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IMPACT OF TRADITIONAL AGROFORESTRY PRACTICES ON WOODY SPECIES CONSERVATION IN THE SAHELIAN AREA OF FAR NORTH REGION, CAMEROON

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Abstract

Agroforestry practices are known for its multiple roles such as contribution to food security, environmental protection and biodiversity conservation. To determine the extent of contribution of some traditional agroforestry practices to woody species conservation, data were collected from the Natural Fallow land, Agroforestry Systems and natural forest in and around the Laf-Madjam Forest Reserve, near Moutourwa subdivision at Far North Region of Cameroon. The area was sampled in a group of twelve 0.04 ha (20 m × 20 m) plots per land use type. All woody plants with diameter at breast height greater than or equal to 5 cm were identified. A total of 0.4 ha of natural fallow, Agroforestry systems and natural forest were surveyed. 366 individuals belonging to 40 taxa and 23 families were identified in the 0.4 ha of natural forest surveyed. In the natural fallow, 344 individuals belonging to 34 taxa in 22 families were encountered while the Agroforestry systems had 228 individuals belonging to 26 taxa in 16 families. The Sahelian forest had the highest density of woody species (907.5 trees/ha) while the lowest (570 trees/ha) was observed on the Agroforestry systems. The values of Shannon diversity index differ significantly among the land use types with the Sahelian forest having the highest (1.56), while the Agroforestry systems the least (1.36). Despite the lowest species diversity of Agroforestry systems, when they were kept well, they constitute an excellent area of biodiversity conservation. However important efforts could be done in order to sensitize the farmers on the organization, improvement and the sustainable management of the agroforestry systems.

Key Words: *Agroforestry systems, Natural fallow, Sahelian forest, Woody species conservation*

Introduction

Deforestation, land degradation, unsustainable farming practices, loss of biodiversity, poverty and malnutrition are the main problems that the developing countries faced actually (Antonios, 2002). Agroforestry has been identified as a land-use option that can address many of these global problems (Mapongmetsem *et al*., 1997, Levasseur and Olivier, 2000). Deliberate inclusion of trees in agricultural landscapes has been a common practice among farmers for a very long time and the farming communities have played important roles in conserving crop and tree diversity (Larwanou *et al*., 2006). Although the traditional agroforestry practices have contributed immensely to food security and environmental protection (Alao and Shuaibu, 2011), the need to meet the increasing needs of the burgeoning population has led to the development of modern agroforestry practices with simplified ecosystem structure and consequent destruction of biological diversity. In recent decades, many benefits (carbon retention in the plant-soil system, conservation of biodiversity) have led scientists to focus on the environmental services that can be provided by agroforestry practices (McNeely and Scherr, 2003; Schroth *et al*., 2004). Particular attention is being paid to these traditional practices that are so widespread in the traditional land use of tropical region. Unfortunately, in the Sahelian area of Cameroon, the traditional agroforestry practices are little numerous and the most important are scattered trees on farmland or pasture and bush fallowing (Oboho and Anyia, 1992; Chup, 2004). Traditionally, farmers grow crops under scattered trees of different species and they sometimes incorporate animal production. However, they had no special technique, species type or density per unit area when they resorted to agroforestry practices.

