Original Research Article

Litter production and organic compound contents in the sudano-guinea savannahs of Ngaoundere, Adamawa, Cameroon

Abstract: Litter production which is important for understanding nutrient cycling and assessing productivity in forest ecosystems is poorly studied in the African savannahs, particularly in the Savannahs of Cameroon. Thus, litter production and organic compounds of the thirty-six (36) contrasting plant species were studied in the Sudano-guinea savannahs of Ngaoundere, Cameroon. Litter collected in framework of 50 cm x 50 cm under the three tree of each plant species in three sites of the savannahs of Ngaoundere during the period of their maximum fall that from November and January. After two years of collection, mean annual litter production varied from 0.36 in *S. longepedunculata* to 10.06 $t.ha^{-1}.year^{-1}$ in *F. polita* at Dang, from 0.14 in *G. aqualla* to 9.39 $t.ha^{-1}.year^{-1}$ in *V. paradoxa* at Biskewal, and from 0.35 in *G. aqualla* to 3.64 $t.ha^{-1}.year^{-1}$ in *S. guineense* var. *macrocarpum* at Wakwa. Contribution of leaf litter, fruits and wood were respectively more than 50%, 1.40% and 32% to the total litter. Litter production varied from 2.35 $t.ha^{-1}.year^{-1}$ at Wakwa to 2.91 $t.ha^{-1}.year^{-1}$ at Dang, but the sites did not differ significantly among them. Litter cellulose content varied from 4.11 in *P. hookeri* to 11.84% in *V. doniana*, that of lignin from 2.28 in *V. paradoxa* to 8.12% in *V. doniana*, that of NDF from 21.35 in *S. guineense* var. *guineense* to 75.73% in *S. guineense* var. *macrocarpum*, and that of phenolic compounds from 0.47 in *V. doniana* to 16.11% in *C. molle*. Litter production and organic compounds content were affected by plant diversity, but not by sites in the Sudano-guinea Savannahs of Ngaoundere, Cameroon. These results would contribute to well select plant species for their domestication and to management of Adamawa Savannahs of Cameroon.

Key-words: Litter production, organic compound, Sudano-guinea savannahs, Ngaoundere, Cameroon.

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1. INTRODUCTION

Litter production is a major functional part of any ecosystem as it plays a vital role in regulating carbon and nutrient cycling, and soil fertility [1,2]. A substantial amount of organic matter returns to the forest floor through litter production [3]. Leaves constitute about 50 to 90% of the total litter production in various ecosystems including savannah ecosystems [4,5]. Litter action on soil is especially noted in the improvement of its physical, chemical and biological properties, as well as in the plant nutrition by increasing the availability of water under the canopy [6]. In terrestrial ecosystems, litter production reduces bulk density, increases water holding and the cation exchange capacities of the soil. Xu et al. [7] suggested that greater litter production inputs increase the soil carbon sink despite higher rates of carbon release and transformation. In addition, litter on the forest floor plays a significant role in determining the moisture status, runoff pattern and release of nutrients accumulated in the aerial parts of the vegetation [8,9]. Litter production in the forest ecosystem is also essential in the exchange of carbon from terrestrial ecosystems to the atmosphere [10]. It also provides nutrient input and organic matter replenishment and hence, an important stage in habitat conservation [11]. Recent studies indicated that litter production in forest ecosystem formed an important source of nutrients and organic matter over the past decades [3,12].

However, climate, seasonality, tree species composition, stand structure, soil fertility, elevation, latitude and logging alter directly the litter production in ecosystems [8,13,14, 15,16,17]. According to Spain [18], the most extreme variability of litter is seen as a function of seasonality. He reported that individual species of plants have seasonal losses of some parts of their body and can be determined by the collection and classification of plant litter production throughout the year. Qiu et al. [19] also observed that abiotic factors such as rainfall, temperature and light play an important role in litter production, flushing among dominant canopy species in the forest. Other workers reported that seasonal litter production

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is highest in dry months and lowest in the wet months of a year particularly in tropical forests [20,21,22,23].

In the Sudano-guinea savannahs of Cameroon, economic activities are based on agriculture and livestock farming. Agricultural soils dominated by cotton growing and cultivated with food crops are becoming depleted of nutrients year after year under the combined pressure of livestock, bush fires and crop exports. The physical qualities of soils are becoming increasingly poor (depletion of clay, reduction of water holding capacity, induration of shallow horizons) and the fertility of cultivable soils is gradually decreasing [24]. In this context, cropping systems must integrate judicious soil management in order to improve and maintain their productivity. Therefore, the addition of organic or mineral fertilizers could help to meet the nutrient requirements of the crops [25,26]. However, organic fertilizers are poorly used because agriculture is not systematically integrated with livestock and mineral fertilizers are inaccessible to average farmers [27,28]. It is therefore necessary to find other ways to improve agricultural production and diversify farmers' sources of income while protecting the natural environment. The best accepted alternative currently is agroforestry.

