becomes important, because of the possible implications for regional or countrywide natural resources management policies. Thus the present study aims at describing the current state of woody species diversity in farmed lands versus neighbouring forest reserves in different ecological zones and to find out how much ecological conditions (mainly rainfall) influence parkland species composition.

In this chapter we therefore deal with the following research questions:

1. Is parkland species composition similar in the two eco-zones?
2. Is parkland diversity lower than in the natural vegetation in any ecozone of Burkina Faso?

Methods

Site description

The study was conducted in two different ecozones. The first site was located in Malou area (in the Sanmatenga province) in the Sahelian ecozone and the second site was located in Manga area (in the Zoundweogo province) in the Sudanian ecozone (table 3.1 and Fig. 3.1).

The forest reserves mentioned in this study are state-owned forests, officially protected from uncontrolled exploitation for at least 30 years. The forest reserve at Pô has the status of a National Park and therefore is under more restricted access policy. Hunting and grazing are forbidden. The Malou forest on the other hand has a status of "*forêt classée*" which allows gathering and exploitation of firewood under the strict control of local foresters. However, exploitation of firewood has not yet been carried out in Malou forest.

The two study sites were selected to represent different ecological zones in Burkina Faso, the Sahelian and the Sudanian zone (Fontes and Guinko (1995). In every study site contiguous protected forest and parkland were selected for the species inventory. The vegetation types are savanna shrubland for the first site and savanna woodland for the second site.

Table 3.1: Location of the study sites

Study sites	**No. of subsamples**	**Geographical positions**	**Rainfall (mm year^{-1})**	**Bioclimate type (following Fontes and Guinko 1995)**
1. FC Malou	20	12°58′ 01°27′	600-700	Sahelian (transition Sahel-Sudanian)
2. PN Pô	20	11°15'02 N 01°08'06 W	700-900	Sudanian north

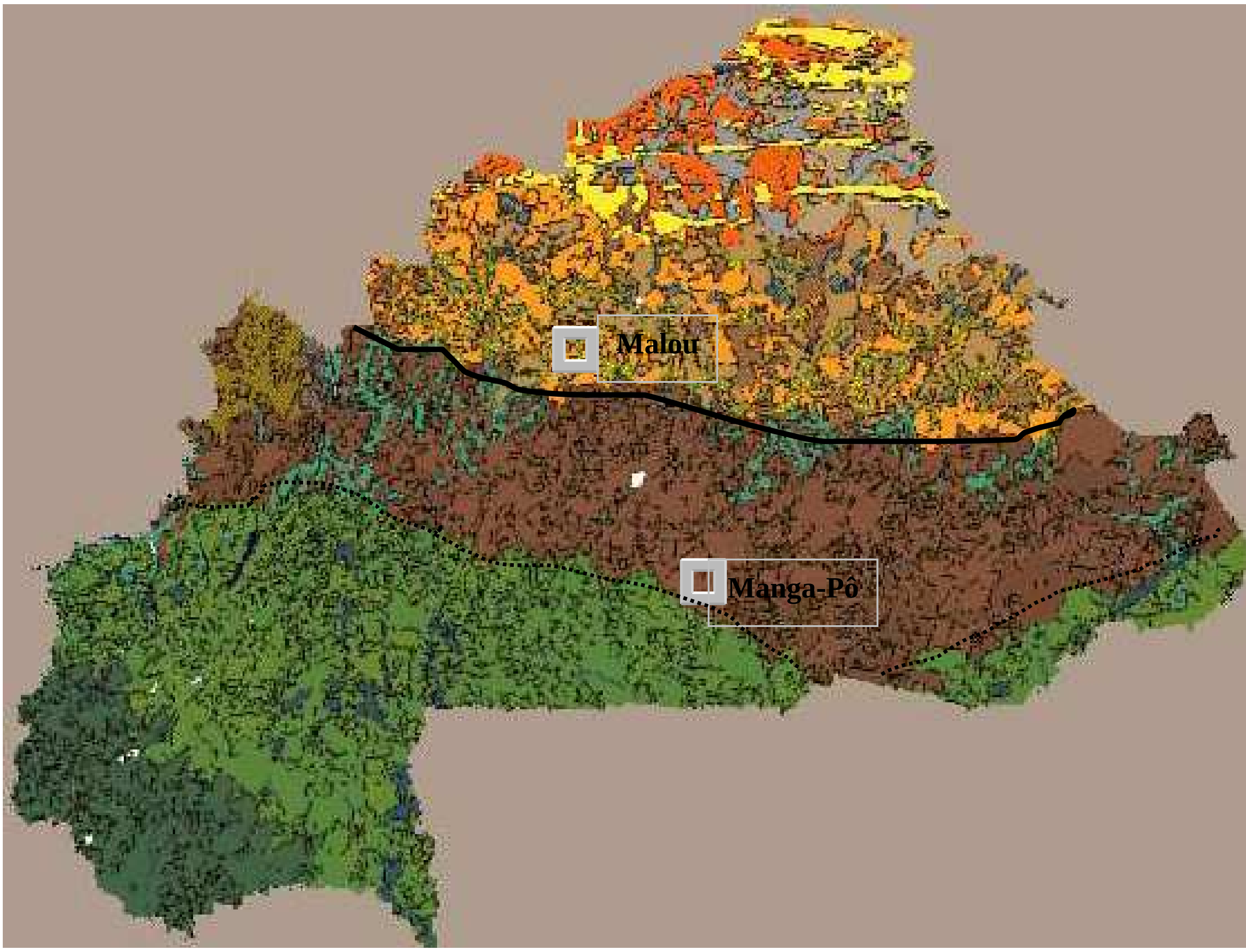


Fig. 3.1. Vegetation map of Burkina Faso with the two study sites location.

▬▬▬ Limit between Sahel and Sudan zone

.... Limit between Sudanian north and Sudanian south

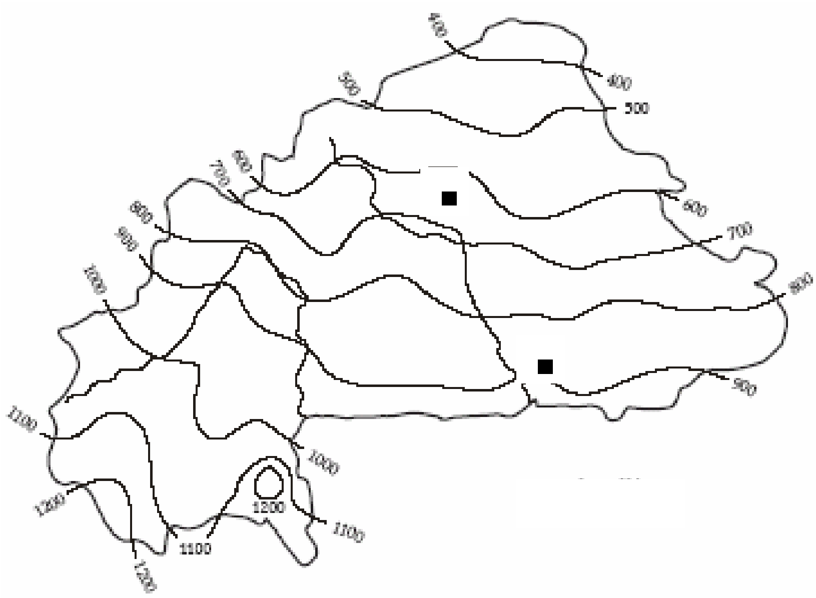


Fig. 3.2. Rainfall pattern in Burkina Faso and study sites (■).

Sampling

Species inventory was conducted using quadrats placed along line transects at regular intervals of 250 m. Quadrat sizes were 25 m x 25 m in the forest and 50 m x 100 m in the cultivated areas. Non-targeted habitats such as riverside, rocky hills, farmers' compounds were avoided by terminating the transect line or by-passing the area. A margin of 100 m was observed in the latter case. Sample size was large enough for most species in each land use type to be recorded (Table 3.2).

Sampling in the parklands concerned only the cultivated area (fallow land was excluded) because fallow areas were too small in the Sahelian ecozone. Therefore, in this paper the term parkland is used to designate land under cultivation only.

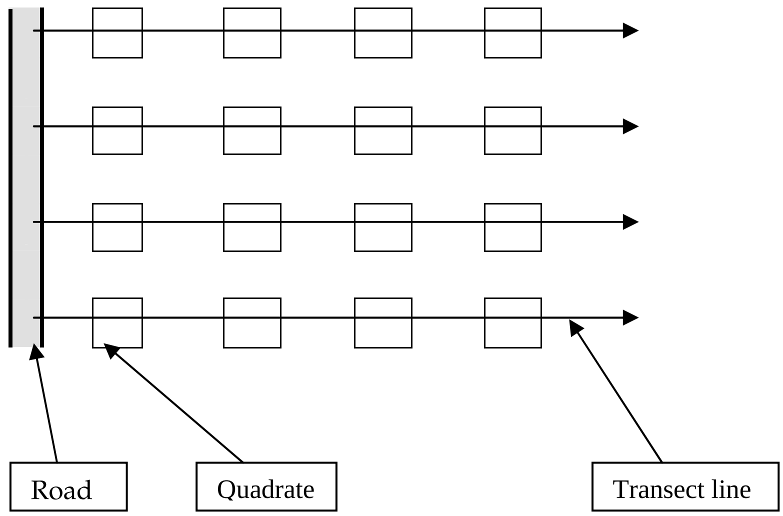


Fig. 3.3. Sampling scheme in the different land uses and ecozones

Table 3.2: Sampling scheme

Eco-zone	Land use	Total sample area (ha)	Sample population (indiv.)	Sub-sample size (indiv.)	Sub-sample No	Total Sub-sample size (indiv.)
South Sahel	Forest reserve	0.94	1107	20	20	400
	Cultivated area	7.6	472	20	20	400
North Sudan	Forest reserve	1.56	3062	20	20	400
	Cultivated area	16	646	20	20	400

Data analysis
To compare diversity indicators, quadrat data within each ecozone and land use type were merged for drawing subsamples of constant size (n=20) repeated 20 times. Subsamples of constant size allowed direct comparison of land.

Random sampling of the subsamples was performed with Minitab 13. The biodiversity indicators, species numbers (richness), Shannon diversity index (H'), and Pielou equitability index (J) were calculated following Kent and Coker (1999). Then an analysis of Variance with multiple comparison was performed following Daniel (1991) with the help of Minitab 13.

Results

Species inventory

Table 3.3: Woody species recorded in natural forest and parkland of two ecozones in Burkina faso. S= total sample area.

	Ecozone	Sahel		North Sudan	
No	Species	Forest reserve S= 0.94 ha	Park land S= 7.6 ha	Forest reserve S= 1.56 ha	Parkland S= 16 ha
1	*Combretum nigricans*	640	3	0	0
2	*Combretum micranthum*	119	16	0	0
3	*Guiera senegalensis*	107	1	3	0
4	*Acacia macrostachya*	42	3	0	0
5	*Combretum glutinosum*	41	7	91	63
6	*Feretia apodanthera*	34	2	45	11
7	*Anogeissus leiocarpa*	26	74	63	1
8	*Grewia flavescens*	13	0	0	0
9	*Grewia bicolor*	10	1	3	0
10	*Boswellia dalzielii*	9	0	0	0
11	*Sclerocarya birrea*	8	38	3	16
12	*Dalbergia melanoxylon*	7	1	0	0
13	*Commiphora africana*	7	0	0	0
14	*Pterocarpus lucens*	6	1	0	0
15	*Acacia ataxacantha*	4	3	0	0
16	*Balanites aegyptiaca*	3	28	2	19
17	*Stereospermum kunthianum*	2	2	87	11
18	*Dichrostachys cinerea*	2	0	38	4
19	*Ximenia americana*	2	3	5	1
20	*Combretum aculeatum*	2	3	0	0
21	*Adansonia digitata*	2	2	0	2
22	*Terminalia avicennioides*	1	0	217	0
23	*Strychnos spinosa*	1	0	126	0
24	*Entada africana*	1	5	38	0
25	*Lannea acida*	1	0	20	6
26	*Bombax costatum*	1	19	11	8
27	*Piliostigma reticulata*	1	8	7	1
28	*Lannea microcarpa*	1	7	3	53
29	*Sterculia setigera*	1	23	1	7
30	*Cassia sieberiana*	1	4	0	0
31	*Acacia senegal*	1	3	0	0

32	*Boscia salicifolia*	1	1	0	0
33	*Vitellaria paradoxa*	0	165	226	218
34	*Combretum collinum*	0	0	208	0
35	*Ptelopsis suberosa*	0	0	208	0
36	*Acacia dudgeoni*	0	0	163	1
37	*Detarium microcarpum*	0	0	150	2
38	*Grewia cissoïdes*	0	0	148	0
39	*Acacia gourmaensis*	0	0	117	20
40	*Piliostigma thonningii*	0	0	109	30
41	*Pterocarpus erinaceus*	0	5	88	1
42	*Pseudocedrela kotschyi*	0	0	78	23
43	*Combretum molle*	0	0	74	1
44	*Terminalia laxiflora*	0	0	70	7
45	*Annona senegalensis*	0	0	67	28
46	*Maytenus senegalensis*	0	0	67	0
47	*Tinnea barteri*	0	0	65	0
48	*Cochlospermum tinctorium*	0	0	62	0
49	*Gardenia ternifolia*	0	1	61	5
50	*Combretum fragrans*	0	0	38	0
51	*Crossopteryx febrifuga*	0	0	38	0
52	*Securinega virosa*	0	0	35	21
53	*Burkea africana*	0	0	31	1
54	*Gardenia triacantha*	0	0	26	0
55	*Gardenia erubescens*	0	0	24	5
56	*Afrormosia laxiflora*	0	0	22	0
57	*Prosopis africana*	0	0	17	0
58	*Acacia hockii*	0	0	13	0
59	*Diospyros mespiliformis*	0	4	10	13
60	*Securidaca longepedunculata*	0	0	10	0
61	*Lannea velutina*	0	0	9	0
62	*Ziziphus mucronata*	0	0	8	1
63	*Bridelia ferruginea*	0	0	6	2
64	*Grewia mollis*	0	0	6	0
65	*Sarcocephalus latifolius*	0	0	6	0
66	*Tamarindus indica*	0	26	5	0
67	*Ampelocissus africanus*	0	0	5	0
68	*Combretum sericeum*	0	0	5	0
69	*Sapium grahamii*	0	0	5	0
70	*Telosma africana*	0	0	5	0
71	*Cissus populnea*	0	0	3	0
72	*Strychnos innocua*	0	0	3	0
73	*Trichilia emetica*	0	0	3	0
74	*Parkia biglobosa*	0	1	2	10
75	*Mitragyna inermis*	0	0	2	0
76	*Vitex simplicifolia*	0	0	1	0
77	*Acacia seyal*	0	5	0	38
78	*Khaya senegalensis*	0	4	0	0
79	*Ficus platyphylla*	0	3	0	0
80	*Acacia sieberiana*	0	0	0	5
81	*Azadirachta indica*	0	0	0	2
82	*Senna singueana*	0	0	0	3
83	*Daniellia oliveri*	0	0	0	1
84	*Ficus ingens*	0	0	0	4
85	*Vitex doniana*	0	0	0	1
	Total individuals	**1097**	**472**	**3062**	**646**
	Total number of species	**32**	**34**	**62**	**39**

It is apparent from table 3.3 that the Malou forest reserve in the Sahelian ecozone is dominated by species of the Combretaceae family *(Anogeissus leiocarpa, Combretum glutinosum, Combretum micranthum, Combretum nigricans,* and *Guiera senegalensis*) which represent 94% of the woody species. Previous study on this forest came to similar conclusion (Compaore & Laban 1983). This vegetation composition corresponds to the vegetation type described as Sub-Sahel by Guinko (1985) or South Sahel by Fontes and Guinko (1995).

Most parkland species are present in the Sahelian zone as well as in the Sudanian: *Vitellaria paradoxa, Bombax costatum, Balanites aegyptiaca, Sclerocarya birrea, Sterculia setigera, Diospyros mespiliformis, Acacia seyal, Parkia biglobosa*.and *Combretum glutinosum*. However, all these species occur in only one ecozone in the forest reserves, except for *Combretum glutinosum* and possibly *Balanites aegyptiaca*. In the Sahelian parkland, farmers keep many species of which typical examples are: *Balanites aegyptiaca, Bombax costatum, Combretum micranthum, Sclerocarya birrea, Sterculia setigera, Tamarindus indica,* and *Vitellaria paradoxa*.

