

Ethno-botanic study of *Tamarindus indica* L. in Moutourwa-dry zone of Cameroon

Jules Balna^{1*}, Etame Sone Diabe¹, Hamawa Yougouda², Temgoua Kevine Blondelle³, Ganota Boniface⁴, Bernard Gonné⁴, Oumarou Palou Madi⁵ and Sali Bourou⁶

¹Department of Geography, Faculty of Arts, Letters and Social Sciences, University of Maroua, P.o BOX 644 Maroua, Cameroon;

²Department of Agriculture, Livestock and Derived products, National Polytechnic, University of Maroua; P.o BOX 46 Maroua, Cameroon;

³Department of Environmental Sciences, National Polytechnic, University of Maroua, P.o BOX 46 Maroua, Cameroon

⁴Department of Geography, Higher Teacher Training College (University of Maroua), Cameroon, P.o BOX 46 Maroua

⁵Agricultural Research Institute for Development in Wakwa, P.o BOX 65 Ngaoundéré, Cameroon

⁶Agricultural Research Institute for Development of Maroua; P.o BOX. 33 Maroua, Cameroon

Abstract

This work focuses on the uses of *Tamarindus indica* and its impacts on the renewal of this resource in Moutourwa-Cameroonian Sahel zone. This tree plays a vital socio-economic role in this area but, it is threatened towards extinction. A flora inventory in 62 plots, an ethno-botanical and socio-economic surveys of 60 people constituted the methodology. Results show that; of the 60 species divided into 21 botanic families, this specie has a density of 2.82 ± 0.3 feet/ha, a chest height diameter of 0.41 ± 0.21 m; a height of 7.47 ± 3.36 m; a land surface of $0.5 \text{m}^2/\text{ha}$; a recovery rate of $26.41 \pm 4.61\%$ and a regeneration capacity of 0%. The parts of this tree are used as domestic tools, for construction, feed and medicine. Its erratic distribution and its poor harvest methods have rendered this tree old. Given its importance, awareness campaigns to protect its natural regeneration and to introduce young species during reforestation programs are necessary.

Keywords: sustainable management; degradation; conservation; *Tamarindus indica* L.; moutourwa; sahelian zone of Cameroon

1. Introduction

In rural Africa, agro-pastoral activities are highly climate-dependent, mainly in its Sudan and Sahelian areas (Gonné and Bring, 2016) [4]. However, this part of the tropical zone is suffering the adverse effects of climate change which propels the rural population to make greater use of bush plants for survival, as they find drugs, tools and energy source in the woody stratum as well as fruits and other food supplements (Belem *et al.*, 2008; Gonwakinnou *et al.*, 2011) [8]. As a result, this leads to overexploitation of multi-purpose trees with high socio-economic potential, placing the trees density in a dynamic regression characterized by the scarcity or absence of young species (Diallo, 2001; Ouédraogo *et al.*, 2006) [16, 26]. Among these useful forest species available in Cameroon's dry zone is *Tamarindus indica* L., an agroforestry and a species for the future (Bourou, 2012; El-Siddig *et al.*, 2006) [11, 19].

However, there is a "technical package" consisting of an institutional, legal and regulatory framework that governs the management of natural resources. In order to specifically manage these forest resources, Cameroon has adopted a set of laws and regulations. This includes; Law 94/01 of 20 January 1994 on forests, wildlife and fisheries regime and its decree of implementation Nr. 95/53/PM of 23 August 1995. These frameworks were strongly inspired by international legal instruments to which he adhered, such as the International Trade Convention on Endangered Wildlife Species and Flora (CITES) and the United Nations Convention on Biological Diversity (UNCBD). To implement these tools, Cameroon has developed a number of plans and tools, including the National Environmental

Management Plan (NEP) adopted in 1996 and the Forest Environment Sector Programme (PSFE) finalized in 2005. However, their implementation currently poses many problems due to inadequate coordination interventions between sectors.

In the African savannah, several studies on this species have been made on its eco-physiology (Bourou, 2012) [11] or on its socio-economic, cultural and ecological functions (Lamien and Traoré, 2002; Gautier *et al.*, 2002; Ba *et al.*, 2006; Dakouo, 2009) [32, 21, 14]. These authors analyzed the factors that largely explain the decline in the number and its use by the population. However, the analysis of the link between forestry practices and population dynamics has remained discreet. It is in this view that this study was conducted. It sheds light on the question of the degradation of wood resources due to strong pressure from man on them.

2. Materials and Methods

The study was conducted in Barawa Laddé and Barawa Chefdoms, two villages belonging to the Moutourwa council in the most populous and arid Far North region of Cameroon. They are located respectively between latitudes $10^{\circ} 12' 55''$ N and $10^{\circ} 14' 57''$ N and longitudes $14^{\circ} 08' 51''$ E and $14^{\circ} 07' 57''$ E (Figure 1) at 52 km from the city of Maroua exerting pressure on these peripheries due to its population doubling every 30 years. The choice of these villages is based on the current critical condition of the number of *Tamarindus indica*, which is under strong zoo-human pressure in the Sudano-Sahelian zone of Africa. They are marked by long dry season (October-May), low annual rainfall (500-1000 mm) irregularly distributed over

time and space, high thermal amplitudes (20°C in January and 45°C in April). They have a savannah vegetation and dominated by species such as *Acacia seyal*, *Combretum micranthum*, *Anogeissus leicarpa*, *Ziziphus mauritiana*, *Balanites aegyptiaca*, etc. (Letouzey, 1985; André, 1996) [34].