One of the functions of this technique is the maintenance or improvement of soil fertility through the introduction into farming systems, plant species whose litters are an important source of organic matter and nutrients. The production of these litters is a key process to build a nutrient reserve that will be available for plants and soil biological activities. Although many studies have been done on the litter decomposition in the Ngaoundere Savannahs [29,30,31,32,33,34], researches related to litter production and organic compound contents are very small [5,30]. Understanding litter production and factors controlling this process is one of an indispensable step for plant species selection to domesticate in the Sudano-guinea savannahs of Adamawa Cameroon. In the present study the main objective

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was aimed to determine litter production, organic compound contents, and the effect of soil types on litter production in the Sudano-guinea savannahs of Ngaoundere, Cameroon.

2. MATERIALS AND METHODS

2.1 Study Sites

The study site is located in Adamawa region (6º - 8º N, 12º - 15º E, altitude 1100 m asl). The climate is humid Sudano-guinea according to Suchel [35] with two seasons. The rainy season extends from July to September, registering maximum amounts in August. The dry season stretches from November to March. The mean annual rainfall is about 1500 mm, with a variation coefficient of 9.8. The mean annual temperature is approximately 22°C and the mean relative humidity about 69%. The seasonally arid situation of Adamawa region is due to the influence of the Harmattan (dry wind) which recalls the harsh climatic conditions of the Sudano-sahelian savannahs, while its rainfall and its thermal amplitude recall the humid subequatorial regions [36]. While Ferralitic soils are the dominant types [37], with rich clay (40 à 60%), low organic matter (less than 1%), low soil exchange capacity from 15 to 20 meq/100g and the pH 4.7 to 5.6 [38]. Vegetation of Adamawa is a humid savannah type, consisting of shruby and woody savannahs. These savannahs originally populated with *Daniellia oliveri* and *Lophira lanceolata* [39]. There were also hydromorphic prairies that were sometimes inundated and contained *Hypparhenia rufa*, forest galleries with *Syzygium guineense* var. *guineense* and *Berlinia grandifolia*, degraded fallow lands and savannahs, occasionally used as grazing land which were composed of *Acacia hockii*, *Afzelia africana* [39]. Now, this vegetation is much reduced under the influence of zoo-anthropic factors such as wild fires and rearing [40]. Agriculture is still traditional. Livestock remains the main economic activities practiced by the more than 20% of the rural population.

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Three study sites were selected in the Ngaoundere subdivisions. This choice was made according to the type of vegetation, in particular the presence of numerous plant species used in the region, the low disturbance, the type of soil. These sites are Biskewal, Dang and Wakwa. The first is located 2 km east of the Ngaoundere city, the second and third are located 15 km north and 10 km south of this city. The soils of these sites are developed on basaltic (Dang), granitic (Biskewal) and granitic/basaltic (Wakwa) bed rock. These soils are the most representative of the Sudano-guinea savannahs of Cameroon. The geographical coordinates and soil characteristics of these sites are presented in Table 1.

2. 2. Plant species selection

To characterize the litters of plant species of the Sudano-guinea savannahs of Ngaoundere according to their production and biochemical quality in order to choose the best species for the sustainable management of soil fertility of farming systems of Adamawa, thirty-six (36) plant species, including woody and herbaceous, evergreen and deciduous, native and exotic plant species (Table 2) were selected from Ngaoundere savannahs, based on the study sites. All these plant species are commonly used for their wood, roots, fruits, fodder and the drugs or caterpillars they produce, etc.. [5,41,42].

2. 3. Litter collection

The methods for estimating litter production are numerous and varied [4,43]. These several approaches are one of the most controversial issues in the study of litter production [44,45]. Annual litter production estimate was chosen from the seasonal one because of the period of litterfall, bush fires and overgrazing in savannahs. Most African savannah plant species are deciduous that lose their litter once a year, in the dry season. In the present study, the method used by Mitchell et al. [4] and Mapongmetsem [5], which best fits the context of Sudano-guinea savannah was selected. Litter was collected in 3 sites (Dang, Biskewal and Wakwa) of

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Ngaoundere, which constitute our study sites. Litter was collected two successive years (2005/2006 and 2006/2007) under the individual plant (trees or shrubs) canopy, using a square frame of 50 cm side. Collections were carried out just after their maximum fall situated between November and January, depending on the species. The entire litter (leaves, wood, flowers and fruits) present in the frame was picked up. Indeed, the leaf litter of the year n-1 differs from that of the year n by its color and its thickness. In the first year (2005/2006), litters of thirty-three (33) plant species were collected: 30 at Dang, 11 at Biskewal and 7 at Wakwa, whereas in the second year (2006/2007), twenty-two (22) types of litters were collected, including 15 in Dang, 13 in Biskewal and none in Wakwa. For each plant species, three trees or shrubs healthy and completely defoliated were chosen and for each tree or shrub three replicates were made. This gave 9 replicates for each plant species. The experimental design was a completely randomized block with 9 replicates. The collected litter was returned to the laboratory in polyethylene bags. Before going to the oven, the litters were sorted and separated into categories: foliar litter of year n (F0), that of years n-1 (F1), wood of diameter <2 cm and twigs (WO), flower (FL), fruit and seed (FR), and the rest (RE).

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2. 4. Chemical analysis

The litters were analysed chemically after passing through a cyclone mill with a l-mm mesh. Ash content was measured after combustion in a muffle furnace at 550°C for 3h. The concentration of phenol, cellulose, lignin and NDF (neutral detergent fiber) were respectively determined by Dubois *et al.* [46] method, by Folin-Ciocalteu reagent [47], by colometric method [48] and by van Soest’s [49] and detergent method.