Species characteristic of the Sudan savanna parklands are *Diospyros mespiliformis, Piliostigma thonningii, Lannea microcarpa, Acacia gourmaensis, Securinega virosa,* and *Vitellaria paradoxa.Vitellaria paradoxa* appears to be the common dominant species of the parklands in the two ecozones.

Diversity indicators across ecozones and land-use

The analysis of variance showed a significant difference between sampled sites for all diversity indicators (Table 3.4). The forest reserve in the Sudanian zone showed higher diversity than the parkland there while the Sahelian zone revealed the reverse.

Species diversity in the Sahelian forest reserve is the lowest (H′= 1.495) among all 4 sampling environments, but not significantly different from the Sudanian parkland (H′= 1.527). Parkland in the Sahelian ecozone (H′= 1.947) showed higher diversity than in the Sudanian parkland (Table 3.4) although this may be due to the particular social environment. The local forest service in charge of extension activities is located in Malou village.

The comparison showed the similar tendency for all variables: species number, Pielou equitability index (J) and Shannon diversity index (H')

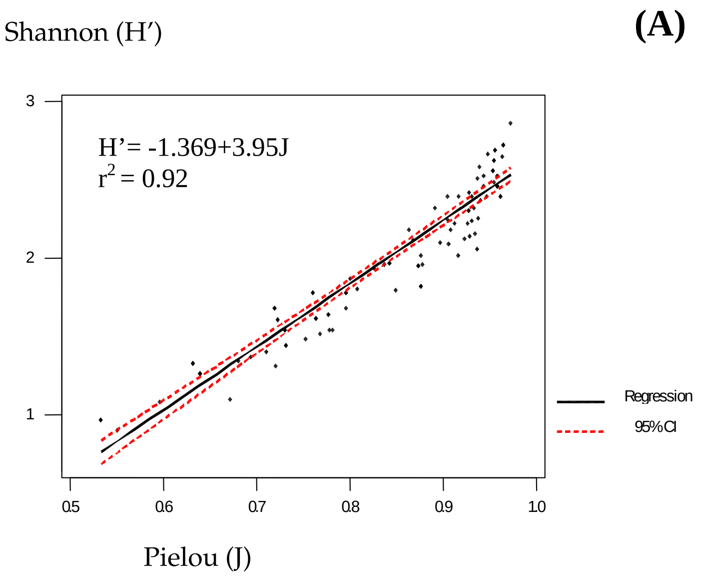
Table 3.4: Comparison of species diversity in forest reserves and parklands across two ecozones in Burkina Faso.

Ecozones & Land use	Nr of samples	Mean nr of species	Mean Shannon (H')	Mean Pielou (J)
Forest reserve				
Malou (1)	20	07.55 ^{a}	1.495 ^{a}	0.741 ^{a}
Manga/Pô (2)	20	14.40 ^{b}	2.564 ^{b}	0.963 ^{b}
Parkland				
Malou (1)	20	09.85 ^{c}	1.947 ^{c}	0.856 ^{c}
Manga/Pô (2)	20	08.35 ^{a}	1.527 ^{a}	0.718 ^{a}
SED		0.567	0.167	0.041

Different superscript letters within columns indicate significant differences between means (Fisher LSD, P=0.05)

Correlation between species diversity indicators

There is a strong correlation between the Shannon diversity index and Pielou equitability index (even-ness) with r^2=0.92 at 95% confidence interval (fig. 3.4A) indicating that the regression equation is a good predictor of the variations in the index. Species richness also shows strong correlation with Shannon index (Fig. 3.4B).



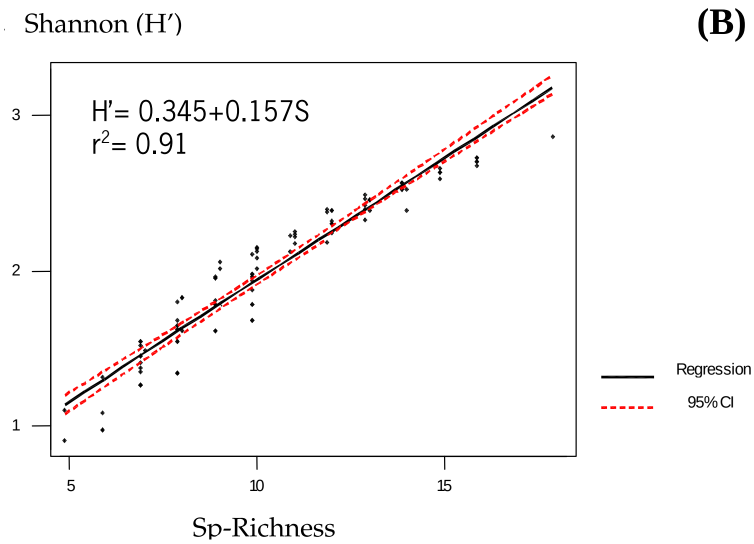


Fig. 3.4. Shannon diversity index (H′) as a function of: (**A**) Pielou equitability index (J) and (**B**) Species richness (S).

Discussion and conclusions

Species diversity

Species diversity indices were higher in the forest reserves of the Sudan ecozone than in the Sahelian ecozone, confirming previous studies, which conclude that species richness tends to increase along rainfall gradients (Wieringa & Poorter 2004, Givnish 1999, O'Brien 1993, Hall & Swaine 1976).

Parkland species richness as a result of farmers' agricultural practices and behaviour vis-à-vis the plant resources could better explain the results presented in table 3.4 where species diversity in the Sahelian ecozone is higher in the parkland than in the forest reserve. Arguments based on the hypothesis that parkland species comes from a pre-existing natural vegetation of the same area do not justify the presence of most parkland species in the Sahelian zone. Species such as *Vitellaria paradoxa, Lannea microcarpa* and *Tamarindus indica,* known as Sudanian (Guinko 1985, Fontes & Guinko 1995) are obviously absent in the forest reserve, but are strongly represented in the Sahelian parkland. This is probably due to the farmers who have contributed to seed dissemination and the development of the plants in their fields. Furthermore, the migration of farmer populations such as the Mossi people, who moved from northern Ghana in the 11th century to colonise the upper Volta region (Balima 1969, Pigeonnière & Jomni 1998), could explain how useful Sudanian species went to the Sahelian zone. A other south–north movement of Vitellaria along with population migration have been mentioned by Maranz (2003), who reported that *Vitellaria* populations spread along the way to the mouth of the Gambia river as a result of Malian migrants who bringing the seeds during their movement.

Furthermore, species diversity in the parkland appeared higher than in the forest reserves in the Sahelian zone (table 3.4) which reinforces the hypothesis that farmers have enabled species which are not prevailing in the natural vegetation, to grow in their agricultural land. The parkland system is therefore contributing to the enrichment of woody species diversity in this area. Statements made by many authors that agricultural activities, specially the parkland system, can contribute to species diversity conservation (Atta-Krah et al. 2004, Boffa 2000) are confirmed in this study.

The parkland woody species diversity compared to that in the forest reserve in the Sudanian ecozone presents a less satisfactory profile. A substantial proportion (about 50%) of species occurring in the forest reserve is not recorded in the parkland. These results suggest that in the Sudanian ecozone, parklands contribute less positively to the local diversity conservation. In these circumstances, it is likely that the state of species diversity will decrease if parkland area has to expand in an uncontrolled manner.

In the light of the present results it is proposed that some species have moved out of their ecological habitat along with the farmers and the establishment of parklands. This hypothesis is supported by the presence of Sahelian species in the Sudan ecozone and *vice-versa*. It is likely that this tendency will grow since the farmer's mobility across ecological zones is increasing in search of agricultural land and fodder for livestock.

The occurrence of typical Sudanian species in the parklands of the Sahelian ecozone suggests that farmers have, either consciously or unconsciously, domesticated those species through selection and/or regeneration practices. This hypothesis has already been supported by Ouedraogo (1995) and Lovett and Haq (2000) who studied respectively *Parkia biglobosa* and *Vitellaria paradoxa* population diversity.

Chapter 4

Woody species in the Kalenga grazing area (Burkina Faso) and their importance for livestock feeding.

In preparation for submission to "African Journal of Range and Forage Science"

Chapter 4

Woody species in the Kalenga grazing area (Burkina Faso) and their importance for livestock feeding.

Nikiema A.[1,4], Hansen H.[2], van der Maesen L.J.G[3].

[1]. *Centre National de Semences Forestières, B.P. 2682 Ouagadougou 01 (Burkina Faso).*
[2]. *The Royal Veterinary and Agricultural University, Department of Animal Science and Animal Health. 2 Groennegaardsvej, DK-1870 Frederiksberg C. (Denmark).*
[3].*Biosystematics Group, Wageningen University and Research Centre, Gen. Foulkesweg 37, 6700 ED Wageningen (the Netherlands).*
[4]. *ICRISAT Sahelian Centre, Niamey, BP 12404 Niamey (Niger).*

Abstract

The importance of woody species in livestock feeding in the Sudanian vegetation of South-Central Burkina Faso was investigated using botanical field inventory and diet identification methods.

The effect of grazing on species richness in the area was analysed using a distance gradient from a water point, but results did not show significant differences between distances. On the other hand, correlations were found between variables such as species number, distance to the water point and quantity of cattle faeces (R^2=0.58 and P-value=0.02). The estimated selectivity index indicates that woody species such as *Capparis corymbosa, Cochlospermum planchonii, Crossopteryx febrifuga, Cussonia barteri, Daniellia oliveri* and *Stereospermum kunthianum* are preferred amongst the available species. The proportion of woody species in the faeces was lower for both cattle (11%) and sheep/goats (30%) than of grasses (85% and 56% respectively). Seeds and pods of legumes and grasses represent a marked portion of the diet with 4% for cattle and 11% for small ruminants.

The results of the present study provide information on woody species preferred by livestock, which can be regenerated in open grazing land to minimize the degradation of the resources and improve livestock feeding conditions.

Key words: Small ruminants, sheep, goat, cow, diet, livestock grazing, selectivity index, species richness

Introduction

In Burkina Faso, the common practice in agriculture is crop-livestock farming or mixed farming which combines animal production with cultivation of annual crops (Slingerland 2000, Ayantunde 1998). The sustainability of this production system has prevailed for centuries but is now questioned because of population growth and the subsequent increased pressure on natural resources. Cultivated lands as well as livestock populations have increased at the cost of fallow lands and natural vegetation (FAOSTAT 2004, Nikiema et al. (2001), the latter almost restricted to state reserves and/or national parks.

Animal production in the Sahelian region is a major component of the economy (Ayantunde 1998). The common practice observed in the region is open herding combined with seasonal transhumance towards water points and pasturelands where natural fodder is available. This uncontrolled livestock farming is often regarded as a source of land degradation. Grazing can induce changes in species composition of pasture (Slingerland 2000; Hiernaux 1997) or lead to irreversible change of the vegetation in arid and semi-arid areas (Rietkerk & Ketner 2001). Herbivores affect plant diversity through their impact on dominant species, plant regeneration opportunities and seed transport (Lykke et al. 1999, Olff & Ritchie 1998, Gijsbers et al. 1994).

Woody species are an important component of livestock food in the semi-arid zone of West Africa (Houérou 1978) and cattle diets may include 11 to 30% of woody species depending on the season (Slingerland 2000, Ickowicz & Mbaye 2001). However, the selective habit of the grazing animals is an important parameter to be considered for sound management of grazing lands. Species with high selectivity index should be specially considered to increase forage stock in the area or undertake conservation measures for threatened species.

The livestock population in Burkina Faso is amongst the largest in West Africa's Sahelian countries with about 5 million cattle and 15 million small ruminants (FAOSTAT 2004). In Burkina Faso, in addition to the Sahelian zone in the north that used to be dominated by pastoral activities, places where the vegetation is still in good condition (e.g. state or communal forests) are open for grazing or sometimes converted into grazing lands. It is one of the policy measures to cope with the increasing need for pasture. That is the case in the Zoundweogo province with the grazing buffer zone established between the National park of Pô and the agricultural crop lands.

Livestock density is one of the highest in this region with 113 700 head of cattle and 200 000 head of small ruminants, distributed in an area of 3453 km^2 (Stroosnijder & van Rheenen 2001; Nana 1999). This high density is a result of north-south migration of many herdsmen with their animals, looking for good pasture and water.

The grazing buffer zone established between the National Park of Pô "Kaboré Tambi" and the agricultural crop lands has become an attraction for many herdsmen. As a contribution to solving the problem of lack of water for the animals, the Project on Integrated Development of Zoundweogo Province has decided to build a dam to supply the animals with water. The construction of the dam in 1998 has resulted in an increase of livestock herds. Because the common livestock herding practice is free grazing, the impact on the vegetation must be controlled in order to avoid severe degradation of the resources. Reliable information on the botanical composition of the grazing area as well as the animal's diet is required to support grazing management decisions (Vallentine 2001).

With the perspective of acting at species level to improve the fodder resources, we chose to use presence and abundance of woody species in the grazing area as well as in the animals' faeces to evaluate the importance of woody species for livestock feeding in the Kalenga grazing area. Apart from carrying capacity, species contribution to livestock diet has been used in pasture management and animal feeding studies (Slingerland 2000, Fahnestock & Detling 1999, Rietkerk et al. 2000, Diaz et al. 2001, Uresk 1984, Kalmbacher et al. 1984).

In the present study, the objectives were:

1. to find out which species are preferred by cattle (cows) and goats/sheep

2. to assess the effects of grazing on woody species diversity in the grazing area

3. to make suggestions that can contribute to improving livestock herding in the area.

Materials and methods

Study site

The study took place in a newly established pasture area at Kalenga, a village in Zoundweogo province in south of Burkina Faso. The pasture land is an area bordering the National Park of Pô, 18 km south of Manga and used to be part of the National Park of Pô. The vegetation is a Sudan savanna type characterised by Sudanian woody species such as *Detarium microcarpum, Combretum glutinosum*, *Piliostigma thonningii, Afzelia africana* and *Daniellia oliveri*. The climate is North Sudanian (Fontes and Guinko 1995), characterised by a long dry season of 8 months (October-May) and a short rainy season of 4 months (June-September) with about 800-1000 mm of annual rainfall.

The main activities in the province are cereal crops production (pearl millet and sorghum) by local sedentary farmers in the northern part and animal herding in the southern part by semi-nomadic Fulani people. Kalenga village covers part of the grazing buffer zone where pastoral activities are promoted and as such it contains a high livestock population compared to other villages in the province.

Botanical field inventory of woody plants

Four parallel transect lines, 200 meters apart, starting from the east side of the dam were permanently marked. Three plots of 20 m x 20 m were marked along each transect with the first plot 100 m from the dam and then with 250 m intervals between successive plots on the transect. This area is supposed to be part of the most frequently visited perimeter by livestock due to the proximity of the water. In this area, where the density of animals is often very high compared to places further away from the dam, palatable species have high risks of being eaten and may provide information on the state of degradation.

All woody plants that were found in the 400 m^2 plots were recorded. Stem diameter at 20 cm above ground was measured, and the number of cowpats within the plot was noted.

The fieldwork was carried out during the dry season in January 2002.

Plants species inventory in livestock faecal droppings

Animal faecal droppings from cattle and small ruminants (sheep/goats) were sampled every 6 weeks from April 2002 to December 2002 covering the end of the dry season, the entire rainy season and the beginning of the next dry season. About 100 g (a small handful) of faeces was taken from 5 spatially separated cow and sheep/goat pats and pooled. This was repeated, to have two replicated samples during the same collection period. The diet choice of at least 10 goat/sheep and 10 cattle were represented in the 2 samples, assuming the samples were taken from different animals. Five slides were made from each sample for microscopic identification of species and plant particles eaten by the animals in 20 independent observation fields on each slide as described by Sparks and Malechek (1968). A reference collection of 250 plant species from the study area was made and formal botanical identification of all species was undertaken by the CNSF herbarium. The diet composition laboratory at the Royal Veterinary and Agricultural University, Department of Animal Science and Animal Health in Denmark carried out microhistological faeces sample analyses.

Elements identified in the faeces were grouped into: (1) grasses and forbs, (2) woody species (3) seeds and pods, to simplify the presentation of the results.

Analysis

The relation between species richness and variables such as distance to the water and density of cow pats was investigated through multiple regression analysis. Estimated r^2 is the sample coefficient of determination as described by Daniel (1991). All data analyses were performed using Minitab 13.

