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Influence of Anthropization on the Diversity of Woody Vegetation in Muskuwaari Transplanted Sorghum Field in the Sudano-Sahelian Zone of Cameroon

Pa Aï Vivien Nenwala [a*], Dongock Nguemo Delphine [b], Tchobsala [c] and Ibrahima Adamou [b]

[a] Agricultural Research Institute for Development (IRAD, CRRA-Maroua), BP-33 Maroua, Cameroon.
[b] Faculty of Science, Department of Biology, University of Ngaoundere, BP-454, Ngaoundere, Cameroon.
[c] Faculty of Science, Department of Biology, University of Maroua, BP-644 Maroua, Cameroon.

Authors' contributions

This work was carried out in collaboration among all authors. Author PAVN designed the study, performed the statistical analysis, wrote the protocol and author Tchobsala wrote the first draft of the manuscript. Author DND managed the analyses of the study. Author IA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

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. 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. Population surveys in six (06) villages and floristic surveys through 50 m^2 plots in two soil types in these villages were conducted. 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, post-harvest soil denudation and the disappearance of plant biodiversity. The exploitation of sorghum led to a reduction in the number of woody species

**Corresponding author: E-mail: viviennenwalapaai@gmail.com;*

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.

Keywords: Muskuwaari; biodiversity; disappearance; anthropization; woody vegetation; Soudano-sahelian; Cameroon.

1. 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 [1]. 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 [2]. Agricultural challenges in Africa therefore remain relevant. The statistics provided by the FAO [3] 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 [4] 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 [5]. 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 [6,7]. 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 [3]. 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 [8-10]. 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 [11,12]. 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. MATERIALS 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 [13]. 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.

2.2 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).

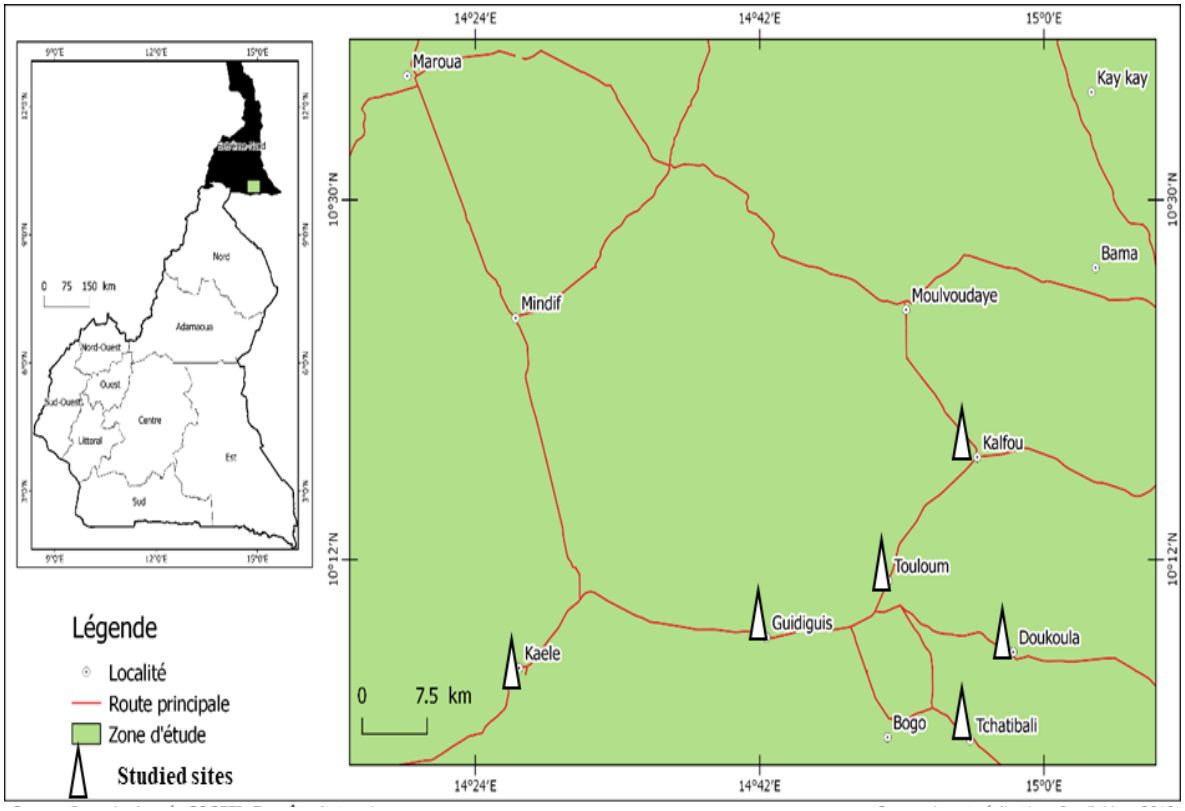

Fig. 1. Cartography of the study sites

2.3 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 [14]. The interviewees were all farmers of transplanted sorghum. A total of 390 farmers were surveyed in the study area, including 65 per village.

2.4 Inventories of Trees

The surveys were carried out sequentially on five strips of 10 m wide and 50 m [15]. 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.

2.5 Analysis of Floristic Composition and Diversity

The Shannon-Weaver diversity index (H') and the Piélou equity index are calculated to determine the diversity within and among species and studied sites.

2.6 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.