2. 5. Statistical analysis

Before forming any analysis, all variables was tested for normality and if necessary, log transformed. Using a one-way ANOVA, following by *Scheffe*’s mean comparison test at 5%

(if ANOVA was significant), we compared litter production among species, and study sites. *Student* t test was also used to compare litter production between 2 sites. These tests were conducted through software package SX for DOS, version 4.0. (Statistix, 1992).

3. RESULTS

3. 1. Litter production

Annual litter production in the Sudano-guinea savannahs of Ngaoundere differed significantly among plant species and varied from 0.36 to 10.06 $t.ha^{-1}.year^{-1}$ at Dang, from 0.14 to 9.39 $t.ha^{-1}.year^{-1}$ at Biskewal, and from 0.35 to 3.64 $t.ha^{-1}.year^{-1}$ at Wakwa (**Table 3**). In each of the three sites, three groups of plant species were observed according to their litter production. The first group was formed by plant species whose litter production was the highest, there are *F. polita*, *V. paradoxa*, *S. g*. var. *macrocarpum*, and *T. macroptera*. While the second group was including *S. longepedunculata* and *G. aqualla* whose litter production was the lowest respectively at Dang, and Biskewal and Wakwa. The other plant species were constituted the third group whose litter production was intermediate in the three sites.

Litter production was composed of leaves (newly and old), wood, and reproductive organs as flowers and fruits with various contributions **(Figure 1 A, B, and C)**. Leaf litter production, particularly those of the last year (F0), was higher in the three study sites, excepted of *P. thonningii* at Dang where the amount of fruits and grains produced (2.24 $t.ha^{-1}$) was higher than that of leaf litter **(Figure 1A)**. Leaves were the main component of litter production accounting for more than 50% of the total litter amount, followed by the woody fraction (less than 32.45%), except for *P. thonningii* at Dang where the fruits accounted about 55%. However, including all plant species, fruit contribution was less than 1.46% of the total litter amount.

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3. 2. Comparison of litter production among study sites

Mean annual litter production varied from 2.35 at Wakwa to 2.91 $t.ha^{-1}.year^{-1}$ at Dang. These three study sites were not differed significantly (F= 0.204, P=0.816) among them according to their litter production. Contrary, litter production of each plant species varied significantly among the study sites, except those of *L. lanceolata* and *T. macroptera*, which were not differed significantly among study sites **(Table 3)**. In fact, *T. albida* produced more litter at Wakwa than at Biskewal, while litter productions of *A. zygia*, *E. sigmoidea*, *V. doniana*, and *V. paradoxa* were higher at Biskewal than at others sites. Differences between Dang and Wakwa were not significant for *V. doniana*, and *V. paradoxa*. For others plant species, it was at Dang that litter production was significantly the highest.

3. 3. Litter nutrient contents

Four organic compounds (cellulose, lignin, NDF and phenolic compounds) of litters of only nineteen (19) plant species were determined (**Table 4**). Cellulose and lignin contents varied from 4.11 to 11.84%, and from 2.28 to 8.12% respectively, while that of NDF from 21.35 to 77.73% and lastly phenolic compounds from 0.47 to 16.11%. Plant species differed significantly among them according to their organic compounds contents. *V. doniana* was the richest in cellulose (11.84%) and in lignin (8.12%), the lowest in phenolic compounds (0.47%) and its fiber content (NDF) was intermediate (63.72%). *P. hookerii* and *V. paradoxa* were the lowest in cellulose and lignin contents respectively and their others organic contents were intermediate. NDF content was lower in *S. g*. var. *guineense* than in the others plant species. It should be noted that plants species as *V. doniana*, the richest in cellulose had the lowest phenolic compounds content and vice-versa. The verbenaceae as *V. doniana* and *V. madiensis*, were not differed significantly between them by their organic compound contents. Similarly, the Myrtaceae as *S. g*. var. *macrocarpum* and *S. g*. var. *guineense* were not also

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differed between them, except that of fibers (NDF) which was three times higher in *S. g*. var. *macrocarpum* than in *S. g*. var. *guineense.*

4. DISCUSSION

4. 1. Litter production

Annual litter production in the Sudano-guinea savannahs of Ngaoundere varied from 0.14 to 10.06 $t.ha^{-1}.year^{-1}$, and ranged between those of Sudanian savannahs and Tropical rain forests. In fact, litter production annually in the Sudano savannahs of North Cameroun ranged from 1.00 to 4.73 $t.ha^{-1}$ [50] and those in the Tropical humid forest of Cameroon and Ivory Cost from 8 to 15 $t.ha^{-1}$ [22,23,51]. Similarly, in Congolese savannah of Teke, Ifo and Nganga [52] have reported a total litter production ranging from 10.63 to 10.97 $t.ha^{-1}$. In south African Savannah, Mitchell et al. [4] have found that litter production of shrubs varied from 3.57 to 4.29 $t.ha^{-1}$ during two years. In the Sudano-guinea savannahs of Adamawa, Mapongmetsem [5] estimated the litter production of eight agroforestry plant species (*Annona senegalensis, Lophira lanceolata, Parkia biglobosa, Syzygium guieense* var. *macrocarpum, Vitex doniana, Vitex madiensis*, *Vitellaria paradoxa* and *Ximenia americana*) was 21.58 $t.ha^{-1}.year^{-1}$ and ranged from 10.87 to 23.29 $t.ha^{-1}.year^{-1}$ according to plant species. These values were higher than ours and would be explained by plant diameter and age, wind action, as well as litter collection period. In fact, Mapongmetsem [5], Celentano et al. [53] and Becker et al. [14] pointed out that these parameters influenced the litter production in savannahs. In addition, the duration of litter collection was two years in our study, unlike that in the Mapongmetsem [5] studies, which was five years.

