Structure of the woody stands of the future pre-release site of North African ostrich (*Struthiocameluscamelus*(Linnaeus, 1858)) in Koutous, Niger

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ABSTRACT

This study aims to investigate the composition and Important Value Index (IVI) of the woody stands of Tchillala, a 130-ha area selected forfutureNorth-African ostriches (*Struthiocameluscamelus*) prerelease in the Koutousregion in Niger. The forest inventory methodwas implemented in 42 plots of 50 m x 20 m (1000m²)for tree-level observation,using stratified random sampling. For each woody specimen, the trunk diameter, total height and crown diameter have been recorded;the specimens with a trunk diameter smaller than 5 cm are considered as regenerations. A total of 17 woody species distributed across 10 families have been identified and most of them belongs either to the Mimosaceae (4 species) or theTiliaceae (3 species). The plants density, domination and frequency were used to determine the IVI:*Acacia tortilis* and *Balanitesaegyptiaca* are the species with the highest IVI(118.43 and 88.28 respectively). The woody plants condition assessment has emphasized that trees have been facingnatural (uprooting) and anthropogenic (cutting, pruning) threats. Consequently, the diameter class structures within the whole woody species community of Tchilala, as well as of the*Acacia tortilis* and *Balanitesaegyptiaca*,are mainlysmall size trees. The results of this study informsilvicultural management actions that would benefit to the North-African ostrich'establishment in Tchilala and the data collected are considered as possible indicators for long-term monitoring of habitat.

Keywords: Tree inventory, Struthiocameluscamelus, prerelease, habitat, dendrometry, Koutous, Niger

1. INTRODUCTION

The relationship between species and their habitat is one of the central themes inanimal population ecology [1].The habitat assessment is therefore a key stepin anyreintroduction planning. In particular, plants fulfill the important ecological function of producing organic compounds for herbivores in the bottom of the food web, but they can also play the roles

ofrefuge for fauna or soil modifiers. Within the plant community, the woody speciesare amongst the good indicators as they are persistent components of the macro-habitat.
According to GleléKakai et al. [2], a methodological approach of the tree diameter distribution is a good alternative to the study of the woody stands life history [3, 4] and would allow to infer the needed landscaping actions to restore or protect the natural habitat [5] when long-term monitoring is not available.
Additionally, as the animal species respond to their environment features, the vegetation characteristics such as taxonomic composition, size, condition and distribution,influence the occupation of the habitat[1]. The physical conditions (e.g., altitude, substrate) also often impact on the plant formations, and indirectly on the animal density[6]. The North African ostrich (*Struthiocameluscamelus*) is a giant flightless bird that was formerly widely distributed in the Sahelo-Saharan region: it was endemic in Niger but has disappeared from its natural environment since 2004 when the last male located in the AïrandTénéréNatural Reserve died [7].
An ongoing national conservation program supports captive breeding of North-African ostriches in threelocations, namely Kellé, Iferouane and Mainé-soroa,managed by non-governmental organizations (NGOs) or citizens. Theseslowly-growing captive populationsconstitute a hope for the sub-species' possible return to areas where it previously existed in Niger.
However, captive-raised animals of many species have had poor success after reintroduction into their natural habitat [8, 9, 10, 11]. To maximize survival, reintroduction candidatesmust be able to procure food and shelter, develop anti-predator skills, interact properly with conspecifics, and orient (navigate, migrate, and/or disperse) in a structurally complex environment [11, 12].
The prerelease phasemay alter behaviors in ways assumed to be beneficialto survival [14, 15, 16, 17, 18]. During this preliminary phase, the animals to be released can be actively trained, as demonstrated with birds trained forphysical fitness and anti-predatory behaviors that survivedbetter than untrained birds [19]. The soft-release methodis another strategy that allows to progressively expose the animals to the new challenges they will have to face to survive in the wild. This is particularly indicated for endangered species of which the ecology is little known, because the project managers will be able to monitor the animals' behavior and implement ad-hoc mitigation solutions when needed.
The North-African ostriches exhibit low population growth rates with high variance, are subject to high environmental variation (e.g., annual fluctuations in hatching or chicks mortality), and have little genetic variability relative to their population size. Thus, ostrich reintroduction presents many challenges. Therefore, the two NGOs involved the species

conservation program in Niger, the Sahara Conservation Fund (SCF) and the Cooperative of Exploitation of Natural Resources of Koutous (CERNK), have agreed to prepare and fencea 130-ha prerelease area, named Tchillala, in the Koutous.