Species relative frequencies (P_{xi}) in the field and in the faeces were calculated, separately for species in the field and species in the faeces, by dividing individual number of a specific species (n_{xi}) by the total number of individuals for all recorded species (with S=number of species):

$$P_{xi} = \frac{nxi}{\sum_{i=1}^{S} nxi}$$

The livestock selectivity index, X_i, on woody species was estimated following Vallentine (2001) and Uresk (1978):

$$X_i = \frac{Pf(xi)}{Pk(xi)}$$

Where X_i is the preference of a given species by an animal, $Pf(x_i)$ the relative frequency of species in the faeces, $Pk(xi)$ the relative frequency of species in the grazing are.

When $X_i < 1$ it means no preference

When $X_i > 1$ it means there is preference for the species

Results

Woody species inventory in the grazing area

The inventory revealed that 45 woody species are present in the grazing area, dominated by *Piliostigma thonningii* (15%), *Combretum glutinosum* (12%), *Acacia gourmaensis* (10%), *Vitellaria paradoxa* (7%) (Table 4.1). Fodder species such as *Acacia dudgeoni*, *Acacia gourmaensis*, *Acacia seyal* and *Sclerocarya birrea* were also present.

Table 4.1: Presence and abundance of woody species inventoried in pasture (Kalenga, Burkina Faso) and in livestock faeces.
ni= species individual numbers; P*f(xi)* = species relative frequency in faeces; P*k(xi)*= relative frequency of species in the grazing land; Xi_1 and Xi_2 are selectivity indices for cattle and sheep/goats respectively.

Species *	**Field**		**Faeces**		**Selectivity index**	
	Number of individuals (*ni*)	Relative freq. P*k(xi)*	Relative frequency for cattle P*f(xi)*	Relative frequency for sheep/goat P*k(xi)*	Cattle X_{i1}	Sheep /goats X_{i2}
Acacia dudgeoni	42	0.051				
Acacia gourmaensis	84	0.101				
Acacia seyal	56	0.068				
Adansonia digitata	5	0.006				
Afzelia africana	*1*	*0.001*		*0.001*		*1*
Annona senegalensis	*17*	*0.021*		*0.001*		*0.048*
Anogeissus leiocarpa	18	0.022				
Balanites aegyptiaca	*12*	*0.014*		*0.001*		*0.071*
Bombax costatum	*3*	*0.004*		*0.001*		*0.25*
Bridelia ferruginea	8	0.010				
Capparis corymbosa	*6*	*0.007*		*0.011*		*1.6*
Chamaechrista mimosoides		0.001*		0.003		3
Cissus populnea	10	0.012				
Cochlospermum planchonii		0.001*	0.006		6	
Combretum collinum	10	0.012				
Combretum fragrans	*3*	*0.004*				
Combretum glutinosum	*100*	*0.121*	*0.004*	*0.006*	*0.033*	*0.049*
Combretum molle	5	0.006				
Cola cordifolia		*0.001**	*0.001*		*1*	
Crossopteryx febrifuga	*3*	*0.004*	*0.007*	*0.036*	*1.75*	*9*
Cussonia barteri		0.001*		0.012		12
Daniellia oliveri		0.001*		0.002		2
Detarium microcarpum	16	0.019				
Dichrostachys cinerea	3	0.004				
Diospyros mespiliformis	*19*	*0.023*	*0.002*	*0.001*	*0.087*	*0.043*
Entada africana	4	0.005				
Erythrina senegalensis	1	0.001				
Eucalyptus camaldulensis		*0.001**		*0.001*		*1*
Feretia apodanthera	*18*	*0.022*	*0.019*	*0.002*	*0.864*	*0.090*
Gardenia aqualla	*7*	*0.008*	*0.001*	*0.001*	*0.125*	*0.125*
Gardenia erubescens	9	0.011				
Gardenia ternifolia	3	0.004				
Gardenia triacantha	1	0.001				
Grewia bicolor	5	0.006				
Grewia cissoides	3	0.004				
Grewia flavescens	3	0.004				
Lannea acida	15	0.018				
Lannea microcarpa	3	0.004				
Mangifera indica		0.001*		0.001		1
Maranthes polyandra		0.001*	0.001		1	
Maytenus senegalensis	15	0.018				

Parkia biglobosa	*4*	*0.005*		*0.001*		*0.20*
Piliostigma reticulata	2	0.002				
Piliostigma thonningii	124	0.150				
Pseudocedrela kotschyi	22	0.027				
Pteleopsis suberosa		0.001*		0.002		2
Sclerocarya birrea	22	0.027				
Securinega virosa	30	0.036				
Stereospermum kunthianum		0.001*		0.008		8
Sterculia setigera		0.001*		0.001		1
Tamarindus indica	2	0.002				
Tectona grandis		0.001*	0.002	0.002	2	2
Terminalia avicennioides	23	0.028				
Vitellaria paradoxa	*59*	*0.071*	*0.001*	*0.006*	*0.014*	*0.084*
Vitex chrysocarpa	1	0.001				
Ximenia americana	21	0.025				
Ziziphus mucronata	*9*	*0.011*	*0.001*		*0.090*	
Others		*0.001**				
	829	**1**	**0.0438**	**0.0967**	**-**	**-**
	45		**11**	**21**	**-**	**-**

* Species not recorded in the plots but found in faeces were given a relative frequency of 0.001.

Woody species richness along livestock grazing intensity gradient

Woody species richness comparison of the area close to the dam with areas at 600 m away shows no significant difference with regard to the number of plant species, number of plants, and number of cowpats. At 100 m from the dam mean density of cowpats was 30.5±16.76 per plot, 21.75±15.75 at 350 m, and 13.25±10.24 at 600 m (Table 4.2). Mean species number and mean plants number show a similar trend.

Table 4.2: Effect of grazing intensity on woody species richness using a gradient of proximity to the dam.

Distance from dam (m)	Mean number of plants per plot (400 m^{-2})	Mean number of species per plot (400 m^{-2})	Mean number of cowpats per plot (400 m^{-2})
100	61.25±16.46	13±3.16	30.5±16.76
350	59.5±11.21	18.25±2.87	21.75±15.75
600	86.5±49.9	17.75±2.5	13.25±10.24

The structure of the woody vegetation in diameter class terms indicates that small diameter classes have more individuals than bigger diameter classes (fig. 4.1), but this is the situation for most natural vegetations.

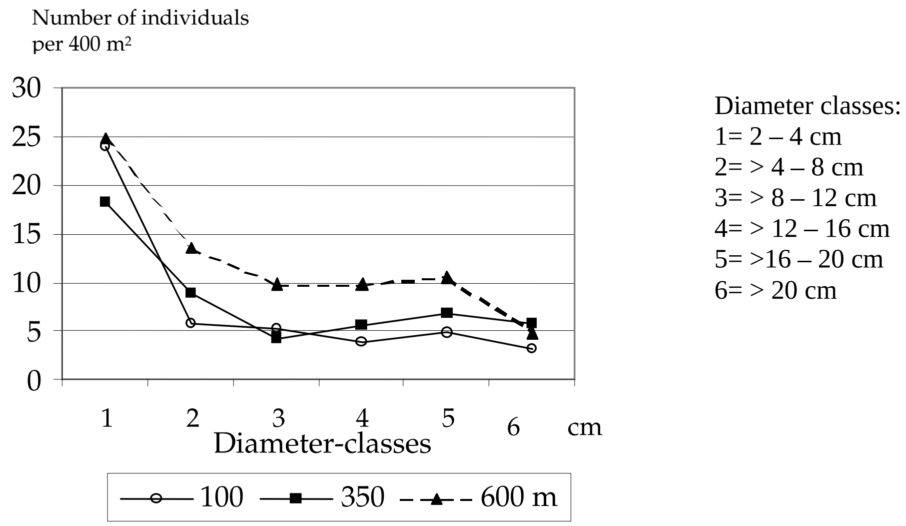


Fig. 4.1. Woody plant diameter distribution along a distance gradient from the water point in Kalenga grazing area in 2002.

Correlation between variables

Multiple regression analysis revealed a significant correlation between species number and the combined factors of distance to the water point and density of cowpats along the distance gradient (r^2=0.58 and P-value = 0.02).

The regression equation is:

Species = 8.31+0.0143 Distance +0.139 Faeces density

Table 4.3: Multiple regression of the effect of distance to water point, and faeces density, on woody species diversity in sample plots.

Predictor	**Coeff.**	**SE coeff.**	**T**	**P**
Constant	8.311	2.473	3.36	0.008
Distance	0.014279	0.00415	3.44	0.007
Faeces density	0.13852	0.05872	2.36	0.043

Separate simple regression analysis did not show significant correlations between the variables. Correlation between distance from the dam and cowpat number per plot was not significant. Correlation between species number and distance gradient from the water dam was not significant although figure 4.1 shows a tendency of decline when getting closer to the dam. Number of species per plot and number of plants recorded were moderately correlated (r=0.500).

Livestock diet and selectivity of species in the study area

In total, 28 different species were found in the livestock faeces. Sheep and goats are interested in more species (21 woody species identified) than cattle (11 woody species identified) as shown in Table 4.1. These results support the common belief that small ruminants, especially goats, browse more than cattle (Houérou 1978).

Species number in the faeces is most of the time higher for small ruminant (sheep and goat) than for cattle (see fig. 4.2). The highest number recorded during the same sampling period was 20 species for small ruminants in July and November.

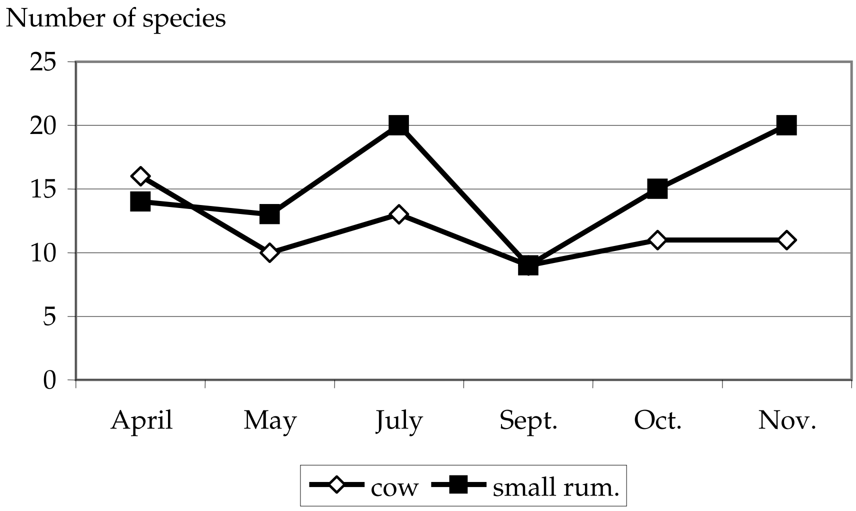
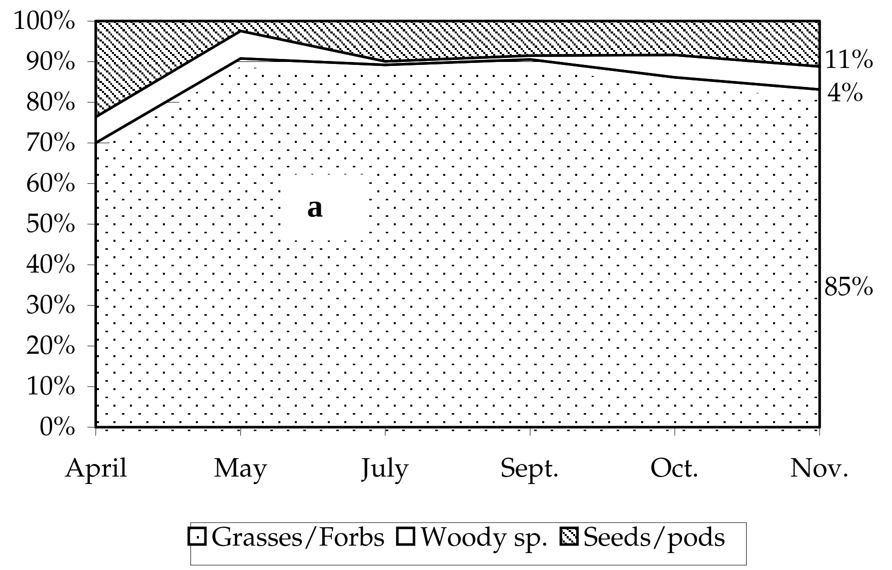


Fig. 4.2. Species richness in livestock faeces in the



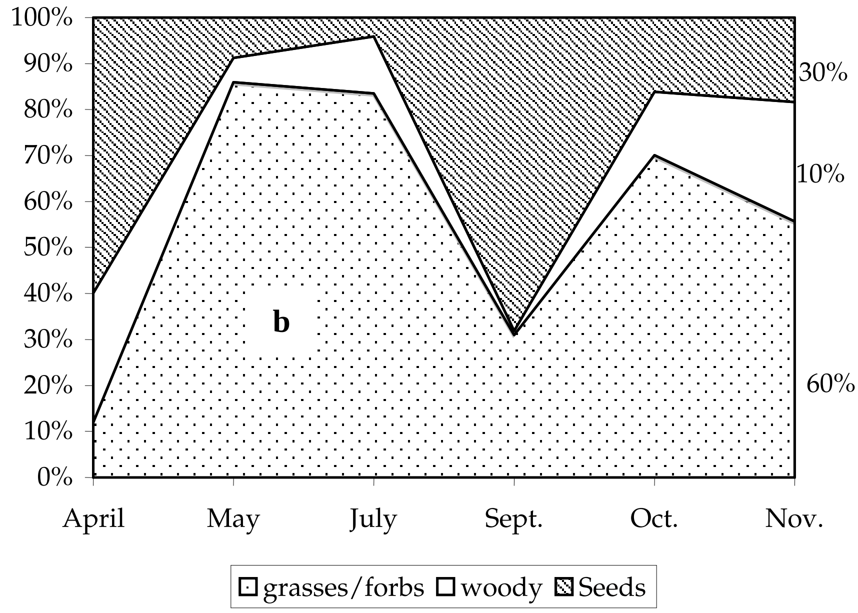


Fig. 4.3. Diet composition of cattle (a) and small ruminants (b) in Kalenga permanent pasture, southern Burkina Faso, 2002.

The micro-histological analysis showed that the cattle diet had a more regular proportion of the three components during the study period than that of sheep/goats with, on average, 85% grasses and forbs, 4% woody species, and 11% seeds and legume pods (fig. 4.3a). Small ruminant diet analysis shows a higher contribution of woody species (10%) and seeds (30%) than cattle diet does (fig. 4.3b). The results indicate that woody species constitute a common and regular portion of livestock diet in the Kalenga grazing area.

Our results show that the herbaceous materials (grasses & forbs) are the dominant diet component from April until December for both categories of animal (see fig. 4.3). The results on field inventory and diet composition must be put into seasonal context to have a proper understanding of the impact of livestock on species richness. It is demonstrated that diet depends on availability and access to species as well as their phenology (Scoones 1994).

Species preferred by livestock

A total of 28 woody species were found in livestock faeces during the study. In the grazing land of Kalenga cattle were browsing on 11 woody species while 16 woody species were browsed in the agroforestry parklands. Sheep and goats in the grazing area fed on 21 woody species.

Species with a high selectivity index were: *Cochlospermum planchonii, Crossopteryx febrifuga,* and *Daniellia oliveri*, for cattle, and *Capparis corymbosa, Chamaechrista mimosoides, Crossopteryx febrifuga, Cussonia barteri, Pteleopsis suberosa,* and *Stereospermum kunthianum* for sheep and goats. These woody species represent a portion of the food intake of livestock varying from 1 to 10% for cattle and from 0 to 30% for small ruminants (sheep and goats) (Fig. 4.3). Similar figures were reported by Houérou (1978) who stated that in the semi-arid tropics, livestock often depend entirely on woody species to balance their diet during the dry season. Other studies have also reported the important role of woody species in livestock diets (Slingerland 2000, Wolfgang 1990, Petit & Malet 2001).

The estimated selectivity ratio shows species with high ratio, which may be subject to risk if the pressure from the livestock is increased. Other well-known fodder species in the ecological region such as *Pterocarpus erinaceus* or *Afzelia africana* were either rare or out of reach of the animals, explaining their absence from the livestock diet.

The selectivity indexes were calculated for all species recorded in the faeces and presented in Table 4.1. Species such as *Capparis corymbosa, Crossopteryx febrifuga,* and *Stereospermum kunthianum* are highly selected by sheep and goats, and *Cochlospermum planchonii* is preferred by cattle. Species with selectivity index lower than one (e.g. *Combretum glutinosum, Feretia apodanthera*) are eaten but are not considered as preferred species.