Leaf litter production was higher at all three study sites, with a contribution of well over 50% of total production, except for *P. thonningii* at Dang where the contribution of its fruit litter was more than 50%. Same results have been reported by Salako and Tian [54] for fallows, by Egbe et al. [55] for *Millettia thonningii* and *Pterocarpus santalinoides* in south-west of

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Nigeria. Ifo et al. [52] found a leaf litter contribution of over 95% of the total production in the Congolese savannahs of Teke. Mapongmetsem [5] has shown that the contribution of leaf litter to total litter was greater than 70% in eight species of Ngaoundere savannahs, except for *P. biglobosa* where the contribution of leaves was less than 50% of total litter. Litter production of *P. thonningii* was low in Dang compared to fruits and seeds (2.24 $t.ha^{-1}$), because its density ($individuals.ha^{-1}$) is low in this site and all energy would be allocated for large fruit production, such as Mapongmetsem [5] pointed out that the production of plant organs varies with the year.

4. 2. Effects of soil types on litter production

Overall, litter production was not influenced by the soil type (or study site). This can be explained by the species composition and diversity of each site, and confirmed those of Mapongmetsem [5] on the eight plant species of the Sudano-guinea savannahs of Ngaoundere, Cameroon. He suggested that litter production was globally independent of soil type and microclimate in the Sudano-guinea savannahs of Cameroon during the period of his studies. Piot [56] had already shown that in the savannahs of Wakwa, Adamawa Cameroon, it is essentially the fire and water factors (forest gallery, water table, etc.) that determine the distribution of woody species, the soil type intervening only secondarily.

However, considering plant species one by one, litter production varied significantly among soil types (or localities), except for *L. lanceolata* and *T. macroptera*, for which the differences between soil types were not significant. Indeed, a characteristic species of the savannahs of Adamawa by its abundance according to Letouzey [39], *L. lanceolata* was currently undergoing a strong anthropic pressure which has led to its low abundance [57] and makes it less exclusive of these savannahs [56], with low litter production that would not likely detect significant soil-type effect. With regard to *T. macroptera*, Piot [56] reported that it is a dominant species of these savannahs at present, and its development occurs in both

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granitic and basaltic soils, and confirmed the absence of soil effect on the litter production for these two sites (Dang and Wakwa).

For the plant species remain, it was in Dang that their litter production was the highest and the lowest in Biskewal. These sites are differentiated by their climatic characteristics, in particular the relative humidity which is 63% in Dang, 93% in Biskewal and 76% in Wakwa [5]. These climatic conditions seem to explain the differences between sites that the soil type as Piot [56] had already shown on the specific development of plants species in these savannahs. In fact, Dang site, which had high litter production, has low relative humidity, whereas Biskewal site had low litter production and high relative humidity. Wakwa site had an intermediate position. These results were consistent with those of Gnahoua et al. [58]), Zhang et al. [59] and Diallo et al. [60], who showed that the largest amount of litter production was done in the dry season when humidity is low and was low during the rainy season when the humidity was high. According to Ogaya and Penuelas [61], and Misson et al. [62], drought-induced xylem cavitation that can accelerate branch and leaf fall in summer.

4. 3. Litter organic compound contents

Cellulose content in litter ranged from 4.11 to 11.84%, that of lignins from 2.28 to 8.12%, that of NDF from 21.35 to 77.73, and that of phenolic compounds from 0.47 to 16.11%. These values were average relative to those reported by previous studies in the different savannahs [4, 63], except for the phenol content which was among the highest values. Indeed, Mapongmetsem [5] reported for 8 plant species of Ngaoundere savannahs, cellulose, lignin, NDF and phenolic compound contents were very low compared to ours. These values were ranged from 1.46 to 3.28 for cellulose, from 1.05 to 3.47% for lignin, from 46.32 to 72.51% for NDF, and finally from 1.26 to 7.48% for phenolic compounds. Mitchell et al. [4] found in their litter production studies that the lignin content ranged from 1.73 to 3.60% for three species (Proteoid, Ericoid and Restiod) of savannahs of South Africa. Oyebamiji et al. [63]

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also reported values from 8.24 to 11.06% for lignin and from 0.57 to 0.75% for phenolic compounds in the litter of *Albizia lebbeck* and *Parkia biglobosa* in the savannahs of Nigeria. The litter of *Jatropha curcas* contains a lignin content of 12.03% according to Abugre et al. [64]. In the Senegalese, Mozambican and Tanzanian savannahs, Dieye et al. [65] found that litters produced contained cellulose and lignin contents ranging from 17.1 to 26.5% and from 22.7 to 27.8%, respectively. In the Miombo savannahs in Zimbabwe, Wuta et al. [66] found that litters of these savannah plant species contained a lignin content of 33.44%, a cellulose content of 20.90, and polyphenols content of 4.85%. These observed differences would related to definition of lignin, phenolic compounds, type of chemical analysis, types of savannahs or study sites that are different.

