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Woody plants structure and composition in Burkina Faso Sahel: case study in Kékénéné village

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ABSTRACT

Understanding woody vegetation composition and structure is important for leading management decisions in the Sahelian vulnerable zones. The objective of the study was to better knowledge woody vegetation structure and richness in natural vegetation and cropland. The study area is Kékénéné village located in Soum province, surroundings Djibo in northern Burkina Faso. In total 54 sample plots were surveyed by means of a botanical inventory of woody vegetation species. All trees ≥ 10 cm dbh were measured. The vegetation structure pattern analyzed were diameter at breast height (dbh), basal area, relative dominance, and relative density, Importance Value Index (IVI) and Family Importance Value (FIV). In total 658 trees recorded was belonging to 21 species, 9 families in natural vegetation and 11 species, 5 families in cropland. Tree density was 15.7 stems/ha and 3.7/ha respectively in natural vegetation and cropland. Tree basal area was 0.54 m² ha^{-1} for cropland and 0.35 m² ha^{-1} in natural vegetation with a mean dbh of 3.5 cm for the two occupation types. The most importance family according to FIV was Balanitaceae in cropland and Combretaceae in natural vegetation. The Sorensen’ similarity coefficient of family in the two landscapes is lowest than 0.5 which means that the similarities in species family are low between the two occupation types. In natural vegetation, *Anogeisus leiocarpus* and *Balanites aegyptiaca* were the most important species in relation to IVI, while in cropland *Balanites aegyptiaca*, *Acacia senegal* and *Acacia seyal* were the most important species. Results reveal an abundance of *Balanites aegyptiaca* in both cropland and natural vegetation in the study site. Given its high socio-economic value in this region, this tree deserves to be more valued in a perspective of management and sustainable use in Kékénéné village.

Keywords: Composition and structure, woody species, management, Sahel ecosystems, Burkina Faso.

INTRODUCTION

Vegetation management is carried out with varying objectives in mind, one of which is biodiversity conservation. Woody vegetation affects ecosystem processes and contribute to livelihoods, as it improves soils nutrient and water availability for agricultural crop and pasture and influences soil water evapotranspiration, soil stability and erosion, soil carbon as well (Müller, 2008; Félix et al., 2015). The species generate multiple provisioning ecosystem services such as medicinal uses, contribution to fodder for livestock and importance for human nutrition (Ganaba et al., 2005; Gouwakinnou et al., 2011; Sarr et al., 2013). Furthermore, hardwooded trees in particular, are used for timber in construction as well as for firewood and charcoal production. These Services and theirs cultural values play an important role in the conservation (Haglund et al., 2011; Sinare et al., 2015; Sacande et al., 2016; Etongo et al., 2017).

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Understanding woody vegetation composition and structure is important for guiding management decisions in the Sahelian vulnerable zones (Mahamat-Saleh et al., 2013; Mahamat-Saleh et al., 2015; Garba et al., 2017). Conservation is imperative since the ecological treats are still persistent (Vincke et al., 2010; Kabore et al., 2013; Elfaig et al., 2015). In Burkina Faso, many studies highlighted several threats on Sahelian ecosystems, as natural factors influencing wind erosion, water resource scarcity explained by the regression of the plant species (Maranz, 2009; Gonzalez et al., 2012). Some results underlined that the degradation of land cover and trees declining in the Sahel zones are due to human high pressure on the vegetation and overgrazing (Ozer et al., 2010) while recently, others authors found that in semi-arid Sahel, farmland management promotes woody cover around villages (Brandt et al., 2018).

Recent findings based on satellite images analyses reveal an increasing trend of biomass in some Sahelian areas of West Africa, known as the re-greening phenomenon (Brandt et al., 2017; Leroux et al., 2017). This implies an increase in the vegetation density, in total contrast with the general narration of the persistence of ecosystem degradation, woody plants declining and increasing drought-resistant species found in literature (Herrmann et al., 2013; Kadeba et al., 2015; Hänke et al., 2016; Rasmussen et al., 2016). Thus, the increase in woody biomass did not always reflect on biodiversity woody species increasing in abundance (Brandt et al., 2015). Therefore, it is useful to further make based field investigations on tree cover in terms of vegetation structure and species composition, in order to support the strategy of biodiversity conservation. The main objective of the study was to explore woody vegetation structure and species richness in contrasted cropland and natural vegetation in Sahelian zones of Burkina Faso.