In accordance with theInternational Union for Conservation of Nature(IUCN)'s recommendations for reintroduction,any conservation translocation must be justified, with development of clear objectives, identification and assessment of risks, and with measures of performance. This studyis part of the broader preliminary assessment of a prerelease site, focusing on the woody species. Indeed, the treesrepresent an important component of the habitat features, particularly in the Sahel, where they providepermanent source of food and shade benefiting to herbivores, small fauna (birds and arthropods) and annual plants. We aim to determine baseline data that will help to implementa long-term monitoring program of the woody stands in Tchilalaand informthe development of habitat management activities for the return of the North-African ostrich in the Koutous.

2. MATERIAL AND METHODS

2.1. Study site

The site of Tchilala belongs to the Municipality of Kéllé, department of Gouré, Region of Zinder (Figure 1). It is a 132.4-ha area surrounded by hills in the form of mounds of the Continental Terminal, located between N13°51'40'' and N14°53'40'' and E9°51'40'' and E11°14'20''. As described by Saadou[20], it is located in the North Sahelian oriental sectorphytogeographic subdivision of Niger. The area is characterized by a long dry season of 8 to 9 months and a short rainy season of 3 to 4 months. The average annual temperature fluctuates between 25 and 30 °C and the cumulative annual rainfall is around 300 mm. The vegetation in the area is a shrub-to-tree steppe and forest galleries along the rivers.

2.2. Data collection

The tree inventory was carried out in 1000m² (50m x 20m) plots following a stratified random distribution based on geomorphology (dune peaks, dune slopes and depressions). A total of 42 plots were installed.

In each plot, the following parameters have been measured foreach woody plant: circumference of the trunk (in cm) with a tape measure,diameter of the crown on the two perpendicular axes with a tape measure, the total height (m) witha graduated pole. The diameter (D) was then calculated by the formula D = circumference / π. These measurements were taken on individuals with a trunk diameter greater than or equal to 5 cm.The individuals thinner than 5cm have been considered as juveniles andcountedfor regeneration rate.

The condition of the individuals encountered has been also classified in the following categories: cutting, pruning and heaving.

2.3. Data analysis

Dendrometric parameters

The following dendrometric parameters were calculated:

- Importance value index (IVI):

The importance of the different woody species in the site was assessed with the IVI [21]. This index is expressed according to the following formula:

IVI = FR (%) + RBA (%) + DR (%),(1) with:

FR: is the relative frequency of a species, it is the ratio of its specific frequency (number of plots in which it is present) to the total of specific frequencies;

RBA: relative basal area, it is the quotient of its basal area (basal area) by the total of the basal areas of the species;

DR: the relative density of a species; it is the ratio of its absolute density to the total of the absolute densities.

- The recovery rate (R) of woody species in percentage (%) was obtained by the following formula:

$$R(\%) = \frac{r \times 100}{S} with r = \frac{\pi}{4} \sum_{i=1}^{n} di^2 \quad (2)$$

r = recovery of all individuals in the plot (m²); di = mean diameter of the crown of the individual i (m); s = area of the plot (m²).

The density of stems (N) expressed in stems per hectare (Stems / ha) was determined by the total number of stems in each plot according to the formula:

$$\mathrm{N} = \frac{\mathrm{n}}{\mathrm{s}} \quad (3)$$

n = total number of trees inventoried in the plot; s = area of the plot in hectare.

- The regeneration density (Nr) was expressed in stems per hectare (Stems / ha) by the following formula:

$$\mathrm{Nr} = \frac{\mathrm{nr}}{\mathrm{s}} \quad (4)$$

nr = total number of seedlings in the plot; s = area of the plot in hectare.

- The average diameter (Dg) expressed in centimeters (cm) was determined for each plot by the formula:

$$D_g = \sqrt{\frac{1}{n} \sum_{i=1}^{n} d_i^2} \quad (5)$$

n = total number of stems encountered in the plot and di = diameter of the stem i (cm).

- The basal area of the stand (G), expressed in m² / ha, is given by the formula:

$$G = \frac{\pi}{40000\ s} \sum_{i=1}^{n} d_i^2 \quad 6)$$

s = area of the plot in hectare and di = diameter of the stem i (cm).

- TheLorey's mean height (HL) is the weighted meanheight (in meters) whereby individual trees are weighted in proportion to their basal area [22]. The formula is as follows:

$$HL = \frac{\sum_{i=1}^{n} gi\ hi}{\sum_{i=1}^{n} gi} \quad with\ gi = \frac{\pi}{4} di^2 \quad (7)$$

Where gi and hi are the basal area and the total height of individual i, respectively.