Discussions & Conclusion

The impact of livestock on species diversity

The multiple regression analysis showed moderate correlation between distance from water, number of species and number of cowpats (r^2=0.58, P-value = 0.02). It indicates that in areas close to the water with a high number of faecal droppings there are smaller numbers of species, although this conclusion needs to be strengthened with additional sampling in the area since the monitoring must continue for years.

The distance gradient from the water used to evaluate livestock impact on species diversity in the grazing land did not show sharp results but this could be explained by the relatively young age of this dam (4 years). The grazing intensity may be classified as moderate for the moment with regard to the impact on the woody component, since the present intensity was proved not destructive for species diversity (Table 4.2).

Woody species found in cattle diets such as *Afzelia africana, Daniellia oliveri, Balanites aegyptiaca, Combretum glutinosum, Cussonia barteri, Feretia apodanthera, Sterculia setigera* and *Ziziphus mauritiana* have also been reported by other authors who have worked in the semi-arid and sub-humid area of West Africa (Houérou 1978, Petit & Mallet 2001, Ickowicz & Mbaye 2001). This suggests that such forage species should not be overlooked in grazing land management.

Diet composition of cattle from a grazing land compare to those from parkland

The diet composition of cattle in the grazing land of Kalenga compared to the agricultural parklands of Nobéré village (unpublished data from Hansen) showed slight differences in the number of species recorded in the faeces. Over the study period, 16 species were recorded in the cattle faeces in Nobéré parklands while 11 were recorded in Kalenga grazing land. Eight species were common to both land use types (Table 4.4). Common agroforestry parkland species recorded in the region (this thesis) were found in cattle faeces. Examples are *Acacia sieberiana, Annona senegalensis, Balanites aegyptiaca, Cassia sieberiana* and *Ziziphus mauritiana*. The limited grass cover in the parkland and the palatability of most of the parkland species may be a reason why more woody species are found in the diet of cattle in the parkland area, than in the diet of those on the grazing land.

High selectivity indicates that species are palatable and may encounter difficulties in regenerating in areas of intensive grazing where young plants are quickly detected and eaten by animals. Such species will therefore be threatened in areas of increasing grazing intensity, such as Kalenga.

To overcome the problem of the regeneration of preferred forage species, management options in the area should consider measures allowing seedlings to germinate and to grow above vulnerable size before opening the area to grazing. For example, cattle should not be allowed to graze for a period of at least two years.

Table 4.4: Relative frequency of species in cattle faeces collected from grazing land and parkland

Woody species	Grazing land (Kalenga)	Parkland (Nobéré)
Acacia sieberiana		0.007
Annona senegalensis		0.001
Balanites aegyptiaca		0.002
Cassia sieberiana		0.0006
Chamaechrista mimosoides		0.0006
Cochlospermum planchonii	0.006	
Cola cordifolia	0.001	
Combretum glutinosum	0.004	0.003
Crossopteryx febrifuga	0.007	0.009
Daniellia oliveri		0.0006
Diospyros mespiliformis	0.002	0.002
Feretia apodanthera	0.019	0.011
Gardenia aqualla	0.0006	0.004
Mangifera indica		0.005
Maranthes polyandra	0.0006	0.001
Tectona grandis	0.002	0.005
Vitellaria paradoxa	0.001	0.001
Ziziphus mauritiana		0.001
Ziziphus mucronata	0.0006	
Number of species	**11**	**16**

Implications for grazing land management

Establishing a dam to provide drinking water alone (in a grazing area) is not enough to guarantee the sustainability of grazing land. Knowing the palatable species, their availability in the area and their nutritional value is basic information that contributes to the development of efficient management. The following actions should therefore improve the management of the grazing area:

1. The list of species recorded in the faeces presents preferred species which could be used to enrich the grazing area by direct sowing. However, complementary information on the nutritional quality of such species should further justify that action.
2. Management of parklands could be improved by enrichment with woody species that produce good quality fodder (e.g. *Afzelia africana, Pterocarpus erinaceus*) during the dry season, and therefore shorten the distance the herders have to cover during that season searching for natural pasture.
3. Regular monitoring of the state of biodiversity, specially plant species and ecological habitats will be necessary to avoid overgrazing in the grazing area.
4. General public consent about grazing frequency should be obtained at village level.

Chapter 5

Bush fire intensity and its effects on plant species of the Sudan savanna, (south-central Burkina Faso)

In preparation for submission to "Forest Ecology and Management"

Chapter 5

Bush fire intensity and its effects on plant species of the Sudan savanna, (south-central Burkina Faso)

Nikiema A.[1 2 *], Hall John B.[3], Oksanen M.[4] and van der Maesen L.J.G.[2].

[1] *Centre National de Semences Forestières, 01 BP 2682 Ouagadougou, Burkina Faso.*
[2] *Biosystematics Group, Wageningen University, Generaal Foulkesweg 37, 6703 BL Wageningen, The Netherlands.*
[3] *School of Agricultural and Forest Sciences, University of Wales Bangor, Gwynedd LL57 2UW, UK.*
[4] *Projet National de lutte contre les feux de brousse. Ouagadougou, Burkina Faso.*

Abstract

Bush fire management requires information on fire behaviour, intensity and its effect on living organisms. The concepts of early fire and late fire have been widely applied in the Sudan savanna with little scientific background supporting it.

An experiment was conducted to measure bush fire temperature and their effects on plant species of the Sudan savanna in southern Burkina Faso. The vegetation is a woodland savanna type dominated by perennial tall grasses (Andropogoneae) and woody species belonging to the Combretaceae family (e.g. *Combretum glutinosum, Terminalia avicennioides*). All individual plants over 2 cm stem diameter at a height of 20 cm were tagged and the effect of fire was assessed.

Temperatures of early fire were lower compared to late fire. The highest temperature recorded was 333 °C for early fire, while in late fire the peak reached 677 °C. Temperature residence time above 60 °C showed clearly that plant tissues were exposed longer to high temperatures in late fire than in the early one. Fire temperatures varied with the height of measurement. The highest temperature was measured at 20 cm above ground while underground temperature at 10 cm was not influenced by fire.

The difference between both fire regimes was clear for the tall grasses (Andropogoneae) which did not burn seriously (only 20%) during early fire but were completely consumed by late fires. Effects on woody species did not show spectacular differences between the two fire periods.

Key words: Bush fire, temperature, savanna, woody species, early fire, late fire

Introduction

Fire is a common feature of savanna ecosystems, and it shapes the vegetation structure and diversity (Nasi et al. 2002, Frost & Robertson 1987, Solbrig et al. 1996). Savanna fire (bush fire) is mostly caused by farmers or hunters as a mean of opening new land for agriculture or to attract wildlife (Monnier 1990, Pyne 1995). The use of fire for savanna management is widespread, but its effect on savanna ecosystems and especially on plant species is very much dependant on the nature of the fire regime.

Plant species are valuable resources for rural people and their suitable management in the farmland as well as in the natural vegetation has become an important issue in rural development programmes. Fire control was identified as one of the important actions to develop; since bush fire can become destructive to plant resources when the fire regime is not controlled (IRBET 1983).

Since the year 2000, a national bush fire management project in Burkina is supporting the rural farmers to better manage bush fire. One of the bottlenecks faced is the lack of sufficient scientific background information on how better to control bush fire effects on useful plant resources.

Young plants can be killed and fruit setting can be inhibited by severe fire. To reduce or control the negative effects of bush fire on plant species we need to identify appropriate fire regimes based on sound information on the effects of seasons on burning, frequency of burning, type of fire, and fire intensity (Trollope & Trollope 2004). This study focuses on gathering the primary information necessary to control the fire regime and its' effects on woody plant species in the Sudan savanna.

Frequent bush fire will reduce the rate of recruitment in tree populations, and most seedlings will not have the chance to grow into big trees although with some species the heat provided by the fire breaks the dormancy of the seeds and favours good germination. Tybirk (1991) and Sabiiti & Wein (1987) reported that Leguminosae seeds had a good germination rate after fire.

Given the fact that bush fires only occur in the dry season, in the Sudan savanna two categories of bush fire are commonly distinguished by referring to the period of the fire event: early fires and late fires. The term early fire refers to fire which occurs at the beginning of the dry season (October-November) while late fire refers to those occurring late in the dry season when most annuals and the perennial grasses are dry. Early fire has minor destructive effects and does not prevent recruitment in the vegetation community of the Sudan savanna. Late fire reducestree density and diversity (Brookman-Amissah et al. 1980, Louppe et al. 1995, Sawadogo et al. 2002). The period and the frequency of bush fire are therefore considered important bush fire variables that affect the severity (Bhima & Bredenkamp 1999, Louppe et al. 1995).

The effect of fire on plants has been an important element in bush fire management. Fires of low to intermediate intensity are capable of producing mortality that is highly selective with regard to plant size and species as demonstrated by Bhima and Bredenkamp (1999) by comparing the regeneration of *Colophospermum mopane* Kirk ex J. Léonard and *Dalbergia melanoxylon* Guill. & Perr. under different fire regimes.

Important criteria that can best describe fire effects on plants are the reactions of the tissues in different organs (leaves, branches, and stem). Wright and Bayley (1982) reported that the vascular cambium can be killed by temperatures above 60^oC for longer than 60 seconds exposure, Archibold et al. (1998) also stated that 60 ^oC is the upper tolerance limit for plant tissue. Apart from killing the plant, bush fire reduces or inhibits fruiting if it occurs during a sensitive phenological phase (e.g. flowering or fruiting).

The objective of the present study is to quantify the major parameters necessary for estimating the fire intensity. These variables are: fuel biomass, fuel moisture content, temperature and temperature residence time. Effect on plant species are evaluated using visual methods.

Method

Study site

The study site is located in the Sudan savanna zone in the national park of Pô, named "Parc National Kaboré Tambi" (11^{o}15'02"N, and 01^{o}08'06"W). The climate is Sudanian with an average rainfall of 1000 mm year^{-1}. Two seasons characterise the climate, a rainy season (May to October) and a dry season (November to April). The seasons are determined by two main winds: the *Harmattan* which blows during the dry season from north to south and the *monsoon* which blows during the rainy season and comes from the Atlantic Ocean. The vegetation is a woodland savanna dominated by combretaceous species such as *Anogeissus leiocarpus, Combretum glutinosum* and *Pteleopsis suberosa,* and legumes such as *Acacia dudgeoni*, and *Detarium microcarpum*. The herbaceous layer is dominated by tall grasses (e.g. *Andropogon gayanus* and *A. pseudapricus*).

Wind speed varies remarkably depending on the period of the year and the time of day. From December to March, from 7a.m. to 3 p.m. wind speed reaches nearly 4 m s^{-1}. Low wind speed occurs late in the afternoon from 4 p.m. until 6 a.m. on the following day (Fig. 5.1c)

Wind speed is often used as an indicator to decide on the appropriate time for starting a bush fire or other type of rural land fire. It is therefore important to have a good knowledge of wind speed variation during the day. When the wind speed exceeds 2 m s^{-1}, bush fire becomes difficult to control no matter the width of any firebreak. For our experiments, the fire was always lit at 6 a.m. as head fire.

Relative humidity and temperature variation of the study area are presented in Fig. 5.1a & Fig. 5.1b.

All information on wind speed, relative humidity and air temperature presented in figure 5.1 were provided by the local meteorological station situated 3 km distance from our experimental site. Botanical nomenclature follows Bosch et al. (2002).

Experimental layout

Two adjacent plots A and B of 50 m x 50 m were delimited with firebreaks of 10 m width and all plants with stem diameter of 2 cm or more at 20 cm above ground (D_{20cm}) were tagged and recorded. From 1 October 2002 regular observations was made by simulating vegetation burning every 2 weeks, to determine when the fuel biomass is catching fire. Plot A was fired 2 December 2002 following an unsuccessful attempt in mid-November. Plot B was fired (in the first week of) 9 February 2003 as a late fire treatment.

All woody species over 2 cm of stem diameter were tagged before burning. In total 296 and 473 individuals, respectively, were tagged in Plot A and Plot B.

The moisture content of the standing grasses and the available litter were estimated for each experiment and so for the fuel load (Table 5.1). Fuel load was assessed by clipping standing grasses from four 1 m x 2 m quadrats spaced at 20 m intervals on two 50 m transects in adjacent stands. An often important component of the fuel load is litter, which was gathered separately from the same 1 m x 2 m quadrats. The harvested material was kept in plastic bags to measure the original weight and dried in an oven at 100 ^{o}C for 96 h to obtain the dry weight and the moisture content.

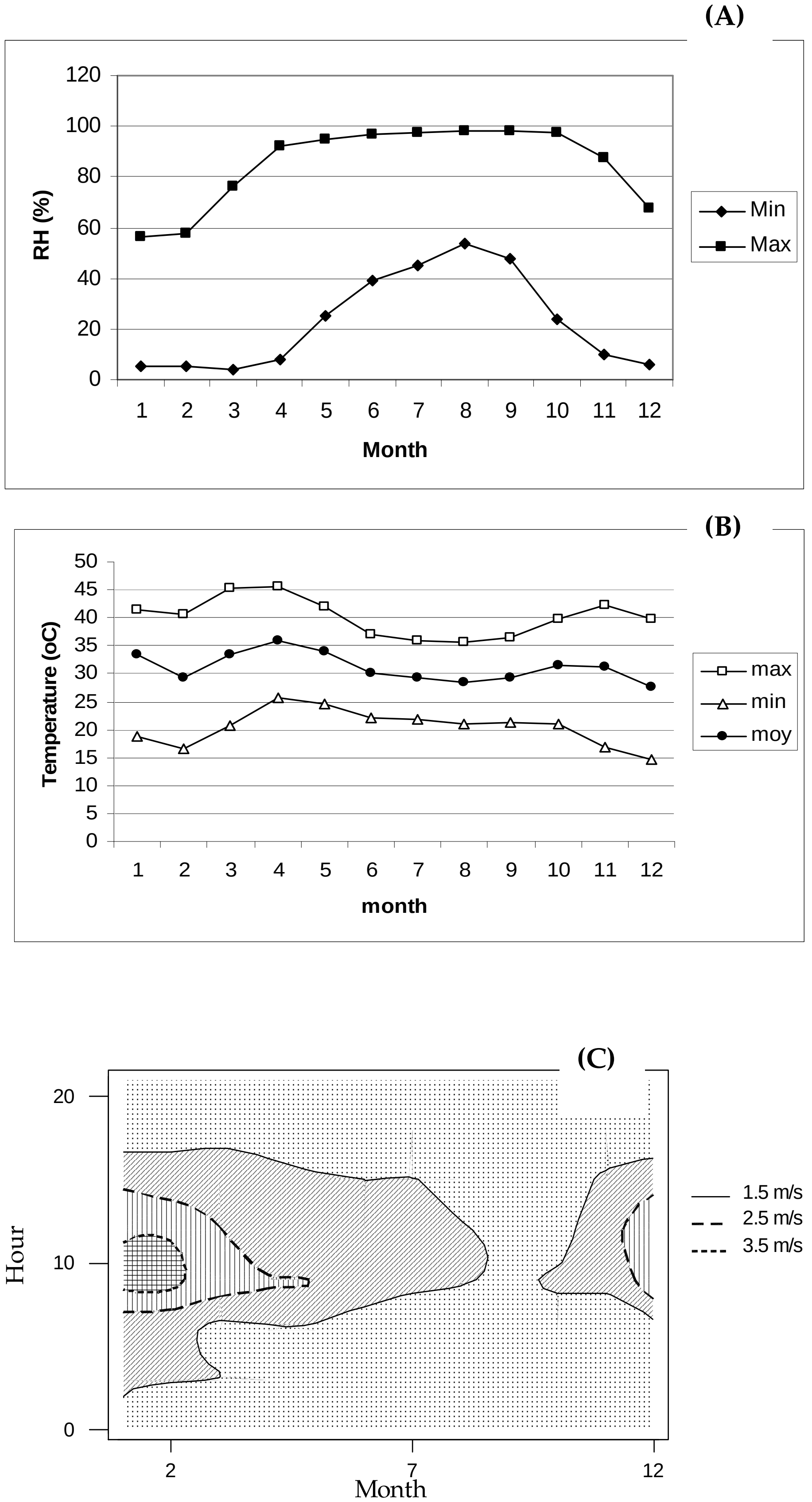


Fig. 5.1. Variation during the year of A: Relative humidity (RH); B: Temperature (°C); C: Wind speed (m s^{-1}) according to the hours of the day.