4. 4. Comparison among plant species

Annual litter production and their organic compound contents in the Sudano-guinea savannahs of Ngaoundere varied significantly among plant species. The highest litter production was found in *F. polita* (10.06 $t.ha^{-1}.yr^{-1}$) and *V. paradoxa* (9.39 $t.ha^{-1}.yr^{-1}$), the lowest one in *S. longepedunculata* (0.36 $t.ha^{-1}.yr^{-1}$) and *G. aqualla* (0.14 $t.ha^{-1}.yr^{-1}$). Overall, trees produced more litter than shrubs and grasses. Mapongmetsem [5] has already reported this finding on the 8 plant species of Ngaoundere savannah of Cameroon. Indeed, according to him, trees such as *P. biglobosa* (32.58 $t.ha^{-1}.yr^{-1}$), *V. paradoxa* (30.03 $t.ha^{-1}.yr^{-1}$) and *L. lanceolata* (27.03 $t.ha^{-1}.yr^{-1}$) produced more litter than shrubs like *X. americana* (18.87 $t.ha^{-1}.yr^{-1}$), *S. guineense* var. *macrocarpum* (17.38 $t.ha^{-1}.yr^{-1}$), *A. senegalensis* (15.44 $t.ha^{-1}.yr^{-1}$), and *V. madiensis* (14.79 $t.ha^{-1}.yr^{-1}$). Sundrapandian and Swamy [21] also found similar types of results in the Koayar site in tropical India. These differences between trees and shrubs can be explained in part by the differences in their crowns, which is more developed in trees than shrubs, as has pointed out by Mapongmetsem [5]. However, exceptions exist and can be explained by the wind effects such as the Harmattan that blows during dry season in these

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savannahs, defoliating insects or plant species habitat. Indeed, the obvious examples were given by trees such as *V. doniana* (1.11 $t.ha^{-1}.yr^{-1}$) and *U. togoensis* (2.62 $t.ha^{-1}.yr^{-1}$) which produced less litter than shrubs, such as *M. senegalensis* (6.23 $t.ha^{-1}.yr^{-1}$) and *P. thonningii* (6.46 $t.ha^{-1}.yr^{-1}$). *V. doniana* and *U. togoensis* are forest gallery species, a wetland and less stressful in the dry season than the upland savannah which constitute a habitat of *M. senegalensis* and *P. thonningii*. Mapongmetsem [5] had previously reported this type of finding on the plant species of Ngaoundere savannah, between the forest gallery tree, *V. doniana* (16.49 $t.ha^{-1}.yr^{-1}$) and the savannah shrub, *S. guineense* var. *macrocarpum* (17.38 $t.ha^{-1}.yr^{-1}$).

In some families, such as Verbenaceae (*V. doniana* and *V. madiensis*) and Myrtaceae (*S. g.* var. *macrocarpum* and *S. g.* var. *guineense*), the plant species did not differ significantly (P>0.05) from one another by their litter production and their organic compounds contents. Indeed, although they differed in their growth form and habitat, *V. doniana* and *S. g.* var. *guineense* on the one hand and *V. madiensis* and *S. g.* var. *macrocarpum* on another hand were not different in their litter production and organic compound contents, except that of fiber (NDF) which was 3 times higher in *S. g.* var. *macrocarpum* than in *S. g.* var. *guineense*. *V. doniana* and *S. g.* var. *guineense* are gallery forest trees, while *V. madiensis* and *S. g.* var. *macrocarpum* are shrubs of savanna upland. This lack of differences between species of the same family despite certain distinctive features may be due to the maintenance of ancestral traits, pure chance or a factor that did not appear clearly in this study.

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4. 5. Implication for Savannah management

The results of this study have practical implications for domestication woody species and savannah management, particularly those of Ngaoundere Cameroon. In fact, wet savannahs contribution in the evaluation of biogeochemical cycles, in particular that of carbon was not negligible, because the present results compared to those of Harmand [50] for the Sudanian savannahs of Cameroon and those of Bernard [51] and Ibrahima et al. [22, 23] for tropical forests showed that litter production in wet savannas was more 170% than that of Sudanian savannahs and just over 40% that of tropical rainforests. This being said, the importance of the Sudano-guinea savannahs is not negligible with regard to the production of organic matter and for a good precision, the evaluations of litter production and organic matter cycle, particularly carbon cycle, must take into account the humid savannas.

With increased demand for forest resources and energy, due to population growth and poverty, savannah exploitations and their conversion to habitats and crops are gaining momentum in recent years in the Ngaoundere of Cameroon [67]. The high litter production obtained in this study suggested that during conversions of these savannahs that a significant litter amount will be lost or transformed into carbon that will be emitted into the atmosphere. To face with these practices, alternatives to sustainable improve the productivity of these savannahs and limit conversions of natural savannahs to crops could be recommended. Population fixation in savannahs and sustainable crop intensification are means of preventing deforestation and subsequent loss of organic matter in natural savannahs. For these recommendations to be effective and timely, to limit losses of organic matter and carbon emissions, incentives measures would be needed leading to an immediate source of income for poor farmers.