Demographic structures

For the structure in diameter and height classes of woody individuals,the trees of at least 5 cm in diameter were divided into seven classes of diameter of amplitude 5 cm and seven classes of height of amplitude 1 m. The structures were adjusted to the Weibull model, chosen for its great flexibility [23]. To ensure a good fit of the observed structure to the theoretical Weibull distribution, a fit test based on a log-linear analysis with R2.15software was carried out. The probability density function of the Weibull distribution is presented in the form of the following equation [3]:

$$f(x) = \frac{c}{b}\left(\frac{x-a}{b}\right)^{c-1} \exp\left[-\left(\frac{x-a}{b}\right)^{c}\right] \quad (8)$$

Where x is the diameter or height of the trees and F (x) its probability density value;

a is the position parameter; it is equal to 0 if all the categories of trees are considered (from seedlings to seeders) during the inventory; it is not zero if the trees considered have a diameter or a height greater than or equal to a;

b is the scale or size parameter; it is linked to the central value of the diameters or heights of the trees in the stand considered;

c is the shape parameter linked to the diameter or height structure considered.

This Weibull distribution can take variousforms depending on the value of the shape parameter (C) related to the diameter structure, as shown in Table 1.

3. RESULTS

3.1. Floristic composition and specific importance

The woody communities of the site comprise 17 species belonging to 10 families. 23.52% of these species belong to the Mimosaceae family followed by the species of the Tilliaceae family (17.64%), Asclepiadaceae (11.76%) and Capparaceae (11.76%). The other families are represented by only one species (Figure 2).

Analysis of the Importance Value Indices shows that *Acacia tortilis* has the largest importance value index (IVI = 118.43) followed by *Balanitesaegyptiaca* (IVI = 88.28) (Table 2). These first two species represent 68.9% of the importance value index of all the inventoried species and determinethe physiognomy of the woody stratum of the site.

3.2. Degradation of woody species

The assessment of the woody plants condition in Tchilalahighlights that 28.4% of the surveyed woody plants have been pruned or over pruned, and 15.2% show signs of debarking (Figure 3a). Other 21.7% has suffered from partial or full uprooting by water of wind, including fallen trees because of soil erosion action (Figures 3b and 3c).

~~In summary, about 65% of the woody plants have been suffering from anthropogenic or natural damages~~.

3.3. Dendrometric characteristics

Table 3 presents the average values of the dendrometric parameters for the whole woody species community and for each of the two dominant species (*Acacia tortilis* and *Balanitesaegyptiaca*). The density of adult woody trees is 83.33 ± 42.80 trees / ha lower than the density of regeneration 227.54 ± 129.87 stems / ha. The overall basal area of all woody species is 0.52 ± 0.51 m^2 / ha (Table 3). Populations of *B. aegyptiaca* have a higher mean diameter (Dg), while populations of *Acacia tortilis* have higher values for all other dendrometric parameters.

3.4. Demographic structures of woody species

Figure 4a shows that the whole woody species community distribution follows an exponential decrease with a C shaped parameter less than 1: the individuals of 5 to 10 cm in diameter are predominant. The distribution of the diameter classes for bothdominant species on the site, *Acacia tortilis* and *Balanitesaegyptiaca*, shows the same distribution in “inverted J” with a shape parameter less than 1. The smallest diameter classrepresents 44.44% and 41.58% of the sampling effortrespectively for *Acacia tortilis* (Figure 4b) and *Balanitesaegyptiaca* (Figures 4c) respectively.

The distribution in height classes shows a shape parameter characteristic of a youngwoody stand with a predominance ofmedium-height trees (3 to 5 m) (Figure 5a). The same trend is observed for *Acacia tortilis* and *Balanitesaegyptiaca* populations, with predominant medium-sized individuals (Figures 5b and 5c).

The results of the log-linear analysis show that the distributions observed in diameter and height classes fit globally with the theoretical Weibull distributions ($P < 0.05$).

4. DISCUSSION

With only 17 species encountered, the woody flora of the future ostrich' pre-release site show a low diversity, and dominated by the Mimosaceae family. While low-diverse single-dominant forests are not rare [25],this number of species is lower compared those found by Laminou et al. [26] (46 species) and Ali et al. [27] (51 species) in south central of Niger.This difference could be related to the fact that the site is confined by the chain of hills which surrounds it; the latter could constitute an obstacle to the flow of seeds, particularly for species with modes of anemochore and hydrochore dissemination.

