<u>Original Research Article</u>

Influence of anthropization on the diversity of woody vegetation in Muskuwaari transplanted sorghum field in the Sudano-Sahelian zone of Cameroon

Abstract

Aims*:* Transplanted sorghum is a staple food crop and represents an important part of cereal production in the Far North region. Its cultivation has led to profound agrarian changes and environmental landscape. ***Study design:*** The main objective of the study carried out from 2017 to 2019 in the Far North area was aimed to study the influence of anthropization on the diversity of woody vegetation, its management and conservation of the transplanted sorghum landscape in the Sudano-Sahelian zone. ***Methodology:*** Population surveys in six (06) villages and floristic surveys through 50 m^2 plots in two soil types in these villages were conducted. ***Results:*** The results show that the use of herbicide, cutting down and stump removal of woody plants, essential in most cases, have led to profound changes in the "kare" with the invasion of the fields by weed plants (*Oryza longistaminata, Paspalum orbicular, Striga hermonthica*), post-harvest soil denudation and the disappearance of plant biodiversity. The exploitation of sorghum led to a reduction in the number of woody species from 20 to 9 at the start to the end of the study respectively. Similarly, the average species density decreased over time. The disappearance of 17 individuals was recorded on the clay soil type and 12 on the hydromorphic soil type during the 2 years. Faced with this threat, the practice of agroforestry (4 to 11%), reduction in the use of chemicals (24.19 to 40.32%), abolish harvesting of green wood (0 to 3.33%) and plough to limit the action of fire have been proposed as alternative measures for sustainable exploitation of transplanted sorghum. ***Conclusion:*** Anthropization deeply modifies the landscape of transplanted sorghum and it is at the origin of the disappearance of biodiversity. Co-management would be an effective method for the preservation of the sorghum field.

Keywords: transplanted sorghum, biodiversity, disappearance, anthropization, plant cover, Far North.

Introduction

Undernutrition is a long everlasting problem and progress in this regard is uneven across sub-Saharan Africa. Cereals till date remain the main source of nutrient for more than 962 million people in this part of the world and are therefore essential for food security (OCDE/FAO; 2017). Although its demand has decreased from 33% in 1990-1992 to 23% in 2014-2016, the percentage of undernourished people remains the highest in the developing world (FAO *et al.,* 2015). Agricultural challenges in Africa therefore remain relevant. The statistics provided by the FAO (2009) on agricultural production in the CEMAC zone for the year 2008 showed that the seven most important productions in this zone were cassava, plantains, maize, taros and other roots, yams, sorghum and dessert bananas. Among these foodstuffs, sorghum occupies a prominent place in the human diet. As part of cereals, it plays an important role in the agricultural production system of the savannah areas of Cameroon (Raimond; 1999) and is one of the main food crops in sub-Saharan Africa. It is mainly grown in the dry season on floodplains, also called recession sorghum (Kebe;2002). The place that off-season sorghum or transplanted sorghum occupies in the agricultural calendar in Northern regions (Far north) of Cameroon makes it an important crop that contributes to maintaining food security (Seignobos; 1998; Mathieu *et al*., 2003). However, farming practices characterized by complete clearing before cultivation and the scarcity of fallow land have remarkable consequences on the sustainable management of agropastoral areas, in particular on woody resources (FAO; 2009). Clearings as is the case with Muskuwaari cultivation reduces space for wood harvesting and grazing leading to a desert environment. In order to mitigate this phenomenon of desertification, the State has developed reforestation strategies all over northern regions and this was declared during the “World Food Security” conference in Rome, 2008. Unfortunately, these reforestations have never taken into account “karal” which is still in a state of degradation and the disappearance of plant biodiversity in these environments remains very advanced. The present work therefore aims to study the influence of anthropization of transplanted Muskuwaari sorghum on the floristic diversity in the Sudano-Sahelian zone of the Far North region of Cameroon.

2. MATERIAL AND METHODS

2.1 Description and justification of the study site

The study site is located in Mayo-Kani and Mayo-Danay divisions with headquarters Kaélé and Yagoua respectively. Mayo-Kani division has the surface area of 5,033 km^2 and 404,646 inhabitants. As for Mayo-Danay division, it registers a surface area of 5,303 km^2 and 529,061 inhabitants (OIM; 2017). In total, six (06) villages were chosen from these divisions.

Guidiguis, Touloum and Kaélé in Mayo Kani division and Kalfou, Doukoula and Tchatibali in Mayo Danay division.

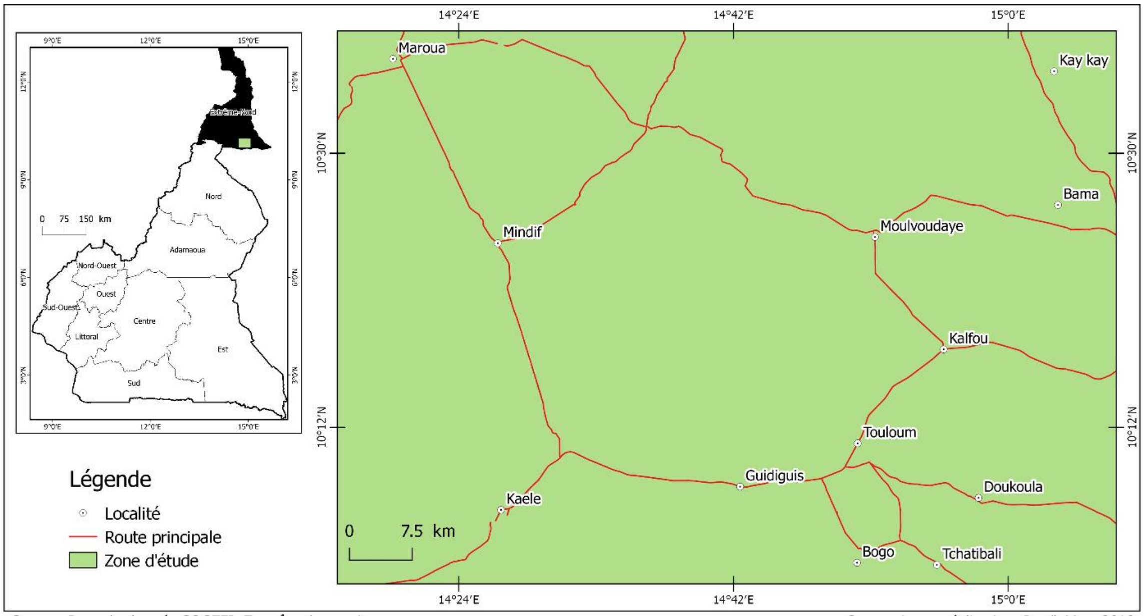

Figure 1 : Cartography of the study sites

2.2 Justification for the choice of study sites

This choice was based on the fact that little or no scientific work has been carried out on Muskuwaari sorghum in these sites and on the other hand, the ease of accessing to information (dialects) and the reconciliation of sites in relation to reduced time for land preparation and sorghum transplanting. Additionally, the choice was based on the vulnerability of the area to climatic hazards and the reduction in the yield of transplanted sorghum according to the surveys. The six chosen villages in this study are those in which there has been a decline in yield with an advanced degradation of the vegetation for the past years and which is gradually leading to the abandonment of several hectares of unexploited fields each year.

2.2.1 Experimental design

The study took place from 2017 to 2019 for two successive years. The data were collected in two phases: before soil tillage (July, August and September) and during harvest (February, March and April). To study the influence of the exploitation of transplanted sorghum on the plant cover, the Split-plot experimental design with two factors was used. The first factor was made up of two (02) types of soil (clay soil (CS) and hydromorphic soil (HS)) as main treatments meanwhile the second factor houses six (06) villages as secondary treatments and six (06) plots of 50 m^2 per village including three (03) per soil type as repetition: Mayo-

Kani division (Village 1: GUIDIGUIS, Village 2: TOULOUM, Village 3: KAELE) and Mayo-Danay division (Village 1: KALFOU, Village 2: DOUKOULA, Village 3: TCHATIBALI).