MATERIALS AND METHODS

Area description

The study was conducted in the Sahelian region of Burkina Faso in the Kékénéné village located in Soum province (Djibo town) (Figure 1). The study area lies approximately between latitude 14 °23 ' to 14 °25 ' N and longitude 1 °01 ' to 1 °04 ' W covering about 480 km^2. This area is characterized by an arid climate, with a unimodal rainfall pattern, marked by a fluctuation of dry season from November to April and a rainy season, from May to October. The average annual rainfall of the area is about 400 mm/year for the period 1981-2018. The average annual temperature of the Dori Station is around 30 °C.

The Kékénéné landscape is located in the northern Sahelian phytogeographical area, characterized by vegetation dominated by steppe shrubby vegetation (Thiombiano et al., 2010) composed mainly of *Combretum glutinosum*, *Balanites aegyptiaca*, *Acacia seyal*, and *Acacia raddiana*. The herbaceous carpet consists mainly of *Schoenfeldia gracilis*, *Cenchrus biflorus*, and *Aristida spp*. The relief is mainly a vast peneplain with some massifs and buttes battled in places. The dominant soils are sub-modal brown soils with a sandy-loam texture and sometimes gravelly cover.

The population of Kékénéné is 1665 inhabitants in 2006 according to the National Institute of Statistics and Demography - INSD - (INSD, 2009). The annual rate of change in density between 1996 and 2006 is 4.15%. The study area is farming and grazing zone, with a population consisting mainly of Mossi migrants and Fulcé natives. Livestock is also important. The livestock is mainly composed of cattle, goats and sheep. The breeding is extensive and mainly sedentary type.

Ground data collection

A stratified systematic design was applied along transects on the land use map of Kékénéné. The land use map of the recent period (2015) from numerical classification was used as a background to layout the plots along transects in each main land use unit. Square plot of 100 x 100 meters (e.g. 1 ha) were used for the ecological description and the measurements of tree species. The GPS was used during the field work to find the plots. In each plots, dbh ≥ 2.5 cm and height above 1.5 m were measured for all individual trees of that range. The identification of all trees in the inventory follows the nomenclature of Arbonnier (2009).

The floristic composition and structure was examined by Importance Value Index (IVI), which is the sum of relative density, relative dominance and relative frequency of a species. Importance Value Index is an important parameter that indicates the ecological significance of species in a given ecosystem. Species with high IVI values are regarded as more important than those with low IVI values. The IVI values are also used in conservation programs, where species with low IVI values are prioritized for conservation and those with high IVI values need monitoring management (Neelo et al., 2015). For all families, we determined Family Importance Value (FIV), which is the sum of relative density, relative dominance and relative diversity, where relative diversity is number of species of family/total number of species. The relative density = (number of individuals of a species /total number of individuals) x100; the relative dominance = (total basal area for a species/total basal area of all species) x100 and the relative frequency = (frequency of a species/sum of all species) x100. The frequency is defined as the number of occurrence of the species within a plot. The theoretical range of relative dominance, relative frequency, relative density, and relative diversity is 0-100%; therefore the IVI and FIV may be between 0 and 300%. For the structural characteristics, the stem density, basal area, and diameter were computed for each plots; the average was calculated for the vegetation unit for all individual of 2.5 cm dbh.

To compare family diversity between occupation types, Sorensen's similarity coefficient (Krebs, 1999) was calculated using the similarity in species composition of seedlings in cropland and natural vegetation by using the following formula:

$$Ss = 2a / (2a + b + c)$$

Where, S_s= Sorensen's similarity coefficient, **a** = number of species with seedlings present in cropland and natural vegetation, **b** = number of species with seedlings exclusively present in cropland, and **c** = number of species with seedlings exclusively present in natural vegetation. Sorensen's coefficient has a range between zero (no species in common) and 1 (complete similarity).

