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Trend and Structure of Populations of *Balanites aegyptiaca* in Parkland Agroforestsin Western Niger

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Authors' contributions

This work was carried out in collaboration between all authors. Authors BI, IS and YI designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AJMK, JCW and AM managed the analyses of the study. Author SM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Current and future trends of the parklands and the population of *Balanites aegyptiaca* in western Niger were investigated through the analysis of the diversity, the regeneration status and the size class distributions of the woody plants. A total of 21 plots, measuring 2500 m² (50 m x 50 m) each were randomly selected to represent the parklands of *B. aegyptiaca* in the study area. Across all plots 1180 individual plants were recorded, representing 13 species, 10 genera and 7 families. The most diverse family is Fabaceae and the most dominant family is Balanitaceae represented by only

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one species *B. aegyptiaca*. The density of the regeneration was 71.16 and 33.31 plants ha^{-1} for the entire parkland and the population of *Balanites aegyptiaca*, respectively, while the diversity and the evenness indices of *B. Aegyptiaca* were 2.52 and 0.24, respectively. *B. aegyptica, Faidherbia albida*, *Hyphaene thebeica* and *Acacia nilotica* populations had the highest values for the importance value index (IVI). Results from the analysis of the size class distribution indicate that the parklands and the population of *B. aegyptiaca* appear to be healthy and stable with high regeneration rates. However, low recruitment of juveniles to adults was observed due to seedling and sapling mortality, and high disturbance regimes, which in the long term can affect the population turnover. *Acacia tortilis*, *A. senegal*, *Azadirachta indica* and *Prosopis juliflora* populations had the lowest IVI values and may be the most sensitive to the disturbance regimes in the study area. Therefore, we suggest designing and implementing a conservation programme in the study area, which will protect and facilitate the growth of the juveniles of both overexploited and underexploited populations.

Keywords: Trees and shrubs; population structure; IVI index; regeneration; agroforestry.

1. INTRODUCTION

In Sub-Saharan Africa, trees and shrubs are intentionally cultivated with crops for multiple ecological and socioeconomical benefits [1-3]. Agroforestry systems are important for improving crop productivity, maintaining ecosystem integrity, and limiting capital resources depletion such as water, nutrients and soil [4,5]; mitigating the effect of global climate changes due to permanent tree cover that stores terrestrial carbon [6-9]; and reducing forest destruction by providing wood and non-timber products for human wellbeing [10].

Classically, agroforestry systems have been classified into six categories in which the woody plant component has the central role in the functioning of the agroforestry systems. These systems include crops under tree cover, agroforests, agroforestry in a linear arrangement, animal agroforestry, sequential agroforestry and minor agroforestry techniques [11]. The systems of crops under tree cover include all combinations of trees and crops in which the woody component creates an upperstorey covering the crops. This system includes agroforestry systems in which trees are scattered in croplands (e.g. parklands), crops under shade trees, crops in orchards, plantation crops in combination (e.g. *Faidherbia albida* parklands in the Sahel). Agroforestry systems are those which have dense tree component, mixed and multi-layered, and if the crop component is more diverse, the agroforestry association looks like a forest (e.g. coffee with shade and timber trees). The system of agroforestry in a linear arrangement integrates trees in lines, such as in hedges, contour lines or soil conservation hedgerows, alley cropping (regularly spaced hedgerows in crop land), living fences, boundary plantings, roadside plantings, windbreaks, shelterbelts, and woody strips. Animal agroforestry refers to a system in which livestock are fed with browse trees that grow naturally on farms. Sequential agroforestry is a system in which trees and crops are not to be found simultaneously on the same piece of land, but follow each other in time (e.g. Taungya system). Finally, minor agroforestry systems refer to those in which trees are associated with particular animal rearing such as bees (e.g. apiculture) and worms (e.g. sericulture).