2.2.2. Socioeconomic surveys

Semi-structured questionnaires comprising of closed (which are answered with yes or no), open (which are answered deliberately according to their point of view) and oriented (some answers of which are offered to the respondent) questions (Tchobsala; 2011). The interviewees were all farmers of transplanted sorghum. The surveys targeted three main aspects: anthropic impacts of the transplanted sorghum on biodiversity, the environment and alternative measures for sustainable and ecological exploitation of transplanted sorghum. A total of 390 farmers were surveyed in the study area, including 65 per village.

2.2.3 Inventories of trees

The surveys were carried out sequentially on five strips of 10 m wide and 50 m. A total of 36 plots of 50 m^2 were chosen from all the six villages at the rate of six (06) plots per village. A 50 m tape was used to delimit these plots, with a labelled stake attached to each of the four corners. An area of 9 ha corresponding to the surface of the 36 plots were explored in all six (06) villages. All the woody species were assessed in 9 ha. The dendrometric parameters used are: height; the number of individuals of each species; the diameter at breast height (DBH at 1.30 m from the ground), measured using a tape; the diameter of the trunk was estimated at the foot of each tree or shrub according to the four cardinal points (North-South and East-West) using a measuring tape. The average of these measurements was determined.

2.2.4 Analysis of floristic composition

Absolute density

It was determined using the formula: **D = N/S**; N = number of individuals on the site and S the unit of area occupied by a taxon.

Relative density

It is determined using the formula: **D = N/S*100**; N = number of individuals on the site and S the unit of area occupied by the species.

Basal area of a tree (BAT)

It represents the area of foliage projection expressed in m^2/ha. It is calculated as follows: **BAT = D2π/4**; where D is the average horizontal distance between the ends of the crown and π = 3.14.

Ecological importance of biodiversity

Tree stand structure was assessed using the Species Importance Value Index (SIVI). It is calculated by the following formula:

$$\textbf{SIVI} = 100*[(Ni/\Sigma Ni) + (Gi/\Sigma Gi) + (Fi/\Sigma Fi)]$$

Where Ni is the number of individuals of species i; Gi the basal area of species i; and Fi the frequency of this species. Species with SIVI ≥ 10 are those that are ecologically important.

Floristic diversity indices

The Shannon-Weaver diversity index (H') is calculated according to the following formula and is expressed in bits:

$$H' = -\sum \frac{Ni}{N} \log 2\left(\frac{Ni}{N}\right)$$

Ni is the number of species i and N is the total number of species.

H' is minimal (= 0) if all the individuals in the stand belong to one and the same species and maximal when all the individuals are equally distributed over all the species (Frontier; 1983).

Piélou equity index [20]

Also called the equipartition index (Blondel; 1979), the Piélou evenness index corresponds to the ratio of H' to the theoretical maximum index in the stand (Hmax). Its formula is: $\mathbf{J' = H'/log_2 N}$, where N is the total number of species, log_2 is the natural logarithm to base 2 and H' is the Shannon index.

Simpson's dominance or diversity index

It is determined from $\mathbf{D = 1/\Sigma(Ni/N)^2}$

Hill's diversity index [22]

This is a measure of proportional abundance, allowing the Shannon-Weaver and Simpson indices to be associated: $\mathbf{Hill = (1/\lambda) / e^{H'}}$

$1/\lambda$: this is the inverse of Simpson's index. $e^{H'}$ is the exponential of the Shannon-Weaver index.

2.2.5. Data analysis

The data collected during this study was recorded on an Excel sheet. Indeed, Excel was used to draw the histograms, calculate the averages and the percentages of the data collected in the field. Data were analysed using Statgraphic Plus 5.0 software. Xlstat was used for principal component analysis (PCA).

3. RESULTS

3.1 Anthropization of the transplanted sorghum field

3.1.1 Stump removal

Grubbing up of woody plants is a major anthropization activity (Guidiguis, 80.00% on clay soil (SA) and 24.62% on hydromorphic soil (SH); Touloum (55.38% on SA and 32.31% on the SH); Kaélé (55.38% on the SA and 64.62% on the SH); Kalfou (81.54% on the SA and 75.38% on the SH); Doukoula (69.23 % on the SA and 10.77% on the SH); Tchatibali (20.00% on the SA and 58.46% on the SH) (Table 1)). Stump removal is more practiced on clay type soil (Guidiguis, Touloum, Kalfou, Doukoula) than on hydromorphic type soil (Kaélé and Tchatibali). This would be due to the fact that soils of the hydromorphic type are less diversified in plant species than those of the clay type; which reduces the stump removal activities of woody plants on this type of soil. The grubbing up of woody plants is a major cause of the disappearance of plant biodiversity in the karal. It is practiced not only by farmers but also by women in search of firewood who have a preference for the roots of *Piliostigma reticulatum* (Plate 1). This species cut every year develops an important root system which provides a good quality of wood. Farmers, on the other hand, practice stump removal only in order to reduce competition between the tree and the sorghum plants which develop in the dry season. To these two actors (farmers and loggers) are added the individuals who search the ground in search of the fish, the lungfish. This group also leads to a significant disappearance of plants. The concern is that an uprooted tree is bound to disappear and this happens every year; which leads to the disappearance of several individuals per year.

Plate 1 : Trace of uprooting of *Guiera senegalensis* (A) and *Piliostigma reticulatum* (B) on clay soil

3.1.2 Weeding

Weeding is an essential activity for the establishment of the sorghum crop. “Weeds” should be cleaned from the field before transplanting. The activity consists of either manual mowing, spraying, clearing, ploughing or burning after spraying or mowing (Table 1). Every farmer is called upon to clean everything or almost everything before planting the crop. Deforestation is reserved for new unexploited plots since those already exploited have very few or no trees. Shrubs are mainly found on the old exploited plots. Generally, deforestation takes place before the arrival of the flood in July and/or early August to allow the water to settle on the trunks cut flush and thereby causing them to wilt by asphyxiation. Few of these plants are left by a minority, generally the trees serving as shade for rest or for their food or pharmacopoeial importance. Weeding or clearing for karal is not selective. Trees, shrubs and grasses are all or almost cut. This leads to the total disappearance of natural greenery in the dry season.

3.1.3 Manual mowing

Manual mowing is practiced today by only a minority with a greater percentage on hydromorphic soil in Tchatibali (23.08%) and less in Kalfou on clay-type soil (1.54%). This activity does not depend on the type of soil but on the capacity of the farmer.

3.1.4 Spraying

Spraying has been the main land preparatory activity in the last decade. At least by 49 % of farmers in the 6 villages and on the two types of soil practiced spraying. On both soil types, it is more practiced on hydromorphic soil in 4 villages (Guidiguis 89.23%, Touloum 70.77%, Kaélé 93.85% and Doukoula 56.92%). On the hydromorphic soil type, there are more adventitious crops such as *Paspalum orbicular, Oryza longistaminata*, which are difficult to eliminate manually; reason why farmers use more herbicide treatment on these plots. Spraying followed by burning dead ground cover were two strongly related activities. Today, after spraying, we go directly to transplanting in most cases since, according to Muskuwaari operators, burning causes rapid drying of the soil. It is therefore preferable to transplant the sorghum without burning the dead vegetation, which has no negative effect on the plants. Transplantation on unburned farmlands is practiced by more than 20% of farmers and is used more on clay type soil (Table 1).

3.1.5 Wood collection

The primary activity that threatens plant biodiversity remains the collection of wood and secondly by the phenomenon of uprooting of woody plants. It is practiced on both soil types in the 6 villages at 100%. *Piliostigma reticulatum*, is the species that suffers much more threats from cuts in the Kare. Before the arrival of the flood during the rainy season, the field is used for grazing. Grazing is practiced on both soil types of the 6 villages at 100% but access to which is highly prohibited from the end of July until March-April after harvest. During this pasture, the remains of sorghum most often (leaves, stems, ears) are eaten by the animals likewise branches of certain ligneous species (*Acacia albida*, *Ziziphus mauritiana*) are cut for fodder. Similarly, persistent herbaceous species are equally consumed leaving behind a bare ground characteristic of desert environment. Fishing, hunting or digging for fish are not abundant in the karal. Fishing is effective only when flooding occurs but this ranges from 0.00% on the SA at Kaélé and Kalfou to 83.08% on the SH at Touloum. This activity varies with villages and soil types (Table 1). As for excavations to capture lungfish, the favourable periods are periods of flooding and after transplanting sorghum.