Numerous agroforestry systems played various roles in reduction of biodiversity loss, restoration of degraded areas and biodiversity conservation (Nair *et al*., 2005; Mcneely and Schroth, 2006; Ashley *et al*., 2006; Bhagwat *et al*., 2008). Some of these agroforestry systems have been studied for their roles in biodiversity conservation (Moguel and Toledo, 1999; Oke and Odebiyi, 2007; Harvey and Gonzalez-Villalobos, 2007; Mapongmetsem *et al*., 2016). However, the importance of biodiversity varies according to the region or to the large anthropic pressure on the vegetation. In the tropics, several studies have been devoted to the study of the impact of traditional agroforestry practices on the conservation of biodiversity. In a survey on the conservation of floristic diversity in southwestern Bangladesh, Kabir and Webb (2009) reported 419 species. In the Guinean region of Cameroon, Mapongmetsem *et al*. (2007) reported in their work that 246 species were fund in the homegardens. A work of Backes (2001) on the contribution of agroforestry land use to the conservation of indigenous trees in western Kenya shows how species diversity is ultimately linked to the loss of habitat diversity and landscape diversity. Fifanou *et al*. (2011) recorded twenty-one tree species belonging to 14 botanical families during the survey of traditional agroforestry parkland systems around the Pendjari Biosphere Reserve in Benin. Unfortunately, in the sahelian zone in general and in the Sahelian zone of Cameroon in particular, there is no study on the impact of traditional agroforestry practices on the conservation of woody species. The present study seeks to

evaluate the impact of the traditional agroforestry practices on the conservation of the woody tree species in the Sahelian ecosystem of Cameroon.

Materials and Methods

Study Site

The study was carried out in Sahelian zone of Cameroon particularly in and around Laf-Madjam Forest Reserve. It is located between 10°14' and 10°18' north latitude and 14°23' and 14°30' east longitude. The forest reserve of Laf-Madjam is located in the plain of Diamaré. Its climate, characteristic of semi-arid regions, is Sahelian with rainfall less than 900 mm. Despite year-to-year declines in rainfall, the rainy months are from June to September, with the rest of the year being hot and dry with average temperatures approaching 30° C. The soils are clayey and waterlogged. They are commonly called "karal". Their moisture and relative fertility have favored the development of specific vegetation in the dry tropical zone, which is increasingly colonized by a double season of growing the transplanted sorghum (Mouskwari) (Seignobos and Iyebi Mandjeck, 2000; Yengue, 2000).

Experimental Design and Data Analysis

Three land-use types (undisturbed natural forest, Agroforestry systems and natural Fallow) were identified around the Laf-Madjam Forest Reserve. Three transect lines were cut through the natural forest and grazing land or agroforestry systems land at a minimum distance of 100 m apart. Four sampling plots of 20 m × 20 m in size were laid in alternate pattern along each transect at 50 m intervals. Four abandoned Fallow (10-15 years of natural Fallow) were selected from the encroached area very close to the Forest Reserve. Three 20 m x 20 m plot was demarcated within the centre of each Fallow land and data were collected from each plot. Assessment of tree diversity was done in sample plots demarcated within each land-use type and also on 20 m × 20 m demarcated within four natural Fallow lands in the fringe settlements.

With the assistance of an experienced taxonomist, all woody species (diameter at breast height, dbh ≥ 5 cm) encountered in each of the demarcated sample plots were identified and their frequency of occurrence recorded. For unknown tree species, leaves, slash and bark of such trees were collected and taken to the National Herbarium of Yaounde and to the Laboratory of Biodiversity and Sustainable development of the University of Ngaoundere for identification. The total number of each tree species encountered in the ten sample plots (0.4 ha) for each ecosystem was calculated (frequency) and the figure was used in estimating number of trees per hectare (tree density). Species diversity was calculated as $H'=-\sum\{(ni/N)\log e(ni/N)\}$, where H'= Shannon index of general diversity, ni = number of individuals of a species, N = total number of individuals in the community.

Descriptive statistics (calculation of percentages, averages) were made and SPSS software was used for this purpose.

Result

Diversity of Land-use Systems in the Sahelian Region

Agroforestry in Sahelian region is characterized by a variety of techniques of which the most important are improved fallows, tree parks and bright hedges. This diversity in traditional farming systems actually reflects the opportunities offered by the practice as well as the expression of biodiversity in the different parts of the landscape.