The common feature of the six systems is of course the woody plant which component in interaction with the other components, has positive effects on land productivity and soil conservation, so long-term availability of these services hinges on our capacity to manage the woody plants. In these systems, woody plants are managed for a wide variety of products such as food, fodder, medicines, firewood, etc. and services such as soil stability, erosion control, carbon storing [12,13]. Understanding the current structure of the woody component of the agroforestry systems can help to better manage these systems. Some studies have been conducted on parklands of *Vitellaria paradoxa* [14], *Prosopis africana* [15], *Neocarya microphylla* and *Vitellaria paradoxa* [16], and on farmer managed natural regeneration [17,18] with the main objective of producing scientific information that could help in improving management strategies. *Balanites aegyptiaca* (L.) Del. commonly known as the desert date is one of the common but neglected wild plants species found in the dry land areas of Africa and south Asia [19]. It is one of the most widespread woody plants of the Sahel and the Middle East contributing substantially to the people's welfare because of its potential to provide fodder, food, fibber, wood and medicine. *Balanites aegyptiaca* produces fruits even in dry season which are sold in urban areas around Africa. Pounded fruits make a refreshing drink which becomes alcoholic if left to ferment [20]. In general, during the dry season when forage becomes scarce in the rangelands, *Balanites aegyptiaca* trees as well as some other woody plants are pruned to feed livestock due to the high quality of the fodder [21,22]. Despite the wide utilisation of the species, there is scant information on the structure and the functioning of the systems subservient to the *B. aegyptiaca*. In this study, we investigated the current structure of the parklands and the population of *Balanites aegyptiaca* in western Niger through the analysis of the size class distributions of the woody plants as well as their biological and ecological traits. These methods combined with local information and demographic studies have the potential to provide useful information on the current trends of woody vegetation that can be used to develop sustainable management plans [23,24].

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted at Liboré (13º70'-13º71 N, 2º26'-2º32' E), about 10 km from Niamey, the capital city of Niger. The study sites are parklands of *Balanites aegyptiaca* and other wood species that are extensively cultivated primarily for production of pearl millet and livestock (Fig. 1). The tropical semiarid climate of the study is characterized by high variability in rainfall among years and episodic droughts [25]. For the period 1970 to 2008, mean annual temperature was 36±3ºC and mean annual precipitation was 514±125 mm, measured at the Niamey airport located about 20 km from the study sites (Direction Nationale de la Météorologie du Niger, unpublished data). Mean temperatures are lowest in December and January (32±2º and 33±1ºC, respectively) and highest in April and May (41±1º and 40±1ºC, respectively). Rainfall is highest in July (143±56 and 166±71 mm, respectively: Fig. 2). The natural vegetation is classified as thicket of Combretaceae (locally referred as tiger bush) on the lateritic plateaus, and as steppe on the sandy terraces, fixed dunes and dry valleys [26,27]. The thicket of Combretatceae consists of *Guiera senegalens* is J.G. Gmel*., Commiphora africana* (A.Rich.) Engl*., Combretum micranthum* G. Don*., Acacia macrostachya* Reich. ex Benth*. Lannea acida* A. Rich*., Croton gratissimus* Buch*., Acacia ataxacantha* DC*., Combretum nigricans* var. elliotii (Engl. Ex Diels) Aubrev*., Boscia senegalensis* (Pers.) Lam. Ex Poirand *B. angustifolia* A. Rich*.* The steppe vegetation is dominated by *Hyphaene thebaica* (L.) Mart*., Bauhinia rufescens* Lam., *Annona senegalensis* Pers., *Combretum glutinosum* Perr. ex DC. And *Faidherbia albida* (Del.) A. Chev.

2.2 Data Collection

The inventory of the woody plants of the parklands was carried in August and September of 2014, in 21 square plots of 50 m x 50 m (2500 m²) randomly selected to represent the parklands of *Balanites aegyptiaca* in the study area. The criteria for selection of the plots were based on the homogeneity of the vegetation and the soil surface characteristics. In each plot, we recorded the height and diameter at breast height (height breast = 1.3 m above the ground) of all woody plants which diameter at height breast > 4 cm. The number of saplings (diameter at height < 4 cm) classified into height classes were recorded in ten subplots of 5 x 5 m laid on the diagonal of the main plots of 2500 m². Height was measured with a graduated measuring pole, and diameter