3.1.6 Use of herbicides

A great portion of farmers used herbicides during field preparation. The most commonly used herbicide is the water dispersible granulated glyphosate commonly called Roundup followed by others called Kalach and Machete. Apart from the aforementioned, the herbicides gramazon and diuron are also used. More than 92% of sorghum farmers employ the use of herbicides (Guidiguis 93.85% on SA and 92.31% on SH, Touloum 87.69% on SA and 96.92% on SH, Kaélé 86.15 % on SA and 95.38% on SH, Kalfou 92.31% on SA and 98.46% on SH, Doukoula 96.92% on SA and 90.77% on SH and Tchatibali 72.31% on SA and 89.23% on HS). Farmers repeatedly use herbicides on the same farmland on yearly basis to ease work, reduce cost of bowing and to fight against crop weeds (*Paspalum orbicular* and *Oryza longistaminata*). The high used of herbicides is catastrophic for plant cover. Herbicides can change habitats by altering vegetation structure, and ultimately lead to decline in plant population.

Table 1 : Anthropization activities according to villages and soil types

		Guidiguis (%)		Touloum (%)		Kaélé (%)		Kalfou (%)		Doukoula (%)		Tchatibali (%)	
Anthropic activities	Detail of activities	CS	HS	CS	HS	CS	HS	CS	HS	CS	HS	CS	HS
Ploughing or uprooting		80.00	24.62	55.38	32.31	55.38	64.62	81.54	75.38	69.23	10.77	20.00	58.46
Weeding and clearing of woods	Mechanical mowing and burning	4.62	16.92	3.08	6.15	9.23	6.15	1.54	10.77	7.69	13.85	10.77	23.08
	Spraying	49.23	89.23	58.46	70.77	56.92	93.85	58.46	52.31	49.23	56.92	60.00	27.69
	Spraying and burning	60.00	21.54	49.23	16.92	63.08	24.62	52.31	13.85	47.69	43.08	33.85	20.00
Anthropics activities on the study sites	Wood harvesting	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Pasturage	100,.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Fish hunting	12.31	50.77	18.46	83.08	0.00	23.08	0.00	41.54	3.08	33.85	4.62	46.15
Anthropics activities on limitrophic space	Site of wood harvesting	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Fish hunting	12.31	64.62	12.31	44.62	0.00	47.69	0.00	33.85	3.08	26.15	3.08	10.77
	Pasturage	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Digging of sumps		73.85	93.85	89.23	60.00	41.54	41.54	64.62	70.77	41.54	44.62	40.00	43.08
Use of herbicides		93.85	92.31	87.69	96.92	86.15	95.38	92.31	98.46	96.92	90.77	72.31	89.23

3.2 Consequences of human activities on floristic composition

The number of species, genus and family of ligneous plants was evaluated according to the phases of the surveys, the villages, the type of soil and the years. Of the 20 species identified, from the start of field preparation up to the end of operations, the number of inventory species decreased from 20 to 13 in 2017/2018 and from 20 to 11 in 2018/2019. In the same train, the genders also decreased from 17 to 11 in 2017/2018 and from 17 to nine (9) in 2018/2019 and the number of families fell from 12 to 10 in 2017/2018 and from 12 to 8 in 2018/2019. The decrease in the number of species, genus and family from the first phase before preparing the field for transplanting at the end of the work (after harvest) is due to clearing and cutting for plot preparation and weeding. This decline in woody diversity does not reflect a complete disappearance of species but just that the regeneration of species is so slow. The highest number of species and genera are observed in Tchatibali on clay soil and Doukoula on hydromorphic soil (13 species) followed by Guidiguis and Kaélé on clay soil (12 species). The lowest number is observed in Touloum (3 species). The largest number of families is found in Guidiguis on both types of soil (10 families) followed by Tchatibali and Doukoula (9 families) and the lowest number of families was found in Touloum (2 families). Between the two years of study, there is no difference in the number of species, genus and family. The loss is rather observed at the level of the density of individuals within the species.

Table 2: Variation of the ligneous stratum according to years, villages and soil types

			Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
Phases	**Years**	**Groups**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**
Start	**2017/2018**	Species	12	6	3	4	12	11	6	6	11	13	13	10
		Genera	10	6	3	3	12	10	5	6	11	11	11	9
		Families	10	10	2	3	8	8	5	6	9	3	9	9
	2018/2019	Species	12	6	3	4	12	11	6	6	11	13	13	10
		Genera	10	6	3	3	12	10	5	6	11	11	11	9
		Families	10	10	2	3	8	8	5	6	9	3	9	9
End	**2017/2018**	Species	8	5	2	2	6	8	2	1	5	7	8	6
		Genera	7	5	2	2	6	8	1	1	5	7	7	5
		Families	7	8	2	2	5	8	1	1	5	2	6	5
	2018/2019	Species	8	5	2	2	6	8	2	1	5	7	8	6
		Genera	7	5	2	2	6	8	1	1	5	7	7	5
		Families	7	8	2	2	5	8	1	1	5	2	6	5

3.3 Endangered woody species in the karal by population

Table 3 presents the level of endangered woody species by village. *Terminalia glaucescens* species has completely disappeared from the kare (100%) of the six villages. Beside this species is *Anogeissus leiocarpus* (100% in Guidiguis, Touloum and Doukoula on the two soil types and 95.38% on the SA and 98.46% on the SH in Kaélé, Kalfou and Tchatibali), *Balanites aegyptiaca* (100% in Touloum and 97% in Guidiguis) and *Burkea africana* (100% in Guidiguis and Tchatibali, 99% in Touloum and Doukoula and 98% in Kalfou) which suffer from extinction. These species are threatened because of repeated cutting and stump removal of trees and shrubs for the cultivation of Muskuwaari.

Table 3: Endangered woody species in the karal according to villages and soil types

	Guidiguis (%)		Touloum (%)		Kaélé (%)		Kalfou (%)		Doukoula (%)		Tchatibali (%)	
Species	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**
Acacia albida	92.31	93.85	87.69	92.31	80.00	89.23	73.85	83.08	95.38	98.46	89.23	93.85
Anogeissus leiocarpus	100.00	100.00	100.00	100.00	95.38	98.46	96.92	95.38	100.00	100.00	93.85	100.00
Balanites aegyptiaca	90.77	96.92	92.31	98.46	47.69	73.85	50.77	55.38	86.15	90.77	87.69	95.38
Burkea africana	100.00	95.38	98.46	90.77	80.00	87.69	95.38	92.31	98.46	95.38	100.00	96.92
Combretum molle	75.38	92.31	89.23	83.08	98.46	90.77	92.31	89.23	87.69	80.00	75.38	72.31
Terminalia glaucescens	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Ziziphus Mauritiana	49.23	93.85	53.85	89.23	10.77	90.77	4.62	83.08	76.92	92.31	49.23	72.31

3.4 Impact of Muskuwaari harvesting on the floristic composition of species with a stem circumference < 10 cm depending on the period

The floristic composition of the vegetation of the Muskuwaari fields for woody plants with a stem circumference of less than 10 cm is summarised in table 4. It is noted that there is a reduction in the number of species from the beginning to the end of the exploitation in all the sites and on the two soil types throughout the exploitation. The same observation is made for the genus and the families. Exploitation has therefore led to a reduction in the number of species on both soil types. In all the villages, the number of species on the clay soil type is higher than that of the hydromorphic soil type with the exception of Kalfou where the number of species on the two soil types remained the same (SA = SH = 6). In all the sites, the reduction in the number of species went from the period of field preparation till harvesting (Guidiguis, the SA from 11 to 7 and the SH from 4 to 3; Touloum, the SA from 4 to 2 and the

SH from 3 to 2; Kaélé, the SA from 11 to 5 and the SH 10 to 7; Kalfou the SA from 6 to 2 and the SH from 6 to 1; Doukoula, the SA 11 to 5 and the SH from 13 to 7 and Tchatibali, SA from 12 to 7 and SH from 9 to 5). However, it was noticed that the clay soil was more diversified than the hydromorphic soil in almost all the sites except in the Doukoula village which has 11 species on the SA and 13 on the SH. There is no appearance of new species observed during the exploitation of sorghum. Cut ligneous plants emit shoots mainly based on their ability to regenerate. Some species with difficult regeneration even begin to give suckers towards the end of sorghum exploitation or much later. Others wait for the next rainy season; it is for this reason that their number decreases from the beginning to the end of the culture. Year after year, the number of species decrease according to the operators since certain species no longer regenerate after their cutting and others are uprooted by women for firewood (case of the species *Piliostigma reticulatum*) or by the farmers themselves. Some plots are sprayed without clearing the ligneous plants; which usually causes them to wilt and may or may not regenerate depending on the intensity of the fire. In such circumstances, these individuals no longer bud and disappear permanently. This method is practiced by several farmers; which then leads to the disappearance of several species per crop cycle. No great difference is observed in the averages of the number of species, genus and family for the two types of soil from the beginning to the end of cultivation (the difference is a maximum of 1 for the three rows studied).