Fire temperature was measured using N type thermocouples connected to a data logger ("Delta-T Logger Dl2e"). The logger was programmed to record the temperatures every 5 seconds and to store the average of two measurements every 10 seconds. Each thermocouple was made of 50 m wire, allowing representative coverage of the 50 m x 50 m quadrate.

The series of temperature measurements were also used to calculate the temperature residence time above 60°C, the highest temperature plants tissues can tolerate (Archibold et al. 1998)

Twelve thermocouples were placed in the plot during each experiment. Fire temperature was measured at 10 cm below ground, at ground level, and at 20 cm, 1 m, 2 m, 3 m, 4 m and 5 m above the ground. The measurements at ground level and 20 cm above ground used three separate thermocouples.

During late fire (9 February 2003), the effect of fire on the eight dominant species (*Acacia dudgeonii, Annona. senegalensis, Combretum collinum, Combretum glutinosum, Detarium microcarpum, Pteleopsis suberosa, Terminalia avicennioides, Vitellaria paradoxa*) was evaluated using a visual scale of 1 to 5 : **1**= no fire effect on the plant and undergrowth; **2**= fire burnt the undergrowth but no effect observed on the plant; **3**= leaf, fruit or flowers burnt; **4**= branches burnt; **5**= entire stem burnt.

Results

Biomass and moisture content

The fuel biomass yield during the early fire (2 December) 324 g m^{-2} composed of 116 g of litter and 208 g of standing grasses. During late fire (9 February) total fuel biomass was 483 g m^{-2} composed of 274 g of litter and 219 g of standing grasses (Table 5.1). Fuel biomass increases in late fire because trees gradually lose their leaves after the rainy season thus progressively increasing the litter. Moisture content was 29% during the early fire and 10% during the late fire for the standing grasses. In mid-November, the attempt to burn with 48% of moisture content for the standing grasses was not successful.

Table 5.1. Biomass and moisture content of the standing grasses and litter.

Material	No burning : 13 November	Early fire : 02 December		Late fire : 09 February	
	Moisture content	Dried biomass g m^{-2}	Moisture content	Dried biomass g m^{-2}	Moisture content
Litter (tree leaves)	8%	116	7%	274	9%
Standing grasses (Andropogoneae)	48%	208	29%	219	10%
Total fuel		324		483	

Temperature released by the fire and temperature residence time

The temperatures recorded with the data logger showed that the highest temperatures occur at ground level and at 20 cm above ground (respectively 677.1 °C and 641.9 °C).

The highest temperature recorded during the early fire is 333.4 °C with the time of exposure to temperature above 60 °C being 80 seconds (Table 5.2). A positive correlation appears between temperature and temperature residence time above 60 °C (Fig. 5.2).

Temperatures recorded at different heights showed that late fire affected the air temperature at all heights including the highest level of measurement at 5 m where a temperature of 207 °C was recorded. In contrast, the sensor below ground (10 cm) recorded temperatures below those of the control sensor placed inside the data logger (table 5.2).

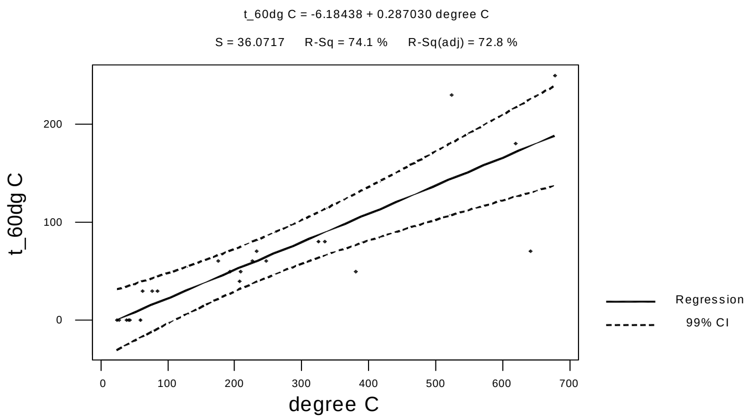


Fig. 5.2: Time above 60°C (s)($t_{60\,°C}$) as a function of the temperature during the experimental fire. (r^2=0.74; P<0.001).

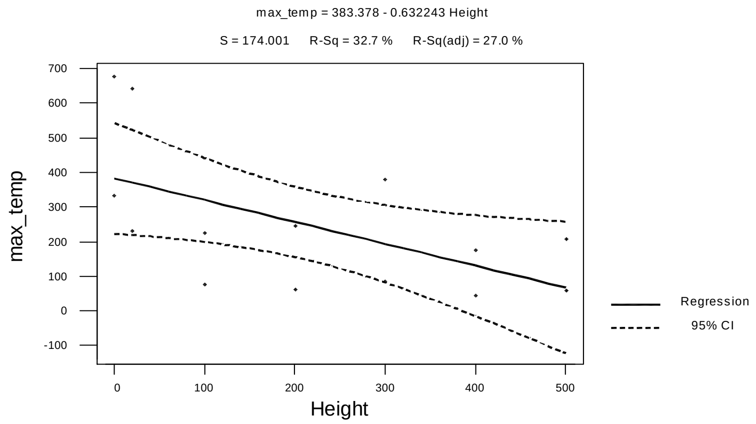
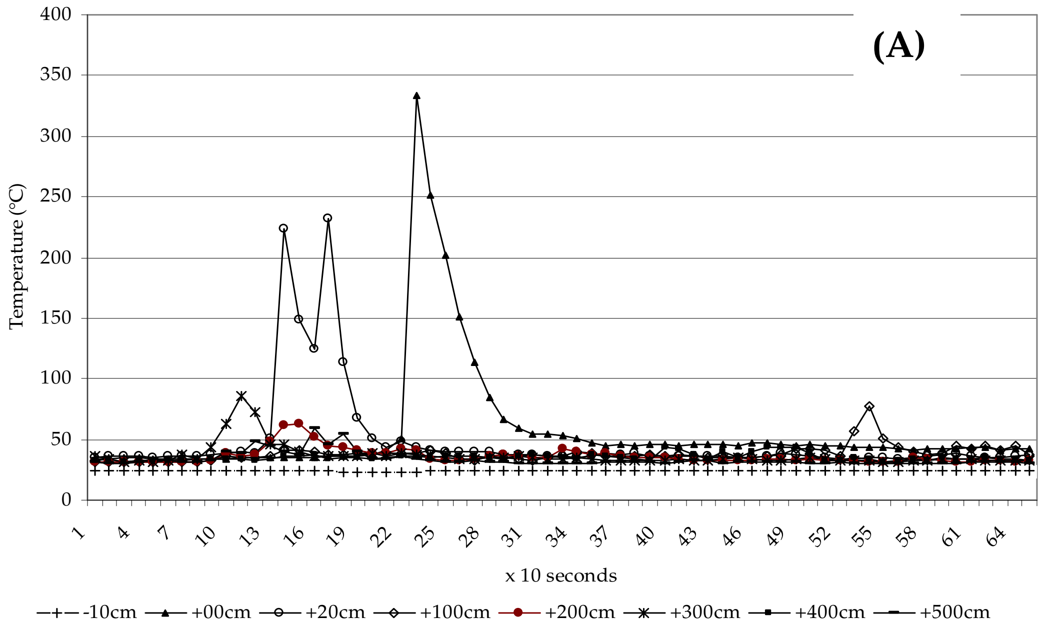


Fig. 5.3: Maximum temperature (°C) as a function of the height (cm) above ground (r^2=0.33; P<0.05).



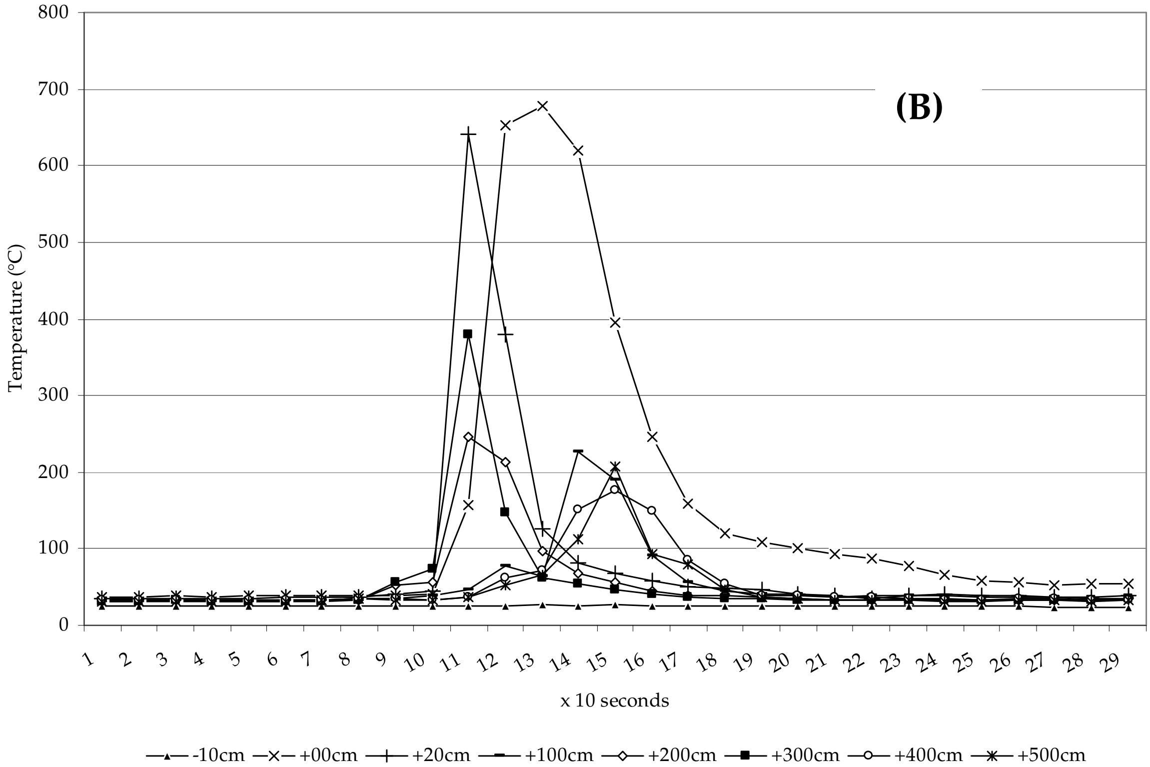


Fig. 5.4. Temperature curves at different heights (cm), in Sudan savanna in south–central Burkina Faso. Early experimental fire in December 2, 2002 (A) and late experimental fire in February 9, 2003 (B).

Table 5.2. Temperatures of early and late fire and times above 60 °C at various heights.

Sensor height	Temperature before fire (°C)		Maximum temperature reached		Temperature residence time above 60°C	
	02/12/02	09/02/03	02/12/02	09/02/03	02/12/02	09/02/03
T_0*	30.68	35.82	-	-	-	-
Tc -10 cm	24.02	25, 55	24.29	26,94	00s	00s
Tc 00 cm	34.25	38,69	333.44	677,10	80s	150s
Tc 20 cm	35.33	34.51	231.68	641.90	70s	70s
Tc 100 cm	31.97	33.13	76.96	226.20	20s	60s
Tc 200 cm	31.71	32.27	62.24	246.16	30s	50s
Tc 300 cm	35.67	31.15	83.92	379.50	30s	50s
Tc 400 cm	32.98	33.35	43.36	175.50	00s	60s
Tc 500 cm	31.19	32.70	58.88	207.44	00s	50s

* T_0 = temperature recorded by the built-in data logger sensor.

The regression analysis shows that temperature residence time is a linear function of the maximum temperature registered (Fig. 5.2). It also shows that maximum temperature registered at a certain point depends on the height of this point above ground (Fig. 5.3)

Temperature curves in early fire and late fire are presented in figure 5.4 A and B respectively. Temperatures at different heights show more or less skewed curves. From these curves it appears clearly that it takes shorter time for the temperature to arise to its maximum than to cool down to the normal.

Bush fire and plant species

Late fire burnt all the grasses and forbs in the area. Despite the fact that the period was favourable for the spread of fire, few observations (less than 1%) show damage of level 5. On the other hand, more than 10% of the plants were affected at level 4. The proportion of plants affected at level 3 was less in late fire than in early, while in contrast this proportion is higher for level 2 with the late fire. The most affected species is *Annona senegalensis* with more than 50% of its population showing burnt branches. Stem mortality was also recorded amongst *Annona senegalensis* plants and *Terminalia avicennioides,* as shown in figure 5.6. It can be noted that stem mortality does not necessarily lead to the killing of the entire tree. In most cases the root system stays alive and produces new shoots later.

Early fire causes minor harmful effects to the woody species. Level 3 effects concerned 50% of the plants. Visually we could estimate that 80% of the standing grass biomass was not burnt due to the high moisture content (29%).

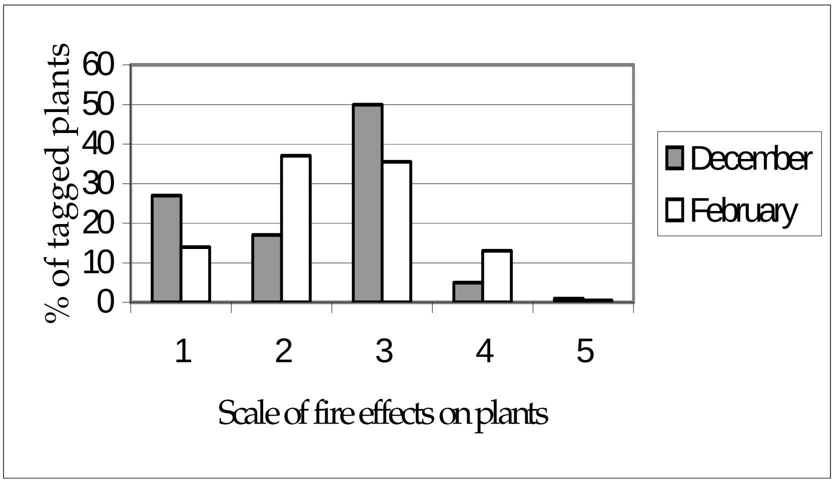


Fig. 5.5. Effect of early (2 December) and late fire (9 February) on woody species estimated on a visual scale of 1 to 5. **1**= no fire effect on the plant and undergrowth; **2**= fire burnt the undergrowth but no effect observed on the plant; **3**= leaf, fruit or flowers burnt; **4**= branches burnt; **5**= entire stem burnt.

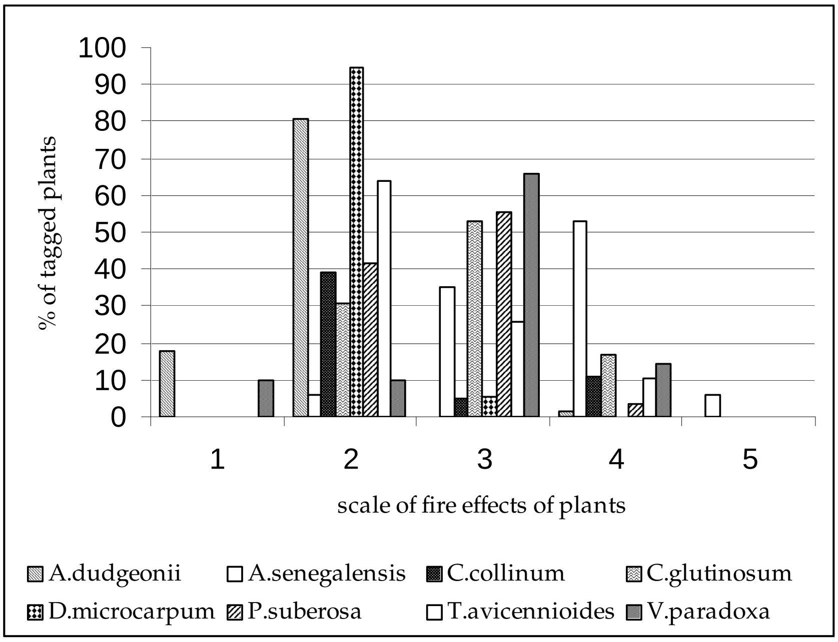


Figure 5.6. Effect of late fire on woody species individuals in a scale of 1 to 5. **1**= no fire effect on the plant and undergrowth; **2**= fire burnt the undergrowth but no effect observed on the plant; **3**= leaf, fruit or flowers burnt; **4**= branches burnt; **5**= entire stem burnt.