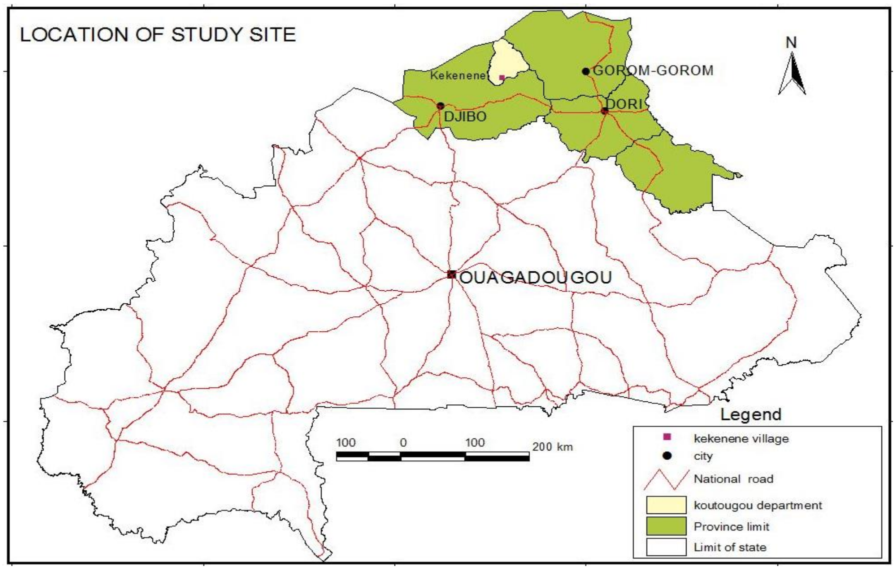

Figure 1: Location of Kékénéné in Djibo, Soum Province.

RESULTS

Tree species richness and similarity in the two occupation types

The total number of trees recorded was 658 belonging to 21 species, 9 families in natural vegetation and 11 species, 5 families in cropland (Table 1). Tree basal area was 0.54 $m^2 \cdot ha^{-1}$ for Cropland and 0.35 $m^2 \cdot ha^{-1}$ in natural vegetation with a mean dbh of 3.5 cm for two occupation types.

In natural vegetation, five families were represented by a single species each; two families were represented by 4 species each, one family was represented by 6 species. In cropland, two families were represented by a single species each and one family was represented by four species (Table 2). The most diverse family was Combretaceae, with 23.19% of the total number of species, followed by Balanitaceae (20.29%) in natural vegetation (Table 2). In cropland the most diverse families were Mimosaceae (33.33%) and Balanitaceae (25%). Combretaceae family had the highest relative density (63.04) in natural vegetation, while Balanitaceae (56.14) had in cropland (Table 2). The family with the highest relative dominance was Combretaceae (55.00) in natural vegetation. In cropland, it was Balanitaceae with a relative dominance of 42.47. The highest family importance value (FIV) observed was 141.22 for Combretaceae in natural vegetation and 123.61 for Balanitaceae in cropland.

The highest similarity in family composition recorded between cropland and natural vegetation was 0.42. Four of the families, namely Capparaceae, Anacardiaceae, Asclepiadaceae and Rubiaceae were exclusively found in natural vegetation. The similarity coefficients in families of the two occupation types is lowest than 0.5 (Table 3).

Vegetation structure of the occupation types

The analysis of the results shows that the plant species *Balanites aegyptiaca* is most frequent in natural vegetation and cropland with respectively the relative frequency of 20.29 and 25.00.

The highest relative dominance encountered in the natural vegetation was 45.93 for *Anogeissus leiocarpus* which yields an absolute basal area of 5.01 $m^2 \cdot ha^{-1}$. In the cropland, the dominant species was *Acacia Senegal* with a relative dominance of 6.72 and a basal area of 0.096 $m^2 \cdot ha^{-1}$ (Table 4).

In terms of density, *Combretum micranthum* and *Balanites aegyptiaca* are highest in natural vegetation with respectively a relative density of 42.09 and 16.84. This species could be considered as the most abundant in the study area. *Acacia seyal* and *Acacia Senegal* are the most abundant species in cropland with a relative density of 19.75 for both.