The species with the greatest importance value indices (IVI), i.e. those which are ecologically important in terms of their overlap, frequency and density, are *Acacia tortilis* and *Balanitesaegyptiaca*, two species with high resistance to drought [28]. These species represent 74.6% ofthe overall woody species diversity encountered in Tchilalaand the number of juvenile individuals is predominant. These results reflectthe remarkable potential of these species to regenerate as the result of their high germination capacity and the current pastoral vocation of the area where flocks disperse the seeds in the pasture [29, 30]. They align with previous works that have also evidenced the high percentage of juvenile trees in Niger [34, 35]. This could be explained by the inability of young individuals to reach the adult stage because of climatic or wide-spread anthropogenic disturbances.

The results provide measurable indicators of the logging pressure and we suggest to monitor them as the project goes. They stress the need of controlling the land use as the sustainability of the woody stand depends on the seed production and resilience to climate changes [36, 37]. During the dry season, when herbaceous fodder is scarce, the pastoralists prune the woody species to feed their animals or make fires. Since cutting and pruning generally happen on the biggest -and therefore mature- trees, this harmful practice could jeopardize the long-term dynamics of woody stands if no protective measure is taken.Our results support the decision of fencing the prelease site to maximize the survival rate of juvenile trees.

The average diameter and height of the trees are consistent with the characteristic of the Sahelian vegetation essentially made of shrubs[34, 35]. Bringing North-African ostriches in such site will represent an unprecedented opportunity to document the impact of the pruning practices on their behaviour and performances and will provide key information for future release in the Sahelian landscape. It is expected the woody species serve as a resting area during the hottest hours of the day and allow some biological functions (e.g. nesting) to happen.

While this tall ratite subspecies is morphologically adapted to feed on the highest parts of the trees (including fruits, leaves, flowers), ongoing reintroductions in Tunisia demonstrate that they are well-adapted to aridland with no tree and therefore they should not be considered as a necessary nutritional resources [38, 39]. However, observations of captive-bred ostriches also revealed that the *Acacia tortilis* and *Maeruacrassifolia* pods are greatly appreciated by ostriches [31, 32, 33]. This would be factor in favour of the establishment of sedentary groups in these wooded areas.

5. CONCLUSION

This study shows that Tchilala area has a low diversity of woody species (17 species), and a physiognomy of the woody stratum marked by *Acacia tortilis* and *Balanitesaegyptiaca*. The dendrometric parameters and the demographic structures of the trees match the characteristics of a regenerating ecosystem, despite continuing natural (soil erosion, wind) and anthropogenic (cutting and pruning) damages. This suggests that further recovery will happen when the site will be fenced and this should also impact the herb layer.Additionally, in arid climates, the woody species play an important role not only in the structure of the habitat (perennial source of food, shade) but also in the development of biodiversity (e.g., habitat for microfauna, microclimate for annual plant species): they are good biodiversity indicators. This study shows that the site has qualitative and quantitative characteristics consistent with the Sahelian habitat in which North African ostriches used to live naturally before having been extirpated by over-hunting.It will contribute to the wider feasibility study of the North-African ostrich introduction project. The study also suggests that implementing a long-term monitoring on the prerelease site to counteract the harmful effects of anthropogenic activities and animal grazing on the woody species will be instrumental for a comprehensive silvicultural managementand future full-release of the giant flightless bird in the Sahelian steppes of Niger.

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COMPETING INTERESTS

The authors of this manuscript declare that there is no conflict of interest between them

AUTHORS' CONTRIBUTIONS

MIM, the lead author of the article, developed the research protocol, collected field data, and wrote the manuscript. MKAH participated in the data collection and revision of the manuscript. RT contributed in the choice of the theme and the revision of manuscript. HR gave methodological advice for carrying out this work and revised the manuscript. MP contributed to the revision of the manuscript. The author AM contributed in supervising the work and revised the final version of the manuscript.

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Table 1. Shapeof the Weibull distribution as a function of the value of the parameter c (Husch et al., 2003)

Value of parameter C	Interpretation
C<1	Distribution in “inverted J”, characteristic of multispecific or uneven-aged stands.
C = 1	Exponentially decreasing distribution, characteristics of extinct populations.
1 <C < 3.6	Positive asymmetric or right asymmetric distribution, characteristic of monospecific stands with predominance of young or small diameter individuals.
C = 3.6	Symmetrical distribution (normal structure), characteristic of monospecific stands with individuals of unequal diameter.
C > 3.6	Negative asymmetric or left asymmetric distribution, characteristic of monospecific stands predominantly of elderly individuals.