Table 4: Floristic composition of species with stem circumference < 10 cm depending on the period

		Number of species		Number of genera		Number of families	
Villages	Soil types	Start	End	Start	End	Start	End
Guidiguis	Clay	11	7	9	6	9	6
	Hydromorphic	4	3	4	3	8	6
Touloum	Clay	3	2	3	2	2	2
	Hydromorphic	4	2	3	2	3	2
Kaélé	Clay	11	5	11	5	7	4
	Hydromorphic	10	7	9	7	7	7
Kalfou	Clay	6	2	5	1	5	1
	Hydromorphic	6	1	6	1	6	1
Doukoula	Clay	11	5	11	5	9	5
	Hydromorphic	13	7	11	7	3	2
Tchatibali	Clay	12	7	10	6	8	5
	Hydromorphic	9	5	8	4	8	4
Mean ± SD	Clay	9±3,32	5±2,05	8±3,08	4±1,95	7±2,49	4±1,77
	Hydromorphic	8±3,30	4±2,34	7±2,79	4±2,31	6±2,11	4±2,21

3.5 Impact of Muskuwaari harvesting on the floristic composition of the vegetation of species with a stem circumference ≥ 10 cm depending on the period

Trees with a stem circumference greater than or equal to 10 cm are not numerous in the karal. The value zero (0) in half of the villages (Touloum, Kalfou and Doukoula) does not reflect the non-existence of large ligneous plants in the sorghum fields of these villages but simply the non-presence of these ligneous plants in the plots chosen for the study. Even when they are present, their number does not exceed 3. The number of species, genera and families does not vary for this group of woody species since the individuals are not cut during exploitation. Regardless of the size of the farmer's plot, the number of tall trees (trees) does not exceed 5 since these trees are left just to serve as shade for rest during harvesting. The main problem at this level is the birds, which also use these plants as a resting place during heading and massively destroy the crop. Reason why almost all of these woody plants are cut and uprooted. There is no difference between the species for their choice of the tree which will remain but the operator chooses simply according to the individuals which are in his plot and which can serve better as shade or with an edible character as well. The average for all villages, soil types, species, genus and families is 1. There is therefore no difference observed.

Table 5: Floristic composition of species with a stem circumference ≥ 10 cm depending on the period

		Number of species		Number of genera		Number of families	
Villages	Soil types	Start	End	Start	Start	End	Start
Guidiguis	Clay	1	1	1	1	1	1
	Hydromorphic	2	2	2	2	2	2
Touloum	Clay	0	0	0	0	0	0
	Hydromorphic	0	0	0	0	0	0
Kaélé	Clay	1	1	1	1	1	1
	Hydromorphic	1	1	1	1	1	1
Kalfou	Clay	0	0	0	0	0	0
	Hydromorphic	0	0	0	0	0	0
Doukoula	Clay	0	0	0	0	0	0
	Hydromorphic	0	0	0	0	0	0
Tchatibali	Clay	1	1	1	1	1	1
	Hydromorphic	1	1	1	1	1	1
Mean ± SD	**Clay**	**1±0.55**	**1±0.55**	**1±0.55**	**1±0.55**	**1±0.55**	**1±0.55**
	Hydromorphic	**1±0.75**	**1±0.75**	**1±0.75**	**1±0.75**	**1±0.75**	**1±0.75**

3.6 Impact of Muskuwaari harvesting on the density of species with a stem circumference < 10 cm depending on the soil type per village.

3.6.1 Specific densities of kare vegetation on clay soil

Table 6 presents the number of individuals on clay soil. *Ziziphus mauritiana* is the densest species in the villages with values of 142, 59 and 40 individuals per hectare in Kaélé, Guidiguis and Doukoula respectively for the densest sites and 7 in Kalfou for the site which has less and *Combretum micranthum* with a density which hardly exceeds 1. The total number of individuals decreases from the beginning of the exploitation work to the end in all the 6 villages, which reflects the decrease in the number of individuals species present.

Table 6: Density distribution of individual plants species on clay soil

	Guidiguis		**Touloum**		**Kaélé**		**Kalfou**		**Doukoula**		**Tchatibali**	
Names of species	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Acacia albida	14	4	33	4	0	0	3	0	9	5	12	0
Acacia seyal	9	4	0	0	22	4	0	0	9	3	6	4
Acacia sieberiana	0	0	0	0	0	0	0	0	0	0	2	2
Anogeissus leiocarpus	0	0	0	0	1	1	0	0	0	0	0	0
Balanites aegyptiaca	0	0	0	0	21	0	0	0	0	0	2	0
Calotropis procera	3	3	0	0	33	29	2	0	5	2	4	2
Cassia singueana	0	0	0	0	1	0	0	0	0	0	0	0
Combretum aculeatum	30	4	0	0	0	0	0	0	1	0	2	0
Combretum micranthum	1	0	0	0	2	0	0	0	1	1	0	0
Dichrostachys cinerea	19	0	0	0	1	1	0	0	11	0	26	16
Ficus gnaphalocarpa	0	0	0	0	0	0	1	0	0	0	0	0
Gardenia ternifolia	1	0	0	0	0	0	1	0	2	0	12	0
Guiera senegalensis	0	0	0	0	0	0	0	0	2	1	0	0
Hyphaene thebaica	1	1	0	0	0	0	1	0	0	0	1	1
Ipomoea carnea	0	0	2	1	0	0	0	0	4	4	0	0
Lannea microcarpa	8	7	0	0	1	0	1	0	1	1	0	0
Leptadenia hastata	0	0	0	0	3	0	1	0	1	0	1	0
Piliostigma reticulatum	17	0	6	0	9	0	12	4	19	6	16	7
Ziziphus mauritiana	59	24	0	0	142	11	7	2	40	26	26	20
Total	**162**	**47**	**41**	**5**	**236**	**46**	**29**	**6**	**105**	**49**	**110**	**52**

3.6.2 Specific densities of kare vegetation on hydromorphic soil

The number of individuals on hydromorphic soils is regressive from the beginning to the end of Muskuwaari cultivation (Table 7). It goes from 66 to 16 at Guidiguis, from 110 to 52 at Tchatibali which is regarded as the densest, from 16 to 8 at Kaélé and from 29 to 6 at Kalfou for the loweest. The densest species here is *Piliostigma reticulatum* and the least dense is *Azadirachta indica* in all of the six villages.

Table 7: Density distribution of species on hydromorphic soil

	Guidiguis		**Touloum**		**Kaélé**		**Kalfou**		**Doukoula**		**Tchatibali**	
Names of species	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Acacia albida	0	0	9	2	2	0	1	0	21	12	7	2
Acacia seyal	0	0	2	0	8	3	0	0	1	1	12	9
Azadirachta indica	0	0	0	0	1	1	0	0	0	0	0	0
Balanites aegyptiaca	0	0	0	0	18	12	1	0	0	0	5	4
Calotropis procera	1	0	0	0	3	1	2	0	0	0	1	0
Cassia singueana	0	0	0	0	0	0	0	0	0	0	2	0
Combretum aculeatum	0	0	0	0	6	0	0	0	0	0	0	0
Combretum micranthum	0	0	0	0	0	0	0	0	0	0	2	2
Dichrostachys cinerea	0	0	0	0	23	0	0	0	0	0	0	0
Gardenia ternifolia	38	14	0	0	0	0	0	0	0	0	0	0
Ipomoea carnea	0	0	1	1	0	0	1	0	2	2	0	0
Lannea microcarpa	0	0	0	0	18	13	0	0	0	0	1	0
Piliostigma reticulatum	18	1	0	0	80	52	2	0	0	0	16	10
Ziziphus mauritiana	9	1	10	0	7	1	9	8	1	0	4	0
Total	**66**	**16**	**22**	**3**	**16**	**8**	**25**	**15**	**25**	**15**	**50**	**27**

3.6.3 Average densities of individual plants on clay and hydromorphic soil

Table 8 presents the average density of individuals with a stem circumference of less than 10 cm according to soil types and study sites. In each site, from the beginning of the operation to the end, there is a decrease in the density of the overall species on the two (02) types of soil. From the first point of view, the clay soil is more densely populated than the hydromorphic soil type with a very large difference between the numbers observed. This decrease in density was characterised at the end by the loss or non-regeneration of more than half of the individuals encountered on the sites. The difference between the two soil types is large. The nature of hydromorphic soil (saturation at the top) does not favour the development of any type of plant species and more so, plants of the arid environment.