The highest important value index (IVI) recorded in natural vegetation was 58.71 for *Anogeisus leiocarpus*, followed by *Balanites aegyptiaca* and *Combretum micranthum* with an IVI of 57.33 and 51.64, respectively. In cropland, *Balanites aegyptiaca* had the highest important value index of 43.11 (Table 4).

Table 1: Summary of vegetation composition and structure of study area.

Occupation type	No. Sample plots	No. stem	No. stems per hectare	Richness			Average DBH	Basal area
				No. Family	No. Genera	No. Species		
Natural vegetation	31	487	15.7	9	14	21	3.5 (cm)	0.35 (m^2/ha)
Cropland	23	171	3.7	5	9	11	3.5 (cm)	0.54 (m^2/ha)

Table 2: FIV index for the two occupation types. ReDiv = relative diversity; ReDom = relative dominance; ReDens = relative density; FIV = family importance value.

Occupation type	Family	N° species	ReDiv	ReDom	ReDens	FIV
Natural vegetation	Combretaceae	4	**23.19**	**55.00**	**63.04**	**141.22**
	Balanitaceae	1	20.29	20.20	16.84	57.33
	Caesalpiniaceae	4	18.84	15.25	8.42	42.51
	Mimosaceae	6	15.94	8.10	8.01	32.05
	Capparaceae	2	11.59	1.26	2.05	14.91
	Rhamnaceae	1	5.80	0.06	0.62	6.48
	Anacardiaceae	1	1.45	0.10	0.41	1.96
	Asclepiadaceae	1	1.45	0.00	0.41	1.86
	Rubiaceae	1	1.45	0.05	0.21	1.70
	Family	**N° species**	**ReDiv**	**Re Dom**	**ReDens**	**FIV**
Cropland	Balanitaceae	1	25.00	**42.47**	**56.14**	**123.61**
	Mimosaceae	4	**33.33**	10.89	15.79	60.01
	Combretaceae	3	16.67	32.01	11.11	59.79
	Rhamnaceae	1	12.50	7.11	8.77	28.38
	Caesalpiniaceae	2	12.50	7.51	8.19	28.20

Table 3: Sorensen’s similarity coefficient in family for the two occupation types.

Occupation type	Natural vegetation	Cropland
Natural vegetation	-	
Cropland	0.42	-

Table 4: List of species according to IVI in occupation types.

Occupation type	***Species***	***BA m²/ha***	***ReDens***	***ReFreq***	***ReDom***	***IVI***
Natural vegetation	Anogeisus leiocarpus	**5.01**	6.98	5.80	**45.93**	**58.71**
	Balanites aegyptiaca	2.20	**16.84**	**20.29**	20.20	**57.33**
	Combretum micranthum	0.25	**42.09**	7.25	2.30	**51.64**
	Pterocarpus lucens	1.63	6.98	**14.49**	14.97	36.44
	Combretum glutinosum	0.46	12.32	8.70	4.24	25.26
	Acacia seyal	0.43	2.87	4.35	3.96	11.18
	Boscia angustifolia	0.14	1.23	7.25	1.24	9.72
	Acacia raddiana	0.03	2.67	5.80	0.28	8.74
	Ziziphus mauritiana	0.01	0.62	5.80	0.06	6.48
	Acacia laeta	0.38	1.23	1.45	3.49	6.17
	Mitragina Inermis	0.28	1.64	1.45	2.53	5.62
	Piliostigma thonningii	0.02	1.03	2.90	0.18	4.10
	Boscia senegalensis	0.00	0.82	2.90	0.02	3.74
	Acacia senegal	0.04	0.62	1.45	0.35	2.41
	Sclerocarya birrea	0.01	0.41	1.45	0.10	1.96
	Acacia siberiana	0.00	0.41	1.45	0.01	1.87
	Calotropis procera	0.00	0.41	1.45	0.00	1.86
	Piliostigma reticulatum	0.01	0.21	1.45	0.06	1.71
	Bauhinia refuscens	0.01	0.21	1.45	0.05	1.70
	Feretia apotanthera	0.01	0.21	1.45	0.05	1.70
	Acacia pennata	0.00	0.21	1.45	0.02	1.67
	Species	***BA m²/ha***	***ReDens***	***ReFreq***	***ReDom***	***IVI***
Cropland	Balanites aegyptiaca	0.000	14.62	**25.00**	3.49	**43.11**
	Acacia senegal	**0.096**	**15.79**	12.50	**6.72**	35.01
	Acacia seyal	0.031	**15.79**	14.58	4.30	34.67
	Ziziphus mauritiana	0.000	12.28	12.50	3.45	28.23
	Piliostigma reticulatum	0.000	14.62	8.33	3.48	26.43
	Combretum aculeatum	0.001	14.04	6.25	3.47	23.75
	Anogeisus leiocarpus	0.018	7.02	10.42	3.44	20.87
	Acacia raddiana	0.000	3.51	4.17	2.98	10.66
	Pterocarpus lucens	0.018	1.17	4.17	2.92	8.26
	Combretum glutinosum	0.096	0.58	0.00	2.47	3.06
	Acacia pennata	0.002	0.58	2.08	0.05	2.72