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5. CONCLUSION

It emerges from this study that the litter production of humid savannahs of Ngaoundere varied from 0.14 to 10.06 $t.h^{-1}.year^{-1}$ and among the lowest values of the humid savannahs. These values were situated between these of Sudanian savannahs and Tropical rainforests. The contribution of the leaf litter to the total litter production was higher than that of the other fractions, more than 50%. This production showed interannual variation, due to the phenology of the vegetation. The litter production was affected by plant species and soil type (or study site) according to plant species, but not overall. The litter organic compound contents as cellulose (4.11 – 11.84%), lignin (2.28 – 8.12%), NDF (21.35 – 77.73%) and phenolic compounds (0.47 – 16.11%) were among the mean values of the same savannahs types. These results would contribute to the soil fertility management in the sudano-guinea savannahs of Ngaoundere by selecting plant species based on the quality and quantity of their produced litter.

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Table 1: Geographical coordinates and soil characteristics of these sites.

Parameters	**Study sites**		
	Dang	**Biskewal**	**Wakwa**
Latitude	7º25’	7º18’	7º15’
Longitude	13º33’	13º37’	13º34’
Altitude (m)	1106	1139	1222
Bed rock	Basalt	Granit	Granit/Basalt
Soil color	Brown-red	Brown olive to brun fonce	Brown-red
Structure	Medium polyedric	Medium polyedric	Fine polyedric
Texture	clay	Clay	Clay-sandy
Compacity	Compact	less compact	Medium
Relative humidity (%)	63.0	93.0	76.0
Ph	4.6	6.1	4.4
N (%)	0.2	0.6	0.1
C (%)	2.9	3.6	1.9
P	0.2	0.4	0.1
K	0.7	2.0	0.4
Ca	52.0	28.3	6.0
Mg	20.0	71.0	3.0
Na	0.4	0.2	0.2

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Table 2: Composition of selected plant species.

Families	Plant species	Code	Habitat
Broad-leaved deciduous très			
Anacardiaceae	*Lannea schimperi* (Hochst. ex A. Rich.) Engl.	LS	Various
Apocynaceae	*Voacanga africana* Stapf.	VA	Planted
Bixaceae	*Bixa orellana* L.	BO	Planted
Caesalpiniaceae	*Daniellia oliveri* (Rolfe) Hutch. et Dalz.	DO	Savannah
Combretaceae	*Combretum molle R. Br. ex G. Don*	CM	Savannah
	Terminalia albida Scott Elliot	TA	Savannah
	Terminalia glaucescens Planch.	TG	Savannah
	Terminalia macroptera Guill. et Perr.	TM	Savannah/Forest-gallery
Euphorbiaceae	*Bridelia ferruginea* Benth.	BF	Savannah
Fabaceae	*Erythrina sigmoïdea* Hua	ES	Savannah
Moraceae	*Ficus polita* Vahl	FP	Savannah
	Ficus thonningii Blume	FT	Savannah
Ochnaceae	*Lophira lanceolata* Van Tiegh. ex Keay	LL	Savannah
Sapotaceae	*Vitellaria paradoxa* Gaertn. C. F.	VP	Savannah
Verbenaceae	*Vitex doniana* Sweet	VD	Forest-gallery
Broad-leaved evergreen trees			
Anacardiaceae	*Anacardium occidentale* L.	AO	Planted
Euphorbiaceae	*Uapaca togoensis* Pax	UT	Forest-gallery
Mimosaceae	*Albizia zygia* (DC.) J.F. Macbr.	AZ	Savannah/Forest-gallery
Myrtaceae	*Syzygium guineense* var. *guineense* (Willd.) DC.	SG	Forest-gallery
Broad-leaved deciduous shrub			
Annonaceae	*Annona senegalensis* Pers.	AS	Savannah
Asteraceae	*Thitonia diversifolia* (Hemsl.) A. Gray	TD	Open savannah
Celastraceae	*Maytenus senegalensis* (Lam.) Excell	MS	Savannah
Caesalpiniaceae	*Piliostigma thonningii* Milne-Redh.	PT	Savannah
Fabaceae	*Mucuna stans* L.	MS	Savannah
Guttifereae	*Psorospermum febrifugum* Spach	PS	Savannah
Hymenocardiaceae	*Hymenocardia acida* Tul.	HA	Savannah
Loganiaceae	*Strychnos spinosa* Lam.	SS	Savannah
Myrtaceae	*Syzygium g.* var. *macrocarpum* (Engl.) F. White	SM	Savannah
Olacaceae	*Ximenia americana* L.	XA	Savannah
Rubiaceae	*Gardenia aqualla* Stapf. et Hutch.	GA	Savannah
Verbenaceae	*Vitex madiensis* Oliv.	VM	Savannah
	Lantana camara L.	LC	Savannah
Broad-leaved evergreen shrub			
Guttifereae	*Harungana madagascariensis* Lam. ex Poir.	HM	Humid savannah
Broad-leaved semi-deciduous shrub			
Polygalaceae	*Securidaca longepedunculata* Fres.	SL	Semi-Décidu
Herbs			
Fabaceae	*Pseudarthria hookeri* Wright & EL. Arn.	PS	Open savannah
Proteaceae	*Protea madiensis* Oliv.	PM	Open savannah

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Table 3: Mean annual litter production in the three study sites of the Sudano-guinea savannah of Ngaoundere during two years (2006 and 2007).