In both sites live the Guiziga, an ethnic group occupying the northern part of the Diamaré plain. The latter is experiencing a significant dynamism following the settlement of peasants from the southern part of the said plain and even Chad for the cultivation of off-season sorghum (Watang Ziéba, 2009) [43]. Like other areas, they are experiencing famine as a result of drought, invasions of locusts and elephants, whose impact on basic cereal production are enormous. At the regional scale, the poverty rate is still highest (65.9%) compared to the national average of 40% (INS, 2008). Activities are focused on rain-fed and off-season agriculture, with local livestock, firewood harvesting and small-business becoming increasingly successful.

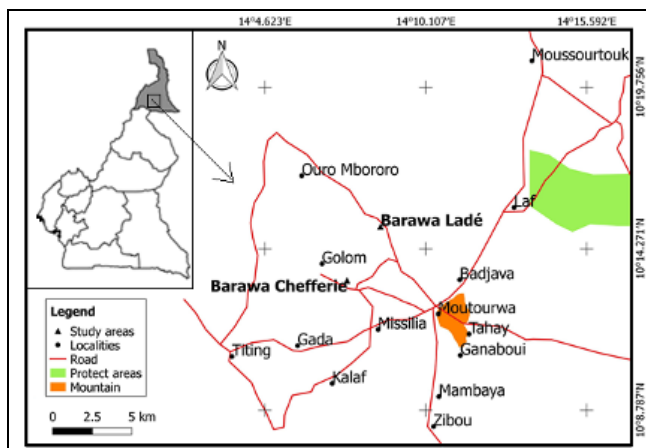


Fig 1: Location map of study sites

2.1. Sample and inventory device

To extract the population to be surveyed, a simple random sampling was chosen from the total population of 1500 inhabitants following a previous census carried out in both localities. As a result, the sample size was calculated by the proportional choice technique at a threshold of 4% using Miller's formula (1988): $n = N \times \beta$; where n is the sample size, N the total population size of each locality and the significant threshold set at 0.04. A total of 60 individuals were surveyed in the two villages, 32 in Barawa Laddé and 28 in Barawa Chieftdom selected on the basis of primary activities, sex, age, average annual income and level of education.

In terms of forest inventory, systematic sampling was adopted because of its easy and practical implementation in the field. The adopted device is a circular square with a radius of 20m within which was placed smaller squares of 5m. The distance between two squares were 200m and 300m between transects. In addition within a radius of 100m, species sharing the same area with the *tamarind* tree have been recorded. Thus, the number of plots was determined by the total sample area (459 ha) shared between these two localities. To this effect, the sampling rate was set at 1.7% which is scientifically acceptable (Lecomte and Rondeux, 2002; Richter, 2012) [33, 37]. Taking into account

the step between the plots and transects, the area censored was 7,803 ha spread over 62 plots and 18 transects.

2.2. Data collection

Questionnaire administration and interviews with the local population as well as floristic inventory constituted our method. An exploratory survey was initially carried out in the Moutourwa council jointly led by a forestry agent and 03 farmers with a good knowledge of the bush. The objective was to determine the sites of *Tamarindus indica* and where the exploitation of its products is taking place. This pre-survey also allowed the study area to be characterized and demarcated using GPS.

Investigations assessed the interest put on the tree species in a peasant environment. The questions asked were; closed, open and oriented questions to which several answers were proposed for the respondent to choose. Emphasis was laid on the various aspects relating to the current situation of the emblematic specie particularly on the actors profile, the ethno-botanical characteristics of the resource, its current state, its economic value, the uses and methods of harvest of the various parts of the tree. In order to make an economic assessment of the products derived from the *tamarind*, a follow-up survey was carried out among 20 traders at the Moutourwa market.

For the forest inventory, botanical surveys were carried out on species with a girth diameter ≥ 5 cm. in each plot and on each tree, these surveys focused exclusively on the Dendron-metric parameters. The data taken are the diameter at chest height (dh=1.30m from the ground), the height and health of the tree (normal, affected, dead). However, not all trees were accounted for in the same way. A limit diameter called "minimum range of interest" was defined, at 5cm in the dry Sudan area and in the Sahel (Thiombano *et al.*, 2016). When measuring diameter and height, species were divided into Six classes namely the 10cm diameter stems considered regeneration; [10-20]; [20-30]; [30-40]; [40-50] and >50 cm). In terms of height, 04 classes were defined: <4 ; [4-8]; [8-12] and [12-16](cm) knowing that there are trees less than 7m high. A forest compass was used to measure diameters and a clinometer for heights.

2.3. Data analysis

The data analyzed are quantitative and qualitative. They were treated with SPSS 21.00 and analyzed with Excel. To this effect, descriptive statistical techniques such as frequencies, minimum, maximum, average and standard deviation were used. This permitted the data to be presented in the form of histograms and tables to show the trend of the observed phenomena. Their analysis consisted of calculating the parameters to assess the current state of the number of *Tamarind*, namely; the diameter at 1.30m, the diameter of the crown, the height, the abundance of the species, the density and the rate of renewal. Thus, the density was calculated according to the $Ad = N/A$ formula with Ad the absolute density, N the total number of species sampled and A total sample area in hectares. Species abundance was calculated using the $Ad(Z) = nA(Z) / \sum n(Z)$ formula with $nA(Z)$ being the number of A species in Z zone, $\sum n(Z)$ considered as the number of all species in zone Z . For the renewal rate, it was calculated using the Formula $Rg = Nrg / (Nrg + Nda) * 100$ with Rg the regeneration rate, Nrg the total number of seedlings and/or young plants and Nda the number of mature plants.