Table 2. Importance value index (IVI) of ten predominant woody species in Tchilala (Koutous, Niger).

Species	DR (%)	RBA (%)	FR (%)	IVI
Acacia tortilis	41.14	47.13	30.16	118.43
Balanitesaegyptiaca	28.86	35.61	23.81	88.28
Maeruacrassifolia	9.14	3.89	13.49	26.53
Acacia senegal	8.86	5.67	11.90	26.43
Bosciasenegalensis	3.43	0.33	7.14	10.90
Commiphoraafricana	4.57	1.39	3.17	9.14
Leptadeniapyrotechnica	1.71	0.21	3.97	5.90
Sclerocaryabirrea	0.29	4.46	0.79	5.54
Ziziphusmauritiana	0.57	0.81	1.59	2.97
Faidherbiaalbida	0.29	0.23	0.79	1.31
Others	1.16	0.26	3.16	4.48
Total	**100**	**100**	**100**	**300**

DR: relative density RBA: relative basal area; FR: relative frequency.

Table 3. Averages and coefficient of variation of the dendrometric parameters of woody plants and two dominant species on the site

Dendrometric parameters		M±σ	CV (%)
Total density (individuals/ha)	Global	315.88±126.68	40.75
	Acacia tortilis	163.8±110.27	67.31
	Balanitesaegyptiaca	64.52±127.87	198.18
Density of adults (trees/ha)	Global	83.33±42.80	51.36
	Acacia tortilis	34.28±29.80	86.93
	Balanitesaegyptiaca	24±28.03	115.44
Basal area(m²/ha)	Global	0.52±0.51	98.56
	Acacia tortilis	0.27±0.33	128.41
	Balanitesaegyptiaca	0.26±0.32	123.09
Lorey height(m)	Global	4.64±1.33	28.86
	Acacia tortilis	4.61±1.51	32.78
	Balanitesaegyptiaca	4.21±1.59	37.78
Diameter (cm)	Global	12.35±5.68	46.98
	Acacia tortilis	12.50±7.19	57.54
	Balanitesaegyptiaca	13.67±6.80	49.76
Recovery rate (%)	Global	17.07±13.21	77.44
	Acacia tortilis	9.26±10.05	108.54

	Balanitesaegyptiaca	3.90±4.88	125.17
Regeneration density (seedlings/ha)	Global	227.54±129.87	57.07
	Acacia tortilis	129.52±108.91	84.09
	Balanitesaegyptiaca	40.23±114.22	283.86