Table 8: Average densities of individual plants on the two types of soil

	Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
Soil types	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Clay	18	5	5	1	26	5	3	1	12	5	12	6
Hydromorphic	7	2	2	0	2	1	3	2	3	2	6	3
Mean ± SD	12.67± 7.54	3.50± 2.44	3.50± 1.49	0.44± 0.16	14.00± 17.28	3.00± 2.99	3.00± 0.31	1.17± 0.71	7.22± 6.29	3.56± 2.67	8.89± 4.71	4.39± 1.96

3.7 Impact of Muskuwaari harvesting on the number of individuals with a stem circumference ≥ 10 cm depending on soil types per study site

3.7.1 Specific densities of kare vegetation on clay soil

Table 9 presents the number of species with stem circumference greater than or equal to 10 cm present on clay soil. It appears from this study that the maximum density is one (01) individual for *Acacia albida, Azadirachta indica* and *Piliostigma reticulatum*; there is no more than one (01) individual per hectare in the fields, they are almost absent. The total density remains 1 individual in Guidiguis, Kaélé and Tchatibali and 0 in Touloum, Kalfou and Doukoula from the beginning to the end of the exploitation works. There is no variation in the number of individuals observed; individuals and species remained the same during exploitation.

Names of species	Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Acacia albida	0	0	0	0	0	0	0	0	0	0	1	1
Azadirachta indica	0	0	0	0	1	1	0	0	0	0	0	0
Piliostigma reticulatum	1	1	0	0	0	0	0	0	0	0	0	0
Total	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**1**

Table 9: Number of individuals with stem circumference ≥ 10 cm on clay soil

3.7.2 Specific densities of kare vegetation on hydromorphic soil

Species on the ground of hydromorphic type are almost absent. They are represented only in Guidiguis, Kaélé and Kalfou with a density of 2, 2, 1, 1 individuals respectively for *Acacia seyal, Gardenia ternifolia, Ziziphus mauritiana* and *Ficus gnaphalocarpa*. Their number does not vary according to the data recording phases since they are not cut during sorghum exploitation.

Table 10: Number of individuals with stem circumference ≥ 10 cm on hydromorphic soil

Names of species	Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Acacia seyal	0	0	0	0	2	2	0	0	0	0	0	0
Ficus gnaphalocarpa	0	0	0	0	0	0	0	0	0	0	1	1
Gardenia ternifolia	2	2	0	0	0	0	0	0	0	0	0	0
Ziziphus mauritiana	1	1	0	0	0	0	0	0	0	0	0	0
Total	**3**	**3**	**0**	**0**	**2**	**2**	**0**	**0**	**0**	**0**	**1**	**1**

3.7.3 Absolute densities of individuals on clay and hydromorphic soil according to villages

Individuals with a stem circumference greater than or equal to 10 cm are so poorly represented on both soil types. Depending on the villages, only three (03) villages out of the six (06) have individuals from this group. The overall average density varies between 2 and 1 for Guidiguis, Kaélé and Tchatibali. The difference between soil types is not significant. Overall density does not decrease during Muskuwaari cultivation. The sites of Touloum, Kalfou and Doukoula have no individuals with a stem circumference greater than or equal to 10 cm on the two types of soil (Table 11).

Table 11: Absolute densities of individuals on clayey and hydromorphic soil

	Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
Soil types	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Clay	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1
Hydromorphic	0.3	0.3	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	0.1	0.1
Mean ±	**0.2**	**0.2**	**0.0**	**0.0**	**0.2**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**
SD	**0.16**	**0.16**	**0.00**	**0.00**	**0.08**	**0.08**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

3.8 Impact of Muskuwaari harvesting on the frequency of species with stem circumference ≥ 10 cm on clay soil

Woody species with a stem circumference of less than 10 cm are presented in Table 12. Most of the species are accidental (Frequency less than 20%); which once again confirms that the backgrounds are not very diversified. The species of plants in the two divisions are either fairly frequent, frequent or very frequent or they are only encountered accidentally or at random. The Muskuwaari fields are heavily anthropized since the presence of the tree are seen as impairment by farmers. The most frequent species are *Ziziphus mauritiana* (36.20% in Guidiguis and 59.92% in Kaélé) and *Combretum aculeatum* (18.4 % in Guidiguis), *Piliostigma reticulatum* (41.38%), *Ziziphus mauritiana* (24.14%) in the six villages. The specific contribution varies with the frequency. The species with the highest frequency also has the highest contribution and vice versa. The difference is observed only between the individuals and the phases of data collection.

Table 12: Species frequencies with stem circumference ≥ 10 cm on clay soil

Names of species	Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Acacia albida	8.59	8.33	80.49	80	0	0	10.34	0	9	10	11.71	1.89
Acacia seyal	5.52	8.33	0	0	9.28	8.51	0	0	9	6	5.41	7.55
Acacia sieberiana	0	0	0	0	0	0	0	0	0	0	1.80	3.77
Anogeissus leiocarpus	0	0	0	0	0.42	2.13	0	0	0	0	0	0
Azadirachta indica	0	0	0	0	0.42	2.13	0	0	0	0	0	0
Balanites aegyptiaca	0	0	0	0	8.86	0	0	0	0	0	1.80	0
Calotropis procera	1.84	6.25	0	0	13.92	61.70	6.90	0	5	4	3.60	3.77
Cassia singueana	0	0	0	0	0.42	0	0	0	0	0	0	0
Combretum aculeatum	18.4	8.33	0	0	0	0	0	0	1	0	1.80	0
Combretum micranthum	0.6	0	0	0	0.84	0	0	0	1	2	0	0
Dichrostachys cinerea	11.7	0	0	0	0.42	2.13	0	0	10	0	23.42	30.19
Ficus gnaphalocarpa	0	0	0	0	0	0	3.45	0	0	0	0	0
Gardenia ternifolia	0.61	0	0	0	0	0	3.45	0	2	0	10.81	0
Guiera senegalensis	0	0	0	0	0	0	0	0	2	2	0	0
Hyphaene	0.6	2.0	0	0	0	0	3.4	0	0	0	0.9	1.8

thebaica	1	8					5				0	9
Ipomoea carnea	0	0	4.88	20	0	0	0	0	4	8	0	0
Lannea microcarpa	4.91	14.58	0	0	0.42	0	6.90	0	1	2	0	0
Leptadenia hastata	0	0	0	0	1.27	0	0	0	1	0	0.90	0
Piliostigma reticulatum	11.04	2.08	14.63	0	3.80	0	41.38	66.67	18	12	14.41	13.21
Ziziphus mauritiana	36.20	50	0	0	59.92	23.40	24.14	33.33	38	53	23.42	37.74
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

3.9 Impact of Muskuwaari harvesting on the frequency of species with stem circumference ≥ 10 cm on hydromorphic soil

Table 13 presents the frequency of large woody species in kare on hydromorphic soil. It appears from the study that the species present are almost all incidental (Frequency between 20% and 40%) except for *Calotropis procera* at Guidiguis; *Acacia seyal* and *Ipomoea carnea* in Touloum; *Acacia albida*, *A. seyal*, *Azadirachta indica, Calotropis procera*, Combretum aculeatum, and *Ziziphus mauritiana* in Kaélé, *A. albida*, *Balanites* and *I. carnea* in Kalfou; *A. seyal* and *Z. mauritiana* in Doukoula; *C. procera*, *Cassia singueana*, *Combretum micranthum*, *Ficus gnaphalocarpa* and *Lannea microcarpa* which are considered as accidental species (F = 11.11%). Of the 20 species cited, only 13 are present in this group and almost all of low frequency (11.11 < F < 33.33) to an extent several hectares are barren. Nevertheless, *G. ternifolia* at Guidiguis *A. albida* and *Z. mauritiana* at Touloum, *P. reticulatum* at Kaélé, *Z. mauritiana* at Kalfou and *A. albida* at Doukoula are the common recurrent plant species since the abundance of large trees attract the birds that can lead to destruction of plantation.