ReFreq = relative frequency.

DISCUSSION

In this present study, the result revealed that the maximum species richness and abundance were comparable to those in some areas in West Africa Sahel (Diouf et al., 2002; Charahabil et al., 2013; Sarr et al., 2013).

The highest family importance value (FIV) observed was 141.22 for Combretaceae in natural vegetation and 123.61 for Balanitaceae in cropland. The high presence of Combretaceae in natural vegetation is due to the fact that some species of that family are able to resist to some perturbations. The similarity in family composition recorded between cropland and natural vegetation is lowest than 0.5 which means that the floristic composition is different between the two occupation types.

Although the number of plots inventoried did not allow for statistical comparisons, some tendencies in diversity and density can be observed in Table 2. Of the two occupation types, natural vegetation exhibited the highest number of families and species which were more than 2 times higher than that recorded in cropland. The flora of natural vegetation is more diversified than that of cultivated ecosystems. This is because some plant species are cut when new fields are being prepared (Bassene et al., 2014). Combretaceae family had the highest relative density (63.04) in natural vegetation, while Balanitaceae (56.14) had in cropland. The most diverse family was Combretaceae followed by Balanitaceae in natural vegetation. In cropland the most diverse families were Mimosaceae and Balanitaceae. The relatively low diversity between families at both landscape types can be attributed to the habitat conditions and species characteristics.

In natural vegetation, *Anogeisus leiocarpus, Balanites aegyptiaca* and *Combretum micranthum* can be considered the most ecologically important woody species, especially *Balanites aegyptiaca* with IVI values of more than 20 contributed by its high value of density, frequency and dominance. In cropland, *Balanites aegyptiaca* with an important value index of 43.11 is considered the most ecologically important woody species.

In terms of density, *Combretum micranthum* and *Balanites aegyptiaca* are highest in natural vegetation with respectively a relative density of 42.09 and 16.84. *Acacia seyal* and *Acacia Senegal* are the most abundant species in cropland with a relative density of 19.75 for both. The domination of *Acacia* species, which are indicative of heavy grazing is rational with the fact that cropland is used as a cattle post by people living in the village during dry season. Thus, seed scattering, which is known to be facilitated by ruminants that usually browse *Acacia* species, could be responsible of their relatively high number and density recorded.

In terms of relative frequency, the results also show that *Balanites aegyptiaca* is most frequent in natural vegetation and cropland (respectively 20.29 and 25.00). This species is widespread in the study site and is a thorny shrub characteristic of Africa's drylands. This supports the observation of Sop et al. (2011). Indeed, the high frequency of this species testifies to its resistance to the drought that has raged in this Sahelian zone since the 1970s. These results corroborate those of Ndiaye et al. (2013) which stipulate that a modification of the flora in the sense of an invasion of species considered desert is possible following a rapid increase in erosion (hence aridity) on a larger scale. Herrmann and Tappan (2013) also noticed a shift of Sahelian species towards more arid-tolerant, since 1983.