3. Results and discussion

3.1. State of species

The vegetation of Moutourwa is both tree and shrub savannah. It is a question of taking stock of the woody population by indicating the compositional diversity, abundance, horizontal, vertical structures and capacity of regeneration.

3.1.1. Compositional diversity of species

The study identified 60 species of 38 kinds and 21 families.

The biological spectrum indicates dominance of Mimosaceae (18.64%), Combretaceae (15.25%), Ceasalpinaceae family in which *Tamarindus indica* is one of the species, (8.74%), Anacardiaceae (8.74%), Fabaceae (6.78%), Moraceae (6.78%) and Rhamnaceae (6.78%). The remaining families (Arecaceae, Burseraceae, Annonaceae, Bombacaceae, Balanitaceae, Ebenaceae, Bignoniaceae, Euphorbiaceae, Capparicaceae, Olacaceae, Rubiaceae, Ulmaceae and Sterculiaceae) represent only 17.47% of the taxons (Figure 2).

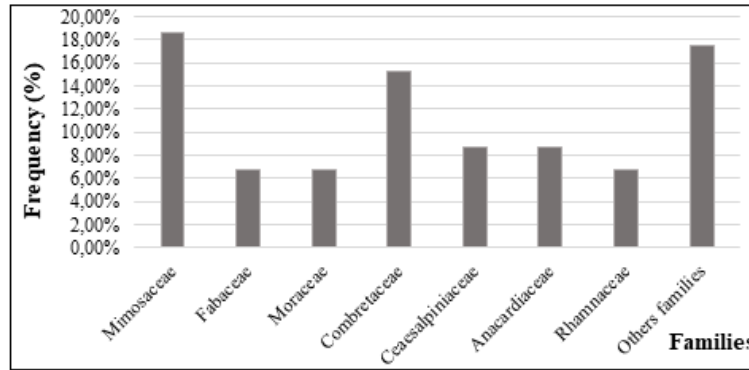


Fig 2: Specific composition of the stand of the woody

In Burkina Faso (Thiombiano, 1996; Hahn-Hadjali, 1998; Ouédraogo, 2006, Guigma *et al.*, 2012) [26, 36], Chad (Bashir, 2010) and North Togo (Badjaré *et al.*, 2018), similar results with the same dominant families were obtained under the same ecological conditions. In the dune zone of Niger, the study conducted by Kaou *et al.* (2017) highlighted a relatively small flora with the presence of 38 species divided into 17 families. In the same view, the Sudano-Guinean zone of Benin, Gbesso *et al.* (2014) discovered that there are 64 woody species divided into 25 botanical families with a predominance of leguminosae whose abundance in the total sample is often lower than other families.

3.1.2. Plenty of trees in the plant community

The abundance and density of each species is presented in Table 1. The average population density is 149 feet/ha, of which 52.64% are represented by *Acacia* family (18.42%), *Combretum* (13.16%), *Ficus* (10.53%) *Ziziphus* (10.53%). The most abundant species in the plant community are among others: *Anogeissus leiocarpus* with a relative abundance of 9%, *Azadirachta indica* (7%), *Combretum aculeatum* (3.50%), *Combretum glutinosum* (2.83%) and *Sclerocarya birrea* with a relative abundance of 3.17%. These species alone account for 25.5% of the total population. It appears that *Tamarindus indica* represents only 1.88% of the population with an average density of 2.82 feet/ha. This further reflects the level of threat to this high-potential value species in this savannah area.

Table 1: Species population, abundance and density

N°	Species	Number	Abundance (%)	Densité (ind/ha)
1	<i>Acacia ataxacantha</i>	18	1,54	2,31
2	<i>Acacia hockii</i>	11	0,94	1,41
3	<i>Acacia polyacantha</i>	13	1,11	1,67
4	<i>Acacia senegal</i>	23	1,97	2,95
5	<i>Acacia seyal</i>	5	0,43	0,64
6	<i>Acacia sieberiana</i>	15	1,28	1,92
7	<i>Acacia sp</i>	10	0,86	1,28
8	<i>Albizia chevalieri</i>	53	4,54	6,79
9	<i>Anogeissus leiocarpus</i>	105	8,99	13,46
10	<i>Azadirachta indica</i>	77	6,59	9,87
11	<i>Balanites aegyptiaca</i>	30	2,57	3,84
12	<i>Bombax costatum</i>	32	2,74	4,10
13	<i>Borassus aethiopum</i>	14	1,20	1,79
14	<i>Boscia senegalensis</i>	7	0,60	0,90
15	<i>Boswellia dalzielii</i>	31	2,65	3,97
16	<i>Bridelia scleroneura</i>	21	1,80	2,69
17	<i>Cassia arrereh</i>	21	1,80	2,69
18	<i>Cassia singuana</i>	8	0,68	1,03
19	<i>Celtis integrifolia</i>	17	1,46	2,18
20	<i>Combretum aculeatum</i>	41	3,51	5,25
21	<i>Combretum fragrans</i>	19	1,63	2,43
22	<i>Combretum glutinosum</i>	33	2,83	4,23