M±σ: Mean ± standarddeviation; CV: coefficient of variation

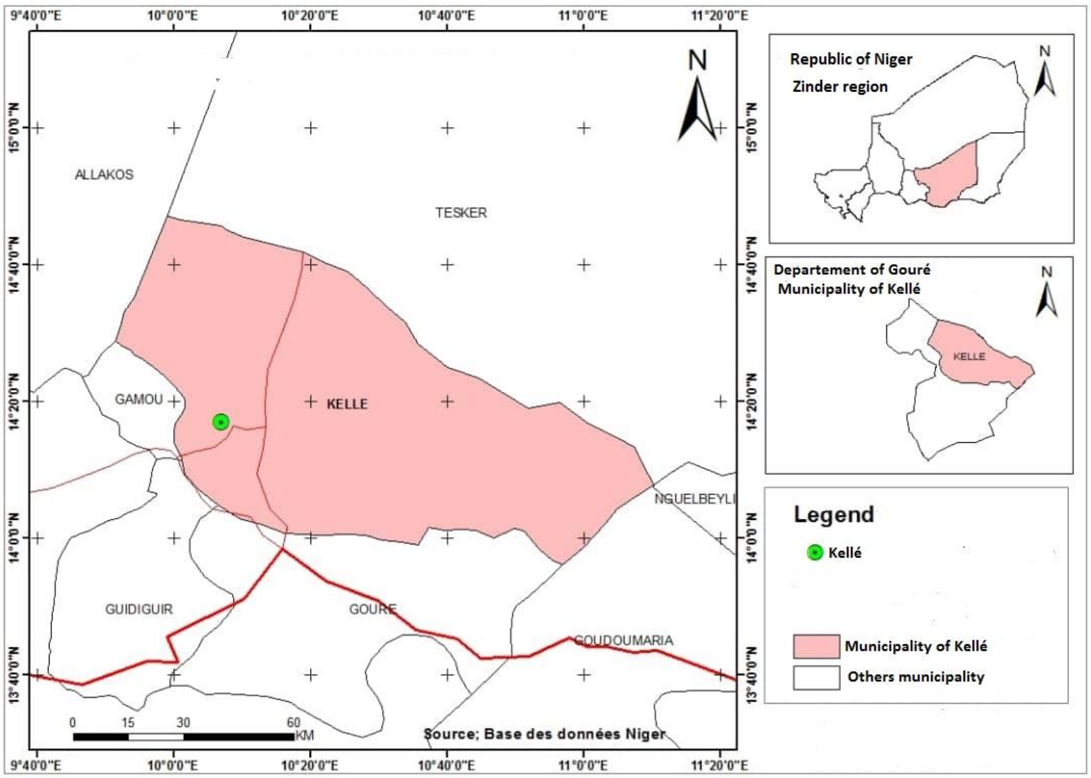


Figure 1. Location of the study area

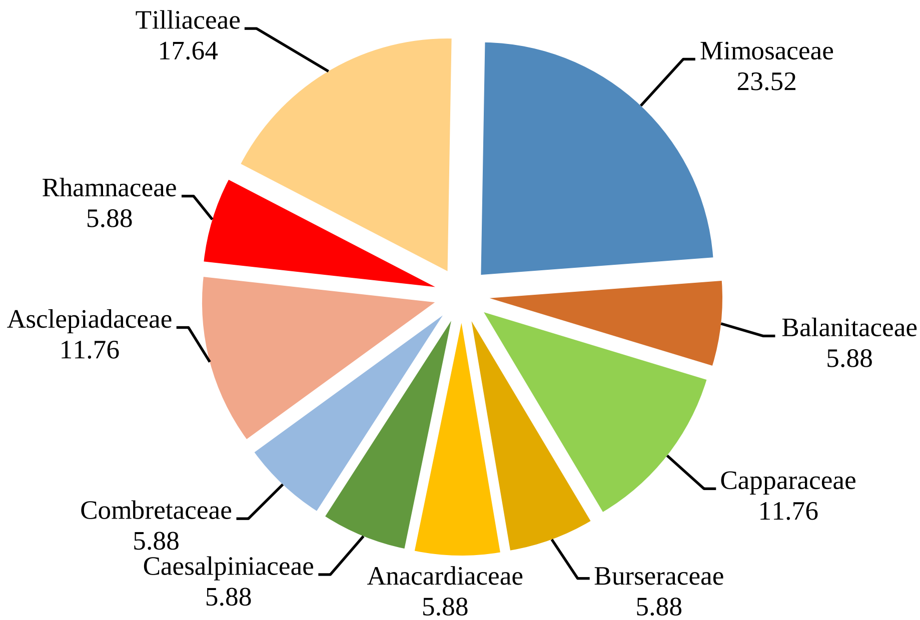


Figure 2. Spectrum of woody species families

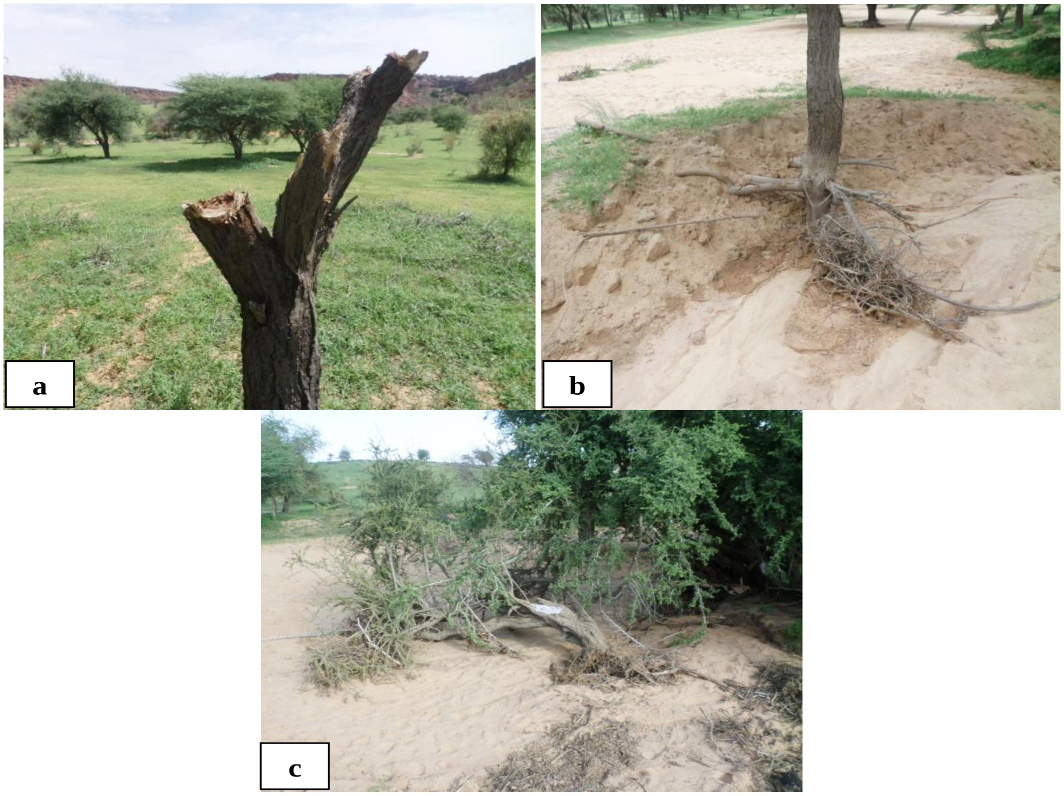
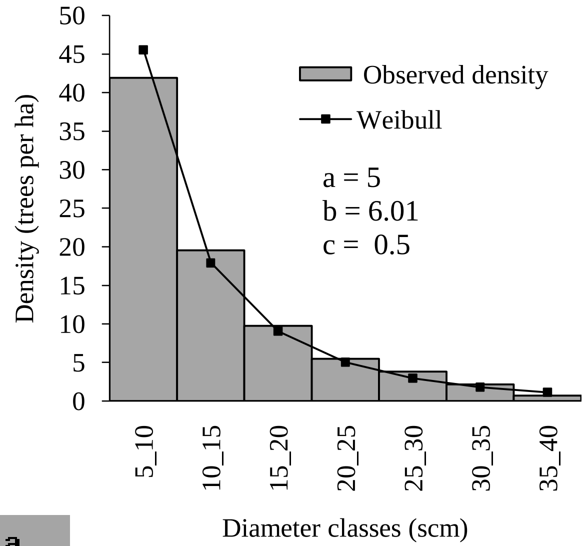
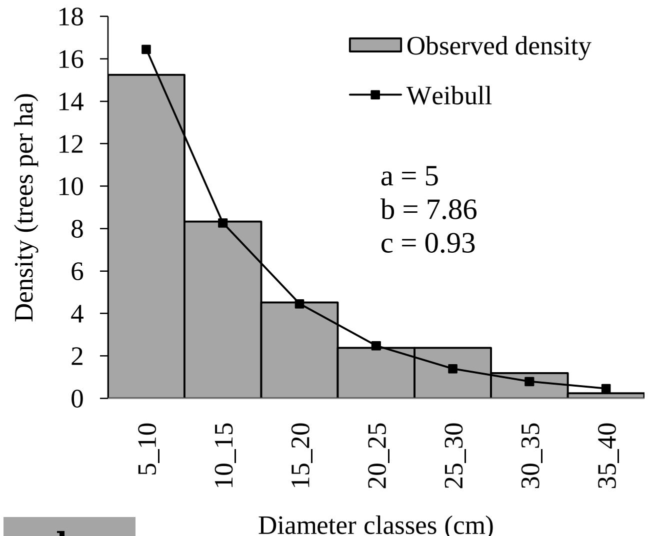


Figure 3. Threats on the woody sites of the site: *Acacia tortilis* pruned (a) and uprooting by water erosion (b), fallen*Maeruacrassifolia*after soil erosion or wind actions


50
45
40
35
30
25
20
15
10
5
0
Density (trees per ha)
Observed density
Weibull
a = 5
b = 6.01
c = 0.5
5_10
10_15
15_20
20_25
25_30
30_35
35_40
Diameter classes (scm)

a


18
16
14
12
10
8
6
4
2
0
Density (trees per ha)
Observed density
Weibull
a = 5
b = 7.86
c = 0.93
5_10
10_15
15_20
20_25
25_30
30_35
35_40
Diameter classes (cm)