Discussion

Bush fire management in the Sudan savanna recognizes that early fire is less damaging to woody species than late fire (Brookman et al. 1980, Swaine et al. 1992, Louppe et al. 1995) but the need to identify key factors that better explain and predict fire impact remains. Models have been developed to predict fire intensity but most involve many variables (biomass, wind speed, relative humidity, and moisture content) which interact with geographic location, the season of the year, the composition of the vegetation (Byram 1959).

The fuel load

The quantities of fuel load found in the study area, 324 g m^{-2} and 383 g m^{-2}, respectively, in December and February appear relatively high; Brookman-Amissah et al. (1980) reported 2.6 t and 1.8 t for Guinea savanna vegetation subjected to late and early fire, respectively. The observed fuel load which is composed of dead standing grasses dominated by *Andropogon gayanus*, and the dead leaf litter increases with time during the dry season. Late fire is therefore supplied with bigger quantity of fuel than early fire. The presence of the dead leaves on the ground is obviously explained by the normal phenological behaviour of the woody plants that drop their leaves after the rainy season to adapt themselves to the long dry season. These dead leaves form a substantial portion of the fuel load in the bush fire: 30-35% in December and 50% in February. It is worth mentioning that the entire grass biomass did not burn with the early fire because of the high moisture content (29%), supporting previous studies in the Guinea savanna (Louppe et al. 1995, Brookman-Amissah et al. 1980).

Bush fire heat released

Maximum temperatures were recorded at the lowest heights: 333°C and 677°C, during the early fire and the late fire respectively. This reinforces the idea that the vertical distribution of the fuel lies more on the soil surface than in the trees crowns as is commonly the case in the savanna. Regression analysis supported this conclusion by showing an inverse relationship between height and temperature (Fig. 5.3).

Maximum temperature is not of major significance in bush fire intensity; temperature residence time plays a more significant role (Pérez & Moreno 1998) although the two variables are correlated as demonstrated in the present study (Fig 5.4).

Bush fire temperature residence time above 60°C and maximum temperature in the Sudan savanna appear to be very much influenced by the period of occurrence. Comparison with other studies is irrelevant in most cases because the timing and the environment conditions is usually not similar. Nevertheless we can note that our records are within the range of previous studies (Archibold et al. 1998, Pitot & Masson 1951, Hopkins 1965, Morgan 1999, Gillon 1970) and very close to the figure given by Monnier (1990) who recorded 700°C and 600°C respectively in *Hyparrhenia/Loudetia* -dominated Guinea savanna vegetation.

Effect of bush fire on plant species

Results on the effect of bush fire on woody plant individuals do not show a clear difference between early fire and late fire despite the higher late fire intensity. During late fire most trees have already dropped their leaves, leaving little fuel in the crowns. This mechanism allows savanna trees to limit fire effects to the lower layers of the vegetation.

During early fire, the high moisture content of the grasses prevented the fire from being severe since not all biomass burns and part of the energy generated is used to release the water contained in the grasses. The temperatures were therefore lower compared to those in the late fire and injuries observed on the plants were visibly of minor effect. Only the proportion of woody plants individuals with burnt leaves was higher (50%) than in late fire because most of plants were without leaves in February (Fig. 5.5)

The results suggest that *Annona senegalensis* is fire sensitive. This is supported by the recorded stem mortality and a high percentage being affected at scale 4 (some branches of the plant were burnt) during late fire (Fig. 5.6). In contrast *Vitellaria* seems very well adapted to the fire climax. After the late fire, 75% of the young plants of stem diameter below 2 cm had survived 26 weeks later (Fig. 5.7).

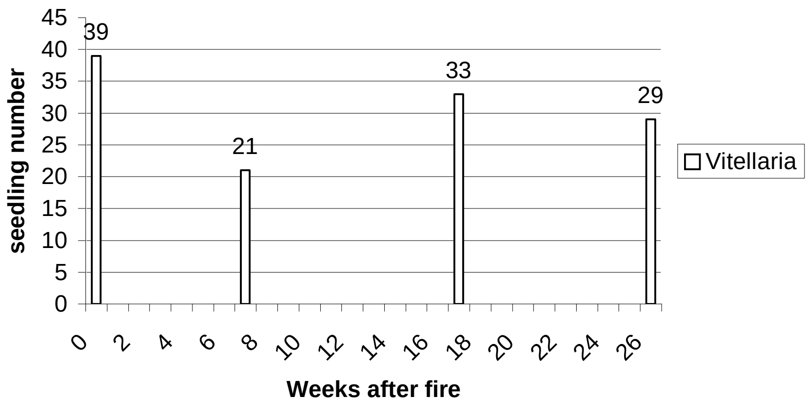


Fig. 5.7. Survival of young plants of *Vitellaria paradoxa* after bush fire.

Many Sudanian woody species flower or fruit during the dry season (de Bie et al. 1998) which coincides with the bush fire period. There are obviously serious risks that bush fire will therefore affect the regeneration of those species through the destruction of the fruits or flowers. Prescribing yearly fire will affect flowering and fruiting of species that bear flowers or fruits at this period. This phenomenon could in the long term inhibit the regeneration of sensitive species, while other species will benefit if the fire breaks seed dormancy (Tybirk 1991).

Plants with stem diameter <2 cm are likely to be affected by savanna bush fire through die back of the young shoots as shown in Fig. 5.7 where *Vitellaria paradoxa* regrowth showed nearly 80% stem mortality. These plants survive by developing new shoots which may be killed again the next fire season. This appears to be the mechanism which suppresses the development of the young shoots into mature trees, keeping most Sudan savanna plants small despite of ability to grow into tall trees (Ben-Shahar 1998, Louppe et al. 1995, Hoffmann 1999).

Conclusion and recommendations

This study contributes to understanding of bush fire effects on the woody plants of the Sudan savanna by showing that woody plants of over 2 cm of stem diameter can be seriously fire-damaged. The fire effect reaches scale point 4 (burnt branches observed) although at a low percentage for most of the dominant species.

Bush fire temperature as well as the temperature residence time over 60 °C is higher at low height (ground level and 20 cm above ground), thus preventing many woody seedlings and young re-growth to grow into tall trees as they would in areas without fire.

The results also show that plant root systems are likely to be safe from bush fire effects. During the early and the late fire, temperature at 10 cm below ground never rose above ambient air temperature. These conditions may be to the advantage of woody species with the capacity to produce root suckers.

Moisture content of the composite grass fuel biomass should be used as a practical tool to identify the appropriate period of the season for early fire. Moisture content values around 30% (for standing grasses) were found suitable as an indication of good conditions for early burning in this study. However, more investigations of different vegetation types and at species level will be needed to come to recommendations that could be generalised with confidence for the Sudan savanna as whole.

Chapter 6

Identifying wild food plants for sustainable agroforestry by market surveys

Sustainable dry land agriculture. Proceeding of International Symposium, 2-5 December 2003. Niamey Niger. ICRISAT-IPALAC-INRAN. In Press.

Chapter 6

Identifying wild food plants for sustainable agroforestry by market surveys

A. Nikiema[1,2,3], D. Pasternak[2], L.J.G. van der Maesen[3].

[1] *Centre National de Semences Forestières, 01 BP 2682 Ouagadougou, Burkina Faso*
[2] *ICRISAT Sahelian Centre, BP12404 Niamey, Niger*
[3] *Plant taxonomy laboratory, General Foulkesweg 37, Wageningen, the Netherlands*
Contact for correspondence: nikalb39@yahoo.com

Abstract

Local people in rural areas rely heavily on wild or semi-domesticated plants for food, medicines, building materials, domestic energy, etc. Market demand of harvested plant products is increasing and could be one of the major incentives that direct natural resources management programs.

A survey was conducted in five urban and nine rural markets in central Burkina Faso, to inventory the wild food plants that have market value. All wild plant products exhibited for sale were recorded twice in the urban markets, first during the dry season (February-March) and then during the rainy season (August). About 500 sellers of wild food plants were visited each time.

A total of 16 local species were identified under 24 different products formulas. During the dry season, 14 local species were recorded and 11 during the rainy season. The frequency of the recorded plant products in the urban markets proves that the related species are economically valued in urban areas.

Our results contribute to better visualize actual socio-economic importance and potential of non-wood forest products in Burkina Faso. It also suggests that the agroforestry parkland systems are well managed to insure sustainable production of the non-wood forest products (NWFPs).

Key words: NWFP, market survey, agroforestry parkland, income generation

Introduction

The majority of the population of Burkina Faso still uses natural resources to meet basic needs. Apart from crop plants, wild plants are intensively used by the populations in the rural areas, as well as in the cities of Burkina Faso, as building material, firewood, medicines, and for their fruits or vegetables and fodder (Kéré 1998, SP/CONAGESE 1999, Belem & Guinko 1997, Guinko and Pasgo 1992, M.E.E 1999). The contribution of harvesting wild plant products to the welfare of local people is significant (Helmfied 1998). Nevertheless, non-wood forest products (NWFPs) often have been overlooked in strategies and programmes for forest conservation and management (Crafter et al. 1997).

In this paper, the expression 'wild plants' is used for non-cultivated plants, although some of the species mentioned such as *Parkia biglobosa* (West-African locust bean, néré) and *Vitellaria paradoxa* (shea-butter tree, karité) are commonly regarded as semi-domesticated species. To avoid confusion in the meaning of the concept of NWFP that will be widely used in this paper we adopted the definition worked out by FAO experts. The agreed definition is: "Non-wood forest products consist of goods of biological origin other than wood, as well as services derived from forests and allied land uses" (FAO 1995).

To properly investigate the importance of natural resources to the local people, one should first understand the criteria by which they value these products. This approach is specially needed for rural landscape management including agricultural parklands where most of the recognized useful species grow. A better understanding of the relationship between local people and natural resources will help in identifying important functions of the individual species, as well as of ecosystems as a whole that management plans should consider. Income generation is an important function of plant resources that is highly appreciated by the inhabitants. As stated by FAO (1995), NWFPs are consumed by people from various social backgrounds, from shifting cultivators and subsistence farmers to urban populations. Parts of the harvested products are, therefore, sold in local or urban markets in different forms: fresh, dry (vegetables) or processed (such as the fermented seeds of *Parkia biglobosa* called *soumbala*). Some of the plant products have a real potential to become commercial items. This importance of NWFPs as commercial products seems to be growing due to poverty of the rural communities and the increasing demand from the cities (Ouédraogo et al. 2003).

Many authors have reported the socio-economic importance of some NWFPs in Burkina Faso (FAO 1995, Guinko & Pasgo 1992, Ouédraogo et al. 2003, Nikiema et al. 1997). Daily consumption of fermented *Parkia biglobosa* seeds was estimated to be 3 g person^{-1} day^{-1} in central Burkina Faso (Ouédraogo 1995). Bonkoungou et al. (2002) stated that *Parkia biglobosa* could generate an annual income of US$ 270 for a household, which is about the price for a total seed yield of 20 trees. The shea butter produced from *Vitellaria* *paradoxa* kernels plays an important socio-economic role in Burkina Faso where it is one of the main export products (FAO 1995, Bonkoungou 2003, Becker & Statz 2003).

The cultural role of the NWFPs and especially of the wild food plants should not be overlooked. Many species are given a central place in traditional ceremonies. During wedding ceremonies, in the Mossi ethnic group from central Burkina Faso, the bride is accompanied to her husband's house with a well-defined set of items that include *soumbala* and dry vegetables. These products in addition to shea butter are also exchanged as women's gifts at special occasions in the region (personal observations).

The wild food plants are specially looked for during the period of food scarcity. During the rainy season, farmers consume the *Vitellaria paradoxa* and *Lannea microcarpa* fruits to complement their daily nutrition. In the meantime, leaves of many other plant species are harvested and cooked as vegetables e.g. *Adansonia digitata*, *Ficus sycomorus, Balanites aegyptiaca, Crateva religiosa, Annona senegalensis, Capparis corymbosa,* and *Maerua angolensis* (Ouédraogo et al. 2003, Belem & Guinko 1997). These wild food plants are a valuable contribution to human nutrition by providing vitamins and minerals to the daily diet. The fermented seed of *Parkia biglobosa* is very rich in protein and essential minerals (Ouédraogo 1995, Hall et al. 1997, Glew et al. 1997) and is therefore considered as a valuable condiment. The yellow, floury pulp in which the seeds are embedded contains a high-energy food with up to 60 % sugar and 291 mg/100 g of dry matter of vitamin C (Booth & Wickens 1988, von Maydell 1983). People of various ages eat the néré pulp as couscous, porridge or dried fruits cakes. *Vitellaria paradoxa* is also utilized for various products. The shea butter is the most common vegetable fat traditionally used for cooking and for many other purposes (e.g., soap making, traditional medicines, etc). Baobab leaves are widely used in the Sahelian regions and are known to be rich in iron (FAO 1995). An excellent beverage rich in vitamin C is made out of its fruit pulp (Bonkoungou et al. 2002). *Ziziphus mauritiana*, which grows in the Sahelian zone, produces tasty and nutritious fruits. The above mentioned species are often sold in markets.

The change in land use intensity and the growing pressure on natural resources suggest that more attention should be paid to the management of those resources (Nikiema et al. 1997). The agroforestry parklands are considered a land use system in which sound management of biodiversity including the improvement of the productivity of wild food plants can be carried out (Boffa 2000). As such, parkland development influences the availability of NWFP. Most of the common wild food plant species are taken care of by farmers through agroforestry practices. Since agroforestry parklands in the semi-arid areas of West Africa are degrading (Boffa 1999, Nikiema 1993, Gijsberg et al. 1994) due to continuous land tilling and reduction of fallow periods, the diversity of wild food plants in the area is consequently declining and some valuable plants are locally disappearing. Rural landscape-management projects that are implemented in most West

African countries can contribute to solving this problem by investigating, and investing in, the management of wild food plants.

Investment in parkland trees will require a set of criteria that give value to each of the potential plant products. One set of criteria that justifies the investment is the market potential of the plant resources. This criterion meets the interest of most of the stakeholders, while the issue of the natural resource's ownership should be properly dealt with.

Market information is useful for estimating the harvesting pressure on natural resources. For example, seeds of *Acacia macrostachya* that are used as a pulse are considered a delicacy in central Burkina Faso where the price of 1 kg of seeds can go up to FCFA 200 in Ouagadougou markets. Due to the growing socio-economic value of this plant, the question of whether its management is considered within the agroforestry parklands system in the region becomes more relevant. It seems that the problems of management of other important commercial species have not been adequately integrated in the actual parkland practices; some of these species are *Saba senegalensis, Annona senegalensis* and *Detarium microcarpum.* (Nikiema et al. 1997, Teklehaimanot 2003).

The objective of this research was to describe the importance of woody food plants through market survey in the context of agroforestry parkland management. We have therefore investigated the following subjects:

. identification of the common marketable non-timber forest products;
. estimation of their availability and price in the dry and rainy seasons;
. market information and present parkland management practices will have to be combined in order to identify future management options that will contribute to both income generation for the rural people and sustainable management of natural plant resources.

Study area

The study took place in both urban and rural (village) markets. The urban markets were in Ouagadougou the capital city of Burkina Faso while the rural markets were in the Zoundweogo province in south-central Burkina. These areas are traditionally occupied by the Mossi ethnic group, which represents about 40 % of the population of the country, but as with all African cities, Ouagadougou has a mixed population migrated from all over the country. Markets where the citizens do their daily shopping for food as well as for other goods are scattered in the city. Local and imported products are sold in these markets. The markets are organized by sections where similar products are grouped, e.g. the vegetable section is separated from the cereal section.

Method

This research consists of a literature study and a market survey.

Literature survey

Considerable work has been done to assess NWFPs that are commonly used by the local population in Burkina Faso and reported by many authors. Gathering this information is a good start for a proper assessment of the socio-economic value of these plant resources. To facilitate data analysis, the plant products are classified into commodity groups following Bosch et al. (2002) and species scientific names follow the same source.

Market survey

The diversity of species being used as food plants was assessed through market surveys. In addition to the central market in Ouagadougou, four other markets were chosen in order to cover as many different market places in the city as possible. Furthermore, 9 rural markets were surveyed in Zoundweogo province. Information reported in the literature is in many cases the result of socio-economic surveys with farmers. Most of these surveys have reported farmer's preferences (Belem 2000; Bonkoungou et al. 2002; Nikiema et al. 1997). However, when much of the NWFPs production is to be sold in the city markets for income generation, then studies should be conducted in these markets. Results of such studies are instrumental for the future sustainable development of agroforestry systems with the view of optimization of income generation from the NWFPs.

Results and Discussions

The literature survey provided a basic list of the edible woody plants common in the central region of Burkina (Table 61). Preliminary inventory was carried out in 1997 in the north-central Burkina (Table 6.2).