23	<i>Combretum micranthum</i>	20	1,71	2,56
24	<i>Combretum molle</i>	11	0,94	1,41
25	<i>Commiphora africana</i>	23	1,97	2,95
26	<i>Dalbergia melanoxylon</i>	10	0,86	1,28
27	<i>Diospyros mespiliformis</i>	14	1,20	1,79
28	<i>Entada africana</i>	19	1,63	2,43
29	<i>Faidherbia albida</i>	25	2,14	3,20
30	<i>Ficus abutilifolia</i>	24	2,05	3,08
31	<i>Ficus cycomorus</i>	19	1,63	2,43
32	<i>Ficus sp</i>	5	0,43	0,64
33	<i>Ficus thonningii</i>	19	1,63	2,43
34	<i>Gardenia aqualla</i>	13	1,11	1,67
35	<i>Guiera senegalensis</i>	7	0,60	0,90
36	<i>Haematostaphis barteri</i>	16	1,37	2,05
37	<i>Hexalobus monopetalus</i>	19	1,63	2,43
38	<i>Hyphaene thebaica</i>	4	0,34	0,51
39	<i>Khaya senegalensis</i>	15	1,28	1,92
40	<i>Lannea barterie</i>	8	0,68	1,03
41	<i>Lannea schimperi</i>	23	1,97	2,95
42	<i>Lannea sp</i>	12	1,03	1,54
43	<i>Lonchocarpus laxiflorus</i>	12	1,03	1,54
44	<i>Parkia biglobosa</i>	26	2,23	3,33
45	<i>Piliostigma reticulatum</i>	14	1,20	1,79
46	<i>Piliostigma thonningii</i>	11	0,94	1,41
47	<i>Prosopis africana</i>	10	0,86	1,28
48	<i>Pterocarpus erinaceus</i>	27	2,31	3,46
49	<i>Sclerocarya birrea</i>	37	3,17	4,74
50	<i>Sterculia setigera</i>	17	1,46	2,18
51	<i>Sterganotaeriaaraliace</i>	6	0,51	0,77
52	<i>Sterospermum kunthianum</i>	12	1,03	1,54
53	<i>Tamarindus indica</i>	22	1,88	2,82
54	<i>Terminalia avicennioides</i>	7	0,60	0,90
55	<i>Terminalia sp</i>	11	0,94	1,41
56	<i>Ximenia americana</i>	5	0,43	0,64
57	<i>Ziziphus abussinica</i>	9	0,77	1,15
58	<i>Ziziphus mauritiana</i>	14	1,20	1,79
59	<i>Ziziphus mucronata</i>	7	0,60	0,90
60	<i>Ziziphus spina-christi</i>	11	0,94	1,41
	Total	1168	100,00	149,69

Studied specie	companion specie	non companion species
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The specific importance of the woody species identified also highlights the presence of several other wild fruit trees such as *Balanites aegyptiaca*, *Diospyros mespiliformis*, *Haematostaphis barteri*, *Hexalobus monopetalus*, *Ximenia americana* and *Sclerocarya birrea*. In all, 19 species belonging to 15 botanical families are species cohabiting with the tamarind tree (Table 1): these are companion species. Soumana *et al.* (2012) pointed this out by citing some of the most common species including *Diospyros mespiliformis*, *Tamarindus indica*, *Sclerocarya birrea*, *Balanites aegyptiaca* and *Parkia biglobosa*. These species almost have an irregular horizontal and vertical structure.

3.1.3. Population structure of species in erratic shape and bell

The distribution of specie density by diameter classes (Figure 3a) permitted us to know the horizontal structure of all species. The erratic structural shape reflects an irregular distribution in diameter classes, however, with a significant representation of species with a diameter >50cm. Species

with <10cm in diameter are absent in the study areas. Trees with a diameter of between 10cm and 30cm are poorly represented (22.7%). In contrast, individuals with a diameter of more than 30cm account for 77.3% of trees.

In terms of vertical structure, the height class distribution draws a bell-shaped structure (Figure 3b) whereby, the trees mostly belong to the middle classes. Examining this figure permits us to note a distribution in all height classes. In addition, the total sample is dominated by trees with a height of between 4m and 8m (50%). Tree classes of height between ≥8m make up 40.9% of the total sample, while shrubs less than 4m high are poorly represented 09.1%. It is likely that this distribution is as a result of pruning practices. For the crowns, the distribution of the average diameters of the densities of species reflects a representation of all classes, except that greater than or equal to 12m (0%). The tree class of 4m to 8m in diameter is the most represented (54.5%) trees with a diameter of less than 4m and between 8m and 12m each represent 22.7% of them. This can be explained by the fact that its branches are cut for the making of handicrafts and when picking its fruits.