The figure 1 presents the biological diversities in the three types of land-use. A total of three hundred and fifty six individuals belonging to 40 taxa and 23 families were identified in the 0.4 ha of Sahelian forest surveyed. The richest families were Mimosaceae which had nine species. Caesalpiniaceae and Moraceae came in second position with five species each. Families Anacardiaceae had four species while Families Bombacaceae, Fabaceae and Verbenaceae counted three species each. The predominant 10 woody species present in the Sahelian forest accounted for 45.36 % of total population. They included *Faiherbia albida*, *Sclerocarya birrea*, *Balanites aegyptiaca*, *Anogeissus leiocarpa*, *Acacia nilotica*, *Bombax costatum*, *Daniellia oliveri*; *Detarium microcarpum*, *Prosopis africana* and *Diospyros mespilliformis*

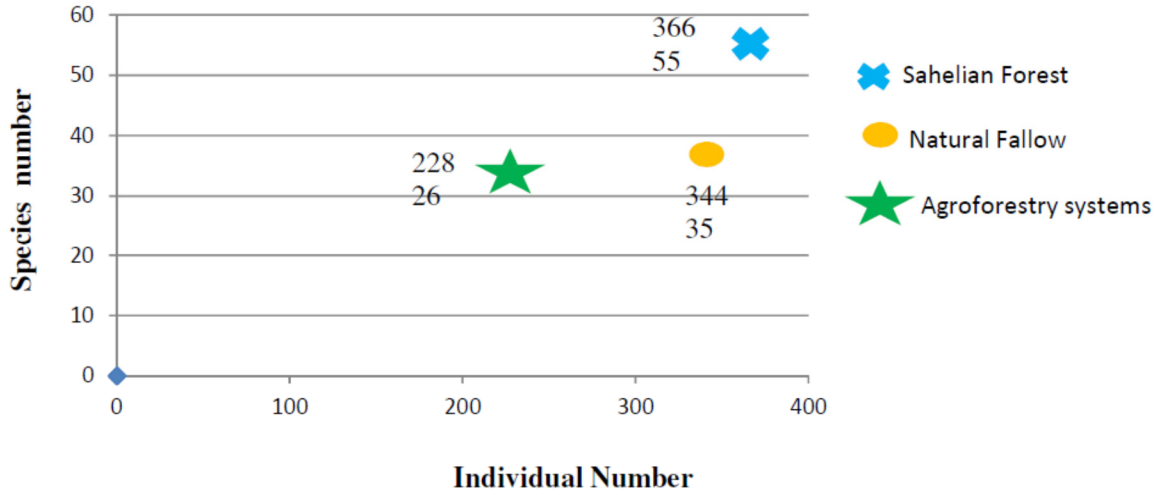

Fig. 1: Biological diversity in the plots

In the natural Fallow surveyed, 344 individuals belonging to 35 taxa distributed in 22 families were recorded. The richest families were Mimosaceae (six species) followed by Caesalpiniaceae (five species). The dominant species were *Piliostigma thonningii*, *Balanites aegyptiaca*, *Faidherbia albida*, *Detarium microcarpum*, *Anogeissus leiocarpa*, *Tamarindus indica*, *Manguifera indica*, *Bombax costatum*, *Bridelia ferruginea*, *Annona senegalensis*.

In the Agroforestry systems surveyed, 228 individuals belonging to 26 taxa in 16 families were encountered. The richest family was Mimosaceae which had four species. Families Caesalpiniaceae and Bombacaseae had three species each while Anacardiaceae, Arecaceae and Myrtaceae had each two species. The most important species were *Balanites aegyptiaca*, *Manguifera indica*, *Sclerocarya birrea*, *Faidherbia albida*, *Azadirachta indica*, *Adansonia digitata*, *Khaya senegalensis*, *Tamarindus indica*, *Citrus lemon*, *Parkia biglobosa*. These species represent 55.70 % of the total population.

Biological Diversity of the System

Family Diversity

Numerous shades were recorded in families' composition of different land-use systems. The family number of Sahelian forest is about 1.5 times upper higher (23 families) than Agroforestry systems one (18 families). The family

number of Fallow is most weak than Sahelian forest (Table 1). According to the individual number by families, Mimosaceae were the most dominant in the three systems of land-use (Table 2).