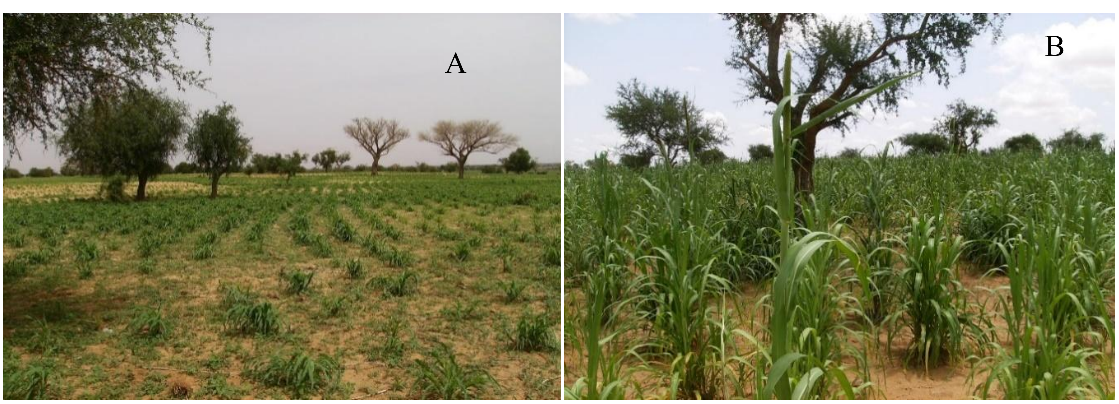

Fig. 1. Landscape of the study area (A) and pruned *Balanites aegytiaca* for fodder (B)

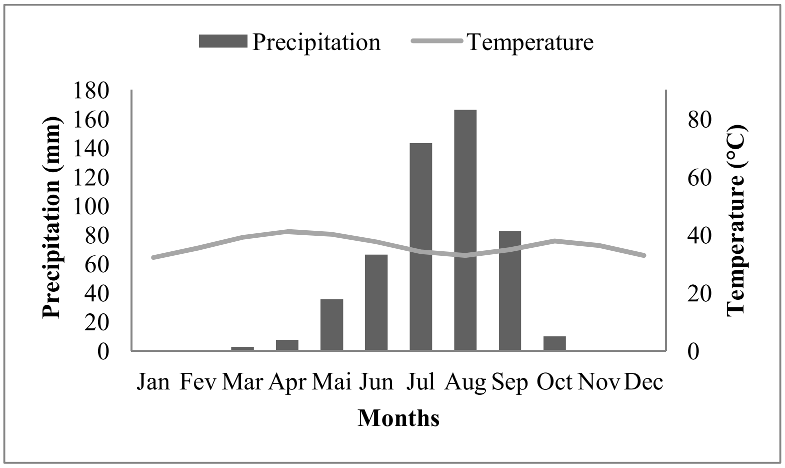

Fig. 2. Ombrothermic diagram of the meteorological station at the Niamey airport located about 20 km from the study sites (data for 1970 to 2008)

at breast height was measured with a calliper. Nomenclature adopted for plants is based on [28] and the list of the species families was arranged according to the Linear Angiosperm Phylogeny Group (APG) [29] which is based on the contain.

2.3 Data Analysis

Density (N), mean diameter (D), height (HL), basal area (G) and the importance value index (IVI) were calculated for each species. N of each taxon was assessed as the number of individuals of the taxon per unit area:

$$N = \frac{n}{s}; \quad (1)$$

where n is the number of individual plants of the species in the area and s is the area in ha. D was calculated in cm for each species using the following formula [28]:

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

where n the number of trees found in the plots and d_i the diameter of the i^{th} tree. HL, Lorey's mean height expressed in m, was calculated for each species using the following formula:

$$HL = \frac{\sum_{i=1}^{n} g_i h_i}{\sum_{i=1}^{n} g_i} \text{ where } gi = \frac{\pi}{4} d_i^2 \quad (3)$$

g_i is the basal area expressed in m² ha^{-1}, h_i is the height (in m) and d_i (in m) is the diameter of the tree i. G of the whole study area was computed by:

$$G = \frac{\pi}{4s}\sum_{i=1}^{n} d_i^2; \quad (4)$$

where d is the trunk diameter (cm) of the tree i at breast height and s is the area of the study plot (ha) [30]. IVI of each species was computed using the following formula (Curtis & Macintosh, 1951):

IVI (%) = relative density + relative frequency + relative basal area (5)