Plant species	Dang	Biskewal	Wakwa	t *Student*
A. zygia	0.99 (1.44)bc	2.78 (0.75)bc	-	3.30**
A. occidentale	-	3.55 (0.94)bc	-	
A. senegalensis	3.57 (0.79)bc	1.73 (1.29)bc	-	3.66**
B. orellana	4.39 (1.42)abc	-	-	
B. ferruginea	2.59 (1.58)bc	1.02 (0.70)bc	-	2.72*
C. molle	0.60 (0.58)bc	-	-	
D. oliveri	5.72 (2.41)abc	-	-	
E. sigmoidea	1.51 (1.24)bc	2.92 (1.41)bc	-	2.24*
F. polita	10.06 (4.57)a	-	-	
F. thonningii	4.93 (1.93)abc			
G. aqualla	1.03 (0.90)bc	0.14 (0.28)c	0.35 (0.52)b	5.06*π
H. madagascariensis	0.82 (1.27)bc	-	-	
H. acida	3.19 (0.80)bc	1.59 (0.56)bc	-	4.91***
L. camara	4.41 (1.16)abc	-	-	
L. schimperi	2.12 (0.57)bc	-	-	
L. lanceolate	2.90 (1.49)bc	-	1.86 (1.51)ab	1.47ns
M. senegalensis	6.23 (2.81)abc	2.66 (1.61)bc	-	3.30**
M. stans	1.55 (0.69)bc	-	-	
P. thonningii	6.46 (4.53)ab	2.42 (1.77)bc	-	2.49*
P. madiensis	0.49 (0.78)bc	-	-	
P. febrifigum	2.90 (1.48)bc			
P. hookeri	1.17 (0.29)bc			
S. longipedunculata	0.36 (0.54)c	-	-	
S .g. var.*Guineense*	3.45 (1.67) bc	-	-	
S. g. var. *macrocarpum*	4.68 (1.00) abc	2.83 (1.10) bc	3.64 (0.62) a	8.94***π
S. spinosa	1.94 (3.47)bc	-	-	
T. albida	-	0.83 (1.69)bc	3.38 (0.76) a	4.15***
T. glaucescens	3.28 (1.03)bc	1.42 (0.80)bc	-	4.28***
T. macroptera	3.61 (1.00)bc	-	3.60 (1.59) a	0.02ns
T. diversifolia	1.81 (0.58)bc	-	-	
U. togoensis	2.62 (3.00)bc	-	-	
V. doniana	1.11 (1.69)bc	5.67 (4.36) ab	0.47 (0.73) b	9.66***π
V. madiensis	1.32 (0.44)bc		-	
V. paradoxa	3.96 (1.53)bc	9.39 (5.33) a	3.16 (1.48) a	9.44***π
V. Africana	1.40 (0.41)bc	-	-	
X. Americana	1.67 (1.62)bc	-		
F1	**11.79*** **	**10.80*** **	**15.30*** **	

Significant at * P < 0.05, ** P < 0.01, *** P < 0.001. Values with same letters in row are not significantly different among sites. π: result of ANOVA test.

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Table 4 : Mean of organic compounds content (%) of leaf litters of year (F0). Standard deviation in parenthesis.

Plant species	**Cellulose (%)**	**Lignin (%)**	**NDF (%)**	**Phenolic compounds (%)**
A. senegalensis	8.57 (1.97) abcd	4.78 (1.31) abcd	77.01 (2.95) a	2.27 (1.95) ef
C. molle	9.45 (1.39) abc	5.83 (0.08) abcd	63.43 (8.85) ab	16.11 (13.30) a
H. acida	5.44 (1.02) bcd	3.83 (0.55) bcd	76.43 (12.15) a	13.54 (9.12) ab
L. schimperi	7.45 (1.90) abcd	5.43 (0.01) abcd	56.38 (12.96) ab	4.98 (2.83) cdef
L. lanceolata	6.48 (1.63) bcd	5.65 (1.30) abcd	60.63 (23.96) ab	1.00 (0.12) ef
M. stans	8.57 (0.01) abcd	6.51 (0.24) abc	72.62 (8.83) a	5.33 (2.49) bcdef
P. thonningii	8.97 (0.66) abc	5.68 (0.53) abcd	70.85 (8,23) a	9.44 (6.92) abcdef
P. madiensis	8.76 (1.93) abcd	4.89 (0.06) abcd	57.51 (18.68) ab	1.05 (0.39) abc
P. hookerii	4.11 (0.3) d	4.29 (2.68) abcd	77.73 (6.57) a	8,71 (5.63) abcdef
S. longepedunculata	6.96 (0.54) bcd	5.43 (1.60) abcd	66.43 (0.24) ab	8.18 (0.08) abcdef
S. g. var. *guineense*	8.34 (0.19) abcd	2.84 (0.68) cd	21.35 (0.17) b	4.79 (0.35) bcdef
S. g. var.*macrocarpum*	9.88 (1.32) ab	5.94 (0.61) abcd	75.78 (6.92) a	3.59 (0.11) def
T. macroptera	9.30 (1.84) abc	4.56 (1.76) abcd	80.41 (4.47) a	10.76 (4.70) bcde
T. diversifolia	9.49 (1.10) abc	5.63 (0.04) abcd	59.61 (17.14) ab	1.21 (0.38) ef
U. togoensis	5.38 (1.52) cd	5.16 (1.18) abcd	77.23 (10.91) a	13.25 (10.02) abc
V. doniana	11.84 (0.17) a	8.12 (1.12) a	63.72 (0.63) ab	0.47 (0.01) f
V. madiensis	7.90 (1.49) abcd	5.37 (1.61) abcd	67.07 (10.37) a	9.91 (2.46) abcdef
V. paradoxa	6.63 (0.91) bcd	2.28 (0.09) d	65.97 (4.59) ab	0.99 (0.02) ef
X. Americana	6.35 (0.90) bcd	4.16 (0.85) bcd	69.18 (6.28) a	7.47 (1.01) abcdef
F	5.08***	3.04**	2.63*	2.18*