Table 13: Frequency of species with stem circumference ≥ 10 cm

	Guidiguis		**Touloum**		**Kaélé**		**Kalfou**		**Doukoula**		**Tchatibali**	
Names of species	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Acacia albida	0	0	40.91	66.67	1.19	0	6.25	0	84	80	13.73	7.14
Acacia seyal	0	0	9.09	0	5.95	5.88	0	0	4	7	23.53	32.14
Azadirachta indica	0	0	0	0	0.60	1.18	0	0	0	0	0	0
Balanites aegyptiaca	0	0	0	0	10.71	14.12	6.25	0	0	0	9.80	14.29
Calotropis procera	1.45	0	0	0	1.79	1.18	12.5	0	0	0	1.96	0
Cassia singueana	0	0	0	0	0	0	0	0	0	0	3.92	0
Combretum aculeatum	0	0	0	0	3.57	0	0	0	0	0	0	0
Combretum micranthum	0	0	0	0	0	0	0	0	0	0	3.92	7.14
Dichrostachys cinerea	0	0	0	0	13.69	0	0	0	0	0	0	0
Ficus gnaphalocarpa	0	0	0	0	0	0	0	0	0	0	1.96	3.57

Gardenia ternifolia	57.97	84.21	0	0	0	0	0	0	0	0	0	0
Ipomoea carnea	0	0	4.55	33.33	0	0	6.25	0	8	13	0	0
Lannea microcarpa	0	0	0	0	10.71	15.29	0	0	0	0	1.96	0
Piliostigma reticulatum	26.09	5.26	0	0	47.62	61.18	12.5	0	0	0	31.37	35.71
Ziziphus mauritiana	14.49	10.53	45.45	0	4.17	1.18	56.25	100	4	0	7.84	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

3.10 Indices of floristic diversity of species on the two types of soil

- **Shannon diversity index (H') of species on clay soil**

The results in Table 13 present the values of the Shannon indices (H') of the species present on the plots. Exploitation has led to a dynamic of species richness from the beginning of the exploitation of sorghum Muskuwaari to the end. Shannon's diversity index varies from 2.69 bits to 2.3 bits in Guidiguis; from 0.87 bits to 0.72 bits in Touloum; from 1.94 to 1.58 bits in Kaélé, from 2.41 to 0.94 bits in Kalfou, from 2.77 to 2.27 bits in Doukoula and from 2.91 to 2.3 bits in Tchatibali. The least diversified species are *Anogeissus leiocarpus* and *Azadirachta indica*. The drop in the index from the start to the end of the operation is due to the decrease in the number of species in the plots cut for the establishment of the crop and during weeding.

- **Shannon diversity index (H') of species on hydromorphic soil**

The species present on hydromorphic soil are not very diversified since their density is too low compared to the species on clay soil. Their diversity index (Table 14) decreases slightly at all sites depending on the data survey phases since the number of species decreases during farming. The most diversified backgrounds in the area are Kaélé with an index which varies from 2.42 to 1.72 bits and Tchatibali which varies from 2.71 to 2.17 bits. Their number of individuals, which is 01 for each species, remains the same during the operation. The most diversified species in Guidiguis, Tchatibali and Kaélé is *Piliostigma reticulatum*, *Acacia albida*, *Ziziphus mauritiana*, *Ipomoea carnea* in Touloum, Kalfou and Doukoula respectively. The diversity gap between the six (06) villages of the two divisions is not significant.

- **Equitability of Piélou**

Table 14 presents the values of the diversity index of Simpson, of Hill and the Equitability of Piélou of the trees and shrubs of the field. The Piélou Equitability Index reflects the degree of diversity reached in relation to the theoretical maximum (Blondel; 1979). It is between the values 0 and 1 and is used to confirm the diversity of an environment or a species. It is regressive on the two types of soils and on all the sites of the study. The Piélou index calculated here does not reflect a very large difference between the data collection phases and between the six villages.

- **Simpson's diversity indices (D)**

For the Simpson index, the value 1 is the minimum diversity and 0 the maximum, with the exception of species whose number of individuals is 0. This diversity index gives more weight to abundant species than to rare species, but the difference in diversity is difficult to observe here since regardless of the number of individuals of each species, the value of the index is the lowest, i.e. 1. Whether it is 401 individuals of *Ziziphus mauritiana* or 1 individual of *Anogeissus leiocarpus*, the Simpson's index value does not change. The drop in the number of individuals during the operation depending on the data collection phases also has no effect on the value of the index. There is not a very big difference observed between the villages but the difference in the indices of all the species at the beginning and at the end of the exploitation reveals a difference. The total index decreases in all villages and on both types of soil from the beginning to the end of cultivation. It is still more important on clay soil than on hydromorphic soil. On the two types of soil, the most diversified environments are Kaélé (0.55 to 0.4) and Doukoula (0.65 to 0.45) on clay soil.

- **Hill's Diversity Index**

Hill's diversity index, which involves Shannon's and Simpson's indices, gives a clearer picture of species diversity; the more the value of the index tends towards 1, the less the species is diversified. Table 33 presents the values according to the sites, soil types and the data collection phases. It appears from this study that the diversity here also follows the variation observed at the level of the Simpson's index; it decreases according to the data collection phases in all the villages and the two types of soil. The indices confirm once again that the most diversified environments are Kaélé (varies from 10.32 to 4.67 on clay soil and 9.96 to 6.49 on hydromorphic soil) and Tchatibali (varies from 10 to 6, 08 on clay soil and 9.79 to 5.09 on hydromorphic soil).

Table 14: Shannon diversity index, Piélou equitability (EQ), Hill and Simpson index of species

		Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
Divesity indices	**Phases**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**	**CS**	**HS**
ISH	**Start**	2.69	1.46	0.87	1.56	1.19	2,42	2,41	1.94	2.77	0.67	2.91	2.77

	End	2.3	0.77	0.72	0.92	1.58	1.72	0.92	0	2.27	0.91	2.3	2.17
EQ	**Start**	0.36	0.01	0.16	0.02	0.25	0.02	0.49	0.02	0.41	0.01	0.43	0.02
	End	0.41	0.01	0.31	0.03	0.28	0.01	0.36	0	0.4	0.01	0.4	0.02
Simpson	**Start**	0.55	0.2	0.15	0.2	0.6	0.5	0.4	0.3	0.65	0.2	0.6	0.5
	End	0.4	0.15	0.1	0.1	0.3	0.35	0.1	0.05	0.45	0.15	0.4	0.3
Hill	**Start**	0.44	0.2	0.11	0.19	0.52	0.5	0.3	0.26	0.65	0.2	0.48	0.49
	End	0.3	0.12	0.07	0.06	0.23	0.33	0.06	0.05	0.45	0.15	0.3	0.25

3.11. Ecological Importance Value Index of species (EIVI) on clay soil

The EIVI presents important ecological species on clay soil. Species with a value index greater than or equal to 10 are those that are ecologically important. This ecological importance varies from village to village. Of the 20 species listed, 7 are ecologically important with 13 and 3 in, Guidiguis and Touloum, 6 in Kaélé and Kalfou and 8 in Doukoula and Tchatibali are ecologically not important. High index species are *Piliostigma reticulatum*, *Ziziphus mauritiana* and *Dichrostachys cinerea* and *Acacia albida*. Those with very low value are *Acacia sieberiana, Ficus gnaphalocarpa, Azadirachta indica, Anogeissus leiocarpus* and *Leptadenia hastata*. Depending on the data survey phases, from the beginning to the end of the exploitation, of the 10 ecologically listed species, 2 lost their value index and became unimportant *Acacia albida* from 15.84 to 6.19 and *Combretum aculeatum* from 14.54 to 2.69. Other species have seen their index increase; *Gardenia ternifolia* from 8.80 to 10.26; *Hyphaene thebaica* from 4.23 to 10.44 and *Ipomoea carnea* from 8.94 to 11.20. The number of ecologically important species is reduced from 15 to 8 from the first to the second phase of data collection High EIVI species have evolved by limiting the regeneration and development of other species more vulnerable to environmental constraints.