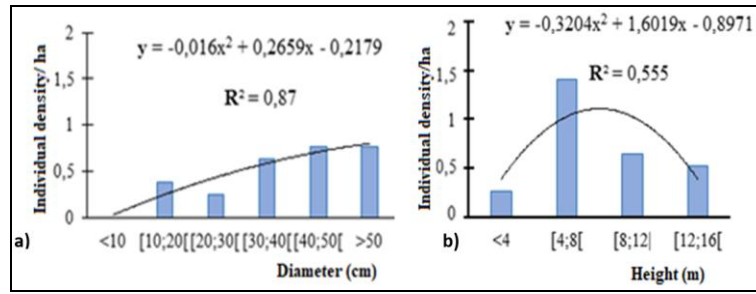


Fig 3: Distribution of the horizontal and vertical structure of individuals

The overall analysis of the *tamarind* specie has a density of 2.82 ± 0.31 feet/ha, a diameter of 0.41 ± 0.21 m, a height of 7.47 ± 3.36 m, a land surface area of 0.5 ± 0.17 m²/ha and a recovery rate of $26.41 \pm 4.61\%$. This low representation is attributed to the zoo-anthropogenic pressure exerted on this valuable specie. The erratic structure reflecting a very irregular distribution in the diameter classes as well as a bell shape of the vertical structure of the *Sclerocarya birrea* specie were also observed in the work of Abdourhamane *et al.* (2017) in the Sahelian sector of Niger as well as those of Soumana *et al.* (2012) on four fruit woody species including *Tamarindus indica*, which has no capacity for regeneration.

3.1.4. Zero regeneration capacity of *Tamarindus indica*

In all, the regeneration rate of species is estimated at 74.49% (Table 2). Species such as *Annona senegalensis* (100%), *Acacia seyal* (97.31%), *Ziziphus mucronata* (94.31%), *Acacia hockii* (92.36%), *Piliostigma reticulatum* (91.62%) and *Combretum micranthum* (90.78) have the highest rates of regeneration meanwhile for *Tamarindus indica*, this rate is zero (0%). Based on Figure 4, an absence of species in the small-diameter class (10cm) is noted. Indeed, no seedlings were observed. This is probably due to zoo-anthropogenic pressure, especially with the high concentration of nomadic herders from neighboring countries (Niger, Nigeria and Chad).

Table 2: Species regeneration rate

Espèces	Total number	Total mature trees	Total young trees	Regeneration rate (%)
<i>Acacia ataxacantha</i>	48	18	30	62,50
<i>Acacia hockii</i>	144	11	133	92,36
<i>Acacia polyacantha</i>	38	13	25	65,79
<i>Acacia senegal</i>	37	23	14	37,84
<i>Acacia seyal</i>	186	5	181	97,31
<i>Acacia sieberiana</i>	55	15	40	72,73
<i>Annona senegalensis</i>	8	0	8	100
<i>Anogeissus leiocarpus</i>	266	105	161	60,53
<i>Balanites aegyptiaca</i>	100	30	70	70
<i>Bombas costatum</i>	59	32	27	45,76
<i>Cassia singuana</i>	64	8	56	87,50
<i>Combretum aculeatum</i>	75	41	34	45,33
<i>Combretum fragrans</i>	89	19	70	78,65
<i>Combretum glutinosum</i>	42	33	9	21,43
<i>Combretum micranthum</i>	217	20	197	90,78
<i>Commiphora africana</i>	33	23	10	30,30
<i>Ficus abutilifolia</i>	42	24	18	42,86
<i>Gardenia aqualla</i>	20	13	7	35
<i>Guiera senegalensis</i>	18	7	11	61,11
<i>Piliostigma reticulatum</i>	167	14	153	91,62
<i>Piliostigma thomingii</i>	71	11	60	84,51
<i>Tamarindus indica</i>	22	22	0	0,00
<i>Terminalia avicennioides</i>	31	7	24	77,42
<i>Ziziphus abussinica</i>	49	9	40	81,63
<i>Ziziphus mucronata</i>	123	7	116	94,31
<i>Ziziphus spina-christi</i>	38	11	27	71,05
Total	2042	521	1521	74,49

3.2. Towards socio-economic importance

3.2.1. Profile of the local population

The profile of the individuals interviewed shows that 100% of the respondents are Guiziga, an ethnic group on the Diamaré plain. Their age ranges from 17 to 90 years dominated by women (52%). The age range from 21year to 40years representing 49% of the population. As a result, the population is young. Their level of education is low, as 60% of them have not been to school. The proportion of the

population in school occupies 40%, i.e. 12% for the primary level and 28% for the secondary level, especially in the first cycle. Their main activity is trade, since 60% of respondents practice it. Agro-pastoral and other so-called marginal activities are carried out by only 40%. The average income per household is between 100,000 and 500,000 CFA francs. Thus, there is a link to be made between this socio-economic profile of this population and the methods of resource harvesting.

3.2.2. Different uses of the parts of *tamarind* tree

The Tamarind tree, thanks to its many products, occupies a special place for households not only in *Moutourwa*, but also among other peoples of the Diamaré plain as well as those of the Mandara Mountains. It is locally called

Mboulam in Guiziga and *Njabbi* in Fulfuldé. Its use depends on the part of the tree harvested and the user. It may vary from one ethnicity to another or from one group of users to another. In all, 06 parts of the tree were identified (Figure 4).

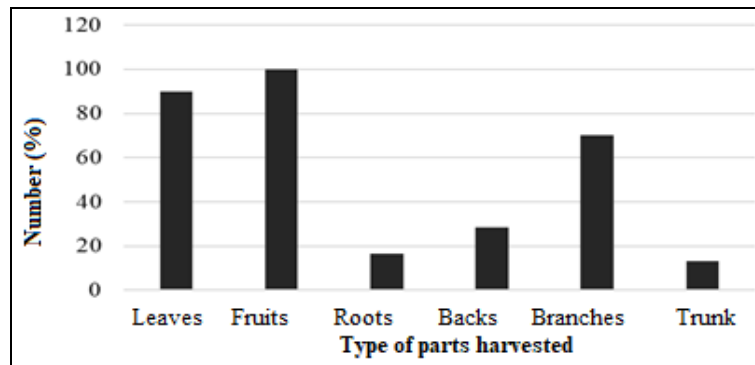


Fig 4: Frequency of collection of different parts of the tamarind tree

Figure 4 highlights the different parts of the *Tamarind* used by the population. It appears that fruits, leaves and branches are the most used parts (70% to 100%). On the other hand,

roots, barks and trunks form the least used parts. In terms of its use by the local population, 18 forms of uses divided in to 07 categories were identified in the study area (Table 3).