The relative basal area of a species is the quotient of its basal area to the total basal area of all the species, expressed as a percentage. The relative density of a species is the ratio of its absolute density to the total absolute density of all species, expressed as a percentage. The relative frequency of a species is the ratio of its specific frequency to the total specific frequencies of all the species, expressed as a percentage. $P_i Log_2 P_i$

The biodiversity of the parklands (i.e. across the 21 sample plots) was evaluated with the Shannon-Weaver (1949) index (H'), evenness (E) of Piélou (1966) and floristic richness (i.e., number of species in a sample unit; R). H' was calculated using this formula:

$$H' = \sum_{i=1}^{n} Pilog2P\text{i}, \quad (6)$$

where pi between 0 and 1 is the relative proportion of frequency of species i; Pi = ni /Σni , n = average frequency of species i and Σni = total frequency of all species. *E* is the degree of diversity of a given site compared with the maximum possible:

$$E = \frac{H'}{Hmax}; \text{ Hmax} = \log_2 S, \quad (7)$$

where Hmax is the maximum theoretical index, H' is the Shannon-Weaver index and S is the number of species recorded in a given site.

Finally, the size classes distribution of the entire parkland and the population of *B. aegyptiaca* were analyzed by adjusting the theoretical distribution of Weibull with three parameters (a, b, and c) to the observed distribution of diameters and heights classes [31]. The probability density function [f(x)] was calculated using the following formula:

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

where x is the diameter or the height of the trees and f(x) the probability density value, a is the position parameter, b is the scale or size parameter and c is the shape parameter related to the observed structure. The shape parameter c was widely used as indicator of community structure [32-34]. Size class distribution with $c < 1$ indicates inversed "J" shaped characteristics of multispecies or uneven-sized population structure that is self-regenerating. Size class distribution with $c = 1$ indicates a distribution that is exponentially decreasing, characteristic of populations in extinction. Shape parameter values between 1 and 3.6 ($1 < c < 3.6$) are related to asymmetric positive or right asymmetric distributions, characteristic of monospecific populations with predominance of young or small diameter individuals. Distributions with $c = 3.6$ refers to symmetric or normal distributions, and is an indicator of single-species or monospecific populations of the same cohort. A distribution with $c > 3.6$ refers to asymmetric negative or left asymmetric distributions, characteristic of predominantly monospecific population of elderly individuals. Weibull with three parameters was computed using Minitab 14 [35].

3. RESULTS

3.1 Plant Composition and Biodiversity of the Parklands and the Populations of *Balanites aegyptiaca*

Overall, 1180 individual plants were recorded in the parklands (i.e. across all sample plots), belonging to 13 species, 10 genera and 7 families. The most abundant family was Fabaceae represented by seven species (Table 1) and the most dominant family was Balanitaceae represented by only one species *B. aegyptiaca*. Fabaceae and Balanitaceae represented respectively the most abundant and dominant families with respectively 38.67 and 74.06 stems/ha out of a total of 152.19 stems/ha. Five families (Arecaceae, Asclepiadaceae, Combretaceae, Meliaceae and Rhamnaceae) were represented by one species each, with density of stems ranging from 0.12 to 17.16 stems/ha.

The saplings density of all species was 71.16 saplings ha^{-1} in the parklands, and 33.31 for the populations of *B. aegyptiaca* in the parklands. Basal area was 2.41 and 1.05 m^2 ha^{-1}, respectively for the parklands and for the populations of *B. aegyptiaca*. Mean diameter and height were 43.8 cm and 12.01 m, respectively for the parklands and 34.82 cm and 6.09 m, respectively for the populations of *B. aegyptiaca,* indicating that some of the other species were taller and had greater stem diameter than *B. aegyptiaca*.

The Shannon diversity index of the parklands was 2.52 and the Pielou evenness index was 0.24. These values indicate that the parklands had relatively low plant diversity with a few plant species dominating the cover. Furthermore, IVI index indicates *B. aegyptiaca* as the most common and widespread species of the parklands with IVI index of 157.97 followed by *Faidherbia albida* (IVI = 67.54), *Hyphaene thebaica* (IVI = 26.82) and *Acacia nilotica* (IVI = 10.98).