Table 15: Ecological Importance Value Index of species on clay soil

Names of species	**Guidiguis**		**Touloum**		**Kaélé**		**Kalfou**		**Doukoula**		**Tchatibali**	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Acacia albida	19.14	17.55	238.75	204.44	0	0	22.65	0	22.20	31.85	54.50	49.79
Acacia seyal	11.04	16.67	0	0	20.62	27.17	0.00	0	25.57	23.69	13.03	18.16
Acacia sieberiana	0	0	0	0	0	0	0	0	0	0	4.71	10.61
Anogeissus leiocarpus	0	0	0	0	3.93	7.15	0	0	0	0	0	0
Azadirachta indica	0	0	0	0	1.87	5.70	0	0	0	0	0	0
Balanites aegyptiaca	0	0	0	0	28	8.70	0	0	0	0	6.93	0
Calotropis procera	5	12.85	0	0	28.16	127.75	13.79	0	12.90	10.45	10.54	13.68
Cassia singueana	0	0	0	0	11.12	1.45	0	0	0	0	0	0
Combretum aculeatum	38.12	16.75	0	0	0	0	0	0	5.28	0	11.37	0
Combretum micranthum	3.19	0	0	0	12.99	2.90	0	0	6.96	6.37	0	0

Dichrostachys cinerea	29.19	0	0	0	0.84	5.70	0	0	21.46	0	47.96	62.22
Ficus gnaphalocarpa	0	0	0	0	0	0	28.47	0	0	0	0	0
Gardenia ternifolia	1.36	0	0	0	0	0	6.90	0	3.81	0	21.73	0
Guiera senegalensis	0	0	0	0	0	0	0	0	22.36	22.05	0	0
Hyphaeca thebaica	1.88	7.69	0	0	0	0	6.90	0	0	0	5.13	16.04
Ipomoea carnea	0	0	31.98	95.56	0	0	0	0	19.42	34.29	0	0
Lannea microcarpa	52.90	114.63	0	0	5.98	0	39.28	0	3.59	6.37	0	0
Leptadenia hastata	0	0	0	0	4.59	2.90	0	0	6.96	0	5.13	0
Piliostigma reticulatum	48.85	13.86	29.27	0	53.84	60.87	82.76	0	39.56	30.21	47.70	41.75
Ziziphus mauritiana	89.36	100	0	0	128.05	49.71	99.26	0	109.92	134.73	71.26	87.74
Total	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**0**	**300**	**300**	**300**	**300**

3.12 Ecological Importance Value Index of species (EIVI) on hydromorphic soil

The majority of species present on the hydromorphic type soil are ecologically important because their ecological importance value index is greater than 10. These species have different ecological importance which vary from one site to another. We can note the case of *Acacia albida* (EIVI = 4.85) in Kaélé, *Azadirachta indica* (EIVI = 1.93), *Cassia singueana* (EIVI = 7.92) and *Combretum aculeatum* (EIVI = 7.64) which are not present on both types of soil nor present in all environments.

Table 16: Ecological Importance Value Index of species on hydromorphic soil

Names of species	**Guidiguis**		**Touloum**		**Kaélé**		**Kalfou**		**Doukoula**		**Tchatibali**	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
Acacia albida	0	0	116.70	166.67	4.85	0	15.44	0	221.57	190.30	29.66	16.85
Acacia seyal	0	0	34.46	0	41.53	29.73	0	0	43.71	73.94	49.27	69.41
Azadirachta indica	0	0	0	0	1.93	4.15	0	0	0	0	0	0
Balanites aegyptiaca	0	0	0	0	48.59	52.19	22.30	0	0	0	25.14	36.26
Calotropis procera	2.90	0	0	0	8.51	4.75	26.96	0	0	0	4.25	0
Cassia singueana	0	0	0	0	0	0	0	0	0	0	7.92	0
Combretum aculeatum	0	0	0	0	7.64	0	0	0	0	0	0	0
Combretum micranthum	0	0	0	0	0	0	0	0	0	0	12.27	19.41
Dichrostachys cinerea	0	0	0	0	32.319	0	0	0	0	0	0	0
Ficus gnaphalocarpa	0	0	0	0	0	0	0	0	0	0	24.95	55.86
Gardenia ternifolia	126.10	255.73	0	0	0	0	0	0	0	0	0	0
Ipomoea carnea	0	0	11.42	133.33	0	0	32.11	0	19.57	35.76	0	0
Lannea microcarpa	0	0	0	0	23.90	36.58	0	0	0	0	5.03	0
Piliostigma reticulatum	53.35	10.74	0	0	117.46	164.27	31.86	0	0	0	125.82	102.20
Ziziphus mauritiana	117.66	33.53	137.42	0	13.27	8.34	171.32	300	15.14	0	15.69	0
Total	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**

3.13 Jaccard's similarity coefficient and Hamming distance between sites

The Jaccard coefficient makes it possible to see the similarity between two environments on the number of species that each environment has and the number of species that the two environments have in common. Table 17 shows that the most similar environments are Doukoula and Tchatibali (J = 64.71%). This similarity would be due to the proximity of the two sites and more so, they share a common agro-ecological zone and the climate that reigns over the zone is also the same the least similar environments are Kaélé and Kalfou (J = 23.53%) which are in two different and distant divisions at a distance of about 70 km.

Table 17: Jaccard similarity coefficient and Hamming distance between sites

Sites	Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
	JP	**H**	**JP**	**H**	**JP**	**H**	**JP**	**H**	**JP**	**H**	**JP**	**H**
Guidiguis	100	0										
Touloum	37.5	62.5	100	0								
Kaélé	31.25	68.75	13.33	86.67	100	0						
Kalfou	33.33	66.67	37.5	62.5	23.53	76.47	100	0				
Doukoula	46.67	53.33	28.57	71.43	50	50	46.67	53.33	100	0		
Tchatibali	37.5	62.5	28.57	71.43	50	50	46.67	53.33	64.71	35.29	100	0

JP = Jaccard's index and H = Hamming Distance

3.14 Specific spatial distribution of kare

Table 18 and Figure 2 (b) present the correlation between the variables number of individuals, their heights, their trunk diameters and their basal areas. The four parameters are positively correlated. The correlation between the number of individuals and their trunk diameters is highly significant (n = 0.658) likewise between the number of individuals, height and basal area (n = 0.269 and n = 0.229). There is also a highly significant correlation between tree height and trunk diameter (n = 0.687). Similarly, for basal area and trunk diameter (n = 0.527) and basal area and height (0.331). Figure 3(a) presents the correlation between villages on the one hand and between villages and the parameters height, number, trunk and basal area on the other hand. This analysis shows that Guidiguis sites on clay soils (GDGA) and hydromorphic soils (GDGH), Kaélé on clay soils (KLEA), Kalfou on hydromorphic soils (KLFH), Doukoula on clay soils (DKLA) and Tchatibali on clay soils (TCHA) and hydromorphic soil (TCHH) are positively correlated with each other and are also positively correlated with the variables number of individuals, their heights, their trunk diameters and their basal areas. This may be due to the fact that these sites have plots of densely populated woody plants. The Kalfou sites on clay soil (KLFA), Touloum on clay soil (TLMA) and hydromorphic (TLMH) and Kaélé on hydromorphic soil (KLEH) are negatively correlated with the variables number of individuals, their heights, their trunk diameters and their surface areas. This can be explained by the fact that these sites are plots less populated by woody species. The villages studied are not then occupied by woody species in the same way. The number of individuals and their trunk diameter are positively correlated with each other and this correlation is strong (axes F1 and F2: 79.70%) but opposed to the x-axis by height and basal area (axis F2: 19.79%). These results show that there is a similarity between the studied parameters. The GDGA, KLEA, DKLA and TCHA villages are positively correlated with each other and with the number of individuals and their trunk diameter (axes F1 and F2: 79.70%) and the GDGH, KLFH and TCHH villages are negatively correlated with each other (F2 axis: 19.79%).