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 (CS) and 24.62% on hydromorphic soil (HS); Touloum (55.38% on CS and 32.31% on the HS); Kaélé (55.38% on the CS and 64.62% on the HS); Kalfou (81.54% on the CS and 75.38% on the HS); Doukoula (69.23 % on the CS and 10.77% on the HS); Tchatibali (20.00% on the CS and 58.46% on the HS) (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.

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.

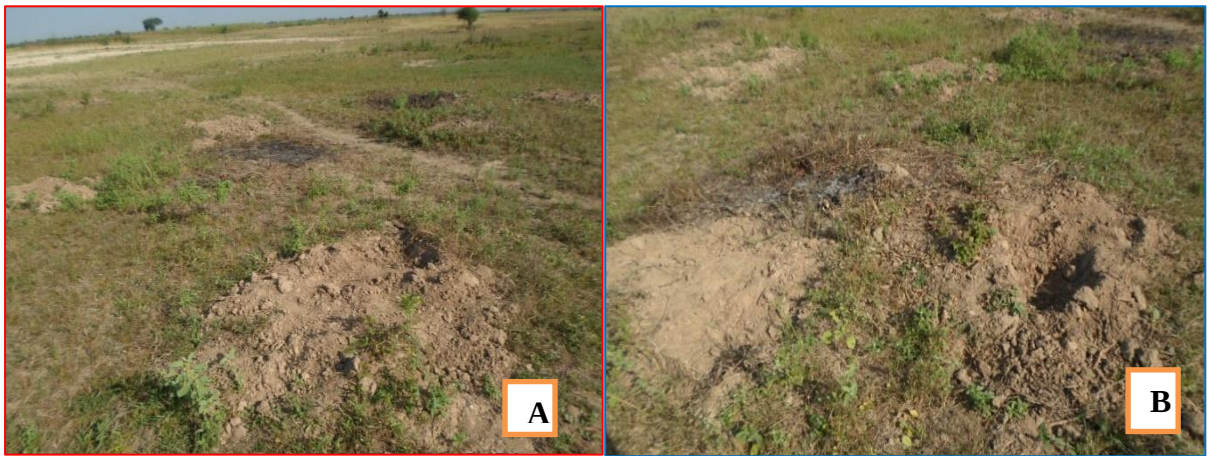

Plate 1. Trace of uprooting of *Guiera senegalensis* (A) and *Piliostigma reticulatum* (B) on clay soil

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 CS at Kaélé and Kalfou to 83.08% on the HS at Touloum. This activity varies with villages and soil types (Table 1).

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 Super Machette. 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 CS and 92.31% on HS, Touloum 87.69% on CS and 96.92% on HS, Kaélé 86.15 % on CS and 95.38% on HS, Kalfou 92.31% on CS and 98.46% on HS, Doukoula 96.92% on CS and 90.77% on HS and Tchatibali 72.31% on CS 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.

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

Table 1. Anthropization activities according to villages and soil types

Anthropic activities	Detail of activities	Guidiguis (%)		Touloum (%)		Kaélé (%)		Kalfou (%)		Doukoula (%)		Tchatibali (%)	
		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

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

Phases	Years	Groups	Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
			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 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.

3.3 Impact of Muskuwaari Harvesting on the Floristic Composition of Species with a Stem Circumference < 10 cm

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 3. 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 (CS = HS = 6). In all the sites, the reduction in the number of species went from the period of field preparation till harvesting (Guidiguis, the CS from 11 to 7 and the HS from 4 to 3; Touloum, the CS from 4 to 2 and the HS from 3 to 2; Kaélé, the CS from 11 to 5 and the HS 10 to 7; Kalfou the CS from 6 to 2 and the HS from 6 to 1; Doukoula, the CS 11 to 5 and the HS from 13 to 7 and Tchatibali, CS from 12 to 7 and HS 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 CS and 13 on the HS. 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 3. Floristic composition of species with stem circumference < 10 cm

		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

3.4 Impact of Muskuwaari Harvesting on the Floristic Composition of the Vegetation of Species with a Stem Circumference ≥ 10 cm

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.

3.5 Indices of Floristic Diversity of Species on the Two Types of Soil

Shannon diversity index (H') of species on clay and hydromorphic soil: The results in Table 5 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.

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 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 5 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 [16]. 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.

3.6 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. But this remains a problem at the same time for biodiversity and the soil, leading in the most extreme cases to desertification.

Table 6 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 4. Floristic composition of species with a stem circumference ≥ 10 cm

		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 ±	Clay	1±0.55	1±0.55	1±0.55	1±0.55	1±0.55	1±0.55
SD	Hydromorphic	1±0.75	1±0.75	1±0.75	1±0.75	1±0.75	1±0.75

Table 5. Shannon diversity index and Piélou equitability (EQ) of species

		Guidiguis		Touloum		Kaélé		Kalfou		Doukoula		Tchatibali	
Divesity index	**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

Table 6. 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 [17] revealed that these activities lead to a loss of biodiversity even as some species are not cut during agricultural activities. According to Gautier [18], 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. [19] 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 [20] 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 [21] 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. [22] 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. [23] 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. [24] 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 [21] 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. [23] 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. [25] in open forests in the Sudanian zone of Ivory Coast who found a Shannon index that is around 5.37 bits. 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. [26] on the impact of anthropization on the floristic composition, the structure and the ecological characterisation in the vegetation of the Ngaoundéré cliff.

5. 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. Reducing the use of chemicals and prohibit the harvesting of green wood are the best methods for the sustainable sorghum exploitation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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