Table 3: Uses of different parts of the Tamarind tree

Utility Categories	Tree Part	types uses
Feed	Fruits	Ripe fruits are consumed (through sucking or added in pap). Used in the production soft refreshing with very good taste very rich in nutritive elements.
	Leaves	Consumed like legumes (young leaves)
Arts	Branches	Used for the production of handles for hoes, axes since it is very solid and appreciated (sold and used by peasants)
	Roots	Used to fix and fortify machete handles
Construction	Branches	Used and construction poles for sheds
Energy	Branches	Used as firewood
	Trunk (wood)	Used like firewood
Commercialisation	Fruits	Sold (important source of revenue for peasants)
	Branches	Configured as handles for tools
Fodder	Leaves	For feeding domestic animals (young plants are very appetizing to animals)
Traditional medicine	Fruits	Treatment of stomach ache, boils, missiles and malaria
	Leaves	Treatment of fever and malaria
		Lutte contre les enflures
Barks	Treatment of stomach, back and tooth ache	

Tamarind trees provide many services to the population. It is a multi-purpose species so its importance is nutritional and medicinal. It is also a significant source of income for the local population and a source of fuel, as it is used in households as firewood. Its wood, for example, is used in the construction as service wood and as firewood; among the Guiziga and the mountain people of North Cameroon, they use it for the making of tool-handles (axe, hoe and planting tools) (Gautier *et al.*, 2002)^[21]. Its young leaves are eaten by both animals and humans. The ripe fruits are often eaten in its fresh state or in the form of syrup. These different uses have been identified in the work of El-Siddig *et al.* (2006)^[19], Douamba (2006)^[17], Mapongmetsem *et al.* (2010), Bourou (2012)^[11] and Balna & Gonné (2016) highlighting the multiplicity of uses of the Tamarind parts. Juice is an ingredient in the sauce and is very rich in vitamin B (Bowe, 2007)^[12]. However, the cultural significance for ritual ceremonies and the intensity of use for charcoal production are discreet. However, the fruits of Tamarind

trees occupy a prominent place in households, as their sale provides significant financial income.

3.2.3. Economic evaluation of *Tamarind* products

Tamarind is of great economic importance to local people as the woody and non-woody products it supplies can be sold in local and international markets. In Cameroon, the contribution of non-woody forest products to GDP (excluding oil) is 0.52% with an added value of 61.06 billion CFA francs (Eba'a Atyi *et al.*, 2013)^[18]. The most marketed *Tamarindus indica* products (Plate 1) consist of dried and shell fruits (1a) and tool-handles (hoes, axes, drumming sticks) made from branches (1c, 1d). The average time spent from harvesting to marketing *Tamarindus indica* fruits is 03 months. A tree in full production can produce between 150kg and 200kg of fruits (Gautier *et al.*, 2002)^[21]. However, harvesting activities are sometimes early in the area, since it begins before fruit ripens. According to Dakouo (2009)^[14], harvesting practices do not ensure the sustainable management of agroforestry species.

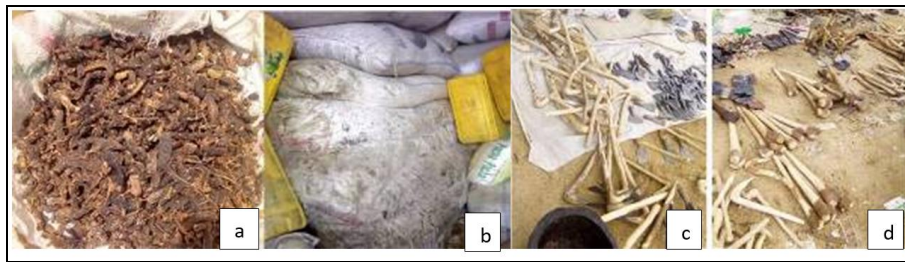


Plate 1: (a) Marketing; (b) Fruit storage; (c) and (d) Tool handles

Actors are grouped into two categories; gatherers/sellers and wholesalers/retailers (Figure 5). gatherers/sellers have direct access to the resource and are at the beginning of the chain. Thus, after their collection operations, the products are sold in the village to the wholesalers/retailers (rural and urban). Wholesalers transport these products to the markets in other Cameroonian cities including Garoua, Ngaoundéré, Garoua-Boulai, Bertoua and Yaounde and even beyond Cameroon's borders, such as Nigeria, Gabon and the Central African Republic. However, some of these actors are seen as intermediaries.