Table 18: Correlation matrix (Pearson (n))

Variables	N	Height	DH	St.
N	1	0.269	0.658	0.229
Height	0.269	1	0.687	0.331
DH	0.658	0.687	1	0.527
St.	0.229	0.331	0.527	1

N = number of individuals; Height; DH: trunk diameter and St = basal area

(a) (b)

Figure 2 : Correlation between villages (a) and between the height, turnk diameter and basal area (b)

3.15 Alternative methods for sustainable harvesting of transplanted sorghum

The cutting and stump removal of trees is a necessary condition for the establishment of the crop, in order to reduce competition for water and to limit the presence of roost for seed-eating birds and woody plants [13]. But this remains a problem at the same time for biodiversity and the soil, leading in the most extreme cases to desertification.

Table 19 presents the co-management measures of the karal vegetation by the population. The ban on harvesting of green wood (Guidiguis 26.56%, Touloum 20.97%, Kaélé 29.69%, 16.92% in Kalfou, 14.52% in Doukoula, 20.63% in Tchatibali) and removal of stumps (Guidiguis 3.13%, Touloum 4.84%, Kaélé 1.56%, 0% in Kalfou, 3.83% in Doukoula and 6.35% in Tchatibali) constitute the management methods applied by the local population to limit the anarchic exploitation of natural resources in order to ensure their sustainability. Farmers believe that chemical inputs alter the vegetation but the limitation of use (Guidiguis 21.88%, Touloum 24.19%, Kaélé 14.06%, 32.31% in Kalfou, 40.32 in Doukoula and 31 75% in Tchatibali) proposed is not applied since this new technique (chemical inputs) facilitates the work and is less expensive compared to the use of labourers. They propose this measure for the restoration of the environment and the return to the old methods which consists of clearing, mowing, burning and then transplanting. Even agroforestry poses a problem for its application for the moment (Guidiguis 9%, Touloum 7%, Kaélé 11%, 8% in Kalfou, 6% in Doukoula and 13% in Tchatibali). Despite all, these strategies are weak in the implementation of their actions by operators whose involvement is not significant. If reforestation in the field is not possible, at least a compensatory reforestation site should be chosen elsewhere to restore the vegetation cover of the area.

Table 19: Proportion of co-management measures of karal vegetation by the population

Proposed solutions	Guidiguis (%)	Touloum (%)	Kaélé (%)	Kalfou (%)	Doukoula (%)	Tchatibali (%)
Agroforestry	7.81	6.45	9.38	4.62	6.45	11.11
Increase rain gauge	29.69	33.87	35.94	44.62	30.65	22.22
Pruning of plant species	3.13	4.84	1.56	0.00	3.23	6.35
Prohibit the harvesting of green wood	26.56	20.97	29.69	16.92	14.52	20.63
Practice of fallowing	3.13	4.84	4.69	1.54	0.00	3.17
Ploughing	0.00	3.23	0.00	0.00	0.00	0.00
Reducing the use of chemicals	21.88	24.19	14.06	32.31	40.32	31.75
Cultural practices prohibiting farming	0.00	0.00	0.00	0.00	1.61	0.00
Use of fertilisers	7.81	1.61	4.69	0.00	3.23	4.76

Total	100	100	100	100	100	100

4. Discussion

4.1 Anthropization of the Muskuwaari transplanted sorghum field

Human activities carried out in the Muskuwaari field (spraying, stump removal, weeding, mowing and use of herbicides) have adverse effects on the vegetation. Butynski (1984) revealed that these activities lead to a loss of biodiversity even as some species are not cut during agricultural activities. According to Gautier (2002), the species in demand in the Sahelian zone of Cameroon are *Anogeissus leiocarpus, Dalbergia melanoylon, Piliostigma reticulatum, Acacia nilotica* and *Balanites aegyptiaca*. The activities of stump removal and spraying have led to profound changes in the vegetation of the karal field. The non-moderate use of chemical inputs (herbicides) has led to a significant disappearance of vegetation species. Aubertot *et al.* (2005) found that the correct adjustment of sprayers and the choice of low impact pesticides, the respect of the conditions of effectiveness of the treatment are options which generally make it possible to reduce the impacts on the environment.

4.2 Consequence of human activities on the vegetation of the field

The floristic composition of the vegetation changed during the farming of Muskuwaari. The number of woody species, genus and families decreased from the beginning to the end of cultivation. The species *Terminalia glaucescens, Anogeissus leiocarpus, Balanites aegyptiaca* and *Burkea africana* have disappeared in certain villages. Letouzey (1985) found that in this zone the most widespread species are *Anogeissus leicarpus, Balanites aegyptiaca, Guiera senegalensis, Piliostigma thonningii, Acacia seyal, A. albida, A. nilotica, A. senegal* and *Ziziphus mauritiana* of which some in the list are extinct species. No great difference is observed in the averages of the number of species, genus and family for the two types of soil from the beginning to the end of cultivation (the difference is a maximum of 1 for the three rows studied). The results obtained by Ntoupka (1999) in the Laf reserve, which had found 53 species, are far superior to those obtained in the present study and those of Sandjong *et al.* (2013) in the Mozogo-Gokoro National Park with 62 woody species in the Far North region of Cameroon. These differences would be due to the fact that the parks and reserves are zones under surveillance whereas the karal is exploited each year and according to the methods desired by the operators. Oumar *et al.* (2019) in the Mayo-Rey gold panning sites had found 113 species divided into 65 genera and 35 families in the Adamaoua region of Cameroon. These differences would be due to the fact that these anthropized sites belong to different agro-ecological zones. The study area is qualified by Lienou *et al*. (2003) as an area of ecological fragility with the increase in the aridification of the environment and the increase in the mortality of woody species which lead to a reduction in biodiversity. Ntoupka (1999) specifies that many woody species, in this case bushy shrubs and other vining species, do not resist in a context of permanent fire which is an important practice for the establishment of transplanted sorghum cultivation.

4.3 Consequence of human activities on species diversity

The diversity of woody species in karal fields is very low. Shannon's diversity index is less than 3 bits on both soil types and in all six villages. These results are lower than those of Oumar *et al.* (2019) who worked in Bénoué and Bouba-Ndjidda National Parks, whose Shannon index value was 3.94 and 3.99 respectively. This could be explained by the fact that the Parks are less anthropized than the agricultural areas since, in the Parks, all the activities that take place there are controlled. These results are also lower than those of Ouattara *et al*. (2016) in open forests in the Sudanian zone of Ivory Coast who found a Shannon index that is around 5.37 bits [18]. The large difference between these indices is believed to be associated with geographical distribution of vegetation which would be more abundant, dense and less anthropized. The species encountered in the study area are almost the same everywhere; these environments are then similar. The results obtained is similar to that conducted by Tchobsala *et al*. (2016) on the impact of anthropization on the floristic composition, the structure and the ecological characterisation in the vegetation of the Ngaoundéré cliff.

CONCLUSION

The study of the impact of the exploitation of transplanted sorghum Muskuwaari on the dynamism of plant cover in the Far North shows that the "kare" present very harmful anthropogenic activities during the crop cycle (use of herbicide treatments, tree stumps, burning, building bunds, digging or repairing sumps, mowing the herbaceous cover and ploughing). These different activities which are essential in most cases have generated very profound changes in the kare with annual variations in species, the invasion of fields by crop weeds (*Oriza longistaminata, Striga hermonthica* and *Paspalum orbicular*), the denudation of the soil after the harvests, the disappearance of biodiversity, soil erosion and the advance of the desert. The exploitation of Muskuwaari led to a decrease in the number of woody species (20 to 11) from the start of exploitation to the end, followed by their diversity indices. The results of the impact study of the exploitation of transplanted sorghum on the vegetation in the district of Guidiguis, Touloum, Kaélé, Kalfou, Doukoula and Tchatibali therefore confirm the need to develop alternative measures for a sustainable exploitation of karal and good environmental management.

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