Table 6.1. Edible woody species of the Sudanian and Sahelian region and their food products

No	Species	Fruit	Vegetables and pulses	Vegetable oil	Spice and condiments
1	*Acacia macrostachya*		x		
2	*Adansonia digitata*	x	x		x
3	*Afzelia africana*		x		
4	*Annona senegalensis*		x		
5	*Balanites aegyptiaca*	x	x	x	
6	*Bombax costatum*		x		
7	*Borassus aethiopum*	x			
8	*Boscia senegalensis*	x	x		
9	*Capparis corymbosa*		x		
10	*Celtis integrifolia*		x		
11	*Crateva religiosa*		x		
12	*Detarium microcarpum*	x			
13	*Dialium guineense*	x			
14	*Diospyros mespiliformis*	x			
15	*Ficus sycomorus*	x	x		
16	*Gardenia erubescens*	x			
17	*Hyphaene thebaica*	x			
18	*Lannea microcarpa*	x			
19	*Leptadenia hastata*		x		
20	*Maerua crassifolia*		x		
21	*Parkia biglobosa*	x			x
22	*Piliostigma reticulata*		x		
23	*Piliostigma thonningii*		x		
24	*Saba senegalensis*	x			
25	*Sclerocarya birrea*	x			
26	*Strychnos spinosa*	x			
27	*Tamarindus indica*	x			x
28	*Vitellaria paradoxa*	x		x	
29	*Vitex doniana*	x			
30	*Ziziphus mauritiana*	x		x	

Sources: Aubreville (1950); Belem & Guinko (1997); Bosch et al. (2002); Von Maydell (1983); Guinko & Pasgo (1992); Belem (2000); Ouédraogo et al. (2003); Kristensan & Lykke (2003).

Many studies have ranked important species as perceived by farmers themselves in different places (Bonkoungou et al. 2002; Nikiema et al. 1997; Belem 2000). Table 6.2 gives an overview of the 16 most important species and their ranking. The most common criteria that appears important for farmers in ranking the species is nutritional value.

Table 6.2. List of 16 of the most common food plant species ranked by decreasing importance in farmers'perception through local surveys in Burkina Faso.

Authors	Bonkoungou et al. (2002)	Nikiema et al. (1997)	Ouédraogo et al. (2003)	Ouédraogo et al. (2003)	Overall Ranking [Average ranking]
Regions Rank	Central Burkina	Sanmatenga province	North Burkina	Mouhoun region	All regions
1	*V. paradoxa*	*V. paradoxa*	*V. paradoxa*	*V. paradoxa*	*V. paradoxa [1]* ☺
2	*P. biglobosa*	*A. digitata*	*T. indica*	*P. biglobosa*	*P. biglobosa [3.2]* ☺
3	*L. microcarpa*	*T. indica*	*P. biglobosa*	*A. digitata*	*A. digitata [3.5]* ☺
4	*T. indica*	*B. costatum*	*A. digitata*	*S. senegalensis*	*T. indica [3.8]* ☺
5	*A. digitata*	*L. microcarpa*	*S. senegalensis*	*D. microcarpum*	*L. microcarpa [5.2]* ☺
6	*B. costatum*	*P. biglobosa*	*L. microcarpa*	*T. indica*	*B. costatum [6]**
7	*B. aegyptiaca*	*Z. mauritiana*	*Z. mauritiana*	*L. microcarpa*	*Z. mauritiana [7.3]**
8	*Z. mauritiana*	*B. aegyptiaca*	*B. costatum*	*S. birrea*	*D. microcarpum [7.5]#*
9	*D. mespiliformis*	*A. macrostachya*	*A. macrostachya*	*B. aegyptiaca*	*B. aegyptiaca [8.5]* ☺
10	*D. microcarpum*	*D. mespiliformis*	*B. aegyptiaca*		*S. senegalensis [8.5]* ☺
11	*S. birrea*	*A. senegal*	*S. birrea*		*A. macrostachya [10.3]**
12	*S. senegalensis*	*X. americana*	*D. mespiliformis*		*S. birrea [10]**
13	*A. macrostachya*	*S. senegalensis*	*X. americana*		*F. sycomorus* ♣
14	*F. sycomorus*	*V. doniana*	*B. senegalensis*		*V. doniana* ♣
15		*S. spinosa*			*S. spinosa* ♣
16		*B. senegalensis*			*B. senegalenlis* ♣

☺ Present in four rankings; * Present in three rankings; # Present in two rankings; ♣ Present in one ranking.

The ranking shows the same tendency of the perceived species importance. *Vitellaria paradoxa* usually comes first, generally followed by *Parkia biglobosa, Adansonia digitata, Tamarindus indica, Lannea microcarpa* and *Saba senegalensis*. The presence and the rank of a species depend on the geographic area and the ethnic group concerned. Ouédraogo (1995) reported that the fermented seeds of *Parkia biglobosa* are the most important and the most widely used NWFP in Burkina Faso. This study confirms that *Parkia* seeds rank among the four most important products found in the markets.

Diversity of wild food plants in markets

It appears that the markets' areas are divided into sections according to products exhibited, so if one needs a product the first thing to do is to search for the area in the market designated to it. In each market, all sellers present in the condiments and vegetable sections of the market were surveyed. The number of surveyed sellers varied from 75 to 126 in the city markets and 4 to 23 in the rural markets (Tables 6.3 and 6.4).

Table 6.3. Number of sellers surveyed in the five markets of Ouagadougou in both seasons.

Ouagadougou Markets	Dry season			Rainy season		
	Female	Male	Total	Female	Male	Total
Dagnoe-yar	84	42	126	109	11	120
Dasasgho-yar	60	35	95	94	20	114
Katre-yar	49	26	75	76	14	90
Rodwoko (central market)	76	13		83	4	87
Toessin-yar	51	25	76	92	19	111
Total	320	141	461	454	68	522

Table 6.4. Number of sellers surveyed in rural markets of Zoundweogo province during the rainy season.

Village markets	Total surveyed	Number of men	Number of women
Béré	23	1	22
Bindé	23	2	21
Guiba	18	0	18
Kaibo	14	0	14
Kalinga	5	0	5
Nobéré	8	2	6
Sakuiliga	13	0	13
Yakin	4	0	4
Yimasgho	14	1	13
Total	122	6	116
%	100	5	95

As presented in Table 6.5, in total 16 woody species products were recorded in the five urban markets. These species cover commodities such as fruits, vegetables, pulses and vegetable oil. Not all species were present in the markets during each of the two recording periods. Table 6.5 shows that 14 species were recorded during the dry season, 11 species were recorded during the rainy season and 9 species were present during both dry and rainy seasons. In all 24 NWFPs were recorded and some of the species provide up to 3 different products from various parts (leaves, fruits, seeds or flowers). Table 6.5 also shows the relative frequency of the species in the markets giving evidence that species such as *Acacia macrostachya, Adansonia digitata, Bombax costatum, Parkia biglobosa, Saba senegalensis, Tamarindus indica* and *Vitellaria paradoxa* are common commercialized species in Ouagadougou markets.

Looking at the social implications of NWFP commercialization, Tables 6.3 and 6.4 show that women dominate the sales activities. They represent 69 % of the sellers during the dry season and 88 % during the rainy season in the urban markets. In the rural markets women represent 95 % of the sellers during the rainy season.

Table 6.5. Total count of selling points of NWFPs in the markets during the dry and the rainy seasons; in decreasing order of importance.

Species	Dry Season	%	Rainy Season	%	Total selling points	Number of products	Number of plant parts
Tamarindus indica	151	25.5	111	19.0	262	2	2
Adansonia digitata	94	15.9	84	14.4	178	3	2
Bombax costatum	96	16.2	62	10.6	158	1	1
Parkia biglobosa	102	17.3	51	8.8	153	3	1
Vitellaria paradoxa	0	0	103	17.7	103	2	1
Acacia macrostachya	59	10	40	6.9	99	1	1
Saba senegalensis	0	0	71	12.2	71	1	1
Gardenia erubescens	2	0.2	29	5.0	31	1	1
Detarium microcarpum	27	4.6	0	0	27	1	1
Sclerocarya birrea	4	0.7	23	3.9	27	1	1
Ziziphus mauritiana	17	2.9	4	0.7	21	2	1
Balanites aegyptiaca	18	3.0	0	0	18	2	3
Borassus aethiopum	8	1.3	0	0	8	1	1
Dialium guineense	8	1.3	4	0.7	8	1	1
Hyphaene thebaica	3	0.5	0	0	3	1	1
Vitex doniana	2	0.3	0	0	2	1	1
Total		100		100		24	

Most of the species also supply products other than food for example firewood, timber, medicines, forage, and soap, but these latter categories have not been addressed in the present study.

The survey in the 5 urban markets revealed the commercialization of 16 wild plant products for human nutrition. These products include fruits, leafy vegetables, vegetable oil, spices and condiment and pulses (Table 6.7). The survey in the rural markets shows nine products from four different species (Table 6.6).

Table 6.6. Number of NWFPs sellers surveyed in nine rural markets of Zoundweogo province during rainy season.

Rural markets	*Vitellaria paradoxa*	*Parkia biglobosa*	*Tamarindus indica*	*Adansonia digitata*
Béré	12	8	2	1
Bindé	10	10	3	-
Guiba	11	6	1	-
Kaibo	9	3	2	-
Kalinga	4	1	-	-
Nobéré	3	2	2	1
Sakuiliga	6	6	1	-
Yakin	2	2	-	-
Yimasgho	10	4	-	-
Total	67	42	11	2
Products (see table 6.8)	3	3	2	1

Table 6.7. Plant uses recorded in Ouagadougou urban markets

Species	Fruits	Vegetables & Pulses	Veget. oil	Spices and condiments
Acacia macrostachya		x		
Adansonia digitata	x	x		x
Balanites aegyptiaca	x	x	x	
Bombax costatum		x		
Borassus aethiopum	x	x		
Detarium microcarpum	x			
Dialium guineense	x			
Gardenia erubescens	x			
Hyphaene thebaica	x			
Parkia biglobosa	x			x
Saba senegalensis	x			
Sclerocarya birrea	x		x	
Tamarindus indica	x			x
Vitellaria paradoxa	x		x	
Vitex doniana	x			
Ziziphus mauritiana	x		x	
Total	14	5	4	3

The NWFPs are sold in the markets using different measurement tools or methods as given in Table 6.8. The most simple to understand is when the measurement unit is equivalent to one unit of the product (e.g. one baobab fruit). The most common units recorded in the markets are *Laga*, which is about a volume of 2 litres and *Tas* (the French word for 'heap') whose size can vary according to products and prices. One other measurement unit that was recorded is the *Boule*, a rounded portion of the product. The latter unit is used for products that need to be dried (i.e. the fermented seeds of *Parkia biglobosa,* and pulp of tamarind fruits).

The variation in selling units allows sale of most of the products in a wide range of prices starting with unit prices as low as FCFA 10 (US$ 0.02) as given in Table 6.8. The use of bags was also observed in some cases.

Table 6.8. Urban market prices of plant products in Ouagadougou in FCFA (FCFA 655 = € 1, FCFA 500 = $ 1).

Species	Product	Measurement Units			
		Laga (2 litre can)	*Tas* (heap)	*Boule* (rounded products)	One fruit
Acacia macrostachya	Pulse	600-800	25-50		
Adansonia digitata	Fruit		100		50
Adansonia digitata	Vegetable	100	25-50		
Balanites aegyptiaca	Vegetable	100	25-50		
Bombax costatum	Vegetable	600	25-50		
Borassus aethiopum	Fruit				
Detarium microcarpum	Fruit	100	25-50		
Dialium guineense	Fruit	500	50-200		
Gardenia erubescens			25-50		
Hyphaene thebaica		100	50		25
Parkia biglobosa	Seed	500-800			
Parkia biglobosa	Pulp	50-100	25		
Parkia biglobosa	Fermented seeds		100-500	25-100	
Saba senegalensis			25-50		10-25
Sclerocarya birrea					
Tamarindus indica	Dried leaves	100-200	50		
Tamarindus indica	Fruit	500-750			
Vitellaria paradoxa	Fruit		25-100		
Vitellaria paradoxa	Butter	500		25	
Vitex doniana	Fruit		50		
Ziziphus mauritiana	Fruit				

Food plants and their occurrence in the agroforestry parklands

Most of the recorded commercialized food plants are present in parklands species lists (Nikiema et al. 2003, Boffa 1999). Species such as *Parkia biglobosa* and *Vitellaria paradoxa* are called semi-domesticated, because they have been managed in farmers' crop fields for centuries, as suggested by the physiognomy of the agroforestry parklands (Lovett & Haq 2000, Hall et al. 1997, Ouédraogo 1995). They are also highly valued because of the variety of products they offer and the income one can make from them.

Although the study shows that most of the commercial species are present in the agroforestry parklands, some were not necessarily from the same ecological area. Inter-regional and trans-boundary trade also covers many plant products such as *Dialium guineense* fruits, which are harvested from south Sudanian and Guinea savanna vegetation zones and sold in the more arid zones. The species present in the parklands can be considered as secured by farmers, in terms of conservation, since they are semi-domesticated. The following species are integrated in the parkland management systems: *Vitellaria paradoxa, Parkia biglobosa*, *Adansonia digitata* and *Balanites aegyptiaca*.

Market value of species and implications for agroforestry parklands management

The occurrence of species products in the markets and the commercial value attached to them indicate that the potential for promoting the wild food plants in the central area of Burkina Faso is significant (Table 6.8). Many wild food plant products are present in the urban markets throughout the year (such as the fermented seeds of *Parkia biglobosa (soumbala)*, shea butter, tamarind, *Dialium guineense*, baobab leaves etc). Other products are seasonal. The seasonality of some products is overcome through processing or drying.

The contribution of wild food plants to generate income for poor rural populations, and especially rural women, can be relatively important. Ouédraogo (1995) estimated the daily consumption of *soumbala* per person in Burkina to be 3 g. The estimated annual consumption of *soumbala* would then be 12,000 t in Burkina. Considering an average price of FCFA 400 kg^{-1} (US$ 0.75) (Hall et al. 1997; this paper), the *soumbala* business represents annual revenue of about FCFA 5 billion (about US$ 8.3 millions) in Burkina Faso alone. These calculations do not consider external trading with neighbouring countries (Ivory Coast, Niger etc.) where Burkinabé communities are settled. Furthermore simple demonstration at farm level shows that, after 10 years, 10 planted *Parkia biglobosa* trees will produce about 25 kg of seeds each, hence 250 kg in total. This production will bring a farmer about US$ 80 to US$ 100 every year adding to the annual income from his crop field. These estimates are supported by specific studies. For example Bonkoungou et al. (2002) stated that *Parkia biglobosa* products contribute the most to the household annual income, by generating up to US$ 267 for a household in the rural areas of Sindou in SW Burkina Faso. A study done by Lamien and Vognan (2001) revealed that Néré and Karité contribute 16% to 27% (equivalent of US$ 35 – 37) of the annual income of rural women in Burkina Faso. Annual production of Karité kernels in Burkina Faso was estimated to be about 60 000 – 85 000 t (Becker and Statz 2003, Kaboré 2004) of which 30 000 t were officially exported in 2003 as kernels and 1500 t as shea butter (Koné 2004, Kaboré 2004). The annual income generated from *Vitellaria paradoxa* is estimated to be US$ 7.6 millions in Burkina Faso (Bonkoungou 2003). A regional karité exchange market annually organised in Burkina revealed that the supply does not meet demand (Kaboré 2004), showing that farmers have good reasons to invest in the tree.

Based on the yield and income that wild food plants can bring to farmers, their household economy can be improved by integrating, in a more organized manner, the use of the major wild food plants (e.g. *Parkia biglobosa, Adansonia digitata, Vitellaria paradoxa, Tamarindus indica, Saba senegalensis,* etc.) as a source of income.

The figures given represent strong arguments for promoting the system of market-oriented agroforestry parklands through national rural development policies

Conclusion

Surveying the urban markets provides reliable information on the value and importance of local species. Frequency and prices of products in the markets should be used as key criteria to identify candidate species for a market-oriented agroforestry system. Appropriate technologies of processing and packaging are needed to improve the transport and storage efficiency of some products, especially the seasonal ones.

Agroforestry parkland management in the future should give priority to proven income-generating species, while domestication programs should accompany the promotion of those species.