Significant at * P< 0.05; ** P< 0.01, *** P< 0.001. Values with the same letters in column are not significantly different.

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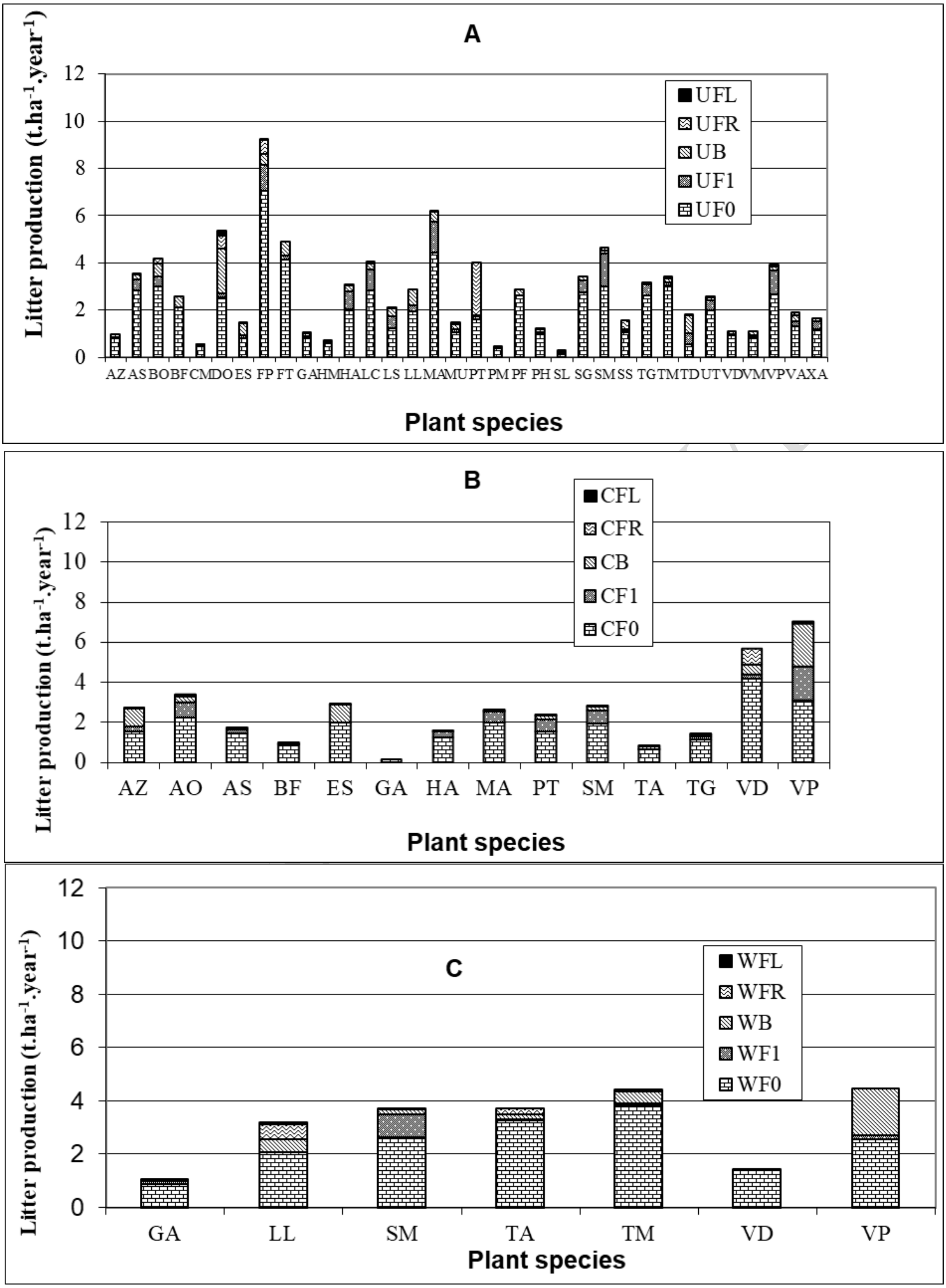

Figure 1: Litter production ($t.ha^{-1}.yr^{-1}$) according to category at Dang (A), Biskewal (B) and Wakwa (C). Leaf litter of year n (F0), previous years (F1), wood litter (B), fruits and seed litter (FR), and Flower litter (FL). Dang (U), Biskewal (C), and Wakwa (W).