3.2 Diameter Class Structure of the Parklands and the Population of *Balanites aegyptiaca*

The diameter size class of the plants in the parklands and the population of *B. aegyptiaca* exhibited inverse J-shaped distributions that fit with the positive asymmetrical distribution of Weibull, with shape parameter c of 1.081 for the parklands and 1.167 for the population of *B. aegyptiaca*. The shape parameter ranged from 1 to 3.6 indicating that both the parklands and the *B. aegyptiaca* population in the parklands were dominated by smaller diameter classes (i.e., younger age classes) with gradually decreasing numbers of individuals in the intermediate and larger diameter classes (i.e., older age classes) (Fig. 3).

3.3 Height Class Structure of the Parkland and the Populations of *Balanites aegyptiaca*

Like the diameter of plants in the parklands and the population of *B. aegyptiaca*, the height class distribution fit with the positive asymmetrical distribution of Weibull with shape parameter c of 1.053 for the parklands and 1.438 for the population of *B. aegyptiaca*. These values indicate the dominance of juvenile plants (Fig. 4).

3.4 Regeneration Trends in the Parklands and the Populations of *Balanites aegyptiaca*

The regeneration density was 71.16 stem/ha for the parklands and 33.33 stem/ha for the populations of *B. aegyptiaca*. Furthermore, 47% of the regeneration of the parklands was *B. aegyptiaca*. The height class distribution of the regeneration of the parklands and the populations of *B. aegyptiaca* had an inverse "J" shaped distribution with high frequency of juveniles of less than 1 m height (Fig. 5) and substantial declines of juveniles with height greater than 1 m, indicating communities with high capacity for regeneration and poor recruitment of seedlings and saplings to adults.

4. DISCUSSION

In comparison to other species, the findings presented in this study were observed in the *Balanites aegyptiaca* parklands agroforests of western Niger. The agroforests are used mainly for production of crop plants and livestock. As a result, farmers did not maintain many woody species in the parklands: only 13 native tree and shrub species were recorded in the 21 plots of 2500 m². The species richness in the parklands in this study was lower than in other studies. For example, between 20 and 110 species were recorded in parklands in the Sahelian region of Burkina Faso [36], 37 species were recorded in the *Faidherbia albida* parklands of southeastern Niger [37], 16 and 35 species respectively were recorded in the parklands of *Neocarya macrophylla* and *Vitellaria paradoxa* in western Niger [16] and 38 species were

Table 1. Dendrometric characteristics of the parklands and the populations of *Balanites aeagytiaca* sampled in western Niger

Parameters	Parklands of *B. aegyptiaca*	Populations of *B. aegyptiaca*
Tree density N (trees ha $^{-1}$)	152.19	74.06
Regeneration density (saplings ha $^{-1}$)	71.16	33.31
Basal areal G (m² ha $^{-1}$)	2.41	1.05
Mean diameter D (cm)	43.81	34.82
Mean height HL (m)	12.01	6.09

Table 2. Importance value index (IVI) of tree species in the parklands sampled in western Niger

Treespecies	Taxon families	Relative basal area (%)	Relative frequency (%)	Relative density (%)	IVI (%)
Acacia nilotica (L.) Willd. ex. Del.	Fabaceae	1.03	5.72	4.23	10.98
Acacia senegal (L.) Willd.	Fabaceae	4.7	1,25	0.93	6.88
Acacia seyal Del	Fabaceae	-	0.36	7.2	-
Acacia tortilis (forsk.) Hayne subsp. *Raddiana* (Savi.) Brenan.	Fabaceae	0.01	1.59	1.18	2.78
Azadirachta indica A. Juss.	Meliaceae	0.61	0,11	0.08	0.8
Balanites aegyptiaca (L.) Del.	Balanitaceae	43.67	65.62	48.68	157.97
Bauhinia rufescensLam.	Fabaceae	-	0.17	4.07	-
Calotropis procera (Ait.) R. Br.	Asclepiadaceae	-	0.43	2.28	-
Combretum aculeatum Vent.	Combretaceae	-	0.17	10.58	-
Faidherbia albida (Del.) A. Chev.	Fabaceae	49.62	10.29	7.63	67.54
Hyphaene thebaica (L.) Mart.	Arecaceae	0.35	15.2	11.27	26.82
Prosopis juliflora (Sw.) DC.	Fabaceae	0.01	0.22	0.16	0.39
Ziziphus mauritiana Lam.	Rhamnaceae	-	0.23	1.44	-