The contribution of wild food plants to the rural household, regional and national level economy is not minor and should not be neglected. As demonstrated some of the valuable species can represent up to US $ 8.3 million a year for producers and traders. Gathering more information on the potential external markets and improving the quality of the products can further expand exports. Export markets are still to be further explored for products such as shea butter, for which interest in Europe (Becker & Statz 2003) and America is growing.

We feel that a growing market value of woody parkland species products is the best incentive for species conservation and better agroforestry parkland management.

Chapter 7

General Conclusions: Future perspectives of parkland species diversity in semi-arid West Africa

Fig. Fire experiment plots in the National park of Pô.

Introduction

The Agroforestry parklands is one of the most ancient and sustainable land use systems that has prevailed in the semi-arid regions of West Africa for thousands of years (Boffa 2000). It also witnesses of the long tradition of knowledge, sustainable management and uses of plant resources in this region. Although local communities have managed species for generations, their practices in the last decades are influenced by changes in land uses and conservation policy, through intensification of agricultural practices (Dhillon & Gustad 2004).

As concluded in chapter 2, it is now observed that agroforestry parklands have been degraded in terms of tree density and diversity richness because of insufficient regeneration due to a reduced fallow period (Boffa 2000, Kelly et al. 2004). The main direct factors of parkland degradation are soil tilling, overgrazing, uncontrolled bush fire and over-harvesting.

By focusing on the effects of the main anthropogenic factors on parkland diversity, this thesis is the first to provide comprehensive information on species composition of the parklands in the semi-arid region in Burkina Faso and to estimate effect of agriculture on their conservation.

Species composition in the parklands, the main factors

Agricultural land sustainability has been widely studied from soil conservation perspective, using criteria such as nutrient balance and vegetation cover to evaluate degradation in the semi-arid regions. It is a rather new approach, to include species diversity among the criteria that should be used to assess agricultural land use sustainability. Examples of pioneer contributions on this issue are from Kindt et al. (2004), Eilu et al. (2003) and Schreckenberg (1999).

Understanding the factors that govern species composition in the parkland is the key to biodiversity conservation in the system. The surveys conducted in two different eco-zones of Burkina provided information on the occurrence of species as well as their population structure in the parklands and show common features for parklands in the two different ecological zones (Sudan and south Sahel Zones). Dominant parkland species in both eco-zones was *Vitellaria paradoxa*, which represents more than 20% of the total number of trees in the areas. Other common species are *Adansonia digitata*, *Lannea microcarpa*, *Sterculia setigera*, *Bombax costatum*, *Diospyros mespiliformis*, *Acacia seyal*, *Parkia biglobosa*, and *Pterocarpus erinaceus.* Common characteristic of these species is their highly valued usefulness by the rural farmers (Kristensen et al. 2003, Bongoungou et al. 2002, Chapters 2 and 6).

Biodiversity conservation within the agroforestry parkland system

Conserving biodiversity in areas where people live is a major challenge, especially in the semi-arid tropics with its growing population pressure on natural resources (McNeely 2004).

It has been proven that indigenous people still living in the traditional manner have managed natural resources with sustainability by respecting to some extent the rules of the ecosystems. The agroforestry parkland system is one of the examples in the semi-arid tropics of Africa where natural resources have been quite well managed under traditional land use practices. The combined production of annual crops, livestock, and various Non Wood Forest Products (NWFP) was a challenge that people defeated during many centuries in these areas. But it will be a mistake to believe without verifying that local management of parklands is still sustainable since local peoples' behaviour and environment are not static.

Parklands of the Zoundweogo province, in the Sudan savanna, show evidence of decline with reduced species richness and ageing tree populations which lack regeneration. Such cases where reported, although in a limited number of studies (Kelly et al. 2004, Schreckenberg 1999, Boffa 1999, Gijsbers et al. 1994, Nikiema 1993).

One of the factors that could better explain the degradation of the parkland resources is the reduction of fallow length from more than 10 years to less than 5 years today. This change in the agricultural practice is due to the increased population pressure on arable land and takes place in many regions.

Case studies have, however, highlighted situations where population growth and agricultural intensification did not lead to degradation of natural resources (Leach & Mearns 1996, Harris 1997). But most of them could be misleading because the most common criteria used were only soil quality and vegetation cover.

Along with the degradation of the agroforestry parklands, farmers are loosing valuable plants genetic resources resulted from hundreds years of selections, targeted local people's needs. In many areas parkland species such as *Vitellaria paradoxa, Parkia biglobosa,* and *Adansonia digitata*, have been subject to recurrent selections through generations (Lovett & Haq 2000, Maranz & Wiesman 2003, Kelly et al. 2004). Conservation actions should not only target species but also the valuable intra-specific genetic resources of species subjected to long time selection by local people.

The agroforestry parklands as a crop diversification strategy

The agroforestry parkland system in which many useful woody species grows together with the annual crops is the result of farmers' strategy to keep the advantage of gathering from the wild plants resources while producing their cereals. Thus vegetables, condiments, fruits, fodder, fire wood, medicines etc. (Chapter 6) are produced within the parklands.

All these common goods used to be gathered from the natural ecosystems and some of them still are. While shifting from gathering to agriculture through out the centuries, the local farmers have converted the natural vegetation into agricultural lands, but have kept some of the valued functions of trees in their fields.

The combination of different trees and cereal crops within the same land participates to crop diversification strategy in order to reduce risks in agricultural production and complement peoples' daily diet.

The limits of this productions strategy is its low productivity since it is difficult to combine high productivity and sustainability (Ewel et al. 1991). Furthermore risk reduction which used to be the main motivation in subsistence farmers practices (Main 1999, Lefroy et al. 1999) is no longer a valid strategy for the commercial maize or cotton farmers who target high income. It is therefore feared that loss of biodiversity in the agricultural areas will extend in pace with time, if technical solutions and appropriate policy are not put in place.

The hidden economy of parkland NWFPs products

Products from parkland species are present in local and urban markets and some of them are exported to neighbouring countries or to the international market (Chapter 6). The shea butter from *Vitellaria paradoxa* and the gum Arabic from *Acacia senegal* are good examples of products which are desirable in the international market. Other species of which the most important include *Adansonia digitata, Borassus aethiopum, Ficus sycomorus, Parkia biglobosa, Tamarindus indica, Bombax costatum, Detarium microcarpum, Saba senegalensis, Ziziphus mauritiana* were found commonly present in urban markets. Many studies based on farmers' appreciation confirm the local importance of the marketed species (Kristensen & Lykke 2003, Keré 1998, Hahn-Hadjali & Thombiano 2001, Lekke et al. 2001, Bonkoungou et al. 2002)

Although the economic figures of the semi-arid West African countries include several export crops, the contribution of non wood forest products (NWFPs) to the Gross Domestic Product (GDP) is not known in these countries, and therefore remains hidden in their economy. This situation could explain why little effort has been developed so far by the governments to promote NWFPs and ensure their sustainable management. This attitude is misguiding in the evaluation of the rural level economy, since the production from valuable trees should be considered in the economic estimates as it is the case for annual crops and livestock. Proper management of parklands will also depend on the recognition at national level, of the role and importance of NWFPs.

An integrated approach for parkland diversity management

The management practices of farmers towards parklands have been guided by the value they give to various products. Thus common parkland species are those that provide products of essential use in the local communities e.g. *Vitellaria paradoxa* and *Parkia biglobosa* in the Sudanian zone of West Africa.

Biodversity conservation is therefore strongly linked with the use of the resources, by the local people. Many parkland products are progressively commercialised in local, urban and international markets. It therefore suggested that parklands' resources management adopts a multi-dimensional approach that integrates factors such as market demand, local domestic uses, threat of anthropogenic origin such as grazing and bush fire (Chapters 4 and 5), and of ecological origin (Chapter 3). Anthropological threats could be turned into management opportunities. For example overgrazed species could be planted in parklands for forage production as suggested in Chapter 4. A multidisciplinary approach to identify management actions in the parklands, based on species information is proposed in Table 7.1.

Table 7.1. Synthesis of information on some useful species: presence, uses and needs of management actions in the agroforestry parkland of the Central Plateau of Burkina Faso.

Species	Market value	Presence in parklands		Present in Natural Forest		Sensivity to threats		Proposed actions in the parklands	
		Sah	Sud	Sah	Sud	Park-land	Forest	Sah	Sud
Acacia macrostachya	M	M	L	M	-	H	L	▲♦♣	♦
Adansonia digitata	H	M	L	M	L	H	M	♦ ♣	♦♣
Annona senegalensis	L	_	L	_	L	H	H	▲	♣
Balanites aegyptiaca	L	M	L	L	L	M	L	▲♣	♣
Bombax costatum	H	L	M	L	L	H	M	♦♣	♦♣
Borassus aethiopum	H	-	L	_	L	H	M		♦♣
Detarium microcarpum	L	-	L	-	M	H	L		▲♣
Diospyros mespiliformis	L	L	M	-	L	M	L	♦	♦♣
Ficus sycomorus	L	L	-	-	L	H	H	♦♣	♦♣
Gardenia erubescens	L	-	L	-	L	H	L		♣
Parkia biglobosa	H	L	M	-	L	H	M	♦♣	♦♣
Pterocarpus erinaceus	L	L	L	L	M	H	H	♦♣	♦♣
Saba senegalensis	H	-	L	-	M	H	L	♦♣	♦♣
Sclerocarya birrea	L	M	L	L	L	M	H	♦♣	♦♣
Tamarindus indica	H	L	M	-	L	H	L	♦♣	♦♣
Vitellaria paradoxa	H	H	H	-	H	L	L	♦	▲♣
Vitex doniana	L	-	-	-	L	H	L		♦
Ziziphus mauritiana	M	L	L	L	L	M	M	▲	▲

H= high; M= medium; L= low; -= not mentioned; ▲= Farmer's induced natural regeneration ♦= Plantating and/or direct seeding ♣= Tree management.

The future of parklands *is in the market*

Investment is motivated by the profit expected from it, this behaviour of common sense is followed by local governments in the semi-arid West African region where the profit from NWFP is not quantified, therefore depriving this production sector from appropriate investment and policy. The assessment and the evaluation of economic importance of NWFP should therefore be an important component of the rural development programs or projects.

Furthermore, the agricultural production is gradually changing from subsistence farming to more intensive agriculture, which will direct the farmers to income-generating crops and trees. Hence the future of the parklands will certainly depend on market opportunities for NWFPs. Species that can generate high income will be more and more planted, provided that farmers are sufficiently remunerated. Plantations of *Parkia biglobosa, Adansonia digitata,* and *Acacia senegal* by farmers can already be observed in many areas of West Africa. Most of the parkland species will need to be regenerated through plantations since natural regeneration is poor or inexistent (Chapter 2).

The concept of the agroforestry parkland systems should be further reflected in the rural landscape management policies in the semi-arid countries of West Africa. Not only should its production be considered in the production figures of rural farming, but also by estimating its biodiversity in qualitative and quantitative sense.

Livestock grazing on fallow land at Kalenga village Burkina Faso

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Acknowledgements

I would like to express my gratitude to all the team members at Centre National de Semences Forstières (CNSF) that gave me full support during my field work, the EU INCO program who funded the field work, the Netherlands Foundation for Science Research NWO that supported financially the finalization of the work in Wageningen, the National Project on bush fire management in Burkina Faso that contributed financially to the field work, the ICRISAT Sahelian Center and IPALAC for funding my visiting scientist fellowship in Niamey and the PETREA project funded by DANIDA for the fruitful collaboration.

My special thanks and gratitude are directed to my promotor Prof. Dr. Ir. L.J.G. van der Maesen and co-promotor Dr. John B. Hall who have guided this thesis and whose useful comments and fruitful suggestions improved the manuscript considerably. I appreciate the efforts of Prof. van der Maesen, who dealt with all administrative matters related to the thesis, my stay in the Netherlands and I am glad of his supportive kindness. My sincere gratitude goes to Dr. P. Ketner for his rigorous and continuous support; his comments and suggestions for the thesis manuscripts are appreciated very much.

I am also grateful to Dr. Zewge Teklehaimanot, the EU parkland project coordinator, for his technical and scientific support in drafting and facilitating the research, and the purchasing and calibrating the scientific equipment used in the field. Prof. Dov Pasternak, Dr. Hansen Hanne, Dr. Fred de Boer, Dr. Claudius van de Vijver and Dr. Ard Lengkeek have made very useful comments on statistics and gave various suggestions which have helped to improve the manuscripts; I would like to address my gratitude to them for their support.

I cannot forget the continuous support from the responsibles and colleagues at CNSF, especially Dr. Lambert Ouédraogo and Ouédraogo Moussa, the successive directors of the National Forest Seed Centre of Burkina Faso.

The field work could not have been undertaken without full collaboration of the farmers and foresters in the various study sites, the devoted technician Baco Grégoire, and the drivers Zida Moumouni and the late Kabore Boniface. I remain very grateful for their services.

I am most grateful to the Biosystematics group, especially the scientists and technical staff who gave me full support during my stay in Wageningen. Many friends contributed to make my stay in the Netherlands pleasant and successful; I would like to specially thank Anne, Edu, Marc, Viviane and Emile who supported me in various aspects and often shared their family warmth with me.

I remain grateful to the late Dr. Ouédraogo Abdou Salam, former regional director of IPGRI Sub-Saharian Africa, who has been a source of inspiration in my professional life, for his advice at the beginning of this thesis.

I could not have completed this thesis without the full support of my wife Blandine and children Brice, Sylviane, Nadège and José to whom I dedicate this work. I apologize for my frequent and sometimes lengthy absence from home.

Curriculum vitae

Albert Nikiema was born on 19th October 1959 in Ouagadougou, Burkina Faso.
He went to school in the capital, as well as to the University, where he obtained his Baccalauréat D in 1981, and his diploma of Ingenieur in Rural Development, options Water and Forests. In 1991-1993 he studied at Wageningen University, obtaining his MSc degree in Sylviculture and Ecology.
His has been and is employed at the CNSF, Burkina's National Tree Seed Centre, in various positions, including Head of the tree propagation section and the Forest Seed Supply Unit. From September 1995 to January 1997 he was Director of CNSF as a National Seed Project, and from 1997 to 1999 Director General of the CNSF which become a National Tree Seed Programme. From 1999 he was PhD fellow on biodiversity management and conservation in the agroforestry parklands at the University of Wageningen (The Netherlands) in collaboration with the University of Wales, Bangor (United Kingdom).
During study leaves, he conducted research on biodiversity assessment and management in the semi-arid region of Burkina Faso in the framework of EU INCO Project N°IC18-CT-98-0261, combining this with a Visiting Scientistship at ICRISAT's Sahelian Centre Niamey, Niger. He has contributed to regional policies and programmes development through membership of the DANIDA tree seed center Technical Advisory Committee from 2000-2003 and as a member of the FAO panel of expert of Forest Genetic Resources since 2001. He got the title of « Chevalier de l'Ordre du Mérite National avec Agrafe Environnement » from the government of Burkina Faso in 1997.
Albert Nikiema is married and has two daughters and two sons.

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The field work was supported by the EU project IC-CT98-0261, co-ordinated by the School of Agricultural and Forest Sciences of the University of Wales, Bangor, Gwynedd, LL57 2UW, UK.
The finalization of the work presented in this dissertation was supported by the Netherlands' Foundation for Scientific Research (NWO grant B 85-372).

Cover design: Maruca M. & Nikiema A.
Photos: Nikiema A.

PROPOSITIONS

1 - Although agricultural practices contribute to a better development of useful species, protected forest remains the best refuge for the majority of woody species in the Sudan savanna region. (This thesis, chapter 2).

2 - As it happened with many edible plants there is evidence that *Vitellaria paradoxa* and *Parkia biglobosa* have been brought out of their ecological zone by farmers through migration movements in West Africa. (This thesis, chapter 3).

3 - The sustainability of local agricultural practices should not be taken as granted, since the times scale of the environmental and social changes, do not always match with the time requirement for sound social adjustment to the new factors.

4 - The problem of development in sub-Saharan Africa is more lack of vision, long term planning and continuity than lack of resources. Most development projects contribute to the build-up of this chaotic management habit.

5 - The elephant and the bee are both very famous in the animal kingdom; the elephant because of its giant body and the bee because of its work. You may not be born an elephant but you can always become a bee.

6 - The smart child buys his millet pancake from his mother. *«Bi yam n dada ma samsa»*. A Mossi proverb (Burkina Faso).

Propositions to the thesis "Agroforestry Parkland Species Diversity: Uses and Management in Semi-Arid West Africa (Burkina Faso)". Albert Nikiema, 8 March 2005. Wageningen University, the Netherlands