Table 1: Density and diversity indices of trees/shrubs in Sahelian forest, Agroforestry systems and fallow ecosystems in the Sahelian zone of Far North Region Means of diversity index followed by same letters are not significantly different ($P < 0.05$).

	Individuals	Species	Density (tree/ha)	Taxa	Families	Shannon index
Sahelian forest	366	55	907.5	40	23	1.56
Fallow	344	35	860.5	34	22	1.50
Agrofrestry systems	228	26	570	26	16	1.36

As regard as density, the ten most important families of Agroforestry systems comprised 192 individuals of diameter ≥5 cm. The individual number recorded in this land-use system represented the half of those of Fallow land-use (244 individuals). The density difference of the main families between the Sahelian forest and Agroforestry systems was considerable. This difference was weak between the Sahelian forest that was 299 individuals and the Fallow was weak. However, it is important to note that despite the important of individuals' number recorded in the Agroforestry systems, it remains the most weakly diversified system in family. Indeed, none families had exceeded fifty individuals. The most important family is Mimosaceae which possessed 38 individuals. Whereas, it recorded 95 and 62 individuals respectively in Sahelian forest and in natural Fallow. In spite of its large density, the Agroforestry systems remained very poor in biodiversity because it counted at total 16 families against 22 for natural Fallow and 23 in Sahelian forest. So in term of biodiversity, natural Fallow was most near to Sahelian forest than Agroforestry systems.

Table 2: Relative density of 10 first families in the three plots (0.4)

N°	Sahelian forest		Fallow		Agroforestry systems	
	Family	Individual number	Family	Individual number	Family	Individual number
1	Mimosaceae	95	Mimosaaceae	62	Mimosaceae	38
2	Anacardiaceae	40	Caesalpiniaceae	47	Anacardiaceae	29
3	Caesalpiniaceae	39	Verbenaceae	23	Bombacaceae	28
4	Bombacaceae	25	Fabaceae	20	Caesalpiniaceae	19
5	Annonaceae	21	Anacadiaceae	19	Balanitaceae	16
6	Balanitaceae	19	Balanitaceae	18	Myrtaceae	16
7	Combretaceae	18	Combretaceae	17	Arecaceae	13
8	Arecaceae	16	Bombacaceae	13	Meliaceae	13
9	Fabaceae	14	Euphorbiaceae	13	Rutaceae	11
10	Ebenaceae	12	Annonaceae	12	Combretaceae	9
	Total	**299**	**Total**	**244**	**Total**	**192**

Taxa and Species Diversity

Table 3 presents the main taxa recorded on the three land-use systems. 40 taxa were noted in Sahelian forest against 35 and 26 respectively in natural Fallow and Agroforestry systems. In together, the

three land-use systems counted 101 taxa whose 17 in shade. This demonstrates in plenty the large disparity between the land-use systems in the area of Sahel at the level of the taxa diversity. It appears so that like the family diversity, the taxa between the land-use systems are different of one land-use system to other. In the Agroforestry systems, four introduced taxa were recorded amongst the 10 dominant of the system; there are *Mangifera*, with 14 individuals (6.14 %), *Azadirachta* with 13 individuals (5.70 %), *Khaya* with 11 individuals (4.82 %) and Citrus with 11 individuals (4.82 %). Logically, the 10 dominant taxa in the Sahelian forest were constituted by the indigenous species (Table 3).

The specific structure of different land-use systems shows that numerous species present in Sahelian forest were absent in the natural Fallow and in the Agroforestry systems. They are *Hexabolus monopetalus* (9 individuals), *Lannea acida* (8 individuals), *Parinari curatellifolia* (1 individual), *Pericopsis laxiflora* (1 individual) and *Ximenia Americana* (8 individuals). The most important species in this system (*Faidherbia albida*, 26 individuals) is present in the two other land-use systems with 19 and 15 individuals respectively in natural Fallow and Agroforestry systems. However, 2 exotic species were least dominant in the natural Fallow. Likewise, in the Agroforestry systems, these two species were most important (*Khaya senegalensis* and *Azadirachta indica* with 1 and 3 individuals respectively). Both these two species were noted in the Sahelian forest with various fortunes.