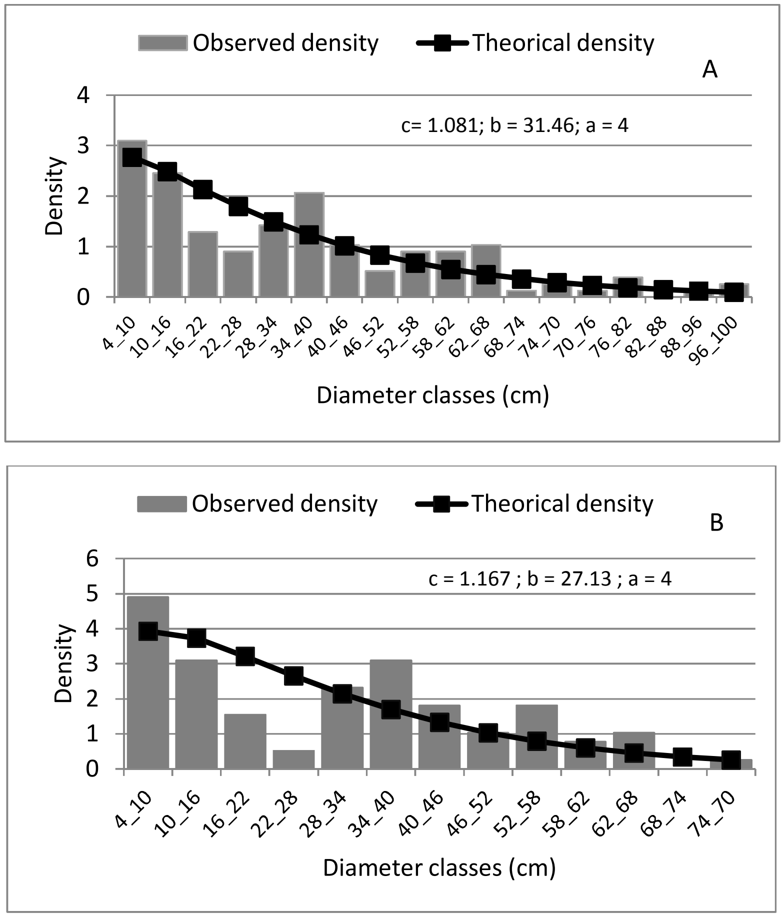

Fig. 3. Diameter class distribution of the woody plants of the parklands (A) and the populations of *Balanites aeagytiaca* sampled in western Niger (B)

recorded in the parklands of farmer managed natural regeneration in Niger [18]. At the regional scale, compared to parklands in the Sahelian ecozone mentioned above, parklands in the more humid Sudanian ecozone have more tree and shrub species: for example, 46 species in the *Parkia biglobosa* and *Faidherbia albida* parklands [38,39], and 54 species in the parklands of the Mar Fafaco of Senegal [38]. Despite the low number of species recorded in the parklands of *Balanites aegyptiaca*, they have the higher density of trees and shrubs compared with the other parklands in the Sahelian and Sudanian ecozones which averaged 10 to 20 per ha [36,38,39]. The parklands of *Balanites aegyptiaca* therefore appear to have lower species richness but higher tree and shrub density compared with some West African parklands. The relatively high density of trees and shrubs in the parklands in this study was not documented but their lower species richness can be linked to the relatively low mean annual precipitation and infertile soils, and farmers' excessive exploitation of some plant species. These have resulted in low species diversity and evenness index which indicate biodiversity losses. Biodiversity losses in dryland systems like the Sahel threaten livelihoods as biodiversity guards against desertification and climate changes through the provision of multiple ecosystem services [40-42]. Hence, substantial conservation actions should be implemented to strengthen farmers' efforts for preservation and sustainable use of biodiversity in response to desertification and climate changes.