b

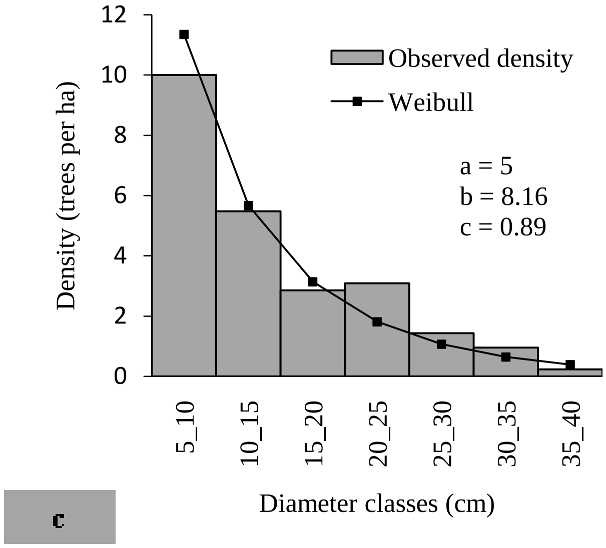


Figure 4. Diameter structure of all woody species together (a), *Acacia tortilis* (b) and *Balanitesaegyptiaca* (c) in Tchilala

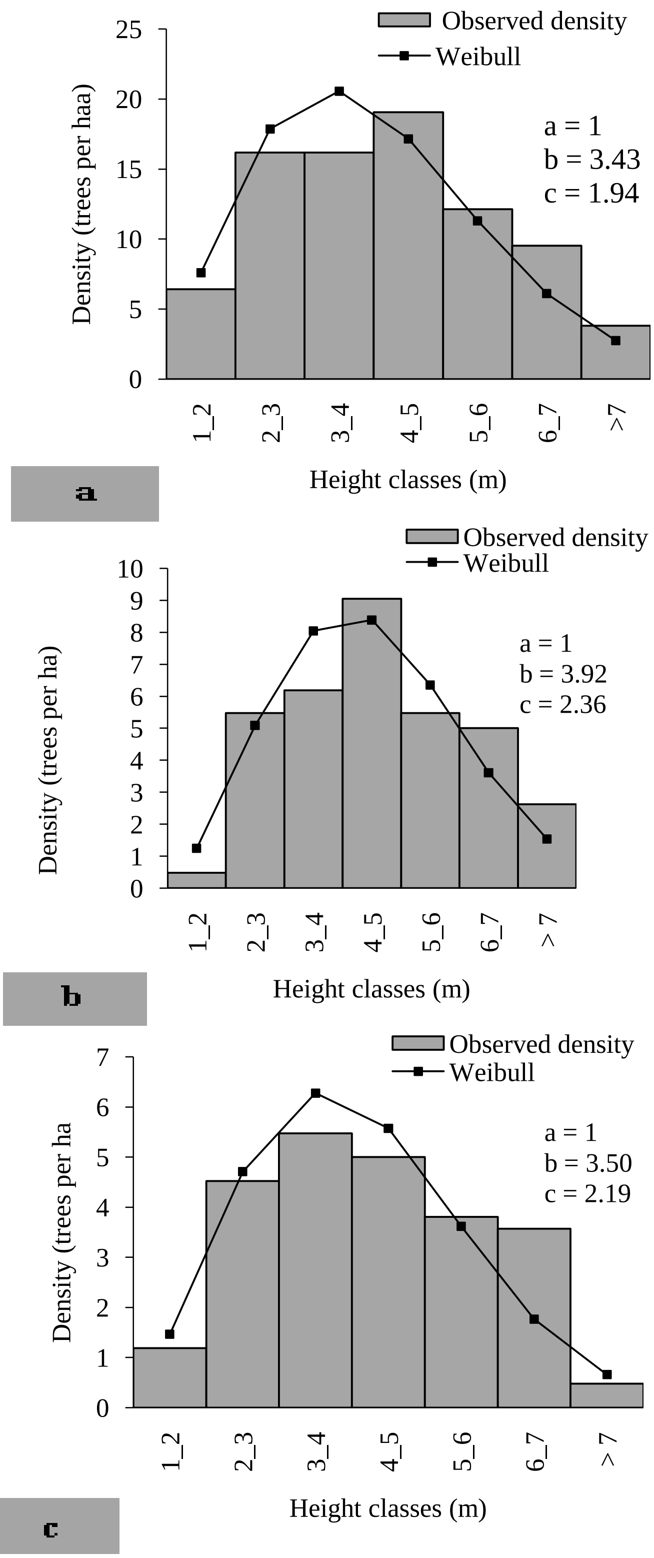


Figure 5. Height structure of all woody species together(a), *Acacia tortilis* (b) and *Balanitesaegyptiaca* (c) in Tchilala.