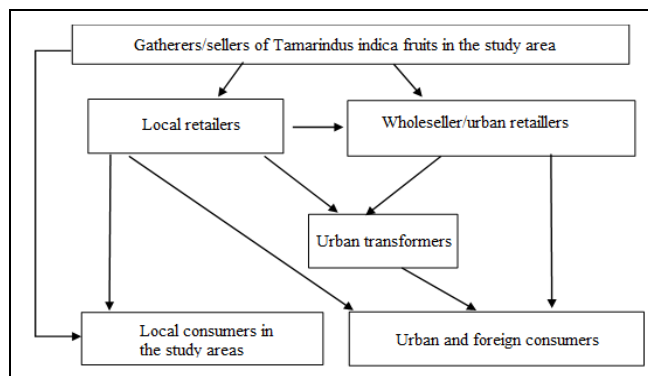


Fig 5: *Tamarindus indica* product marketing circuit

In terms of Tamarind fruit prices in the local Moutourwa market, the price of a 100 kg bag ranges from 7,000 to 12,000 CFA francs depending on the season. The price of 1kg is between 200-400FCFA in the flowering phase (January to December) and 400-500 FCFA in the fruiting/maturity phase (August to February). For products derived from its wood, the price of a hoe-handle varies between 250-400FCFA, that of the axe oscillates between 400-1200 FCFA. However, in Burkina Faso, the research results of Douamba (2006)^[17] revealed that the price of 1kg of fruit sold in local markets is much lower (55-77FCFA) than that mentioned in this study. However, the actors in the sector (gatherers/sellers and traders) are usually the only ones to decide the price of *Tamarindus indica* products.

3.4. Mode of exploitation and impacts on the population

3.4.1. Harvesting

In the context of harvesting *Tamarindus indica*, the local population uses several modes. These are a function of the recipient and the service requested. However, at these farms, no distinction is made on the age of the tree, especially in terms of leaf harvesting. Picking and cutting in uncultivated areas (88.33%) and sometimes in the farms (31.67%) and near residences (18.33%) have been identified as methods of gathering. Intense cutting practice (71.67%) is done as opposed to fruit and leaf harvest (28.33%). Cutting (with a machete or axe) is done for the harvesting of other parts of

the plant ranging from the fruits present on the high branches to the root. The different parts of *Tamarindus indica* are usually harvested at various times: fruits, between November and January to be stored, consumed and marketed; leaves between April and September and other parts like branches, barks, trunks and roots, at all times when need arises.

This plant harvesting by animals and humans begin from the moment it shoots the first leaves and branches, this is due to poverty and the desire to fill the deficit in agricultural products (food crisis). This habit of not taking into account the condition and age of the specie by local populations is associated with grazing and trampling of young plants by livestock during periods of transhumance. In addition, there is little involvement of the local population in the protection of young plants when they see the animals graze on them. In the same view, a study of the number of *Haematostaphis barteri* found that the local population contributes to the conservation of woody resources through good forestry practices (Hamawa *et al.*, 2018)^[28].

3.4.2. Silvi-cultural practices dominated by pruning

The exploitation techniques practiced on the *Tamarindus indica* are diverse. These include complete cutting down of the plant, pruning of branches and bud-cutting (Figure 6 and Plate 2). In all, pruning (88.33%) is mostly practiced, followed by pruning of branches (18.33%), peeling (13.33%) and complete cutting down of the plant (10%). A small proportion of the population (3.33%) is involved in the bud-cutting operations.

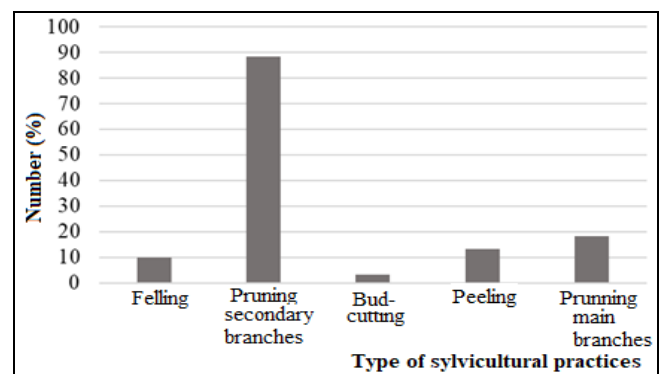


Fig 6: Different forestry practices identified in the two study localities

This result shows that pruning practice that does not take into account the health of the tree, is largely responsible for the decrease in fruiting. It is also responsible for the deformation of the pinnacle of the *Tamarindus indica*. In addition, young plants are absent since they are very appetizing to animals and also suffer trampling effect during transhumance period. Under the same ecological conditions,

the works of Bounkougou (1987), Depommier & Guerin (1996), Boffa (2000) [9] and Balna *et al.* (2015) on the pruning of *Faidherbia albida*, also demonstrated the idea of decline in fruit production.

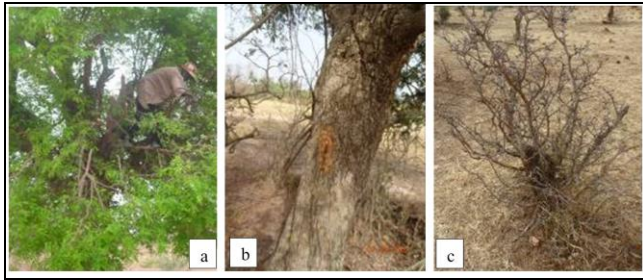


Plate 2: Types of forestry practices: a) bud-cutting b) pruning; c) peeling

3.4.3. Local perception of a decline in the number of *Tamarindus indica*

In all, 80% of the population has seen a significant decline in the number of *Tamarindus indica* for more than 03 decades, 8% noticed its stability and 12% perceived an increase in its number. This tree resource degradation had also been perceived since the 1980s in the Sahel (Cissé 1984; Bonkougou, 1987) [10, 13]. 96% of those surveyed revealed that, the main causes of the decline include: cutting wood to produce tool-handles, cutting branches during fruit harvesting, overgrazing, parasitic pressure and the presence

of nomadic herders especially Mbororos. (4%) accused ageing as the main cause of the decline. According to 84% of the population surveyed, the presence of tree mistletoe disrupts plant production, either by slowing down fruiting periods or by reducing its fruit yield.