Balanites aegyptiaca is an endemic sahelian species with a strong colonizing ability that ensure stable populations for this species even though regeneration happens rarely (Müller, 2008; Sop et al., 2011). In many studies carried out in some regions of West Africa Sahel, *Balanites aegyptiaca*, were mentioned exhibiting moderate survival rates (Wade et al., 2018) and also having vastly increased in number, to be the dominant species. This has been observed at Oursi in northern BF (Maranz, 2009). Brandt et al. (2017) also found a rapid growth of *Balanites* *aegyptiaca* between 2000 and 2013 in Senegalese Sahel. *Balanites aegyptiaca* has a coppicing and resprouting abilities that allow this specie to sustain its persistence in that semi-arid region (Hänke et al., 2016). But some concerns are raised about the population status of species in Sudan where disappearance of *Balanites aegyptiaca* which was abundantly existed and widely spread in the study area becomes very few (Elfaig et al., 2015). Indeed, woody vegetation paid a tribute to drought in Sahel areas but also to human disturbances. The study area has been exposed not only to overgrazing, but also exploitation by rain-fed agriculture. Anthropogenic practices such as logging or cutting trees do not systematically lead to a decline in species diversity and abundance. The reasons for low variation in floristic composition of the two occupation types could be due to moderate anthropogenic disturbances and exploitation of some species, especially in cropland. In the study area, croplands are used as a cattle ranch during dry season by the local people. Therefore, due to the lack of herbaceous at that season some species of Mimosaceae and Balanitaceae are preserved and managed by pruning and use as fodder. The high frequency of *Balanites aegyptiaca* in cropland could be due to low anthropogenic pressure (good practices of harvesting / exploitation). In this village, this specie is only kept for breeding contrary to the surrounding villages in the province of Seno, Oudalan, and Soum in the same ecological zone, where the population namely Foulbe gaobé, Foulbé djelgobé, Sonraï, Bella, Touareg exploit *Balanites aegyptiaca* for many uses such as crafts (camel saddle, stool, pestle, mortar, bowl, spoon, spatula, toothpick) and food supply (Lykke et al., 2004; Ganaba et al., 2005; Sop et al., 2012). This could be explained by the ethnic difference because the population of Kékénéné is mainly constituted of Mossi, who are migrants and settled in the village especially for agriculture, gold-rush and breeding. The population of Kékénéné has an important traditional vegetation management systems and practices, which have contributed a lot for the maintenance of the vegetation resources by the involvement of government bodies. They had important practices that helped for the maintenance of the vegetation in croplands. They retain indigenous trees like *Balanites aegyptiaca* in the farmlands as fodder for livestock. Those management practices in semi-arid Sahel promote woody cover in farmland around villages but also in bush cropland. That is supported in literature (Haglund et al., 2011; Brandt et al., 2018).

Conclusion

The work presented here provides evidence that species belonging to the family of Combretaceae, Mimosaceae and Balanitaceae have a high frequency and abundance in the woody areas of the Sahelian zones of Burkina Faso. A better adaptation of these species to the climatic conditions added to the preservation of *Balanites aegyptiaca* in cropland for breeding, would be the causes of this tendency. Policy makers and development agencies should more address and integrate local people’s species preferences and conservation priorities in their global strategy for poverty relief. This *Balanites* specie need to be better valued in the village site due to its importance for the craft and food use of seeds and fruit encountered elsewhere in the Sahel region. The environmental education programmes at local level-organized as part of capacity building for cattle-breeder and farmers should provide a platform for sharing traditional knowledge about species use elsewhere in Burkina Faso. This could improve the resilience of this Sahelian population. However, there is at the same time, a threat that could weigh on species in this area due to overexploitation and the recent massive arrival and settlement of refugees from neighboring countries (Mali) with their herds. Therefore, the regulation of grazing activities in the area represents an indispensable component for ecosystems conservation. The maintenance of ecosystem balance in the region of Sahel and the conservation of its ecosystems is very important for the survival and the development of rural communities, whose future is bound to the availability of natural resources. Monitoring is equally crucial. This includes tracking and reviewing vegetation structure to improve management and conservation strategies.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

The first author collected the data in Kékénéné village and drafted the present manuscript. The others authors had carefully read and contributed to the present version of the manuscript.

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