Table 3: Dominant taxa of plots (individual number > of 1)

N°	Sahelian forest		Fallow		Agroforestry systems	
	Taxa	Individual number (%)	Taxa	Individual number (%)	Taxa	Individual number (%)
1	*Acacia*	43 (11.75)	*Balanites*	23 (6.69)	*Balanites*	16 (7.02)
2	*Faidherbia*	26 (7.10%)	*Faidherbia*	19 (5.52)	*Faidherbia*	15 (6.58)
3	*Sclerocarya*	23 (6.28)	*Vitex*	18 (5.23)	*Sclerocarya*	14 (6.14)
4	*Balanites*	19 (5.19)	*Piliostigma*	17 (4.94)	*Mangifera*	14 (6.14)
5	*Anogeissus*	17 (4.64)	*Detarium*	16 (4.65)	*Azadirachta*	13 (5.70)
6	*Bombax*	14 (3.83)	*Anogeissus*	15 (4.36)	*Adansonia*	12 (5.26)
7	*Daniellia*	14 (3.83)	*Tamarindus*	14 (4.07)	*Khaya*	11 (4.82)
8	*Detarium*	13 (3.55)	*Acacia*	13 (3.78)	*Tamarindus*	11 (4.82)
9	*Annona*	12 (3.28)	*Bombax*	13 (3.78)	*Citrus*	11 (4.82)
10	*Diospyros*	12 (3.28)	*Bridelia*	13 (3.78)	*Parkia*	10 (4.39)

In Agroforestry systems, the biodiversity is the fruit of a human selection made by two main ways: the introduction and the conservation.

The introduction concerns fruit trees and exotic species such as mango (*Mangifera indica*), guava (*Psidium guajava),* lemon *(Citrus lemon),* papaya *(Carica papaya), Eucalyptus camaldulensis, Azadirachta indica* and indigenous species such as the Baobab (*Adansonia digigtata),* tamaind (*Tamarindus indica) and Sclerocarya birrea*.

The Conservation highlights the trees preserved during clearing. It concerns individuals belonging to species of medicinal value (*Piliostigma thonningii*,

Diospyros mespilliformis) or of high value in timber (*Anogeissus leiocarpa*, *Ziziphus mauritiana*, *Balanites aegyptiaca*). Conservation involves also individuals whose morphology of foliage produces a gentle shading (not too absorbent by compared to light, nor too transparent) as *Borassus aethiopum*, *Ceiba pentandra*, *Boswellia dalzielli*. Otherwise, the other trees spared or even maintained in Agroforestry systems are for ecological values. Leguminous as various species belonging to the genus Acacia and Faidhebia (Mimosaceae) are very popular for their fertilization property. These species develop the ability to capture nitrogen from the air that they hold in the ground. Farmers know that under these trees, the plants grow more vigorously.

Table 4: Exotic or introduced fruit trees repartition in the Fallow and Agroforestry system.

Land-uses	Species total number	Introduced species	Individual Number	(%)
Fallow	37	*Mangifera indica*	13	3.78
		Citrus lemon	6	1.74
		Psidium guajava	7	2.03
		Khaya senegalensis	1	0.29
Agroforestry systems	26	*Mangifera indica*	14	5.58
		Khaya senegalensis	11	4.82
		Carica papaya	8	3.51
		Azadirachta indica	13	5.70
		Psidium guajava	9	3.95
		Eucalyptus camaldulensis	7	3.07
		Citrus lemon	11	4.82

It therefore appears that the diversity of flora is important in Sahelian forest (55 species), few important in national Fallow (37 species) and very low in Agroforestry Systems (25 species). So, 15 years of fallow allowed relative reconstitution, but insufficient of a piece of forest once cultivated. Agricultural development reduced drastically biological diversity in the zone, but does not destroy it completely. The species present in agrosystem foresters occupy a special place in the national Fallow and Agroforesty Systems. Introducing species, enriching slightly plots converted into biodiversity, causes a recomposition of the flora in the area. It significantly influences the dynamics of the biodiversity. This influence is better materialized in table 4.