Generally, there is a greater intensity of decline in the number of *Tamarindus indica*. The aging segment of the population (50-80 years plus) noted a significant decrease in trees. 49% of farmers reported a very high decrease, (26%) indicates an average decrease, while 25% reported a smaller decrease in the number of *Tamarindus indica*.

3.4.4. The impact of the exploitation of *Tamarindus indica* on the population

The removal of different parts of *Tamarindus indica* explains the condition of the tree. In all, 89% are affected, 9% normal and 2% dead. The trunks of the Tamarind tree in the farms and near homes are healthier than those found in the bushes located about 4km away. In addition, *Tamarindus indica* would be better protected in farms and near the homes. Overgrazing, inadequate forestry practices such as poor pruning, bud-cutting, peeling and felling are the main causes of a decline in the number of this specie. In addition, pruning leaves for fodder and household feed would likely be responsible for the reduction of fruit production and deformation of the canopy (Plate 3a and 3b). Termites present on the plant attack the root system and make the tree sensitive to wind (Plate 3c).



Plate 3: Deformed canopy (a) and *Tamarindus indica* tree vulnerable to wind action (b)

In addition, local exploitations were done for pharmaceutical and food purposes which results in significant damage of this specie’s woody material (Thiombiano *et al.*, 2012). The removal of the barks of *Tamarindus indica* causes enormous damage to this plant species to this effect, Hahn-Hadjali & Thiombiano (2000) [27], also concluded that intensive peeling of the tree kills it. Thus, species that are victims of this practice are no longer able to perform their physiological functions to the best of their potential (Traore *et al.*, 2011). During periods of

fruiting, women and children go to the farms and bushes, in search of fruits, hence the absence of seeds to ensure natural regeneration. Also, excessive leaf exploitation is detrimental to fruit production. These different situations reduce the number of *Tamarindus indica* and facilitate its ageing state. Weevil attack on the fruits during flowering and at the early ages of formed fruits destroys more than 70% of the seeds before their maturity. This explains the reason why mature seeds present tiny holes on them indicating unhealthy seed with poor quality Plate 4a and 4b.

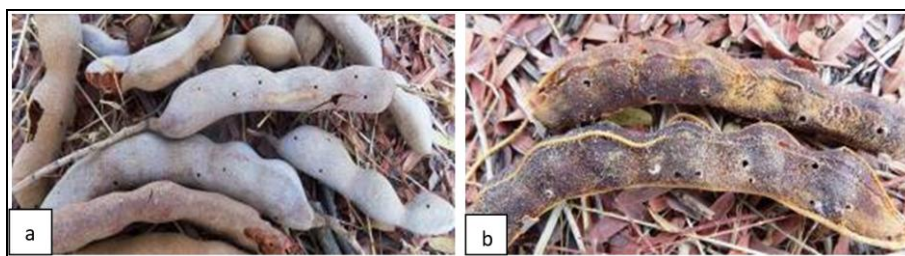


Plate 4: Weevil attack on *Tamarindus indica*, fruits (a and b)

The abundance of the old stumps of this tree is an indication of its disappearance. The same observation was made in

Benin on *Parkia biglobosa* (Koura *et al.*, 2013; Fandohan, 2010) [31] indicating that anthropogenic pressure has a

negative effect on Dendron-metric parameters such as regeneration density and adult plant density but with a positive effect on average diameter.

4. Conclusion

This study provided an understanding of the various factors that contribute to the gradual decline of wild fruit trees, particularly *Tamarindus indica*, as a result of anthropogenic activities in the Sahelian zone of Cameroon. Analysis of the state of the *Tamarindus indica* population revealed that this specie is old and unstable in number, with zero regeneration rate. However, the demographic structure shows a declining number of this tree specie, with a predominance of some with a large diameter. The grazing and trampling of young plants by cattle during transhumance periods and the sample taken from them, the regeneration stratum is vulnerable and rarely matures.

Tamarindus indica trees contribute to the conservation of biodiversity, as several other species coexist there. Although people are aware of the importance of local species in their daily lives and their gradual decline, they do not have the culture to conserve them through plantations or protection of natural shoots. Based on these results, this study recommends that the actors of development regularly create awareness campaigns and plant young *Tamarindus indica* trees in order to sustain it in the area. Meanwhile, the development of the practice of assisted natural regeneration (ANRP) of this emblematic species should be encouraged.

It would be useful to extend this study to other parts of the Sudano-Sahelian zone of Cameroon to assess the degree of threats on this specie. To this effect, an evolutionary study through the analysis and interpretation of satellite images of the last three decades could be envisaged. Characterization of important wild fruit trees such as *Tamarindus indica* L. in the Sudano-Sahelian zone of Cameroon and a perceptible study of its products and by-products could also be considered. However, in order to restore the number of *Tamarindus indica* to combat crises, which are very common in the Sudano-Sahelian zone, it would also be important to set up a pilot project on the creation of *Tamarindus indica* reserve at the level of the Chad basin.

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