As for the richness, different species (such as *Balanites aegyptica, Faidherbia albida*, *Hyphaene thebaica* and *Acacia nilotica*) dominated different parts of the parklands in the study area, and these species were the most important as indicated by their IVI values. The other species (*Acacia tortilis*, *A. senegal*, *Azadirachta indica* and *Prosopis juliflora*) had lower IVI values. These species have been reported as part of the flora of several parklands of the Sahelian and the Sudanian ecozones [16,18,37,38,43]. The predominance of particular species or group of species in a given parkland is related to the influence of the farmers that protect target species from cutting, browsing and fire for their useful range of products and environmental services [12]. Although farmers have great influence on the distribution of plant species in the parklands, ecological conditions such as rainfall, soil properties, land surface condition, geomorphology, etc. are the main factors that influence vegetation patterns. As a result of the ecological conditions and farmers' practices, there are different types of parklands dominated by different species, such as *Faidherbia albida*, *Neocarya microphylla*, *Vitellaria paradoxa*, etc.

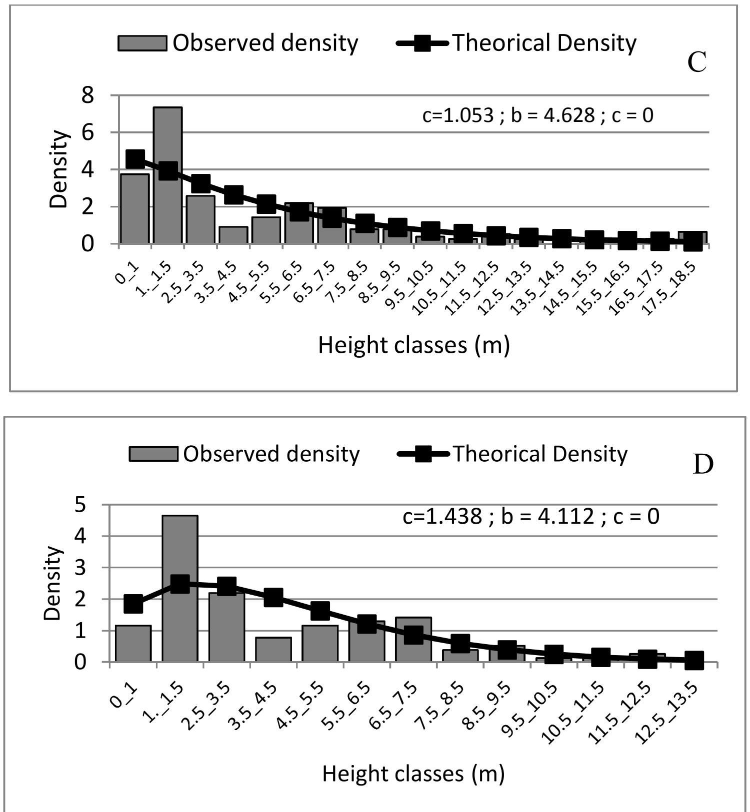

Fig. 4. Height class distribution of the woody plants of the parklands (C) and the populations of *Balanites aeagytiaca* (D) sampled in western Niger

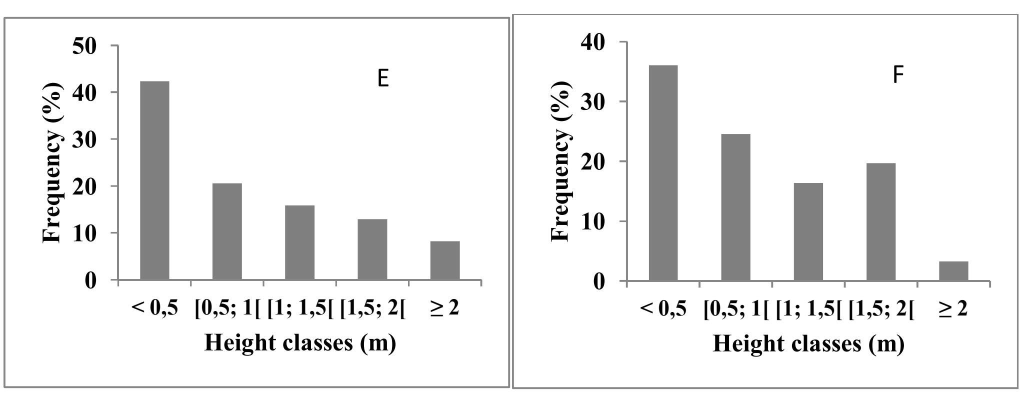

Fig. 5. Structure of the regeneration of woody plants of the parklands (E) and the populations of *Balanites aeagytiaca* (F)