Discussion

Specific diversity had made the study subject of many authors in agroforestry systems in Cameroonian agricultural mosaic (Sonwa *et al*., 2001, 2007; Zapfack *et al*., 2002; Lallah Fotsa, 2011; Mapongmetsem *et al*., 2011). Their results lead to the conclusion according to which agroforestry systems offer a significant forest diversity that varies according to techniques and regions.

This study shows that a large number of woody species occur in the fallow system and scattered trees on Agroforestry systems of the Sahelian ecosystem of Far North region of Cameroon. However a modification of the species composition was observed in both the Agroforestry systems and natural Fallow with more pioneer species and different dominant

species compared with the Sahelian forest. *Balanites aegyptiaca* and *Faidherbia albida* were the dominant woody species in both the natural fallow and the Agroforestry systems while in Sahelian forest, the dominant woody species were *Anogeissus leiocarpa.* The dominance of *Balanites aegyptiaca* in the natural fallow and the Agroforestry systems may not be unconnected with its attribute as a pioneer species which grows well in open forest clearings. Moreover, farmers might have deliberately retained the species because of its usefulness as a fodder species. The species has also been found very useful for various other purposes such as carving and firewood production, provision tanning and dyeing materials and medicinal application (Sagna *et al*., 2014). *Faidherbia albida* is also a very useful fodder species which produce an excellent feed for animals. Its versatility as soil improver and provider of many useful products might have accounted for its deliberate retention on the fields by farmers.

Another woody species that was common to the natural fallow and Agroforestry systems of the study area is *Sclerocarya birrea*. It is an important fodder species whose leaves are browsed by cattle. Its wood is very good for firewood, charcoal and handicraft. Its various parts have been found to be of important medicinal value (Atato *et al*., 2010, Zerbo *et al*., 2011). The high density of woody species recorded in all sites in this study may be attributed to the use of weak diameter at breast height (5 cm minimum) and the inclusion of shrub species in the enumeration. Expectedly, tree/shrub density was highest in the natural forest while the Agroforestry systems had the least value. Although the agroforestry plots contained a large variety of woody species, Shannon index indicated that they show a lower species diversity than the natural forest.

Conclusion

The analysis of the forest diversity in the agroforestry landscape of Sahelian zone leads us to notice a consistent difference in the land-use types. Indeed, the comparison floristic diversity parameters (forest composition by family, genus and species) reflects their evolution in relation to the reference plot. It appears from this analysis that the Sahelian forest is more dense specifically (366 individuals) than natural fallow (344 individuals) and the Agroforestry systems (228 individuals). Similarly, in terms of specific richness, the Sahelian forest is more diversified (55 species) than those in landscape agroforestry including Natural fallow and Agroforestry systems respectively 35 and 26 species. Despite the remarkable difference in biodiversity between plots in agroforestry compared to the Sahelian forest, the agroforestry systems are much more diverse and dense than the cleared land-use or monoculture. Then, density of individuals according to practice confers them a structure close to the sahelian forest in the landscape. But considering the anthropic pressures, the complete regeneration is difficultly possible in Sahelian zone. In addition, the weakness of the practice at regional and local level is explained by the absence of institutional standards and monitoring of farmers who practice agroforestry according to their socio-economic and cultural conceptions. This situation reduced the possibilities of conservation in plantations and fields. In front of the threat of total disappearance of the Sahelian forest, the practice of agroforestry is considered in the area as

the most favourable mean of the floristic biodiversity conservation which is necessary to value and improve.

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