In response to the ecological conditions such as farmers activities, and variably in rainfall, soil fertility, geomorphology, etc., the parklands of *Balanites aegyptiaca* have similar height and the diameter class distributions (asymmetric positive or right asymmetric distribution of Weibull) that are characteristic of monospecific populations with a large number of small (young) trees and relatively fewer large (older) trees. Similar results were reported by Abdou et al. [15] for a *Prosopis africana* parkland. Forest ecosystems such as parklands, protected forests and riparian forests dominated by juvenile woody plants are considered to be healthy and stable systems with self-replacement through natural regeneration [23,44,45]. Healthy and stable ecosystems are resilient and likely to be sustainable, which is the main goal of the global environmental authorities like the intergovernmental platform of biodiversity and ecosystem service and United Nations Environment Programme [10,46,47]. The parklands in the current study are resilient agroforestry systems despite the multiple pressures for food, fodder, timber, firewood, medicines, etc. that can reduce seed production.

Resilient forest ecosystems require favorable microhabitats for seed germination, plant growth and survival. The high regeneration rates observed for the entire parkland and the populations of *Balanites aegyptiaca* in the current study suggests that safe microhabitats are available. Despite the high regeneration rates, low recruitment of juveniles into adults was observed in this study. If the population is to survive, juvenile recruitment to adults is essential for compensating adult mortality. Adult trees produce seeds, so recruitment of juveniles to adults is needed to ensure seed production in the population. Within the Sahelian ecozone, the low recruitment of saplings into adults may be explained by a number of factors, including animal browsing, wood cutting for construction and energy, the long dry season which in some years may be 9-months, and episodic drought. In the parklands, farmers can also reduce woody plant density by eliminating some of them to ensure enough land for crop production.

According to our analysis, the parklands we studied seem to be resilient system despite the high disturbance regimes that limit the number of seedlings and saplings from growing to maturity. It is likely that *Acacia tortilis*, *A. senegal*, *Azadirachta indica* and *Prosopis juliflora* populations which have the lowest IVI values may be the most sensitive to the disturbance factors. For example, these species exhibited either a high degree of grazing damage or traces of wood cutting for timber, fuel wood, fodder or other purposes. According to people in the study area, these species are economically important, and the reduction of the plants population in the study area may be the consequence of their overexploitation. In terms of management and conservation of the small populations, there is a real need to protect the natural regeneration, reduce exploitation and facilitate seedling establishment through natural seed banks and resprouting [48-50]. In the Sahel where shrubs and trees have the ability to resprout and livestock husbandry is widespread, managing natural regeneration and reducing herbivore pressure may be a good option to improve growth and survival [51,52].

5. CONCLUSION AND IMPLICATION FOR SUSTAINABLE LAND MANAGEMENT

The agroforestry parklands of *Balanites aegyptiaca* exhibited low species richness and diversity with low Shannon and evenness indices. The low biodiversity indices indicate the need for conservation programmes to protect these parklands. The size class distributions reveal the current status of the parklands and the *Balanites aegyptiaca* population which appear to be stable and healthy with high regeneration rates. Although they have high regeneration rates, recruitment of juveniles to adults were observed to be low due to human and environmental disturbances, mostly the high herbivory rates, wood cutting, and unfavourable climate conditions with episodic severe drought and long dry season. Low recruitment of juveniles will result in low replacement of adult mortality. As the adults are seed producers, their mortality without replacement in time can lead to the extinction of the local population. The IVI values of the species indicate that *Acacia tortilis*, *A. senegal*, *Azadirachta indica* and *Prosopis juliflora* are the most sensitive, and *Balanites aegyptica, Faidherbia albida*; *Hyphaene thebeica* and *Acacia nilotica* are the most resilient to the disturbance regimes. Therefore, we recommend that the first group of species with low IVI values should be prioritized for conservation programmes with limited exploitation, and the second group of species with higher IVI values can continue to be exploited but with properly designed monitoring programme.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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